International Journal of Nursing Studies 51 (2014) 458–469

Contents lists available at SciVerse ScienceDirect

International Journal of Nursing Studies

journal homepage: www.elsevier.com/ijns

The effectiveness of problem-based learning on development of nursing students' critical thinking: A systematic review and meta-analysis

Ling-Na Kong [a,b], Bo Qin [a,*], Ying-qing Zhou [b], Shao-yu Mou [b], Hui-Ming Gao [b]

[a] Department of Infectious Diseases, The First Affiliated Hospital of Chongqing Medical University, Chongqing 400016, PR China
[b] Nursing College of Chongqing Medical University, Chongqing 400016, PR China

ARTICLE INFO

Article history:
Received 28 November 2012
Received in revised form 10 June 2013
Accepted 16 June 2013

Keywords:
Problem-based learning (PBL)
Critical thinking
Nursing education
Meta-analysis
Systematic review

ABSTRACT

Objectives: The objective of this systematic review and meta-analysis was to estimate the effectiveness of problem-based learning in developing nursing students' critical thinking.
Data sources: Searches of PubMed, EMBASE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Proquest, Cochrane Central Register of Controlled Trials (CENTRAL) and China National Knowledge Infrastructure (CNKI) were undertaken to identify randomized controlled trails from 1965 to December 2012, comparing problem-based learning with traditional lectures on the effectiveness of development of nursing students' critical thinking, with no language limitation. The mesh-terms or key words used in the search were problem-based learning, thinking, critical thinking, nursing, nursing education, nurse education, nurse students, nursing students and pupil nurse.
Review methods: Two reviewers independently assessed eligibility and extracted data. Quality assessment was conducted independently by two reviewers using the Cochrane Collaboration's Risk of Bias Tool. We analyzed critical thinking scores (continuous outcomes) using a standardized mean difference (SMD) or weighted mean difference (WMD) with a 95% confidence intervals (CIs). Heterogeneity was assessed using the Cochran's Q statistic and I^2 statistic. Publication bias was assessed by means of funnel plot and Egger's test of asymmetry.
Results: Nine articles representing eight randomized controlled trials were included in the meta-analysis. Most studies were of low risk of bias. The pooled effect size showed problem-based learning was able to improve nursing students' critical thinking (overall critical thinking scores SMD = 0.33, 95%CI = 0.13–0.52, $P = 0.0009$), compared with traditional lectures. There was low heterogeneity (overall critical thinking scores $I^2 = 45\%$, $P = 0.07$) in the meta-analysis. No significant publication bias was observed regarding overall critical thinking scores ($P = 0.536$). Sensitivity analysis showed that the result of our meta-analysis was reliable. Most effect sizes for subscales of the California Critical Thinking Dispositions Inventory (CCTDI) and Bloom's Taxonomy favored problem-based learning, while effect sizes for all subscales of the California Critical Thinking Skills Test (CCTST) and most subscales of the Watson–Glaser Critical Thinking Appraisal (WCGTA) were inconclusive.
Conclusions: The results of the current meta-analysis indicate that problem-based learning might help nursing students to improve their critical thinking. More research with larger sample size and high quality in different nursing educational contexts are required.

* Corresponding author. Tel.: +86 23 89012887.
E-mail address: cqqinbo@126.com (B. Qin).

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http://dx.doi.org/10.1016/j.ijnurstu.2013.06.009

What is already known about the topic?

- Problem-based learning has been widely used to enhance nursing students' critical thinking in nursing education.
- Many studies have examined the effects of problem-based learning on critical thinking in nursing students, but findings have been mixed.
- Previous literature review indicated a positive relationship between problem-based learning and improved critical thinking in nursing students.

What this paper adds

- This review indicated that nursing students' critical thinking was improved with the use of problem-based learning, compared with traditional lectures.
- There is a need for more research with lager sample size and high quality to further support the effects of problem-based learning on critical thinking development within different nursing educational contexts.

1. Introduction

In a contemporary health-care environment characterized by rapidly changing developments and relentlessly increasing knowledge, professional nurses need to develop critical thinking skills that will provide them with expertise in flexible, individualized, situation-specific problem-solving (Higgs and Jones, 2000). Critical thinking is conceptualized to include both cognitive skills and affective dispositions by the American Philosophical Association (APA) (Facione, 1990), and is considered to be a professional attribute for nurses in the new millennium to make efficient judgments in fast-changing clinical situations (Chen and Lin, 2003). Critical thinking is a significant component of nursing education and integral to the discipline of nursing (Bowles, 2000; Boychuk Duchscher, 1999). It is important to nursing practice where wise decision-making, correct judgment and effective communication are integral to safe and effective patient care outcomes (Jones, 2008). Fostering critical thinking ability in nursing students has become one of the most imperative tasks for nursing education (Lyons, 2008).

Determining instructional strategies which enhance critical thinking abilities of nursing students has been of interest to nurse educators and a focus of nursing research for two decades (Riddell, 2007; Scheffer and Rubenfield, 2000). There are several teaching methods in the nursing literature to enhance critical thinking in nursing students, such as group discussion (Platzer et al., 2000), case studies (Tomey, 2003), concept mapping (Abel and Freeze, 2006) and problem-based learning (PBL) (Jones, 2008). Among these, PBL has become more prominent in nursing education as a strategy for promoting critical thinking (Worrell and Profetto-McGrath, 2007).

PBL originated at the McMaster School of Medicine in Canada in 1965 (Berkson, 1993), and was further refined by Dr. Howard Barrows as both a curriculum strategy and a process approach in 1988. PBL is a student-centered approach to learning which enables the students to work cooperatively in small groups for seeking solutions to situations/problems (Rideout and Carpio, 2001). PBL presents students with a problem or situation to apply previous knowledge and acquire new knowledge. There are five steps in the PBL process: analysis of problems, establishment of learning objectives, collection of information, summarizing and reflection (Lin et al., 2010). In the PBL model students encounter the problem-solving situations in small groups. The groups have to decide what information they need to identify the situation/problem at issue, try to understand it, communicate it to the others in the group, and then re-formulate it in such a way that they can deal with the problem (Yuan et al., 2008b). PBL makes the meaningful of learning and makes the learner to develop skills to thinking critically (Kammanee, 2008).

