Research article

Outcomes of problem-based learning in nurse education: A systematic review and meta-analysis

Sapna Sharma [a], Ita Daryanti Saragih [a], Dame Elysabeth Tuty Arna Uly Tarihoran [b,c], Fan-Hao Chou [a,*]

[a] *College of Nursing, Kaohsiung Medical University, Kaohsiung, Taiwan*
[b] *School of Nursing, Universitas Kristen Krida Wacana, Jakarta, Indonesia*
[c] *School of Nursing Faculty of Medical and Health Sciences, University of Auckland, Auckland, New Zealand*

ABSTRACT

Objective: To investigate the effectiveness of problem-based learning (PBL) in nursing students, including recently reported trials.
Design: Meta-analysis was performed to obtain summary conclusions on the influence of PBL on nursing students' learning outcomes.
Data sources: Academic Search Complete, CINAHL, Cochrane Library, EMBASE, MEDLINE, PubMed, and Web of Science were searched for relevant studies from the period between database inception and March 3, 2022.
Review methods: A random-effects model was used to generate pooled standardized mean differences (SMD) for critical thinking, problem-solving, and self-confidence. The heterogeneity of each variable in the pooled estimate was determined using a random-effects model.
Results: Overall, PBL had a greater positive effect than traditional learning on critical thinking (SMD: 0.44; 95 % CI: 0.14–0.73), analysis (SMD: 0.72; 95 % CI: 0.84–1.25), and evaluation (SMD: 0.33; 95 % CI: 0.05–0.61). However, the impact of PBL on problem-solving and self-confidence need further investigation.
Conclusions: PBL appears to improve nursing students' critical thinking skills, especially their ability to analyze and evaluate. The findings of this study may be used as evidence of PBL being a more effective method than traditional/conventional learning techniques for increasing students' critical thinking.

1. Background

Nurses are the most significant component of the healthcare environment and have a major role in healthcare provision, favorable health outcomes, and care promotion (Considine et al., 2021; Rivaz et al., 2017). Nurses must develop critical thinking skills in order to be competent in flexible, personalized, and situation-specific problem-solving in today's healthcare environment, which is marked by rapid change and ever-increasing information (Ahmady and Shahbazi, 2020). This means that nurse education must prepare nursing students to handle patients' needs, function as leaders, develop scientific rigor in their practice to benefit patients, and make judgments based on critical thinking (Fawaz et al., 2018; Wong and Kowitlawakul, 2020). Several educational strategies can be used to develop the critical thinking and problem-solving abilities of nursing students, including team-based learning (Alberti et al., 2021; Ulfa et al., 2021), concept mapping (Kaddoura et al., 2016), case studies (Seshan et al., 2021), and problem-based learning (PBL) (Song, 2020).

Problem-based learning is a student-centered method and strategy that allows nursing students to collaborate in small groups with the goal of improving their clinical skills and cognitive capacities (Jamshidi et al., 2021a, 2021b; Owen, 2019). It allows students to actively participate, interact with peers in small groups to define learning goals, engage in self-study, discuss and apply new knowledge, and eventually integrate a variety of material during the learning process (Savin-Baden, 2016; Yew and Goh, 2016). This teaching method also improves self-directed learning, self-confidence, teamwork, and students' communication abilities, as well as self-assessment, peer evaluation skills, critical thinking, and interpersonal skills (Demirören et al., 2016; Mohamed et al., 2017). Furthermore, this method enables nursing students to solve problems and improve critical thinking through scientific and clinical scenarios, as well as being an effective and enjoyable teaching strategy

---

for nursing educators (Gholami et al., 2016; Rao, 2019).

Critical thinking is a term used by educators to describe the process of clarifying, simplifying, organizing, and rationalizing ideas (Farrelly and Linse, 2019). It comprises various fundamental elements, such as seeking for and grasping relevant information, making links between knowledge, reasoning, and cognitive inclinations, self-confidence, and investigating different frames of reference (Fero et al., 2010). The development of critical thinking, problem-solving ability, and self-directed learning, including self-efficacy and self-confidence, are the main goals of PBL (Lee, 2020; Song, 2020). According to the majority of studies, PBL is a method of connecting theoretical learning with real-world clinical problems (Li et al., 2020; Liu et al., 2020). This combination is viewed as a vital foundation for the clinical reasoning of health practitioners. In addition, the capacity to engage in self-directed learning is critical to the performance of healthcare provider students, especially nursing students, in college and after graduation and employment in the healthcare area (Ali, 2019; Da Silva et al., 2018).

Several systematic studies have been conducted to assess the effect of PBL on nurse education, but the conclusions require further investigation (Kong et al., 2014; Li et al., 2019; Sayyah et al., 2017; Yuan et al., 2008b). For example, a 2014 review study showed that PBL increased critical thinking in nursing students compared to traditional training; nevertheless, the number of papers included in the study ($n = 3$) was insufficient, and more recent intervention studies are needed to make more rigorous conclusions (Kong et al., 2014). Moreover, a theoretical framework is necessary to analyze the effectiveness of PBL in nursing instruction, but the previous study used a mixed-model method of teaching based on PBL and lectures (Sayyah et al., 2017). However, the question remains whether PBL has a greater impact than other instructional strategies on the development of related outcomes for nursing students. Furthermore, two previous review studies only reported descriptive findings due to lack of data in the studies used to perform pooled analysis (Li et al., 2019; Yuan et al., 2008b). In addition, there is growing concern in nurse education about the pedagogical method that could increase the quality of learning of nursing students. Such a method will encourage nursing students to learn and develop a lifelong respect for the learning environment. Thus, the purpose of this study was to determine the effectiveness of PBL in nursing students, including recent trials that have been conducted.

2. Materials and methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) were used to conduct this systematic review and as meta-analytical standards (Supplementary Document 3) (Page et al., 2021). This study was registered on the International Prospective Register of Systematic Reviews (PROSPERO; CRD42022326839).

2.1. Search strategy

A search method was created to find relevant material for Academic Search Complete, CINAHL, Cochrane Library, EMBASE, MEDLINE, PubMed, and Web of Science databases from their establishment until March 3, 2022. A professional librarian supported the authors in establishing the search technique and MeSH terms. The following MeSH terms: Nurs* students; ab OR nurs*education; ab OR nurs*; ab OR undergraduate student nurs*; ab OR pre-licensure nurs*; ab OR nursing diploma; ab AND Problem-based learning; ab OR PBL; ab OR problem based learning in nursing; ab OR problem-based approach; ab OR problem-solving; ab AND Randomized controlled trial; ab OR RCT; ab OR randomized control* trial; ab OR randomized; ab OR randomization; ab OR quasi-experiment stud; ab OR, experimental study; ab (Supplementary Document 1). A summary of the search strategy is presented in Supplementary Document 1.

2.2. Eligibility criteria and study selection

To construct inclusion criteria, the Population, Intervention, Comparison, Outcomes, and Study (PICOS) approach was employed (Amir-Behghadami and Janati, 2020). The population comprised nursing students. Trials with a PBL intervention were included; they used a quasi-experimental design or were randomized controlled trials. In addition, only studies published in the English language were included. Studies that did not meet the PICOS criteria or were not available as a full article were excluded. Additionally, duplicate articles were found by comparing the search results across the database, focusing on the title, publication year, and author name. The titles and abstracts of all papers were reviewed independently by two authors (SS and DET) following PICOS. Study eligibility was reported using the PRISMA flow diagram, and the authors independently selected each study, retrieving the complete texts for those that passed the first level of screening. Data extraction was performed in duplicate by two authors (SS and DET) for each publication after a full-text examination of the publication. Based on a comparison of the records of the authors, mutual consensus was used to reach an agreement. A third author (IDS) was consulted to resolve all disagreements.

2.3. Data extraction

Two authors (IDS and SS) discussed and decided on data extraction using an Excel spreadsheet with a bespoke format. The following information was extracted: author and year of publication of study; country; study design; participant information, including total number, total number of females in intervention and control groups, and the university year of the participant; intervention types in both groups; frequency or duration of intervention; duration of follow-up; and outcomes.

