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REVIEW

Exploring the Application of Teaching Models to Foster Creativity in Nursing Students: A Systematic Literature Review and Bayesian Network Meta-Analysis

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ABSTRACT

Aim: To identify current knowledge on applying teaching models to foster creativity in nursing students through a systematic literature review and Bayesian network meta-analysis.

Background: Nursing requires adaptability while facing the challenge of the holistic patient care approach, expecting nurses to exhibit creative thinking beyond routine practice and predefined protocols. Studies advocate for innovative pedagogical methods to cultivate creativity in nursing, potentially surpassing conventional lectures in effectiveness. During at least two decades, various interrelated teaching models have emerged. Yet, their efficacy varies and requires validation. This study summarized randomized controlled trials comparing teaching models' efficacy in fostering creativity in nursing students.

Design: Network meta-analysis of randomized controlled pilot studies. In the literature review, PubMed, Embase, Scopus, Cochrane Library, Web of Science, ScienceDirect and major scientific websites were screened.

Method: Randomized controlled trials of students majoring in nursing (junior, undergraduate and graduate) were included. Studies including multiple treatments at the same time in the same group or comparing variants of the same intervention were excluded. The primary endpoint was the score of creativity. This meta-analysis adhered to the PRISMA statement, the PRISMA network meta-analysis extension statement and the Cochrane Collaboration recommendations (PRISMA checklist). WinBugs and Stata software were the primary tools employed for conducting network analyses, standardized pairwise comparisons and sensitivity analyses.

Results: Sixty-three studies, including 23 teaching models, were identified. Theory, drill, practice, combine (TDPC) (surface under the cumulative ranking curve [SUCRA] = 98.3%), Six Thinking Hats (SUCRA = 94.8%) and 3D printing models (SUCRA = 88.4%) than other teaching models were associated with a higher probability of scoring higher in creativity. Treatment ranking indicated that TDPC had the highest probability of being the most effective for scoring higher in creativity. However, the comparative efficacy of TDPC, Six Thinking Hats and 3D printing models was similar for scoring in creativity (mean difference 4.70, 95% credible interval −7.99 to 17.31; mean difference 9.18, 95% credible interval −3.54 to 21.72). Neither sensitivity analysis nor metaregression analysis demonstrated any significant heterogeneity in either scenario.

Conclusion: As a result of the network meta-analysis, it was identified that TDPC, Six Thinking Hats and 3D printing models seem more adequate than other new-generation teaching models in terms of efficacy while generating potentially improved nursing students' decision-making and problem-solving skills through theoretical learning, skill practice, role-playing and teamwork, fostering creative thinking and innovation. Hence, evidence suggests that these methods can be used as a standard comparator in teaching experiment research to increase the real-world applicability of the results.

Summary

What Is Already Known About This Topic?

- Nursing requires adaptability while facing the challenge of the holistic patient care approach, expecting that nurses exhibit creative thinking beyond routine practice and predefined protocols. Previous studies advocate for innovative pedagogical methods to cultivate creativity in nursing and potentially surpassing conventional lectures methods. For over two decades, various interrelated teaching models have emerged. Yet, their efficacy varies and many still require validation.

What This Paper Adds?

- This study summarized randomized controlled trials comparing teaching models' efficacy in fostering creativity in nursing students. This is a scarce type of study as applied to better understand the role of creativity in nursing education.

The Implications of This Paper:

- International evidence indicates some level of scale bias in different teaching modes, leading to concerns regarding the potential impact of scale standards on teaching publications. One main implication is the need to promote an international debate on the need to revise and harmonize the use of scales adopted in evaluating nursing education, namely, the promotion of creativity and related skills.

1 | Introduction

What is the relationship between teaching models and creativity in nursing education?

Nursing is a profession that frequently acts in unexpected situations and involves providing holistic care for patients with different health conditions. Hence, nurses must be able to go beyond routine nursing and develop creative thinking to make beneficial decisions (Chan 2013). The term 'Creativity' is used to refer to the ability to generate new ideas, start something new or solve complicated problems in creative ways (Beitz and Wolf 1997). Scholars (Z. Zhang et al. 2016) have made contributions to developing students' critical thinking. However, few studies have been conducted to explore learners' creativity in nursing education, particularly in Chinese contexts. Munir and Awan (2022) and Yang and Hung (2021) suggested that creative thinking should be valued and evenly balanced with critical thinking to tackle new and unique clinical conditions.