Some studies have examined the use of PBL as a teaching method to enhance critical thinking, but findings have been mixed. Some studies have showed PBL produced clear benefits for students, such as increased autonomous learning, critical thinking, problem-solving and communication (Cook and Moyle, 2002; Morales-Mann and Kaitell, 2001). Joe and Elizabeth (1999) found that nursing students who participated in a one-year PBL course showed improved critical thinking. When compared with traditional lectures, some researchers have found PBL does not improve critical thinking (Choi, 2004; Lyons, 2006), however many researchers have found PBL is more effective in fostering critical thinking skills of nursing students (Dehkordi and Heydarbejad, 2008; Jones, 2008; Ozturk et al., 2008; Tiwari et al., 2006; Wang, 2009).

A systematic review in 2008 (Yuan et al., 2008b) including studies between 1999 and 2006 was conducted to demonstrate whether PBL actually had more effect on developing nursing students' critical thinking compared with other instructional methods. Keywords that guided the search were problem-based learning, critical thinking, nursing and effect. Ten articles were selected, among which, six were descriptive. The ten studies were described from the six following aspects: study level of evidence, design, sample, instruments, intervention and findings. The authors concluded that in theory, the use of PBL may promote critical thinking in nursing students, but the available evidence in this review did not provide supportive evidence on developing nursing students' critical thinking through PBL. In another review (Oja, 2011) the literature search were identified through the formulation of a PICO (Population, Intervention, Comparison and Outcome) question to examine the evidence regarding the use of PBL to improve critical thinking. The literature search included the keywords nursing, problem-based learning and critical thinking. The systematic review in 2008 (Yuan et al., 2008b) and an additional four studies were included. In addition to the key information of the included studies, the author added the strengths and weaknesses. The evidence indicated a positive relationship between PBL and improved critical thinking in nursing students. The two previous reviews gave the detailed description of the studies that compared PBL with traditional lectures on the effectiveness of development of nursing students' critical thinking, however, a quantitative evaluation is still lacking.

The objective of the present systematic review and meta-analysis was to determine the effectiveness of PBL on developing critical thinking in nursing students, compared with traditional lectures, and make quantitative evaluation using meta-analysis. The hypothesis was that PBL will have a positive effect on nursing students' critical thinking.

2. Methods

The current study is a systematic review and meta-analysis of randomized controlled trials (RCTs) comparing PBL with traditional lectures on developing nursing students' critical thinking skills and abilities. Results of the trials regarding overall critical thinking scores and subscale scores were synthesized to retrieve a pooled effect. The review utilized reporting checklist of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement by the Centre for Reviews and Dissemination (Liberati et al., 2009) and the Cochrane Collaboration (Higgins and Green, 2011). The PRISMA statement consists of a 27-item checklist and a four-phase flow diagram. The checklist includes items deemed essential for transparent reporting of a systematic review.

2.1. Search strategy

We searched the electronic databases PubMed, EMBASE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Proquest, Cochrane Central Register of Controlled Trials (CENTRAL) and China National Knowledge Infrastructure (CNKI) for articles comparing PBL with traditional lectures on developing nursing students' critical thinking. The search was restricted from 1965 to December 2012 since PBL originated at the McMaster School of Medicine in Canada in 1965 (Berkson, 1993), and no language restrictions were imposed. The mesh-terms or key words ("Problem-based learning") AND ("thinking" OR "critical thinking") AND ("nurs*" OR "nurs* education" OR "nurs* students" OR pupil nurse) were used to obtain the search string. The search in PubMed used the search terms below.

1. nurs* education [mesh terms]
2. nurs* students [mesh terms]
3. pupil nurse [mesh terms]
4. nurs* [mesh terms]
5. problem-based learning [mesh terms]
6. thinking [mesh terms]
7. 1 or 2 or 3 or 4
8. 5 and 6 and 7
9. limit 8 to yr="1965–2012"

2.2. Study selection

Articles were included if they (1) described RCTs, (2) included nursing students, (3) used PBL as an educational approach in the intervention group, (4) used traditional lectures in the control group, (5) evaluated critical thinking as an outcome, (6) reported the sample size, the mean difference and associated 95%CI of critical thinking scores for the intervention group and control group. We excluded studies if they (1) were non-RCT, (2) included other subjects than nursing students, (3) utilized other interventions than PBL, (4) did not evaluated critical thinking, (5) were articles with incomplete data, such as not reporting the mean difference and associated 95%CI of critical thinking scores (5) were duplicate articles.

2.3. Data extraction

Data were extracted by two independent reviewers. Disagreements about eligibility were resolved by consensus. For each study, the following information was extracted in the current analysis: the first author, publication year, country of origin, sample size (intervention group and control group), characteristics of participants, intervention method, teaching method in the control group, outcomes (the mean difference and associated 95%CI of critical thinking scores for the intervention group and control group), time of measuring outcome, outcomes measured and length of intervention.

2.4. Quality assessment

The quality of the included studies was assessed as adequate, uncertain, or inadequate by two members and was based on the six general sources of bias described in the Cochrane Handbook for Systematic Reviews of Interventions (Higgins and Green, 2011). The quality items checked were the following: adequacy of the generation of the allocation sequence, concealment of allocation, blinding procedures, incomplete outcome data, selective outcome reporting and other sources of bias. Information addressed by these items was obtained from the published reports and authors were contacted if additional information was required (Ndosi et al., 2011). The Cochrane Collaboration's tool for assessing risk of bias is available on line at http://handbook.cochrane.org/.

2.5. Statistical analysis

The literature data including authors, publication year, cases of participants and etc. were input in Review Manager 5.0 software (The Nordic Cochrane Centre, 2008) to tests of heterogeneity and meta-analysis. We analyzed the critical thinking scores of the PBL group and control group. Since continuous data from different scales were extracted, the standardized mean difference (SMD) was calculated for effect size based on sample size (Cohen, 1988) and 95% confidence intervals (CIs) for each study, and for the pooled studies using variance analysis. Weighted mean difference (WMD) and 95% confidence intervals (CIs) were calculated for continuous data from the same scale. A two-sided P value less than 0.05 was regarded as significant for all analyses. There were two models of meta-analysis. The fixed effect model was used to pool data if there was no heterogeneity, otherwise we used random effects model. Heterogeneity was considered significant for P value of Cochran's Q statistic < 0.10 and $I^2 > 50\%$ (Higgins and Thompson, 2002; Higgins et al., 2003). I^2 was the percentage of variation attributed to

heterogeneity and was easily interpreted. I^2 statistic of 25–50% was considered low, 50–75% was considered moderate, and ≥75% was considered high.