2.4. Risk of bias in assessment

This study employed a methodological assessment based on an evaluation quality scale to limit the possibility of bias in the studies selected depending on study design (Ma et al., 2020). Each study was examined independently by two authors (IDS and SS) using the JBI (Joanna Briggs Institute) approach to quasi-experimental studies. For each study, the JBI Critical Appraisal Checklist was used to assess the methodological quality, with scores ranging from high risk to low risk of bias (Buccheri and Sharifi, 2017; Morgan et al., 2016). The response to each question in the 12-item questionnaire was graded on a scale of 0 (high risk of bias) and 1 (low risk of bias), with ≤6 points indicating low quality and > 6 points indicating high quality. This review evaluated the methodological quality of the randomized controlled studies included in this review using RoB-2 with five domains, the revised tool for assessing risk of bias in randomized trials (Sterne et al., 2019). Risk of bias was assessed for (a) the randomization procedure, (b) the recruitment time, (c) changes from the intended treatments, (d) missing outcome data, and (e) reported findings. A risk of bias was assigned to each dimension based on three levels: low, unclear, and high. A mutual consensus was reached based on the comparison of the methodological assessment results of each author. A third author (IDS) was consulted in order to resolve all differences.

2.5. Statistical analysis

The standardized mean difference (SMD) with a 95 % confidence interval (CI) was calculated when various scales were used to measure the same outcome in the trials included in the meta-analysis (Andrade, 2020; Murad et al., 2019). As a result, before estimating the effect size (Cohen's d), the reviewers estimated the raw mean difference and standard deviation of the intervention group and control group. Furthermore, the pooled standardized mean differences (SMD) for

critical thinking, problem-solving, and self-confidence were calculated using a random-effects model. The heterogeneity of each variable in the pooled estimate was demonstrated for a random-effects model by Q and I^2. For I^2, a score of 25 %–49 % indicated low heterogeneity, 50 %–74 % moderate heterogeneity, and > 75 % severe heterogeneity (Higgins and Thompson, 2002). The data were displayed using a forest plot. Furthermore, publication bias was evaluated using visual funnel plots and Egger's regression test (Egger et al., 1997). Stata 16.0 was used for the statistical analyses.

3. Results

3.1. Study selection

Seven databases yielded a total of 1253 studies. Using Endnote's Find Duplicates feature, 630 studies were deleted. As a result, we screened a total of 623 studies for title and abstract and found 26 studies, which we then reviewed in full for eligibility. A total of 17 articles were excluded because they were not original research ($n = 11$), the intervention did not apply PBL ($n = 4$), or the published study was not in English ($n = 2$). We finally obtained and examined 16 studies, with an additional four studies from Google Scholar and three studies identified from a previous review (Choi et al., 2014; Choi, 2004; Choi and Ahn, 2021; Gholami et al., 2016; HASAnPour-DeHKorDi and SolAti, 2016; Hassanpour
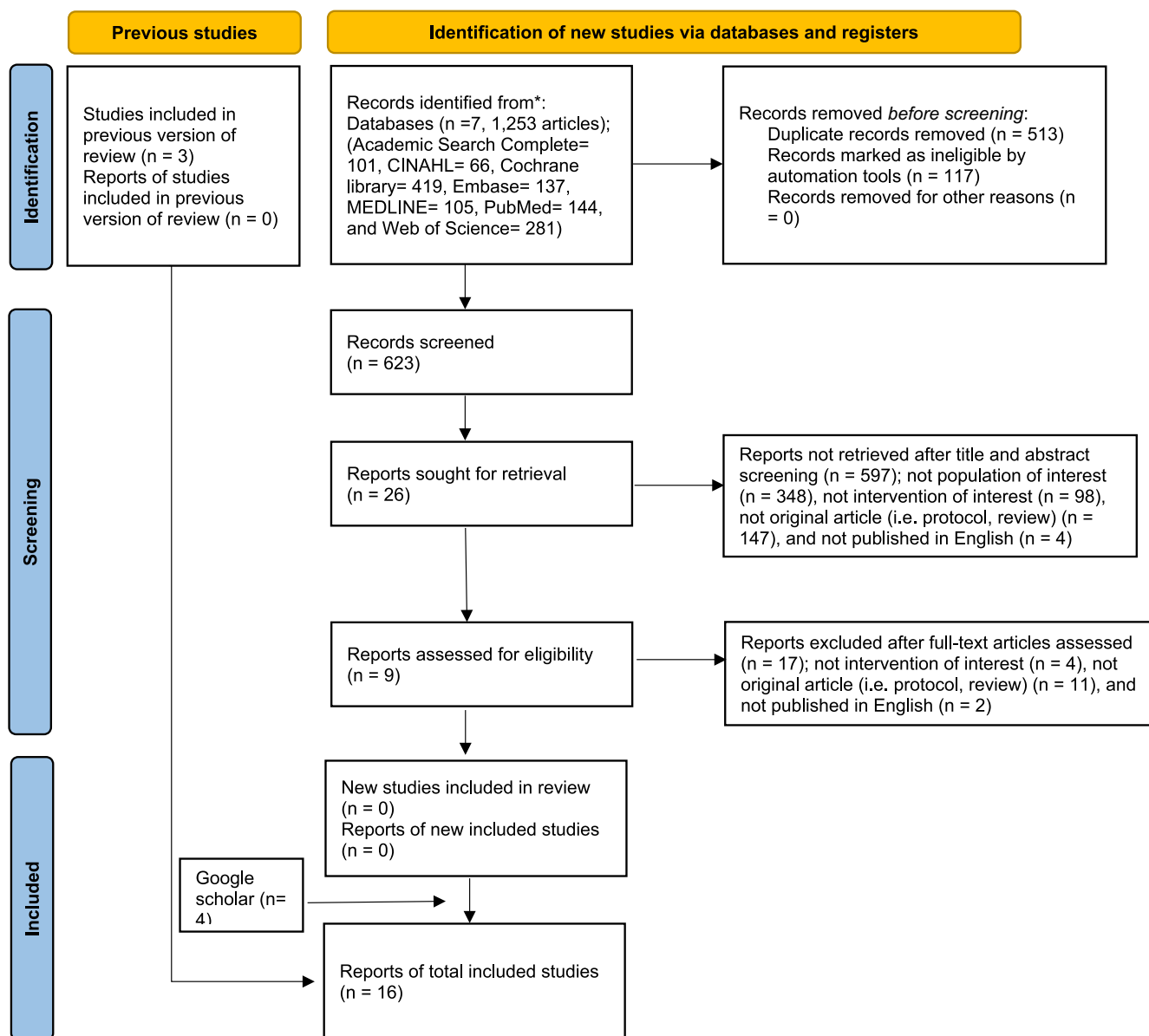
Fig. 1. PRISMA flowchart diagram
*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).
**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.
From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: https://doi.org/10.1136/bmj.n71
For more information, visit: http://www.prisma-statement.org/

Dehkordi and Heydarnejad, 2008; Jamshidi et al., 2021a, 2021b; Kang et al., 2015; Lee and Son, 2021; Moradi and Taghadosi, 2016; Penjvini and Shahsawari, 2013; Safa et al., 2021; Tiwari et al., 2006; Tseng et al., 2011; Yu et al., 2013; Yuan et al., 2008a). A summary of study selection is presented in Fig. 1.

3.2. Characteristics of studies

All studies took place between 2004 and 2021. Iran conducted seven studies, South Korea five, China three, and Taiwan one. The total number of nursing students that took part in the 16 studies was 1143. The intervention and control groups varied in age from 18.67 to 22.95 years old and 18.57 to 23.26 years old, respectively. The 16 studies included nursing students in first to final (fourth) year of university. Furthermore, the PBL method adopted was integrated with clinical scenarios, case-based learning, or learning content. The intervention was given once a week for 10 min to 2 h for a period of 3 to 32 weeks. The length of follow-up in all trials included in the analysis was measured from baseline to post-intervention. A summary of study characteristics is presented in Table 1.

3.3. Risk of bias in studies

Overall, all of the studies assessed were considered to have a low risk of bias (Supplementary Document 2 and Table 2). An analysis of the five domains of the RoB-2 instrument and the nine-item JBI Critical Appraisal Checklist for quasi-experimental studies found a potentially high risk of bias originating from the randomization technique due to (a) a lack of treatment concealment and blinding of treatment to participants, (b) a therapist delivering the intervention, and (c) an assessor.