Beitz and Wolf (1997) and X. Ma et al. (2018) proposed that using creative teaching approaches at school or the workplace can foster nurses' and nursing students' creativity and enhance the productivity of traditional lecture approaches. Other authors (Chan 2013) identified studies that discussed the concept of creative thinking in nursing education or reported a strategy that improved students' creative thinking and group work, while improving student creativity in nursing education. Other studies have suggested that artistic expression, self-directed learning and teamwork can boost nurses' and students' creativity and yield positive outcomes (X. Ma et al. 2018). A qualitative study investigated how nurses perceive and experience creativity in clinical settings, demonstrating its benefits for patients, nurses, their colleagues, hospitals and universities (Shahsavari Isfahani et al. 2015). In summary, the design of an instructional model should integrate students' psychological attributes and social contexts to optimize teaching and learning outcomes.

Analysis of existing nursing education literature reveals other ongoing challenges in training objectives, faculty, teaching methods and evaluation, including a theory-practice gap and curriculum flaws. In the past 20 years, several teaching models have emerged to enhance the creative ability or creative thinking of students, many of which are structurally interrelated and have similar mechanisms of action. However, the validity of these teaching models in terms of efficacy remains uncertain and in need of further evidence. To transform nursing education's design thinking, we need tools and knowledge that foster creativity and innovation. Fostering the skilful and inspired application of creative strategy to solve problems by using teaching models is one approach to tackle this challenge.

We have assumed the following definitions for this research: Creativity is the interaction among aptitude, process and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context (Plucker et al. 2004). Teaching models are relatively stable frameworks and procedures constituting teaching activities under the guidance of certain teaching ideas and theories, which, as frameworks, highlight the relationship and function between the whole teaching activity and its elements and, as procedures, emphasize orderliness and operability (Joyce and Calhoun 2024).

Existing research has highlighted creativity's significance in nursing practice, explored preliminary pedagogical strategies for fostering creative thinking and recognized structured teaching models' potential to enhance such abilities. However, a critical gap persists: Despite two decades of creativity-oriented

teaching models, their efficacy, structural interconnections and mechanisms lack sufficient empirical validation, with uncertain validity requiring further evidence. This study employs Bayesian methods uniquely suited to integrating prior evidence with new data, quantifying uncertainty and modelling complex variable interrelationships—to evaluate these models' effectiveness, addressing current ambiguities in their mechanisms and comparative efficacy to yield robust insights for evidence-based nursing education improvements.

2 | Methods

This study reports an overview of all randomized controlled trials that compare teaching models in terms of efficacy in enhancing the creative ability or creative thinking of nursing students. Network meta-analysis, also known as mixed treatment comparison (MTC) meta-analysis, is a method that expands pairwise meta-analysis by incorporating more intricate data structures, which enables enhancing inference on treatment effectiveness by integration of direct and indirect comparisons and facilitating simultaneous inference on all treatments to select the best option (Lu and Ades 2004). The aim of our study is to provide a clinically useful summary of the results of the network meta-analysis that can be used to guide teaching decisions.

In Bayesian statistics, the Markov chain Monte Carlo (MCMC) method is a powerful computational technique for drawing samples from complex posterior distributions. The Brooks–Gelman–Rubin (BGR) method assesses MCMC convergence by comparing multiple independent chains' posterior distributions to see if they converge to the target distribution. Node splitting is a method used to evaluate model assumptions, especially in Bayesian networks. By dividing the network nodes into subnodes, a more detailed model evaluation of assumptions and parameters is possible, thus facilitating problem identification and more precise parameter estimation.