If there is heterogeneity, we conduct sensitivity analysis to assess if this significantly altered the results of the meta-analysis. A sensitivity analysis was performed by excluding each one of these studies and then recalculating the pooled estimates for the remaining studies did not significantly alter the results.

Publication bias was assessed by funnel plot and Egger's test of asymmetry (Egger et al., 1997) which were conducted using STATA 11.0. Funnel plot shapes didn't reveal obvious evidence of asymmetry, and all the *P* values of Egger's tests were more than 0.05, providing statistical evidence of the funnel plot symmetry.

3. Results

3.1. The search results

The literature search identified 662 abstracts and a further five potential articles were identified from citations in retrieved papers, out of which 275 duplicates were removed. A further 268 articles were excluded after reading the titles and abstracts, among which, 26 were review articles, 242 were obviously not relevant to this investigation. According to inclusion and exclusion standards, relevant full-text articles ($n = 124$) were assessed for eligibility. It was found that 88 were non-RCT, twenty didn't measure critical thinking, five did not focused on nursing students, one used PBL and concept mapping as the teaching methods in the intervention group, and one did not report outcome data. We e-mailed the corresponding author to ask for the available outcome data but received no reply. Thus, nine articles were included in the meta-analysis. The data abstraction process is shown in Fig. 1.

3.2. Characteristics of included studies

Nine articles (Choi, 2004; Jones, 2008; Lyons, 2006, 2008; Ozturk et al., 2008; Tiwari et al., 2006; Wang, 2009; Yuan et al., 2008a; Zhu, 2011) which represented eight studies were included in the meta-analysis. They were all published between 2004 and 2011. Among these, six were English language articles, two were Chinese language articles, and one was Korean language article. The sample size ranged from 46 to 311 participants and the pooled sample size was 985 (PBL group = 439, control group = 546). Studies were performed in Korea (Choi, 2004), the United States (Jones, 2008; Lyons, 2008), Turkey (Ozturk et al., 2008) and China (Tiwari et al., 2006; Wang, 2009; Yuan et al., 2008a; Zhu, 2011). Five studies were conducted in one school (Lyons, 2008; Tiwari et al., 2006; Wang, 2009; Yuan et al., 2008a; Zhu, 2011) and two studies in two schools (Choi, 2004; Ozturk et al., 2008). The lengths of intervention varied between one semester to two semesters. Six studies (Choi, 2004; Jones, 2008; Lyons, 2008; Tiwari et al., 2006; Yuan et al., 2008a; Zhu, 2011) measured the participants' critical thinking before and after using PBL as the teaching method. Two studies (Ozturk et al., 2008; Wang, 2009) measured the participants' critical thinking after using PBL. One study (Tiwari et al., 2006) collected data four times to assess the longitudinal effects of the PBL approaches. The characteristics of the included studies are summarized in Table 1.

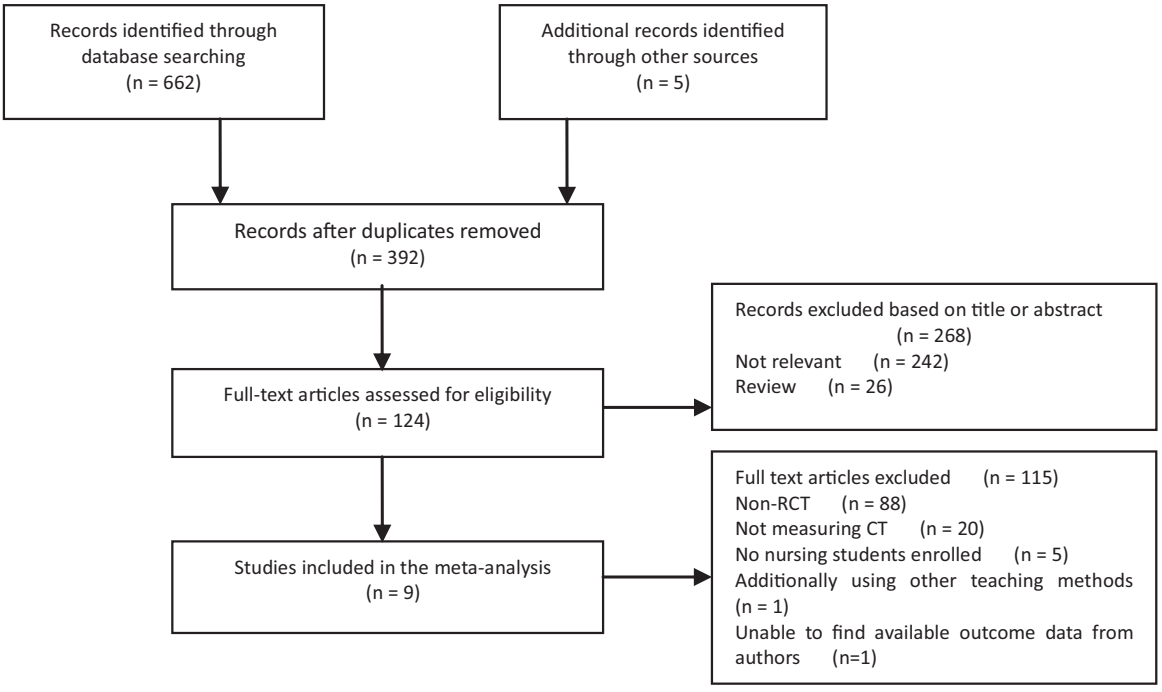

Fig. 1. Flow chart for selection of included studies.

Table 1
Characteristics of included studies.