3.4. Effects of PBL on nursing students' learning skills

3.4.1. Critical thinking

Eight studies used the Critical Thinking Ability Scale for College Students (Choi et al., 2014), the California Critical Thinking Skills Test (Choi and Ahn, 2021; Gholami et al., 2016; Lee and Son, 2021; Moradi and Taghadosi, 2016; Safa et al., 2021; Yuan et al., 2008a), or the Critical-Thinking Scale (Tseng et al., 2011). The weighted pooled SMD was 0.44 (confidence interval [CI]: 0.14–0.73, $I^2 = 65.56$ %, $p < .001$), indicating that the PBL group showed greater improvement in critical thinking compared to the control group. A forest plot is shown in Fig. 2.1. Egger's test yielded a non-significant result ($t = 2.84$, $p = .294$). Furthermore, the subscales of critical thinking, i.e., analysis and evaluation abilities, were analyzed. The pooled SMD of analysis and evaluation was 0.72 (CI: 0.84–1.25, $I^2 = 74.56$ %, $p = .01$) and 0.33 (CI: 0.05–0.61, $I^2 = 0.00$ %, $p = .02$), respectively, indicating that in terms of analytical and evaluation ability, the nursing student group that undertook PBL showed greater improvement than the control group. The forest plots for the two groups are displayed in Figs. 2.2 and 2.3, respectively.

3.4.2. Problem-solving

Three studies were pooled to generate data for problem-solving of nursing students; one study used the Problem-Solving Scale for College Students (Choi et al., 2014) and another used the Problem-Solving Skill Measurement (Choi and Ahn, 2021), whereas one study did not provide the scale (Choi, 2004). The weighted pooled SMD was 0.25 (CI: −0.02–0.52, $I^2 = 0.00$ %, $p = .07$). The forest plot is shown in Fig. 2.4. Egger's test yielded a non-significant result ($t = 0.30$, $p = .817$).

3.4.3. Self-confidence

Three studies were pooled to generate data for the self-confidence of nursing; the three studies used the Numeric Rating Scale (Lee and Son, 2021), the California Critical Thinking Disposition Inventory (Tiwari et al., 2006), or the California Critical Thinking Disposition Inventory

Chinese Version (Yu et al., 2013). The weighted pooled SMD was 0.31 (CI: −0.02–0.65, $I^2 = 47.20$ %, $p = .07$). The forest plot is shown in Fig. 2.5. Egger's test yielded non-significant results ($t = 0.79$, $p = .574$).

4. Discussion

This meta-analysis investigated the efficacy of PBL in enhancing nursing students' learning. The pooled analysis found that PBL was more effective than traditional learning in promoting critical thinking, including the ability to analyze and evaluate, in this population. This meta-analysis strengthens the conclusions of studies conducted over the past decade which demonstrated that PBL is highly effective and contributes positively to the development, promotion, and improvement of nursing students' critical thinking and problem solving abilities (Kong et al., 2014; Oliveira et al., 2016; Song and Park, 2020). According to only two studies (Choi, 2004; Yuan et al., 2008b), PBL is not associated with improvements in critical thinking among nursing students. It is important to note that all studies that found a significant effect of PBL were published within the past decade, while those that found no significant effect were published more than a decade ago. According to Hung et al. (2019), this phenomenon appears in three phases over the years 1990s, 2000s, and 2010s. Furthermore, the investigation of the effects of PBL on self-confidence in nursing students may be regarded as a novel finding that has not been previously published in prior systematic reviews or meta-analyses (Kong et al., 2014; Li et al., 2019; Sayyah et al., 2017; Song and Park, 2020; Yuan et al., 2008b).

Problem-based learning is a comprehensive teaching and learning method for mastery of knowledge, skills, and attitudes and uses real-life situations to identify patient problems and the necessary solutions (Jeon and Park, 2021). In PBL, students face a situation or problem that encourages them to apply the knowledge they already have and are stimulated to think of new solutions (Kong et al., 2014). This process trains students to think critically by shifting the learning process from memorizing abstract scientific concepts to gaining implementable knowledge, from passive to active learning to seek knowledge, and from individually developing understanding to collaboratively sharing knowledge with others (Hung et al., 2019).

In contrast to nursing students' critical thinking skills, their problem-solving skills are not significantly affected by PBL. A recent meta-analysis reported a similar finding that emphasized that students' problem-solving skills do not change after PBL (Park et al., 2015; Song and Park, 2020). Our results are in contrast to a previous PBL study that stated that participants who take part in PBL have better problem-solving abilities (Uys et al., 2004). However, Uys et al. (2004) studied graduate nurses, whereas our study included only undergraduates. Problem-solving skills are complex, take time to acquire, and involve comprehensive cognitive, attitudinal, and behavioral processes (Kanbay and Okanlı, 2017). Therefore, the characteristics of PBL participants can be a factor that affects the level of problem-solving skills gained. Graduate nurses have an advantage in that they have greater experience in cognitive, attitudinal, and behavioral development, whereas in this study, all participants were nursing students. PBL alone does not significantly affect the problem-solving skills of nursing students; therefore, additional strategies are needed for inexperienced students. Some studies have reported that a modified PBL structure with sessions on problem-solving skills improves these skills of nursing students (Ahmady and Shahbazi, 2020; Lin et al., 2022).

The PBL environment facilitates students to learn to be more independent and comfortable with expressing their thoughts without fear, leading to increased self-confidence. Our results confirmed that there is no significant relationship between PBL and self-confidence. Confidence is achieved when nurses can use their critical thinking skills to solve a problem (Lee and Son, 2021; Song, 2014). The absence of problem-solving skills in this study might affect students' self-confidence and ability to develop their critical thinking. Self-confidence is rarely considered a target of the PBL method; only a few studies have measured

Table 1
Summary of included studies.