2.1 | Data Sources and Study Strategy

This meta-analysis adhered to the PRISMA statement, the PRISMA network meta-analysis extension statement and the Cochrane Collaboration recommendations (PRISMA checklist) (Higgins et al. 2011; Hutton et al. 2015; Moher et al. 2009). Randomized controlled trials comparing at least two different teaching models were searched in PubMed, Embase, Scopus, Cochrane Library, Web of Science and ScienceDirect electronic databases, as well as major scientific websites (www.clinicaltrials.gov). Abstracts and presentations from major educational conferences were reviewed. The electronic search process was complemented by exploring the bibliography of relevant nursing education reviews and key teaching model publications.

The web appendix details the subject headings used for study identification. No language restrictions or filters were applied. The search was conducted from the inception date of the databases until 27 April 2023.

2.2 | Selection Criteria and Study Design

Inclusion criteria were as follows: randomized controlled trials of students majoring in nursing; students of any educational level; and the primary endpoint was the score of creativity, irrespective of the creativity scale used. While enriching the study with diverse data and perspectives, inconsistencies in scales and scoring may hinder the comparability of findings.

The exclusion criteria applied were comparison between variants of the same type of teaching model (same treatment group) and studies involving combinations of multiple treatments within the same group simultaneously; to ensure accurate results, studies with incomplete data, missing outcome measures or duplicate publications were also omitted.

Three reviewers independently conducted searches and screened retrieved records at the title and abstract level. Full-text eligibility for identified studies is assessed by the same three reviewers, and discrepancies are resolved by consensus under the supervision of two additional investigators. Before statistical analyses, we evaluated the quality of the study design and methods using the risk of bias tool recommended by the Cochrane Collaboration (Higgins et al. 2011). The data from the original reports have been carefully compiled and organized into specific electronic spreadsheets for ease of access and analysis. Investigators were contacted to provide additional data to supplement incomplete original articles.

2.3 | Patient Involvement

Patients did not play a role in the study, neither in establishing the research question or outcome measures, nor did they contribute to the study's design and implementation.

2.4 | Statistical Analyses

The study applied the continuous creativity scale score for efficacy analysis (provided baseline scores, endpoint means and standard deviations for creativity rating scales such as TCI-C [Yubo 2012] or Williams Creativity Scale [Xiaoling et al. 2016]). Intention-to-treat data were utilized in this meta-analysis. The network meta-analysis was conducted for each endpoint utilizing random-effects consistency models and was based on 'node splitting', where evidence for a particular comparison (node) is categorized into 'direct' and 'indirect' to verify the consistency of direct and indirect evidence (Dias et al. 2010; Lu and Ades 2006).

First pairwise meta-analyses with the weighted noniterative method estimating the overall treatment effect were undertaken (DerSimonian and Laird 1986). The pooled estimates in the frequentist framework were represented by summary mean differences (MDs), along with their corresponding 95% confidence intervals. The study examined global heterogeneity using forest plots and the I^2 statistic, with inconsistency considered significant for p values below 0.05. The analyses were conducted applying Stata Version 17.

Second, a random-effects model computed with MCMC simulations in WinBUGS, utilizing four chains with overdispersed initial values, with Gibbs sampling applied with 50,000 iterations after a burn-in phase of 20,000 iterations was undertaken. The study assessed the convergence using the BGR method. The data were inputted following the arm-based approach and modelled using sample means (i.e., normal likelihood and identity link) with a normal distribution (Salanti et al. 2008). For each pair of treatments, the study calculated the posterior mean effect or MD and determined 95% credible intervals. The methodology also defined the probability associated with each teaching model as the most efficacious interventional strategy, as well as second, third and so on, by calculating the MD for each teaching model compared to a common control group when significant variations in treatment effect were observed.

The Q test and I^2 statistic were applied to grade the observed variance, which indicated variations in the effect size across the studies, with the values corresponding to mild (25%), moderate (25%–75%) and severe (75%) heterogeneity (Higgins et al. 2003). The calculation was performed to determine the variation of the true effect size among the studies that were included (Borenstein et al. 2009).