Study ID (country)	Sample size (IG/CG)	Participants characteristics	Interventions	Comparator	Outcome measurements		Duration of intervention
					Timing	Measurement tools	
Choi (2004) (Korea)	76 (34/42)	Year two undergraduate nursing students who took a "Nursing Process" course from two nursing schools	Using PBL as the educational approach. There are 4 PBL tutorial groups and each group consisted of 8 students. Students took PBL process with one scenario during 3 weeks. There were four scenarios.	Using lecturing as the teaching approach.	Before/after	California Critical Thinking Skills Test Form 2000 (CCTST)	1 semester (14 weeks)
Jones (2008) (New York, USA)	60 (30/30)	Second-year nursing students enrolled in the maternal-newborn nursing course at an associated degree community college Mean age 25.6, ages ranging from 25 to 41 48 females and 12 males	The students followed the normal curriculum, with pre- and post-conference lectures on a specific topic by the clinical preceptor for the first two weeks and then were introduced to the PBL strategies. The students worked in groups of 10. A problem was presented based on an actual current patient in the clinical setting. Students were given one hour during the preclinical conference to work on the problem.	The students followed the normal curriculum, with pre- and post-conference lectures on a specific topic by the clinical preceptor.	Before/after	Bloom's taxonomy of the cognitive learning domain	1 semester
Lyons (2006, 2008) (Mississippi, USA)	54 (27/27)	Fourth semester associate degree nursing students enrolled in an NCLEX-RN Review Course at a rural community college Mean age IG: 31.1 (SD 7.62) CG: 30.3 (SD 7.12) ACT Scores IG: 19.1 (SD 3.25) CG: 18.9 (SD 3.10) 90% of the sample were female and 75% were Caucasian	Using twelve problem-based learning case scenarios on topics ranging from Health Promotion to Physiologic Integrity. The PBL group consisted of groups of 5–7 students. The participants worked collaboratively to solve the PBL cases presented and met two hours weekly for 17 weeks.	Using lecturing as the teaching approach. The students received a two hour lecture each week on nursing content and NCLEX-RN review questions.	Before/after	Assessment Technologies Institute Critical Thinking Test (ATI, 2002)	1 semester (17 weeks)
Ozturk et al. (2008) (Izmir, Turkey)	147 (52/95)	Fourth-year nursing students from two schools of nursing Mean age IG: 22.9 (SD 1.53) CG: 22.9 (SD 1.26) Working status *n* (%) Working IG: 16 (30.8) CG: 31 (32.6) Not working IG: 36 (69.2) CG: 64 (67.4)	Using PBL as the educational approach. Students worked with peers in small groups to identify learning goals, then engaged in self-study and returned to discuss and applied new learning.	Using lecturing as the teaching approach.	After	California Critical Thinking Disposition Inventory (CCTDI, Turkish version)	1 semester

Tiwari et al. (2006) (Hong Kong, China)	74 (38/36) 59 (32/27) 65 (32/33)	Year one undergraduate nursing students at a university who enrolled on the 4-year undergraduate nursing degree program underwent a course in nursing therapeutics Mean age 20.16 (SD 1.83) All were Chinese, born and bred in Hong Kong.	Using PBL as the educational approach. The PBL approach was modeled on the reiterative problem-based design as described by Barrows. Each tutorial group consisted of 10 students by a PBL tutor. The group had 3–6 h of PBL tutorials each week for a total of 28 weeks over 2 semesters.	Using lecturing as the teaching approach. Each lecture lasted 2–3 h. There were 3–6 h of class contact each week. Lecture notes were provided for the students for each of the lectures.	Before/after/1-year interval/2-year interval	California Critical Thinking Disposition Inventory (CCTDI)	2 semesters
Yuan et al. (2008a) (Shanghai, China)	46 (23/23)	Year two undergraduate nursing students who registered for the course of "Introduction to Nursing" at a university Mean age 19.59	Using PBL as the educational approach. Each PBL tutorial group consisted of either 11 or 12 students and a tutor. The students did small-group work with five learning packages over 36 learning hours, with 2 h per week. Each learning package consisted of a core concept map, learning goals, scenario, and trigger questions.	Using lecturing as the teaching approach. The students received course content during 36 learning hours, with 2 h per week. Sometimes, classroom or large group discussion was conducted between the teacher and students, but the teacher provided the final answers to every question.	Before/after	California Critical Thinking Skills Test Form A (CCTST-A, Chinese Taiwan Version)	1 semester (18 weeks)
Wang (2009) (Qingdao, China)	93 (49/44)	Year three undergraduate nursing students who registered for the course of "Fundamentals of nursing" Mean age IG: 21.9 (SD 2.3) CG: 22.1 (SD 1.9) Gender IG: female (95.9%) CG: female (93.2%) Admission scores IG: 594 (SD 5.1) CG: 592 (SD 4.9)	Using PBL as the educational approach. There are 5 PBL tutorial groups and each group consisted of either 9 or 10 students. The group had 100 min of PBL tutorials each class. Teachers time for 30 min, discussion 20 min, collective summary 50 min.	Using lecturing as the teaching approach.	After	Watson–Glaser Critical Thinking Appraisal (WGCTA, Chinese Version)	1 semester
Zhu (2011) (Hangzhou, China)	311 (122/189)	Second semester nursing students from higher vocational schools and colleges who registered for the course of "Comprehensive Nursing" Ages ranging from 19 to 21, all were female	Using PBL as the educational approach. Each PBL tutorial group consisted of either 6 or 7 students. The teaching process includes laying out problem, discussion and summary.	Using lecturing as the teaching approach.	Before/after	Critical Thinking Disposition Inventory (CCTDI, Chinese Version)	1 semester

IG, intervention group, CG, control group. Before: data were collected before the intervention. After: data were collected after the intervention.

3.3. Outcome measures

The outcome measures in this review included the Assessment Technologies Institute Critical Thinking Test (ATI, 2002) (Lyons, 2008), Bloom's taxonomy of the cognitive learning domain (Jones, 2008), the California Critical Thinking Dispositions Inventory (CCTDI) (Ozturk et al., 2008; Tiwari et al., 2006; Zhu, 2011), the California Critical Thinking Skills Test (CCTST) (Choi, 2004; Yuan et al., 2008a) and the Watson–Glaser Critical Thinking Appraisal (WGCTA) (Wang, 2009). The CCTDI is a 75-item Likert scale tool with seven subscales including truthseeking, open-mindedness, analyticity, systematicity, critical thinking self-confidence, inquisitiveness and cognitive maturity (Facione et al., 1994). The CCTST is a standardized, 34-item, multiple-choice test with five subscale scores including analysis, evaluation, inference, deduction and induction (Facione and Facione, 1993). The WGCTA is a standardized, 80-item, assessment tool for measuring the foundation critical thinking skills including inference, recognition of assumptions, deduction, interpretations and evaluation of arguments (Watson and Glaser, 1994). Bloom's Taxonomy is a multi-tiered model of classifying thinking according to six cognitive levels of complexity. The lowest three levels are: knowledge, comprehension and application. The highest three levels are: analysis, synthesis and evaluation (Anderson and Krathwohl, 2001).