No	Author, year/country	Study design	Participants				Intervention types		Frequency/duration of intervantion	Follows-up length (month)	Outcomes
			Total (n)	Female (IG/CG)	Mean age (IG/CG)	Grade (IG/CG)	Intervention group	Control group			
1	E. Choi, Lindquist, & Song, 2014/ South Korea	Quasi-experimental	90	38/44	18.67/18.57	First year	Received learning packages with clinical scenario	Received traditional learning	Once a week for 2 h/ 16 weeks	Baseline and immediate post intervention	Critical thinking, problem solving, self-directed learning
2	H. Choi, 2004/ South Korea	Quasi-experimental	76	NA	NA	NA	Received learning packages with clinical scenario	Received traditional learning	Once a week for 2 h/ 16 weeks	Baseline and immediate post intervention	Metacognition, critical thinking (total, analysis, inference, evaluation, induction, deduction), problem solving (total, finding problems, defining problems, developing solutions, applying solutions, evaluating)
3	H. G. Choi and Ahn, 2021/ South Korea	Quasi-experimental	48	22/21	NA	Senior Nursing studens	Received learning packages with delivering learning content	Received No intervention	Once a week for 90 min/ 32 weeks	Baseline and immediate post intervention	Communication ability, problem solving ability, subjective conflict resolution ability, and objective conflict resolution ability
4	Gholami et al., 2016/ Iran	Quasi-experimental	40	25	NA	NA	Received learning packages with PBL	Received traditional learning	Once a week for 2 h/ 8 week	Baseline and immediate post intervention	Metacognition, critical thinking (total, analysis, inference, evaluation, induction, deduction)
5	HASAnPour-DeHKorDi and SolAti, 2016/ Iran	RCT	48	24	NA	Senior Nursing studens	Received learning packages with case-based learning and collaborative training	Received traditional learning	NA	Baseline and immediate post intervention	Respect, responsibility, communication skills, self-awareness and self-evaluation, critical thinking
6	Hassanpour Dehkordi and Heydarnejad, 2008/ Iran	Quasi-experimental	40	NA	NA	Second-year nursing students	Received problem-based learning (PBL) following constructive learning	Received traditional learning	NA	Baseline and immediate post intervention	Analysis, inference, evaluation
7	Jamshidi et al., 2021b/ Iran	RCT	78	19/23	22.95/23.26	Fourth-year nursing students	Received problem-based learning (PBL) based education	Received traditional learning	NA	Baseline and immediate post intervention	Knowledge, attitude, perception
8	Kang et al., 2015/ South Korea	Quasi-experimental	205	NA	NA	NA	Received problem-Based Learning (PBL)	Received lecturer based instruction	NA	Baseline and immediate post intervention	Knowledge
9	Lee and Son, 2021/ South Korea	Quasi-experimental	105	41/44	22.54/22.08	Third-year nursing students	Received problem-Based Learning (S-PBL)	Received demonstration based learning	10 min/6 week	Baseline and immediate post intervention	Self-confidence, learner satisfaction, critical thinking
10	Moradi and Taghadosi, 2016/ Iran	RCT	36	44,877	20.94/20.59	NA	Received problem-based clinical education	Conventional clinical education	40 min/ 12 week	Baseline and immediate post intervention	Critical thinking
11	Penjvini and Shahsawari, 2013/ Iran	Quasi-experimental	29	NA	NA	The fourth and fifth semester nursing students	Received problem-based learning	Received lecture based learning	3 h/3 week	Baseline and immediate post intervention	Knowledge and behavior
12	Safa et al., 2021/ Iran	RCT	27	NA	22.07/21.54	Third year nursing students	Received problem-based learning	Received traditional learning	NA	Baseline and immediate post intervention	Critical thinking
13	Tiwari et al., 2006/ China	RCT	79	NA	NA	NA	Received problem-based learning	Received lecture based learning	NA	Baseline and immediate post intervention	Critical thinking (total, truth seeking, open mindness, self-confidence, inquisitiveness, cognitive maturity)
14	Tseng et al., 2011/ Taiwan	Quasi-experimental	120	NA	NA	NA	Received problem-based learning	Received lecture based learning	NA	Baseline and immediate post intervention	Critical thinking, self-directed and students performance
15	Yu et al., 2013/ China	RCT	76	1	NA	Second year undergraduate nursing students	Received problem-based learning	Received lecture based learning	NA	Baseline and immediate post intervention	Critical thinking (total, truth seeking, open mindness, analicity, systematically, self-confidence, inquisitiveness, cognitive maturity)
16	Yuan et al., 2008a/ China	Quasi-experimental	46	NA	NA	NA	Received problem-based learning	Received lecture based learning	Once a week for 2 h / 18 weeks	Baseline and immediate post intervention	Critical thinking (total, analysis, inference, evaluation, induction, deduction)

NA (not available).

Table 2
Quality assessment of the included studies of quasi-experimental study.

No	JBI checklist	E. Choi, Lindquist, & Song, 2014	H. Choi, 2004	H. G. Choi & Ahn, 2021	Gholami et al., 2016	Hassanpour Dehkordi & Heydarnejad, 2008
2	Were the participants included in any comparisons similar?	Y	Y	Y	Y	Y
3	Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Y	Y		Y	Y	Y
4	Was there a control group?	Y	Y	Y	Y	Y
5	Were there multiple measurements of the outcome both pre and post the intervention/exposure?	Y	Y	Y	Y	Y
6	Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	N	N	Y	N	N
7	Were the outcomes of participants included in any comparisons measured in the same way?	Y	Y	Y	Y	Y
8	Were outcomes measured in a reliable way?	Y	Y	Y	Y	Y
9	Was appropriate statistical analysis used?	Y	Y	Y	y	y
	Overall appraisal	Include: 8 Exclude: 1	Include: 8 Exclude: 1	Include: 9 Exclude: 0	Include: 8 Exclude: 1	Include: 8 Exclude: 1
	Level of evidence	2.d Pre-test – post-test control group study	2.d Pre-test – post-test control group study	2.d Pre-test – post-test control group study	2.d Pre-test – post-test control group study	2.d Pre-test – post-test control group study

No	JBI checklist	Kang, Kim, Kim, Oh, & Lee, 2015	Lee & Son, 2021	Penjvini & Shahsawari, 2013	Tseng et al., 2011	Yuan, Kunaviktikul, Klunklin, & Williams, 2008
1	Is it clear in the study what is the 'cause' and what is the 'effect' (i.e. there is no confusion about which variable comes first)?	Y				
2	Were the participants included in any comparisons similar?	Y	Y	Y	Y	Y
3	Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Y	Y	Y	Y	Y
4	Was there a control group?	Y	Y	Y	Y	Y
5	Were there multiple measurements of the outcome both pre and post the intervention/exposure?	Y	Y	Y	Y	Y
6	Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?	Y	N	UC	y	Y
7	Were the outcomes of participants included in any comparisons measured in the same way?	Y	Y	Y	Y	Y
8	Were outcomes measured in a reliable way?	Y	Y	Y	Y	Y
9	Was appropriate statistical analysis used?	y	y	y	y	Y
	Overall appraisal	Include: 9 Exclude: 0	Include: 8 Exclude: 1	Include: 8 Exclude: 1	Include: 9 Exclude: 0	Include: 9 Exclude: 0
	Level of evidence	2.d Pre-test – post-test control group study	2.d Pre-test – post-test control group study	2.d Pre-test – post-test control group study	2.d Pre-test – post-test control group study	2.d Pre-test – post-test control group study

this variable. Our study found only one instance of a significant increase in self-confidence due to specific simulation and demonstration interventions during PBL, similar to results of PBL studies in specific nursing courses such as pediatric and maternity nursing (Salari et al., 2018; Son, 2020). The development of self-confidence through PBL simulations has high potential because the focus of learning is on one specific competency. Students have a positive impression of simulation as a learning tool because they found the experience satisfactory and gained in self-confidence (Zapko et al., 2018).
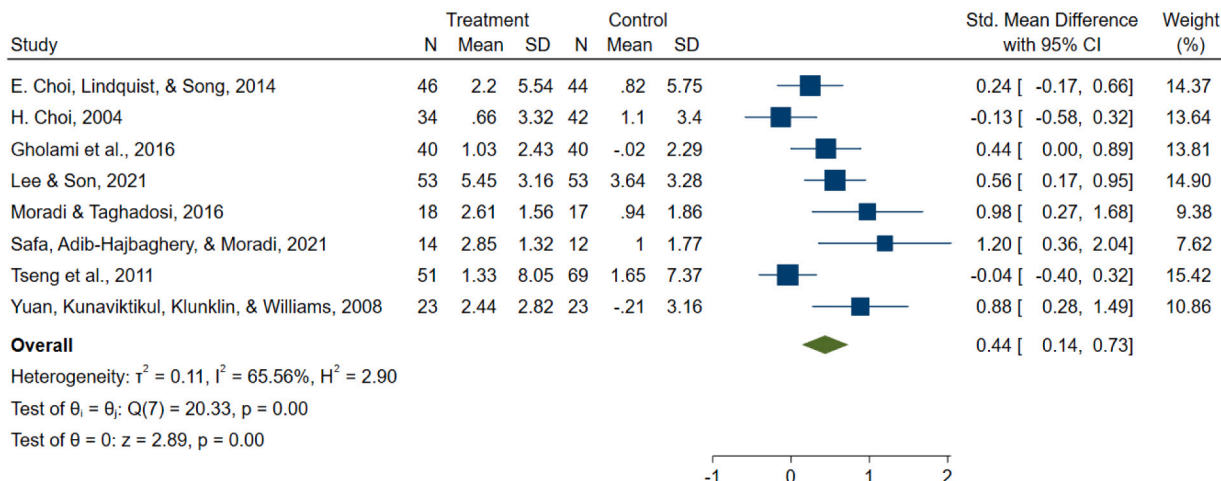
This meta-analysis strengthens the view that PBL is superior to traditional/conventional learning methods and significantly increases students' critical thinking. PBL can be used with first- and final-year nursing students with minimal frequency and duration, e.g., at least once a week, 10 min per session for three weeks. These findings align with the results of previous meta-analyses on the effectiveness of PBL in nurse education from across the globe (Lopes et al., 2020; Oliveira et al., 2016). Moreover, PBL is applied not only in the field of nursing but also in medicine, engineering, financial mathematics, accounting, computing, etc. (Ku and Ha, 2016). PBL is practical and appropriate for teaching and learning, and meets the restrictions imposed after the

COVID-19 pandemic era. In PBL, students are more independent; they are no longer instructor-led learners but become active thinkers and problem-solvers (Ku and Ha, 2016; Sharma et al., 2020). Recent studies have reported that online PBL promotes students' deep active learning, self-directed learning, and problem-solving (Hung and Amida, 2020; Wong and Kan, 2022).