Finally, the study concluded with an analysis comparing the effectiveness of 23 different teaching models. By visually inspecting adjusted comparisons and contour-enhanced funnel plots, we evaluated publication bias. To investigate how scales affect outcome estimates, a metaregression analysis was conducted, and it was complemented with another sensitivity analysis that investigated the influence of a single study on the overall meta-analysis estimates. All analyses were performed using R (Version 4.1.2), Stata (Version 17.0) and RevMan (Version 5.4). Figures 1 and 2 describe the screening process and the weighted network.

3 | Results

3.1 | Systematic Review and Qualitative Assessment

A total of 63 studies and 23 teaching models were included: Six Thinking Hats; hands-on inquiry-based learning; maker education; instructional system design; problem-based learning; situational teaching mode; case-based learning; mind map; behaviour-oriented teaching model; evidence-based nursing; team-based learning; 3D printing models; conceive, design, implement, operate (CDIO); PDCA cycle; quality control circle; TDPC; interactive teaching method; four-step cycle teaching method; microteaching; seminar; project-based learning; heuristic education; and lecture-based learning. Figure 1 shows each phase of the screening process, and Figure 2 shows the weighted network. Cochrane's Collaboration Risk of Bias Tool (Figure S1) indicated that most studies may be affected by performance bias due to open-label design (Higgins et al. 2011).

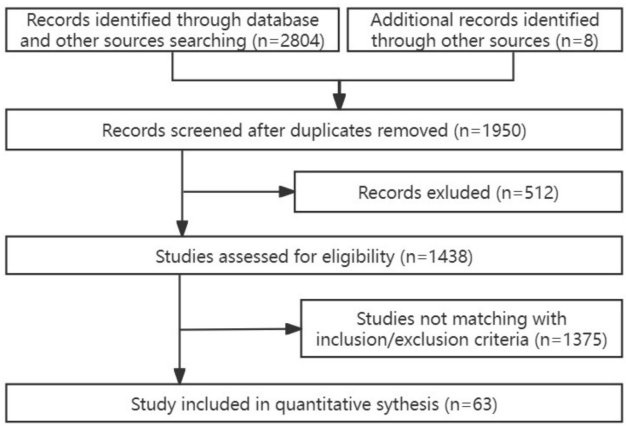

FIGURE 1 | Systematic search and screening process of studies.

Table 1 describes the key characteristics of the included studies (study, age, gender, design and location, treatments, sample size, education, follow-up length and instruments). The total number of participants in the 63 studies was 6287, with a sample size ranging from 30 (L. Chen et al. 2021; Lan et al. 2015) to 516 (A. Wang et al. 2016). Across the 63 studies included participants had a mean age of 20 years and were prevalently female (65%). Fifteen studies included only women (Che et al. 2020; H. Deng and Zeng 2016; L. Deng 2014; Fan 2021; M. Li, Peng, and Chen 2019; L. Lv 2021; Q. Lv et al. 2022; A. Song and Tao 2012; Y. Sun et al. 2013; X. Wang et al. 2018; W. Wei 2021; Wu et al. 2021; Xin and Wang 2022; C. Yan et al. 2011; Z. Zhu 2011), and the other studies were mixed gender. In about 57% of studies, follow-up was performed at the hospital, while 41% of studies had planned clinical follow-up at school. Almost 29% of studies included only students with a bachelor's degree, nearly 57% included only students with a college degree, while nine studies included both degrees. In addition, follow-up periods varied from 1 to 18 months. According to our