3.4. Study quality

Overall, most studies had low risk of bias across the six domains (Fig. 2). In one study (Tiwari et al., 2006), the allocation sequence was adequately generated and concealed by drawing lots from a sealed box. The allocation sequence in Jones (2008) study was adequately generated by flipping a coin. The allocation sequence of two studies (Choi, 2004; Ozturk et al., 2008) was generated by the preference of the researchers, in which the students were assigned to either an experimental group or a control group by the researchers' decision. The other four studies did not report the method used, and therefore the information was not available. Given the nature of the intervention, blinding of students and tutors to the intervention is not feasible but if the outcome was measured by standardized tools, such as the CCTDI and CCTST, and not likely to be influenced by lack of blinding the study was awarded adequate for blinding. Six studies (Choi, 2004; Jones, 2008; Lyons, 2008; Ozturk et al., 2008; Yuan et al., 2008a; Zhu, 2011) reported complete outcome data. Wang (2009) reported the missing outcome data which balanced in numbers between intervention group and control group. Tiwari et al. (2006) didn't mention the reason for missing data. We assessed whether the study was free from selective outcome reporting by checking whether all outcomes mentioned in the reports were adequately reported in the results section. One study (Tiwari et al., 2006) only reported the significant outcomes, and the other seven studies adequately reported the results. All studies seemed free from "other sources of bias" as defined in the Cochrane Collaboration's domain based evaluation.

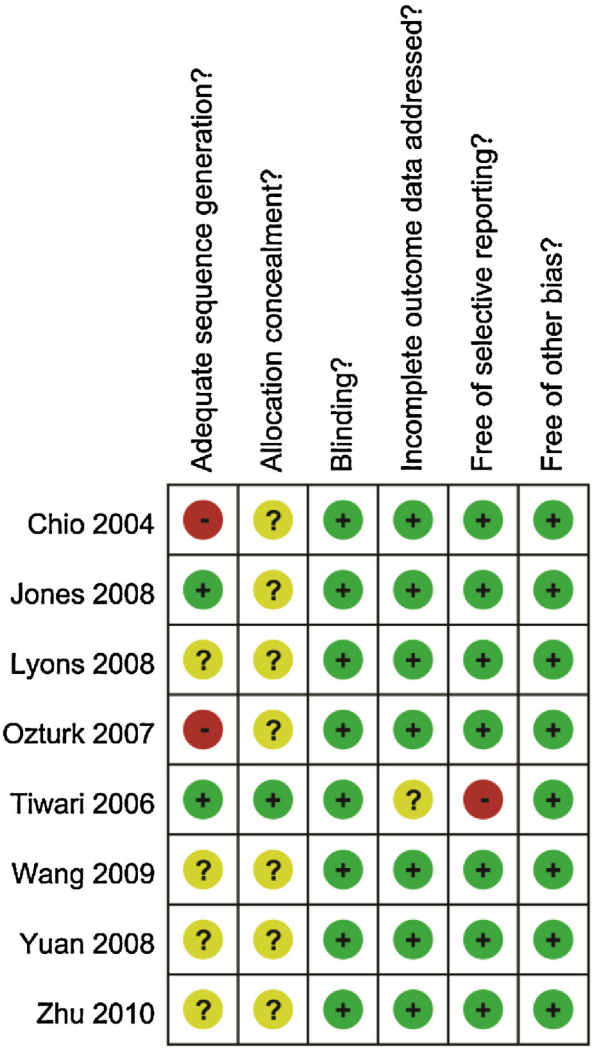

Fig. 2. Summary of risk of bias assessment.

3.5. Effects of interventions

3.5.1. Overall critical thinking scores

Seven studies involving 910 participants (PBL group = 399, control group = 511) reported overall critical thinking scores. Tiwari et al. (2006) reported three outcome data, thus, there were nine reports of outcome data in the meta-analysis. Two studies (Choi, 2004; Lyons, 2008) showed no statistically significant differences in nursing students' overall critical thinking scores between the PBL and the control group, while others showed statistically significant differences. There was low heterogeneity ($I^2 = 45\%$, $P = 0.07 < 0.1$); thus, the random effects model was used. The pooled effect size showed significant difference in overall critical thinking scores (SMD = 0.33, 95%CI = 0.13–0.52, $P = 0.0009$) in favor of PBL, compared with traditional lectures (Fig. 3). The fixed effect model was also applied to pool the data. The pooled effects favored the PBL group (SMD = 0.35, 95%CI = 0.22–0.48, $P < 0.00001$).