The importance of PBL in nurse education is clearly demonstrated in this current study. The application of PBL in the undergraduate nursing curriculum can be expanded by appropriately modifying the evaluation questions to match the clinical situation and enhance favorable outcomes for nursing students. In light of the extensive use of PBL in nurse education around the world, as well as in nursing programs, experts believe that it may be able to bridge the gap between theory and practice (Dolmans, 2019; Salari et al., 2018). The use of PBL in nursing programs requires the inclusion of additional instructors and nurse educators. Therefore, more nursing graduates are required, as well as appropriate skills as teachers or nurse educators who assist in the facilitation of the learning process (Jamshidi et al., 2021a, 2021b; Yang and Yang, 2013).
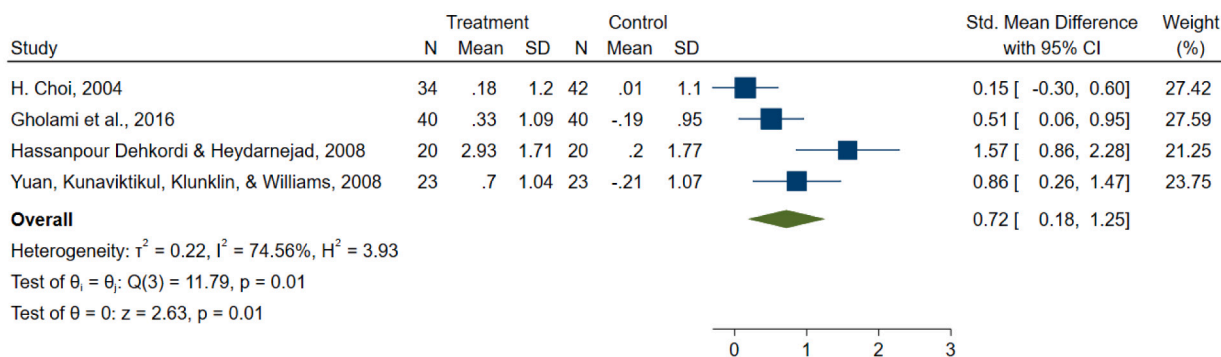
However, our study has some limitations. First, all the studies we used in the meta-analysis were from Asian countries. Therefore, our
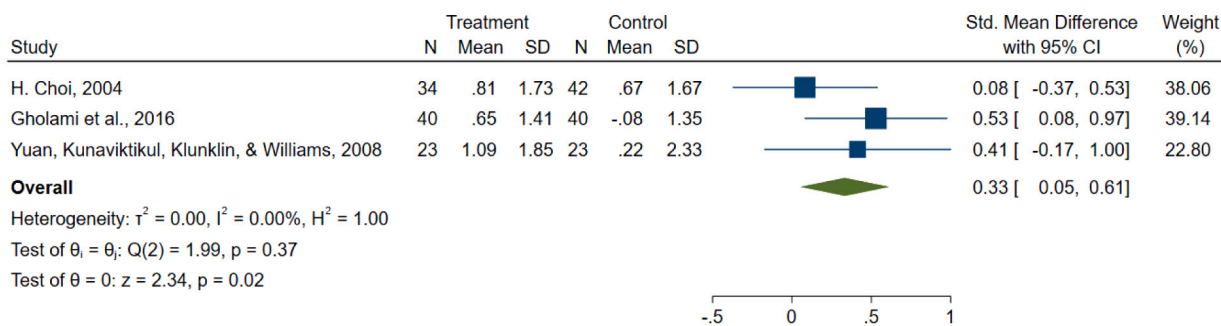
2.1 Critical Thinking

Study	Treatment N	Mean	SD	Control N	Mean	SD	Std. Mean Difference with 95% CI	Weight (%)
E. Choi, Lindquist, & Song, 2014	46	2.2	5.54	44	.82	5.75	0.24 [-0.17, 0.66]	14.37
H. Choi, 2004	34	.66	3.32	42	1.1	3.4	-0.13 [-0.58, 0.32]	13.64
Gholami et al., 2016	40	1.03	2.43	40	-.02	2.29	0.44 [0.00, 0.89]	13.81
Lee & Son, 2021	53	5.45	3.16	53	3.64	3.28	0.56 [0.17, 0.95]	14.90
Moradi & Taghadosi, 2016	18	2.61	1.56	17	.94	1.86	0.98 [0.27, 1.68]	9.38
Safa, Adib-Hajbaghery, & Moradi, 2021	14	2.85	1.32	12	1	1.77	1.20 [0.36, 2.04]	7.62
Tseng et al., 2011	51	1.33	8.05	69	1.65	7.37	-0.04 [-0.40, 0.32]	15.42
Yuan, Kunaviktikul, Klunklin, & Williams, 2008	23	2.44	2.82	23	-.21	3.16	0.88 [0.28, 1.49]	10.86
Overall							0.44 [0.14, 0.73]	

Heterogeneity: $\tau^2 = 0.11$, $I^2 = 65.56\%$, $H^2 = 2.90$

Test of $\theta_i = \theta_j$: $Q(7) = 20.33$, $p = 0.00$

Test of $\theta = 0$: $z = 2.89$, $p = 0.00$

Random-effects DerSimonian-Laird model

2.2 Critical thinking' subscale; Analysis

Study	Treatment N	Mean	SD	Control N	Mean	SD	Std. Mean Difference with 95% CI	Weight (%)
H. Choi, 2004	34	.18	1.2	42	.01	1.1	0.15 [-0.30, 0.60]	27.42
Gholami et al., 2016	40	.33	1.09	40	-.19	.95	0.51 [0.06, 0.95]	27.59
Hassanpour Dehkordi & Heydarnejad, 2008	20	2.93	1.71	20	.2	1.77	1.57 [0.86, 2.28]	21.25
Yuan, Kunaviktikul, Klunklin, & Williams, 2008	23	.7	1.04	23	-.21	1.07	0.86 [0.26, 1.47]	23.75
Overall							0.72 [0.18, 1.25]	

Heterogeneity: $\tau^2 = 0.22$, $I^2 = 74.56\%$, $H^2 = 3.93$

Test of $\theta_i = \theta_j$: $Q(3) = 11.79$, $p = 0.01$

Test of $\theta = 0$: $z = 2.63$, $p = 0.01$

Random-effects DerSimonian-Laird model

2.3 Critical thinking'subscale; Evaluation

Study	Treatment N	Mean	SD	Control N	Mean	SD	Std. Mean Difference with 95% CI	Weight (%)
H. Choi, 2004	34	.81	1.73	42	.67	1.67	0.08 [-0.37, 0.53]	38.06
Gholami et al., 2016	40	.65	1.41	40	-.08	1.35	0.53 [0.08, 0.97]	39.14
Yuan, Kunaviktikul, Klunklin, & Williams, 2008	23	1.09	1.85	23	.22	2.33	0.41 [-0.17, 1.00]	22.80
Overall							0.33 [0.05, 0.61]	