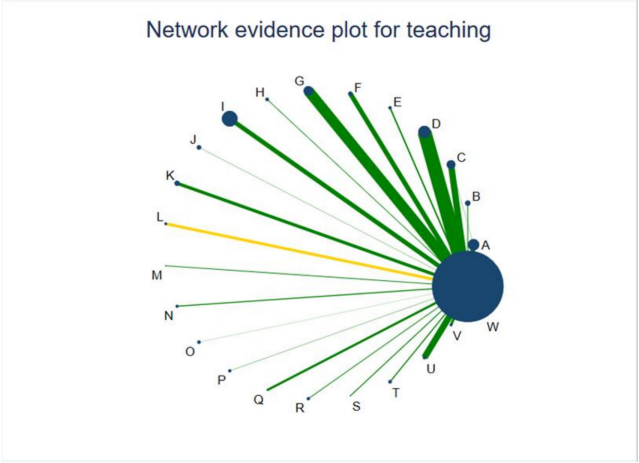

FIGURE 2 | Network of interventional treatments included in meta-analysis. A = situational teaching mode; B = behaviour-oriented teaching model; C = case-based learning; D = evidence-based nursing; E = four-step cycle teaching method; F = hands-on inquiry-based learning; G = maker education; H = microteaching; I = problem-based learning; J = project-based learning; K = seminar; L = 3D printing models; M = CDIO; N = heuristic education; O = instructional system design; P = interactive teaching method; Q = mind map; R = PDCA cycle; S = quality control circle; T = Six Thinking Hats; U = TDPC; V = team-based learning; W = lecture-based learning. The area of the circle represents the sample size of the protocol group, the lines represent head-to-head comparisons, the line thickness represents the number of studies and the yellow lines represent the blind method used in the studies.

TABLE 1 | Main characteristics of included studies.

Study	Age (years)	Female (%, *n*)	Design and location	Treatments (sample size)	Education	Follow-up	Instruments
F. Yan et al. (2019)	NA	NA	1:1 randomization, open label, single, hospital	STH vs. LBL (70/66)	Undergraduate	1 month	The indicator system for evaluating creativity of clinical medical students; self-report
A. Song and Tao (2012)	18	100 (60)	1:1 randomization, open label, single, school	HIBL vs. LBL (30/30)	Junior college/ undergraduate	4 months	Self-made questionnaire; self-report
L. Chen et al. (2021)	26	90 (27)	1:1 randomization, open label, single, hospital	CDIO vs. LBL (15/15)	Undergraduate	3 months	Creative behaviour scale; computer
Y. Sun et al. (2013)	21	100 (120)	1:1 randomization, open label, single, school	Seminar vs. LBL (60/60)	Higher vocational	NA	Self-made questionnaire; self-report
X. Song and Hou (2020)	23	95 (57)	1:1 randomization, open label, single, hospital	Seminar vs. LBL (30/30)	Junior college	12 months	Self-made questionnaire; self-report
H. Hu and Chen (2017)	19	91 (83)	1:1 randomization, open label, single, school	ME vs. LBL (45/46)	Higher vocational	5 months	TCI-C; computer
M. Wei et al. (2021)	21	92 (98)	1:1 randomization, open label, single, school	ME vs. LBL (54/52)	Undergraduate	4 months	TCI-C; computer
Q. Liu (2021)	NA	NA	1:1 randomization, open label, single, school	ME vs. LBL (50/50)	Junior college	NA	TCI-C; computer
X. Xu (2020b)	NA	90 (130)	1:1 randomization, open label, single, school	ME vs. LBL (71/73)	Undergraduate	2 months	Williams Creativity Scale; computer
C. Xu (2020a)	NA	NA	1:1 randomization, open label, single, school	ME vs. LBL (49/48)	Undergraduate	3 months	TCI-C; computer

(Continues)

TABLE 1 | (Continued)