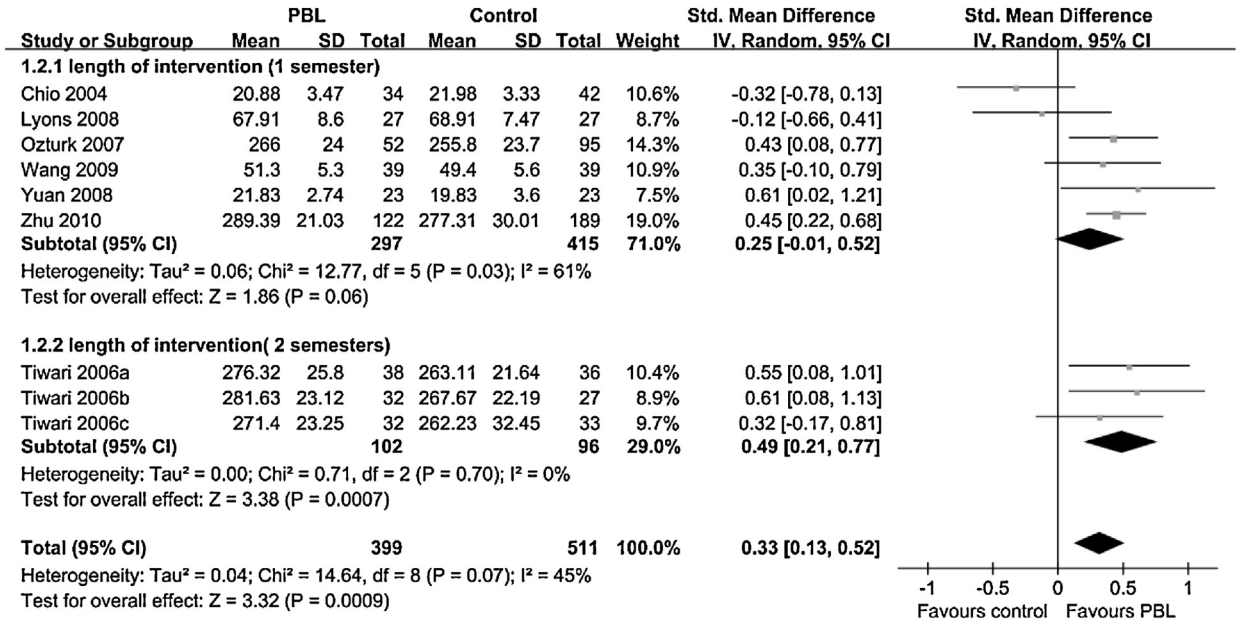

Fig. 3. Meta-analysis and forest plot of overall critical thinking scores after using PBL compared with traditional lectures.

Because of the heterogeneity observed between studies reporting overall critical thinking scores, a sensitivity analysis was carried out to verify the reliability of the result. Sensitivity analysis was performed by sequential omission of individual studies. With the exclusion of two studies (Choi, 2004; Ozturk et al., 2008) with inadequate generation of a randomized sequence from the analyses of overall critical thinking scores, the pooled effect size favored the PBL group (SMD = 0.41, 95%CI = 0.26–0.57, $P < 0.00001$), and did not change the effects observed in the primary analysis.

The funnel plot for the nine reports on overall critical thinking analysis is shown in Fig. 4. The funnel plot's shape is symmetrical. There was no significant publication bias indicated in the main analysis ($P = 0.536$).

A subgroup analysis was conducted to assess the impact of length of the PBL implementation on the nursing students' overall critical thinking scores (Fig. 3). The six studies that used PBL in the intervention group for one semester showed that there was no significant difference between the two groups (SMD = 0.25, 95%CI = −0.01 to 0.52, $P = 0.06$), and there was moderate heterogeneity ($I^2 = 61\%$, $P = 0.03 < 0.1$). The pooled effect size for the one study that used PBL in the intervention group for two semesters showed significant difference in overall critical thinking scores (SMD = 0.49, 95%CI = 0.21–0.77, $P = 0.0007$) in favor of PBL, compared with traditional lectures (Fig. 3). There was no heterogeneity ($I^2 = 0\%$, $P = 0.70 > 0.1$).

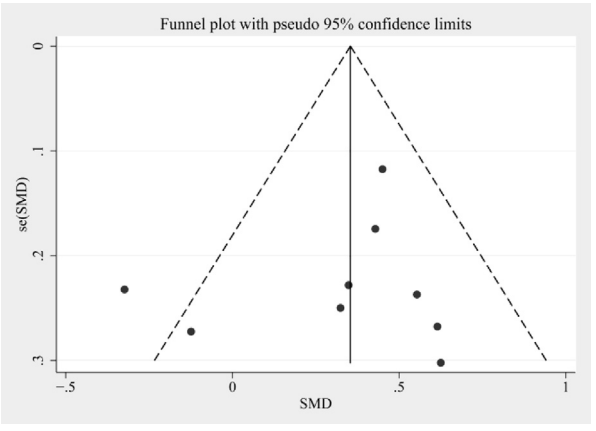

Fig. 4. Funnel plot analysis for overall critical thinking scores.

3.5.2. Subscale scores

Subscale scores of the critical thinking were reported in seven studies. Findings of PBL effects in all subscales are summarized in Table 2.

In three studies (Ozturk et al., 2008; Tiwari et al., 2006; Zhu, 2011) subscale scores of the CCTDI were assessed. The pooled effect sizes for truthseeking (SMD = 0.38, 95%CI = 0.22–0.53, $P < 0.00001$), open-mindedness (SMD = 2.22, 95%CI = 1.46–2.98, $P < 0.00001$), systematicity (SMD = 0.23, 95%CI = 0.04–0.42, $P = 0.02$), self-confidence (SMD = 1.14, 95%CI = 0.22–2.06, $P = 0.02$), inquisitiveness (SMD = 1.19, 95%CI = 0.17–2.21, $P = 0.02$), and cognitive maturity (SMD = 1.25, 95%CI = 0.22–2.28, $P = 0.02$) favored PBL group, while there were no significant difference between the two groups on analyticity scores (SMD = 0.22, 95%CI = −0.10 to 0.55, $P = 0.18$).

Subscale scores of the CCTST were assessed in two studies (Choi, 2004; Yuan et al., 2008a). The pooled effect sizes for analysis (SMD = 0.14, 95%CI = −0.44 to 0.72, $P = 0.64$), evaluation (SMD = 0.20, 95%CI = −0.34 to 0.74, $P = 0.46$), inference (SMD = −0,14, 95%CI = −0.50 to 0.21, $P = 0.43$), deduction (SMD = −0.03, 95%CI = −0.51 to 0.58, $P = 0.91$), and induction (SMD = 0.41, 95%CI = −0.64 to 0.91, $P = 0.72$) were inconclusive.

Table 2
Outcomes and their corresponding effect sizes of subscales.