Heterogeneity: $\tau^2 = 0.00$, $I^2 = 0.00\%$, $H^2 = 1.00$

Test of $\theta_i = \theta_j$: $Q(2) = 1.99$, $p = 0.37$

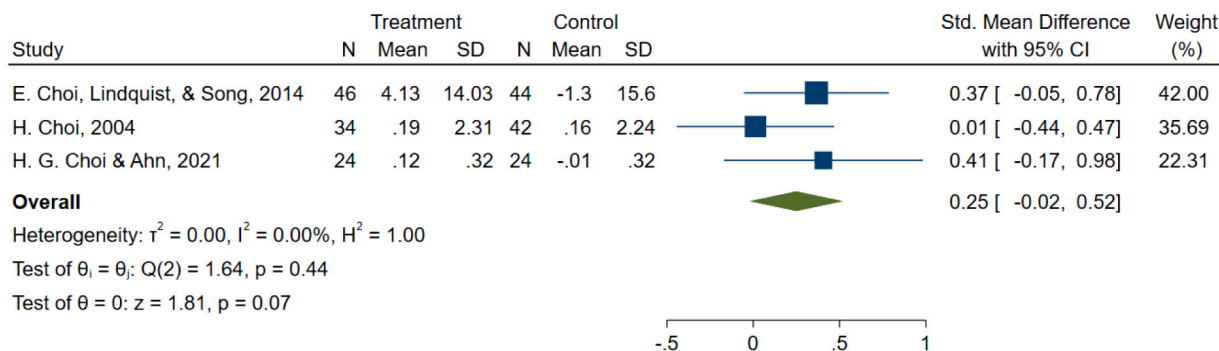Test of $\theta = 0$: $z = 2.34$, $p = 0.02$

Random-effects DerSimonian-Laird model

Fig. 2. Forest plot of effectiveness of problem-based learning for nursing students.

findings might not be generalizable to other countries outside Asia due to different characteristics of teaching and learning. Half of the studies included came from one country, i.e., Iran (seven out of the 16 studies). Therefore, future studies should use larger samples from diverse locations. Second, our s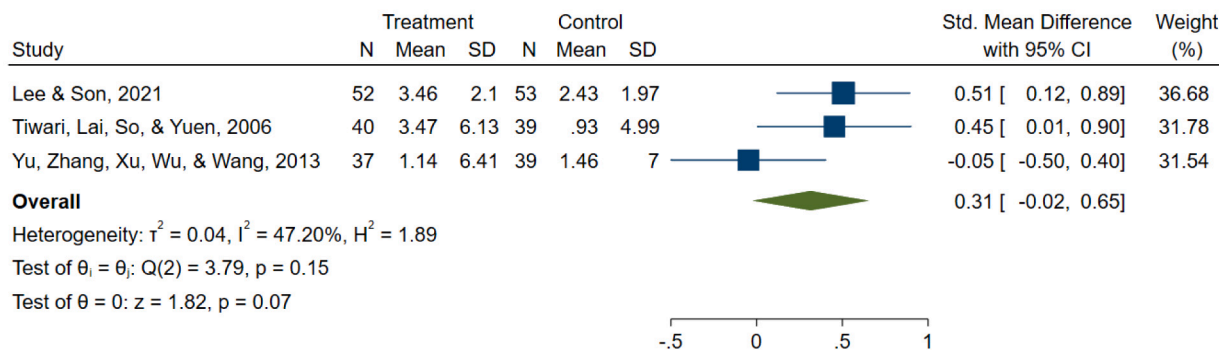tudy looked at only a limited number of learning outcomes, i.e., critical thinking, problem-solving, and self-confidence, while there are many potential outcomes of PBL methods, such as self-directed learning, self-awareness, communication skills, active participation, learning motivation, learning score, learning satisfaction, self-evaluation, responsibility, performance, truth-seeking, and analytical

2.4 Problem solving

Study	Treatment N	Mean	SD	Control N	Mean	SD	Std. Mean Difference with 95% CI	Weight (%)
E. Choi, Lindquist, & Song, 2014	46	4.13	14.03	44	-1.3	15.6	0.37 [-0.05, 0.78]	42.00
H. Choi, 2004	34	.19	2.31	42	.16	2.24	0.01 [-0.44, 0.47]	35.69
H. G. Choi & Ahn, 2021	24	.12	.32	24	-.01	.32	0.41 [-0.17, 0.98]	22.31
Overall							0.25 [-0.02, 0.52]	

Heterogeneity: $\tau^2 = 0.00$, $I^2 = 0.00\%$, $H^2 = 1.00$

Test of $\theta_i = \theta_j$: Q(2) = 1.64, p = 0.44

Test of $\theta = 0$: z = 1.81, p = 0.07

Random-effects DerSimonian-Laird model

2.5 Self-confidence

Study	Treatment N	Mean	SD	Control N	Mean	SD	Std. Mean Difference with 95% CI	Weight (%)
Lee & Son, 2021	52	3.46	2.1	53	2.43	1.97	0.51 [0.12, 0.89]	36.68
Tiwari, Lai, So, & Yuen, 2006	40	3.47	6.13	39	.93	4.99	0.45 [0.01, 0.90]	31.78
Yu, Zhang, Xu, Wu, & Wang, 2013	37	1.14	6.41	39	1.46	7	-0.05 [-0.50, 0.40]	31.54
Overall							0.31 [-0.02, 0.65]	

Heterogeneity: $\tau^2 = 0.04$, $I^2 = 47.20\%$, $H^2 = 1.89$

Test of $\theta_i = \theta_j$: Q(2) = 3.79, p = 0.15

Test of $\theta = 0$: z = 1.82, p = 0.07

Random-effects DerSimonian-Laird model

Fig. 2. (*continued*).

ability (HASAnPour-DeHKorDi and SolAti, 2016; Lee and Son, 2021). Third, half of the included studies considered did not provide detailed information on the frequency and duration of PBL interventions; therefore, this study cannot offer definitive and ideal recommendations for implementing PBL in nurse education. Additionally, we discovered that some trials included in the current study lacked adequate methodological quality, such as lack of treatment concealment and blinding of participants and assessors. As a result, both subjects and assessors may be affected by this factor. Therefore, better methodological quality is recommended in order to reduce bias in the results.

5. Conclusion

This study suggests that PBL is beneficial because it promotes critical thinking in nursing students, including the ability to analyze and evaluate. Well-established PBL has the ability to increase critical thinking in nurse education. However, the impact of PBL on problem-solving skills and self-confidence need further examination. Furthermore, more rigorous randomized controlled trials on the influence of PBL on potential outcomes (i.e., improved communication skills, learner satisfaction, metacognition, and self-directed learning) are needed. In addition, investigations on the long-term impacts of PBL in nurse education are also necessary.

CRediT authorship contribution statement

Study conception and design: SS, IDS, FHC
Data collection: SS, IDS

Data analysis and interpretation: SS, IDS, DET
Drafting of the article: SS, IDS
Critical revision of the article: All authors

Clinical resources

- PROSPERO (york.ac.uk)
- PRISMA (prisma-statement.org)

Declaration of competing interest

No conflicts of interest to declare.

Data availability

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.nedt.2022.105631.

References

Ahmady, S., Shahbazi, S., 2020. Impact of social problem-solving training on critical thinking and decision making of nursing students. BMC Nurs. 19 (1), 94. https://doi.org/10.1186/s12912-020-00487-x.

Alberti, S., Motta, P., Ferri, P., Bonetti, L., 2021. The effectiveness of team-based learning in nursing education: a systematic review. Nurse Educ. Today 97, 104721. https://doi.org/10.1016/j.nedt.2020.104721.

Ali, S.S., 2019. Problem based learning: a student-centered approach. Engl. Lang. Teach. 12 (5), 73–78.

Amir-Behghadami, M., Janati, A., 2020. Population, intervention, comparison, outcomes and study (PICOS) design as a framework to formulate eligibility criteria in systematic reviews. Emerg. Med. J. 37 (6), 387. https://doi.org/10.1136/emermed-2020-209567.

Andrade, C., 2020. Mean difference, standardized mean difference (SMD), and their use in meta-analysis: as simple as it gets. J. Clin. Psychiatry 81 (5). https://doi.org/10.4088/JCP.20f13681.

Buccheri, R.K., Sharifi, C., 2017. Critical appraisal tools and reporting guidelines for evidence-based practice. Worldviews Evid.-Based Nurs. 14 (6), 463–472. https://doi.org/10.1111/wvn.12258.

Choi, H., 2004. The effects of PBL (Problem-based Learning) on the metacognition, critical thinking, and problem solving process of nursing students. J. Korean Acad. Nurs. 34 (5), 712–721.

Choi, H.G., Ahn, S.H., 2021. Effects of a conflict resolution training program on nursing students: a quasi-experimental study based on the situated learning theory. Nurse Educ. Today 103, 104951. https://doi.org/10.1016/j.nedt.2021.104951.