Study	Age (years)	Female (%, *n*)	Design and location	Treatments (sample size)	Education	Follow-up	Instruments
H. Deng and Zeng (2016)	21	100 (120)	1:1 randomization, open label, single, hospital	ISD vs. LBL (60/60)	Junior college/ undergraduate	12 months	Self-made questionnaire; self-report
X. Wang et al. (2018)	NA	100 (120)	1:1 randomization, open label, single, hospital	ME vs. LBL (60/60)	Junior college/ undergraduate	NA	Self-made questionnaire; self-report
R. Wei (2017)	18	96 (75)	1:1 randomization, open label, single, school	HIBL vs. LBL (39/39)	Undergraduate	NA	Self-made questionnaire; self-report
Bian (2019)	NA	NA	1:1 randomization, open label, single, school	Seminar vs. LBL (45/43)	Undergraduate	2 months	Creativity assessment scale; self-report
D. Li, Lu, et al. (2019)	NA	94 (128)	1:1 randomization, open label, single, school	TDPC vs. LBL (70/66)	Undergraduate	NA	Self-made questionnaire; self-report
Du et al. (2010)	NA	NA	1:1 randomization, open label, single, school	PBL vs. LBL (64/62)	Undergraduate	NA	Self-made questionnaire; self-report
Lan et al. (2015)	NA	NA	1:1 randomization, open label, single, school	STM vs. LBL (50/51)	Undergraduate	NA	Self-made questionnaire; self-report
Shi (2020)	20	93 (28)	1:1 randomization, open label, single, school	STM vs. LBL (15/15)	NA	4 months	Self-made questionnaire; self-report
Zheng and Wang (2023)	21	72 (43)	1:1 randomization, open label, single, hospital	MM vs. LBL (30/30)	Undergraduate	NA	Williams Creativity Scale; computer
M. Wei and Zhao (2017)	20	89 (161)	1:1 randomization, open label, single, school	BOTM vs. LBL (90/90)	Higher vocational	4 months	Comprehensive competency assessment scale; self-report
Gao (2020)	20	90 (92)	1:1 randomization, open label, single, school	BOTM vs. LBL (52/50)	Junior college	5 months	Self-made questionnaire; self-report

(Continues)

TABLE 1 | (Continued)

Study	Age (years)	Female (%, *n*)	Design and location	Treatments (sample size)	Education	Follow-up	Instruments
X. Zhu and Huang (2018)	NA	NA	1:1 randomization, open label, single, hospital	EBN vs. LBL (100/100)	Undergraduate	NA	Self-made questionnaire; self-report
Che et al. (2020)	NA	NA	1:1 randomization, open label, single, hospital	STM vs. LBL (58/60)	Undergraduate	18 moths	Health education competency assessment scale; self-report
H. Wang et al. (2021)	21	100 (34)	1:1 randomization, open label, single, hospital	CBL vs. LBL (17/17)	NA	NA	Comprehensive competency assessment scale; self-report
Y. Wang (2014)	NA	93 (74)	1:1 randomization, open label, single, school	PBL vs. LBL (40/40)	Junior college	8 months	Self-made questionnaire; self-report
Lin and Huang (2021)	21	73 (73)	1:1 randomization, open label, single, hospital	PBL vs. LBL (50/50)	NA	NA	Self-made questionnaire; self-report
D. Liu (2016)	17	90 (81)	1:1 randomization, open label, single, school	PBL vs. LBL (45/45)	NA	NA	Self-made questionnaire; self-report
J. Zhao and Xu (2021)	20	42 (25)	1:1 randomization, open label, single, hospital	PBL vs. LBL (30/30)	Undergraduate	3 months	Self-made questionnaire; self-report
Xin and Wang (2022)	22	95 (97)	1:1 randomization, open label, single, school	PDCA vs. LBL (51/51)	Junior college	NA	Self-made questionnaire; self-report
W. Wei (2021)	21	100 (68)	1:1 randomization, open label, single, hospital	TBL vs. LBL (34/34)	Junior college/ undergraduate	NA	Self-made questionnaire; self-report
L. Lv (2021)	19	100 (80)	1:1 randomization, open label, single, hospital	PBL vs. LBL (40/40)	NA	NA	Self-made questionnaire; self-report
Zeng (2021)	20	100 (60)	1:1 randomization, open label, single, hospital	PBL vs. LBL (30/30)	Junior college/ undergraduate	NA	Self-made questionnaire; self-report

(Continues)

TABLE 1 | (Continued)