Outcomes	Trails	Sample size (IG/CG)	Measure of effects	Intervention effect size (CI)	*P*-value of effect	Heterogeneity			
						χ^2	df	*P*-value	I^2 (%)
CCTDI									
Truthseeking	Ozturk et al. (2008), Tiwari et al. (2006), Zhu (2011)	656 (276/380)	SMD[a]	0.38 (0.22, 0.53)	<0.00001	3.28	4	0.51	0
Openmindness	Ozturk et al. (2008), Tiwari et al. (2006), Zhu (2011)	656 (276/380)	SMD[a]	2.22 (1.46, 2.98)	<0.00001	0.65	4	0.96	0
Analyticity	Ozturk et al. (2008), Zhu (2011)	458 (174/284)	SMD	0.22 (−0.10, 0.55)	0.18	2.60	1	0.11	61
Systematicity	Ozturk et al. (2008), Zhu (2011)	458 (174/284)	SMD[a]	0.23 (0.04, 0.42)	0.02	0.40	1	0.53	0
Self-confidence	Ozturk et al. (2008), Tiwari et al. (2006), Zhu (2011)	656 (276/380)	SMD[a]	1.14 (0.22, 2.06)	0.02	3.02	4	0.56	0
Inquisitiveness	Ozturk et al. (2008), Tiwari et al. (2006), Zhu (2011)	656 (276/380)	SMD[a]	1.19 (0.17, 2.21)	0.02	2.60	4	0.63	0
Cognitive maturity	Tiwari et al. (2006), Zhu (2011)	509 (224/285)	SMD[a]	1.25 (0.22, 2.28)	0.02	4.45	3	0.22	33
CCTST									
Analysis	Choi (2004), Yuan et al. (2008a)	122 (57/65)	SMD	0.14 (−0.44, 0.72)	0.64	2.48	1	0.12	60
Evaluation	Choi (2004), Yuan et al. (2008a)	122 (57/65)	SMD	0.20 (−0.34, 0.74)	0.46	2.15	1	0.14	53
Inference	Choi (2004), Yuan et al. (2008a)	122 (57/65)	SMD	−0.14 (−0.50, 0.21)	0.43	1.58	1	0.21	37
Deduction	Choi (2004), Yuan et al. (2008a)	122 (57/65)	SMD	0.03 (−0.51, 0.58)	0.91	2.20	1	0.14	55
Induction	Choi (2004), Yuan et al. (2008a)	122 (57/65)	SMD	0.14 (−0.64, 0.91)	0.72	4.43	1	0.04	77
WGCTA									
Inference	Wang (2009)	78 (39/39)	WMD	0.70 (−0.14, 1.54)	0.10	N/A	N/A	N/A	N/A
Recognition of assumption	Wang (2009)	78 (39/39)	WMD	0.10 (−0.97, 1.17)	0.85	N/A	N/A	N/A	N/A
Deduction	Wang (2009)	78 (39/39)	WMD[a]	1.00 (0.20, 1.80)	0.01	N/A	N/A	N/A	N/A
Interpretations	Wang (2009)	78 (39/39)	WMD	0.10 (−0.88, 1.08)	0.84	N/A	N/A	N/A	N/A
Evaluation	Wang (2009)	78 (39/39)	WMD	0.10 (−3.00, 3.20)	0.95	N/A	N/A	N/A	N/A
Bloom's taxonomy of the cognitive learning domain									
Knowledge	Jones (2008)	60 (30/30)	WMD	−0.10 (−0.44, 0.24)	0.57	N/A	N/A	N/A	N/A
Comprehension	Jones (2008)	60 (30/30)	WMD[a]	1.10 (0.80, 1.40)	<0.00001	N/A	N/A	N/A	N/A
Application	Jones (2008)	60 (30/30)	WMD[a]	1.90 (1.62, 2.18)	<0.00001	N/A	N/A	N/A	N/A
Analysis	Jones (2008)	60 (30/30)	WMD[a]	1.70 (1.26, 2.14)	<0.00001	N/A	N/A	N/A	N/A
Synthesis	Jones (2008)	60 (30/30)	WMD[a]	2.70 (2.33, 3.07)	<0.00001	N/A	N/A	N/A	N/A
Evaluation	Jones (2008)	60 (30/30)	WMD[a]	2.90 (2.58, 3.22)	<0.00001	N/A	N/A	N/A	N/A

Heterogeneity (I^2): <50% = low, 50–75% = moderate, >75% = high.
[a] Favored PBL group.

Wang (2009) reported the subscale scores of the WGCTA. The pooled effect size for deduction favored PBL group (WMD = 1.00, 95%CI = 0.20–1.80, $P = 0.01$), while inference, recognition of assumptions, interpretations and evaluation of arguments showed no significant difference between the two groups.

Jones (2008) reported the scores of the six levels of Bloom's taxonomy of the cognitive learning domain. The pooled effect sizes for comprehension (WMD = 1.10, 95%CI = 0.80–1.40, $P < 0.00001$), application (WMD = 1.90, 95%CI = 1.62–2.18, $P < 0.00001$), analysis (WMD = 1.70, 95%CI = 1.26–2.14, $P < 0.00001$), synthesis (WMD = 2.70, 95%CI = 2.33–3.07, $P < 0.00001$), and evaluation (WMD = 2.90, 95%CI = 2.58–3.22, $P < 0.00001$) favored PBL group, while knowledge scores showed no significant difference between the two groups (WMD = −0.10, 95%CI = −0.44 to 0.24, $P = 0.57$).

4. Discussion

4.1. Summary of main findings

The objective of this meta-analysis was to examine whether PBL is effective in developing nursing students' critical thinking. A comprehensive search of the literature comparing PBL with traditional lectures was undertaken, and nine articles which represented eight studies were found to meet the predefined inclusion criteria. All studies utilized PBL as the educational teaching method in the intervention group and traditional lectures in the control group. Due to different educational environments, the specific processes of PBL and lengths of intervention were different. Also, the outcome measures of critical thinking were not the same.

Most studies were limited in terms of random allocation to experimental and control groups described in the Cochrane Handbook for Systematic Reviews of Interventions. Most studies were lack for adequacy of the generation of the allocation sequence and concealment of allocation. There was low heterogeneity in the meta-analysis of overall critical thinking scores. The funnel plot's shape is symmetrical and there was no publication bias in the meta-analysis.

The overall critical thinking scores were evaluated by the standardized mean difference (SMD) of the PBL group compared with those of the control group, using a random effects model. The pooled effect size suggested that the PBL students had significantly higher overall critical thinking scores on completion of the nursing course compared with the lecture students. Sensitivity analysis was conducted by excluding two studies with inadequate generation of a randomized sequence, and the result did not change the effects observed in the primary analysis. It indicated that the result of the meta-analysis was reliable though there was low heterogeneity. It also indicated the inadequate generation of a randomized sequence had no significant influence on the overall effect of the meta-analysis and it was not a major source of heterogeneity. Within the limitations of the present review, PBL was superior to traditional lectures in the training of critical thinking. This supports the result of a previous systematic review which reported a positive relationship between PBL and improved critical thinking in nursing students (Oja, 2011).

PBL intervention in the included studies lasted for a single or two semesters. Subgroup analysis according to the length of intervention indicated that students in the intervention group for two semesters had higher overall critical thinking scores, while students in the intervention group for one semester did not show improved critical thinking. Due to the outcome data for two semesters from one study, there is a need for more research to further support the effects of the length of PBL on critical thinking development.