Choi, E., Lindquist, R., Song, Y., 2014. Effects of problem-based learning vs. Traditional lecture on korean nursing students' critical thinking, problem-solving, and self-directed learning. Nurse Educ. Today 34 (1), 52–56.

Considine, J., Berry, D., Allen, J., Hewitt, N., Oldland, E., Sprogis, S.K., Currey, J., 2021. Team-based learning in nursing education: a scoping review. J. Clin. Nurs. 30 (7–8), 903–917. https://doi.org/10.1111/jocn.15599.

Da Silva, A.B., de Araújo Bispo, A.C.K., Rodriguez, D.G., Vasquez, F.I.F., 2018. Problem-based learning: a proposal for structuring PBL and its implications for learning among students in an undergraduate management degree program. Rev. Gestão 25 (2), 160–177.

Demirören, M., Turan, S., Öztuna, D., 2016. Medical students' self-efficacy in problem-based learning and its relationship with self-regulated learning. Med. Educ. Online 21, 30049. https://doi.org/10.3402/meo.v21.30049.

Dolmans, D.H.J.M., 2019. How theory and design-based research can mature PBL practice and research. Adv. Health Sci. Educ. 24 (5), 879–891. https://doi.org/10.1007/s10459-019-09940-2.

Egger, M., Davey Smith, G., Schneider, M., Minder, C., 1997. Bias in meta-analysis detected by a simple, graphical test. BMJ 315 (7109), 629–634. https://doi.org/10.1136/bmj.315.7109.629.

Farrelly, W., Linse, C., 2019. Learning how to clarify complex concepts for children through naturalistic inquiry: moving beyond simplification. In: Self-Directed Learning Strategies in Adult Educational Contexts. IGI Global, pp. 183–205.

Fawaz, M.A., Hamdan-Mansour, A.M., Tassi, A., 2018. Challenges facing nursing education in the advanced healthcare environment. Int. J. Afr. Nurs. Sci. 9, 105–110. https://doi.org/10.1016/j.ijans.2018.10.005.

Fero, L.J., O'Donnell, J.M., Zullo, T.G., Dabbs, A.D., Kitutu, J., Samosky, J.T., Hoffman, L. A., 2010. Critical thinking skills in nursing students: comparison of simulation-based performance with metrics. J. Adv. Nurs. 66 (10), 2182–2193. https://doi.org/10.1111/j.1365-2648.2010.05385.x.

Gholami, M., Moghadam, P.K., Mohammadipoor, F., Tarahi, M.J., Sak, M., Toulabi, T., Pour, A.H.H., 2016. Comparing the effects of problem-based learning and the traditional lecture method on critical thinking skills and metacognitive awareness in nursing students in a critical care nursing course. Nurse Educ. Today 45, 16–21. https://doi.org/10.1016/j.nedt.2016.06.007.

HASAnPour-DeHKorDi, A., SolAti, K., 2016. The efficacy of three learning methods collaborative, context-based learning and traditional, on learning, attitude and behaviour of undergraduate nursing students: integrating theory and practice. Journal of Clinical and Diagnostic Research 10 (4), VC01.

Hassanpour Dehkordi, A., Heydarnejad, M.S., 2008. The effects of problem-based learning and lecturing on the development of Iranian nursing students' critical thinking. Pak. J. Med. Sci. 24 (5).

Higgins, J.P., Thompson, S.G., 2002. Quantifying heterogeneity in a meta-analysis. Stat. Med. 21 (11), 1539–1558. https://doi.org/10.1002/sim.1186.

Hung, W., Amida, A., 2020. Problem-based learning in college science. In: Active Learning in College Science. Springer, pp. 325–339.

Hung, W., Dolmans, D.H., Van Merriënboer, J.J., 2019. A review to identify key perspectives in PBL meta-analyses and reviews: trends, gaps and future research directions. Adv. Health Sci. Educ. 24 (5), 943–957.

Jamshidi, H., Hemmati Maslakpak, M., Parizad, N., 2021. Does problem-based learning education improve knowledge, attitude, and perception toward patient safety among nursing students? A randomized controlled trial. BMC Nursing 20 (1), 70. https://doi.org/10.1186/s12912-021-00588-1.

Jamshidi, H., Maslakpak, M.H., Parizad, N., 2021. Does problem-based learning education improve knowledge, attitude, and perception toward patient safety among nursing students? A randomized controlled trial. BMC Nursing 20 (1), 9. https://doi.org/10.1186/s12912-021-00588-1.

Jeon, J., Park, S., 2021. Self-directed learning versus problem-based learning in Korean nurse education: a quasi-experimental study. Healthcare (Basel, Switzerland) 9 (12), 1763. https://doi.org/10.3390/healthcare9121763.

Kaddoura, M., Van-Dyke, O., Yang, Q., 2016. Impact of a concept map teaching approach on nursing students' critical thinking skills. Nurs. Health Sci. 18 (3), 350–354. https://doi.org/10.1111/nhs.12277.

Kanbay, Y., Okanlı, A., 2017. The effect of critical thinking education on nursing students' problem-solving skills. Contemp. Nurse 53 (3), 313–321.

Kang, K.-A., Kim, S., Kim, S.-J., Oh, J., Lee, M., 2015. Comparison of knowledge, confidence in skill performance (CSP) and satisfaction in problem-based learning (PBL) and simulation with PBL educational modalities in caring for children with bronchiolitis. Nurse Educ. Today 35 (2), 315–321.

Kong, L.-N., Qin, B., Zhou, Y.-Q., Mou, S.-Y., Gao, H.-M., 2014. The effectiveness of problem-based learning on development of nursing students' critical thinking: a systematic review and meta-analysis. Int. J. Nurs. Stud. 51 (3), 458–469.

Ku, T.K., Ha, M., 2016. The application of problem based learning in undergraduate nursing education: a strategy for curriculum reform. J. Biosci. Med. 4 (6), 52–59.

Lee, O.-S., 2020. The effect of the problem-based learning on critical thinking disposition, academic self-efficacy and self-leadership of nursing students-diagnostic tests and nursing. J. Digit. Converg. 18 (5), 279–285.

Lee, J., Son, H.K., 2021. Comparison of learning transfer using simulation problem-based learning and demonstration: an application of papanicolaou smear nursing education. Int. J. Environ. Res. Public Health 18 (4). https://doi.org/10.3390/ijerph18041765.

Li, Y., Wang, X., Zhu, X.-R., Zhu, Y.-X., Sun, J., 2019. Effectiveness of problem-based learning on the professional communication competencies of nursing students and nurses: a systematic review. Nurse Educ. Pract. 37, 45–55.

Li, X., Xie, F., Li, X., Li, G., Chen, X., Lv, J., Peng, C., 2020. Development, application, and evaluation of a problem-based learning method in clinical laboratory education. Clin. Chim. Acta 510, 681–684.

Lin, W.-T., Yu, C.-Y., Chou, F.-H., Lin, S.-Y., Lee, B.-O., 2022. The Effects of Sequencing Strategies in Teaching Methods on Nursing Students' Knowledge Acquisition and Knowledge Retention. Paper presented at the Healthcare.

Liu, C.-X., Ouyang, W.-W., Wang, X.-W., Chen, D., Jiang, Z.-L., 2020. Comparing hybrid problem-based and lecture learning (PBL+ LBL) with LBL pedagogy on clinical curriculum learning for medical students in China: a meta-analysis of randomized controlled trials. Medicine 99 (16).

Lopes, R.M., Hauser-Davis, R.A., Oliveira, M.M., Pierini, M.F., de Souza, C.A.M., Cavalcante, A.L.M., da Fonseca Tinoca, L.A., 2020. Principles of problem-based learning for training and professional practice in ecotoxicology. Sci. Total Environ. 702, 134809.

Ma, L.-L., Wang, Y.-Y., Yang, Z.-H., Huang, D., Weng, H., Zeng, X.-T., 2020. Methodological quality (risk of bias) assessment tools for primary and secondary medical studies: what are they and which is better? Military Med. Res. 7 (1), 7. https://doi.org/10.1186/s40779-020-00238-8.