Study	Age (years)	Female (%, *n*)	Design and location	Treatments (sample size)	Education	Follow-up	Instruments
T. Zhang (2022)	20	93 (119)	1:1 randomization, open label, single, school	PBL vs. LBL (64/64)	Technical secondary school	NA	Self-made questionnaire; self-report
Peng (2020)	21	79 (54)	1:1 randomization, open label, single, hospital	PBL vs. LBL (34/34)	Associate college	NA	Self-made questionnaire; self-report
Xia (2019)	22	97 (64)	1:1 randomization, double blind, single, hospital	3D PM vs. LBL (33/33)	NA	NA	Self-made questionnaire; self-report
A. Song et al. (2021)	20	94 (75)	1:1 randomization, open label, single, hospital	PBL vs. LBL (40/40)	NA	3 months	Self-made questionnaire; self-report
S. Ma (2019)	20	99 (237)	1:1 randomization, open label, single, school	STM vs. LBL (120/120)	Higher vocational	NA	Self-made questionnaire; self-report
Z. Zhu (2011)	NA	NA	1:1 randomization, open label, single, school	ITM vs. LBL (48/50)	Junior college	NA	Self-made questionnaire; self-report
W. Li (2022)	20	100 (60)	1:1 randomization, open label, single, hospital	QCC vs. LBL (30/30)	NA	NA	Self-made questionnaire; self-report
N. Wang et al. (2019)	NA	NA	1:1 randomization, open label, single, school	STM vs. LBL (42/41)	Higher vocational	NA	Self-made questionnaire; self-report
Y. Wang (2022)	20	97 (97)	1:1 randomization, open label, single, hospital	STM vs. LBL (50/50)	NA	NA	Self-made questionnaire; self-report
X. Li et al. (2022)	23	89 (55)	1:1 randomization, open label, single, hospital	FCTM vs. LBL (31/31)	Undergraduate	3 months	Self-made questionnaire; self-report
Tao and Tan (2013)	18	87 (61)	1:1 randomization, open label, single, school	HIBL vs. LBL (35/35)	Undergraduate	NA	Self-made questionnaire; self-report

(Continues)

TABLE 1 | (Continued)

Study	Age (years)	Female (%, *n*)	Design and location	Treatments (sample size)	Education	Follow-up	Instruments
R. Li and Li (2017)	20	88 (35)	1:1 randomization, open label, single, hospital	MT vs. LBL (20/20)	NA	NA	Self-made questionnaire; self-report
Wu et al. (2021)	20	83 (105)	1:1 randomization, open label, single, school	CBL vs. LBL (63/63)	NA	NA	Self-made questionnaire; self-report
Lei et al. (2007)	NA	100 (108)	1:1 randomization, open label, single, school	pbl vs. LBL (55/53)	Junior college	NA	Self-made questionnaire; self-report
C. Yan et al. (2011)	NA	NA	1:1 randomization, open label, single, school	pbl vs. LBL (53/53)	Junior college	NA	Self-made questionnaire; self-report
J. Hu et al. (2013)	NA	100 (100)	1:1 randomization, open label, single, hospital	EBN vs. LBL (50/50)	Undergraduate	12 months	Williams Creativity Scale; computer
S. Zhao and Liu (2018)	20	93 (95)	1:1 randomization, open label, single, hospital	EBN vs. LBL (51/51)	Technical secondary school/ junior college/ undergraduate	NA	Self-made questionnaire; self-report
Y. Zhang (2019)	19	88 (35)	1:1 randomization, open label, single, hospital	EBN vs. LBL (20/20)	Associate college/ undergraduate	NA	Self-made questionnaire; self-report
H. Zhang et al. (2022)	21	82 (65)	1:1 randomization, open label, single, hospital	EBN vs. LBL (33/46)	Undergraduate	1 month	Williams Creativity Scale; computer
Fan (2021)	19	92 (61)	1:1 randomization, open label, single, hospital	EBN vs. LBL (33/33)	NA	NA	Self-made questionnaire; self-report
Feng et al. (2015)	20	100 (60)	1:1 randomization, open label, single, hospital	EBN vs. LBL (30/30)	Junior college	NA	Self-made questionnaire; self-report

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TABLE 1 | (Continued)