A multitude of tools were used to measure critical thinking. The CCTDI uses the Delphi Report's consensus definition of critical thinking as the theoretical basis to measure critical thinking disposition. The emphasis is affective dispositions. The pooled effect sizes for truth-seeking, open-mindedness, systematicity, self-confidence, inquisitiveness and cognitive maturity of the CCTDI favored PBL. A higher score in truthseeking shows that the individual is eager to seek the truth, to be honest and objective about pursuing inquiry even if the findings do not support one's interest or preconceived opinions. The difference in open-mindedness reflects that students in PBL group are more tolerant of divergent views with sensitivity to the possibility of one's bias. Systematicity indicates one's disposition toward organized, orderly, focused, and diligent inquiry. The difference in self-confidence shows that students in PBL group have more tendency to trust their own reasoning skills and inclined to use these skills, rather than other strategies, to respond to problems. Inquisitiveness reflects one's intellectual curiosity and one's desire for learning even when the application of the knowledge is not readily apparent. PBL can improve the students' cognitive maturity, that is to say, PBL can make students prudent in making, suspending, or revising judgment. The higher scores in these subscales may be due to the emphasis in PBL on developing students' questioning and information-seeking skills and their discussion and application of new learning within the tutorials (Ozturk et al., 2008), and the focus in PBL on small group work, where students work closely with peers and giving and receiving feedback is an expectation.

Two studies used the CCTST to measure critical thinking skills. The emphasis of the CCTST is cognitive skills. The pooled effect sizes for all subscales (analysis, evaluation, inference, deduction and induction) of the CCTST showed no significant difference between the two groups. The WGCTA is reported to assess general reasoning skills rather than the discipline-specific thinking learned in a nursing program (Walsh and Seldomridge, 2006). Though the effect sizes for the most subscales (inference, recognition of assumptions, interpretations and evaluation of arguments) of the WCGTA were inconclusive, students in PBL group showed improved ability of deduction, who can better determine whether certain conclusions necessarily follow from information in given statements or premises (Magnusseen et al., 2000). The Bloom's Taxonomy is hierarchical; each level is subsumed by the higher levels. The effect sizes for comprehension, application, analysis, synthesis and evaluation favored PBL, while there was no

evidence of difference for knowledge. Considering the small studies, the real difference in these subscales is worthy of further investigation.

PBL as a teaching style is used by a number of tertiary sites across different faculties which suggest an acknowledgment of the merit of this particular approach, but is not a pedagogy that suits everyone both from a student and lecturer perspective (Wells et al., 2009). The different results of the included studies may be due to the complexity of PBL as an educational intervention. Firstly, though all included studies used PBL as the intervention method, the content and methods of delivering PBL interventions differed among the studies and the level of nursing students in each study sample varied greatly across studies (Oja, 2011), which may lead to different results. Secondly, some authors argue strongly that the success or otherwise of PBL has much to do with the role of the facilitator and the facilitator's role across the full program (Hwang and Kim, 2006; Rowan et al., 2008). Thirdly, group member problems, such as poor communication skills, lack of support for one another, distraction or stress in the group, unresolved personal conflict and disregard for getting tasks completed on time (Azer, 2001), may have negative effects.

4.2. Strengths and limitations

The strengths of this review are as follows: (1) we carried out a broad search of both mesh terms and keywords that covered PBL and critical thinking and nursing education, (2) the search was conducted on multiple databases, (3) in this systematic review and meta-analysis, most of the studies were well reported and had a low risk of bias, (4) sensitivity analysis showed the result of the meta-analysis was reliable, (5) publication bias is a major threat to the validity of any type of review. We found no evidence of publication bias, as the result in statistical analyses.

There are some limitations to our meta-analyses. Firstly, the number of included studies is small. It leads to a lack of data on some confounding factors that may influence the accuracy of the results. Secondly, critical thinking had been defined in a variety of ways. There were several standardized tests used to measure critical thinking. The different validity and reliability of instruments might influence the outcome measure (Yuan et al., 2008b). At last, the applied search strategy might have missed or failed to identify some important reports. Results of the current meta-analysis stand only for the specific selected studies and given the mentioned limitations, generalization and interpretation of the results should be done with consideration (Lambrinou et al., 2012).

4.3. Implications for future research

In contrast to previous reviews, this review found some evidence from RCTs to support use of PBL can improve the nursing students' critical thinking. However, further studies with lager sample size and high quality are needed to support the effects. Such studies should be designed using a randomized pretest/post-test format to control for internal and external threats to validity (Kowalczyk, 2011).

Subjects for RCTs were selected according to strict and often limited criteria, researchers were highly trained and a standardized intervention was applied to all subjects, regardless of individual subject characteristics and educational presentations (Sackett et al., 2000). Thus the content and method of delivering PBL intervention in an RCT might not be effective when it is used for other groups of students. Nurse educators must develop the intervention method according to their own actual nursing educational context.

It is not known if the instruments, such as the CCTDI and CCTST, used to measure critical thinking are adequate measures of the construct or valid measures of nursing students' critical thinking abilities. Otherwise, these are all self-report scales. The results might be affected by recall bias and socially desirable responses. Some studies showed these commercial critical-thinking instruments were not sensitive to measuring discipline specific critical thinking (Adams, 1999; Rapps et al., 2001; Simpson and Courtney, 2002; Stewart and Dempsey, 2005). There are continuing calls for different approaches to measuring critical thinking that are more specific to nursing (Worrell and Profetto-McGrath, 2007).

In addition, the training of critical thinking is a long process. Most present studies concluded the impact of PBL on the development of critical thinking through one nursing course and one semester. However, the real difference on development of critical thinking between the two groups should be examined different lengths of intervention, followed up and monitored by comparing the groups' critical thinking developmental curves in subsequent years (Tiwari et al., 2006). Thus we can examine the long-term effects of PBL on the students' critical thinking and understand the trend of critical thinking. We can also find out the weaknesses of the students' critical thinking and strengthen the cultivation of the students' critical thinking ability.

5. Conclusion

The PBL approach is believed to be an effective learning approach that encourages students as self-directed learners. PBL also supports the development of critical thinking, leadership, and teamwork skills to name a few. Our review and meta-analysis presents evidence that the use of PBL can improve nursing students' critical thinking when compared with the traditional lectures. In view of some limitations described earlier, additional RTCs with larger samples are warranted in a variety of educational settings to confirm or refute the findings we presented.

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