Mohamed, H.M., Soliman, M.A.S., Abd ElFattah, M.A.E.-H., Hussein, F.M., 2017. Effect of problem based learning on self directed learning and critical thinking dispositions among faculty nursing students Zagazig University. Zagazig Nurs. J. 13 (2), 114–131.

Moradi, T., Taghadosi, M., 2016. The effect of problem-based learning clinical education on nursing student's critical thinking. Future Med. Educ. J. 6 (3), 20–25. https://doi.org/10.22038/fmej.2016.7970.

Morgan, D.J., Dhruva, S.S., Wright, S.M., Korenstein, D., 2016. 2016 update on medical overuse: a systematic review. JAMA Intern. Med. J. 176 (11), 1687–1692. https://doi.org/10.1001/jamainternmed.2016.5381.

Murad, M.H., Wang, Z., Chu, H., Lin, L., 2019. When continuous outcomes are measured using different scales: guide for meta-analysis and interpretation. BMJ (Clin. Res. Ed.) 364, k4817. https://doi.org/10.1136/bmj.k4817.

Oliveira, L.B., Díaz, L.J., Carbogim, F.a., Rodrigues, A.R., Püschel, V.A., 2016. Effectiveness of teaching strategies on the development of critical thinking in undergraduate nursing students: a meta-analysis. Rev. Esc. Enferm. U.S.P. 50 (2), 355–364. https://doi.org/10.1590/S0080-623420160000200023.

Owen, C., 2019. Problem-based learning. In: Learning and Teaching in Higher Education. Edward Elgar Publishing.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Moher, D., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 372, n71. https://doi.org/10.1136/bmj.n71.

Park, C., Song, M., Cho, B., Lim, J., Song, W., Chang, H., Park, Y.H., 2015. Effects of a multi-disciplinary approached, empowerment theory based self-management intervention in older adults with chronic illness. J. Korean Acad. Nurs. 45 (2), 192–201. https://doi.org/10.4040/jkan.2015.45.2.192.

Penjvini, S., Shahsawari, S.S., 2013. Comparing problem based learning with lecture based learning on medicine giving skill to newborn in nursing students. J. Nurs. Educ.Pract. 3 (9), 53.

Rao, B.J., 2019. Innovative teaching pedagogy in nursing education. Int. J. Nurs. Educ. 11 (4).

Rivaz, M., Momennasab, M., Yektatalab, S., Ebadi, A., 2017. Adequate resources as essential component in the nursing practice environment: a qualitative study. J. Clin. Diagn. Res. 11 (6), IC01–IC04. https://doi.org/10.7860/JCDR/2017/25349.9986.

Safa, A., Adib-Hajbaghery, M., Moradi, T., 2021. The effects of the 1-min preceptor and problem-based clinical educations on nursing students critical thinking. Nurs. Midwifery Stud. 10 (4), 243–248.

Salari, M., Roozbehi, A., Zarifi, A., Tarmizi, R.A., 2018. Pure PBL, hybrid PBL and lecturing: which one is more effective in developing cognitive skills of undergraduate students in pediatric nursing course? BMC Med. Educ. 18 (1), 195. https://doi.org/10.1186/s12909-018-1305-0.

Savin-Baden, M., 2016. The impact of transdisciplinary threshold concepts on student engagement in problem-based learning: a conceptual synthesis. Interdiscip. J. ProblemBased Learn. 10 (2), 1–22.

Sayyah, M., Shirbandi, K., Saki-Malehi, A., Rahim, F., 2017. Use of a problem-based learning teaching model for undergraduate medical and nursing education: a systematic review and meta-analysis. Adv. Med. Educ. Pract. 8, 691.

Seshan, V., Matua, G.A., Raghavan, D., Arulappan, J., Al Hashmi, I., Roach, E.J., Prince, E.J., 2021. Case study analysis as an effective teaching strategy: perceptions of undergraduate nursing students from a middle eastern country. SAGE Open Nurs. 7, 23779608211059265.

Sharma, A., Dutt, H., Sai, C.N.V., Naik, S.M., 2020. Impact of project based learning methodology in engineering. Procedia Comput. Sci. 172, 922–926.

Son, H.K., 2020. Effects of S-PBL in maternity nursing clinical practicum on learning attitude, metacognition, and critical thinking in nursing students: a quasi-experimental design. Int. J. Environ. Res. Public Health 17 (21), 7866.

Song, Y.A., 2014. Effect of simulation-based practice by applying problem based learning on problem solving process, self-confidence in clinical performance and nursing competence. Korean J. Women Health Nurs. 20 (4), 246–254.

Song, Y.A., 2020. Effects of integrative simulation practice on nursing knowledge, critical thinking, problem-solving ability, and immersion in problem-based learning among nursing students. Korean J. Women Health Nurs. 26 (1), 61–71.

Song, Y., Park, S., 2020. Literature review and meta-analysis of problem-based learning in nursing students. J. Korean Acad. Fundam. Nurs. 27 (3), 246–258.

Sterne, J.A.C., Savović, J., Page, M.J., Elbers, R.G., Blencowe, N.S., Boutron, I., Higgins, J.P.T., 2019. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ 366, l4898. https://doi.org/10.1136/bmj.l4898.

Tiwari, A., Lai, P., So, M., Yuen, K., 2006. A comparison of the effects of problem-based learning and lecturing on the development of students' critical thinking. Med. Educ. 40 (6), 547–554.

Tseng, H.-C., Chou, F.-H., Wang, H.-H., Ko, H.-K., Jian, S.-Y., Weng, W.-C., 2011. The effectiveness of problem-based learning and concept mapping among taiwanese registered nursing students. Nurse Educ. Today 31 (8), e41–e46.

Ulfa, Y., Igarashi, Y., Takahata, K., Shishido, E., Horiuchi, S., 2021. A comparison of team-based learning and lecture-based learning on clinical reasoning and classroom engagement: a cluster randomized controlled trial. BMC Med. Educ. 21 (1), 444. https://doi.org/10.1186/s12909-021-02881-8.

Uys, L.R., Van Rhyn, L.L., Gwele, N.S., McInerney, P., Tanga, T., 2004. Problem-solving competency of nursing graduates. J. Adv. Nurs. 48 (5), 500–509.

Wong, F.M.F., Kan, C.W.Y., 2022. Online problem-based learning intervention on self-directed learning and problem-solving through group work: a waitlist controlled trial. Int. J. Environ. Res. Public Health 19 (2). https://doi.org/10.3390/ijerph19020720.

Wong, S.H.V., Kowitlawakul, Y., 2020. Exploring perceptions and barriers in developing critical thinking and clinical reasoning of nursing students: a qualitative study. Nurse Educ. Today 95, 104600. https://doi.org/10.1016/j.nedt.2020.104600.

Yang, J.H., Yang, B., 2013. Nursing Students' experiences with facilitator in problem-based learning class. Asian Nurs. Res. 7 (4), 198–204. https://doi.org/10.1016/j.anr.2013.10.002.

Yew, E.H.J., Goh, K., 2016. Problem-based learning: an overview of its process and impact on learning. Health Profess. Educ. 2 (2), 75–79. https://doi.org/10.1016/j.hpe.2016.01.004.

Yu, D., Zhang, Y., Xu, Y., Wu, J., Wang, C., 2013. Improvement in critical thinking dispositions of undergraduate nursing students through problem-based learning: a crossover-experimental study. J. Nurs. Educ. 52 (10), 574–581.

Yuan, H., Kunaviktikul, W., Klunklin, A., Williams, B.A., 2008. Improvement of nursing students' critical thinking skills through problem-based learning in the People's Republic of China: a quasi-experimental study. Nursing & Health Sciences 10 (1), 70–76.

Yuan, H., Williams, B.A., Fan, L., 2008. A systematic review of selected evidence on developing nursing students' critical thinking through problem-based learning. Nurse Educ. Today 28 (6), 657–663. https://doi.org/10.1016/j.nedt.2007.12.006.

Zapko, K.A., Ferranto, M.L.G., Blasiman, R., Shelestak, D., 2018. Evaluating best educational practices, student satisfaction, and self-confidence in simulation: a descriptive study. Nurse Educ. Today 60, 28–34.