Study	Age (years)	Female (%, *n*)	Design and location	Treatments (sample size)	Education	Follow-up	Instruments
A. Wang et al. (2016)	21	93 (74)	1:1 randomization, open label, single, hospital	EBN vs. LBL (40/40)	NA	NA	Self-made questionnaire; self-report
Bai et al. (2011)	NA	NA	1:1 randomization, open label, single, community	PBL vs. LBL (260/256)	Technical secondary school/ junior college/ undergraduate	1 month	Self-made questionnaire; self-report
L. Deng (2014)	17	83 (66)	1:1 randomization, open label, single, hospital	HE vs. LBL (40/40)	NA	2 months	Self-made questionnaire; self-report
M. Li, Peng, and Chen (2019)	22	100 (56)	1:1 randomization, open label, single, hospital	STM vs. LBL (28/28)	NA	6 months	Self-made questionnaire; self-report
S. Song et al. (2012)	NA	100 (60)	1:1 randomization, open label, single, hospital	PBL vs. LBL (30/30)	Associate college/ undergraduate/ master	NA	Self-made questionnaire; self-report
Zhou et al. (2022)	23	87 (41)	1:1 randomization, open label, single, hospital	FCTM vs. LBL (24/24)	NA	3 months	Self-made questionnaire; self-report
Z. Chen and Dong (2022)	20	53 (104)	1:1 randomization, open label, single, hospital	EBN vs. LBL (99/99)	NA	NA	Self-made questionnaire; self-report
Z. Chen and Xiong (2021)	20	82 (82)	1:1 randomization, open label, single, hospital	STM vs. LBL (50/50)	NA	NA	Self-made questionnaire; self-report
Q. Lv et al. (2022)	20	94 (85)	1:1 randomization, open label, single, hospital	MT vs. LBL (45/45)	NA	NA	Self-made questionnaire; self-report
Cao and Qiu (2021)	19	100 (100)	1:1 randomization, open label, single, hospital	PBL vs. LBL (50/50)	Technical secondary school/ junior college	NA	Self-made questionnaire; self-report

Note: Data are proportion (%) and number of participants for sex; data are pooled mean or median for age.
Abbreviations: NA = not applicable; TCI-C = The Chinese revision of the Test of Creative Imagination.

quality assessment, all studies were deemed unclear and only one study employed double blindness.

For creativity assessment, 49 studies used a self-made questionnaire to assess creativity, 4 studies used TCI-C (H. Hu and Chen 2017; Q. Liu 2021; M. Wei et al. 2021; C. Xu 2020a) and 4 studies used the Williams creativity scale (Shi 2020; X. Xu 2020b; C. Yan et al. 2011; Y. Zhang 2019). Two studies used a comprehensive competency assessment scale (Che et al. 2020; Zheng and Wang 2023), and four studies used other creativity assessment tools, such as the indicator system for evaluating the creativity of clinical medical students (F. Yan et al. 2019), the creative behaviour scale (L. Chen et al. 2021), the creativity assessment scale (Bian 2019) and the health education competency assessment scale (X. Zhu and Huang 2018).

We did direct comparisons (Table 2), showing that efficacy favours situational teaching mode, case-based learning, evidence-based nursing, microteaching, problem-based learning, instructional system design, quality control circle and Six Thinking Hats over lecture-based learning. These results arise from 63 independent analyses without adjustment for multiple testing.

3.2 | Bayesian Network Meta-Analyses

In regard to the main outcome indicators (Figure 3), the use of 3D printing models, Six Thinking Hats or TDPC was the most effective treatments, while the use of lecture-based learning showed the lowest MD in creativity, followed by project-based learning. Although the quality control circle showed fewer clear benefits compared to TDPC, Six Thinking Hats and 3D printing models, there was still some improvement observed when compared to the four-step cycle teaching method, problem-based learning, project-based learning and lecture-based learning, with the credibility interval for SMDs slightly above 0. TDPC ranked as the best therapy in treatment, but its creativity was only slightly higher than that of 3D printing models or Six

TABLE 2 | Creativity score for efficacy in meta-analyses of direct comparisons between each pair of teaching models.

	Number of studies	Number of patients	SMD (95% CI)
Situational teaching mode vs. case-based learning	6	496	−1.73 (−5.56, 2.09)
Situational teaching mode vs. lecture-based learning	7	727	2.55 (1.36, 3.75)
Behaviour-oriented teaching model vs. lecture-based learning	2	282	1.67 (−0.68, 4.01)
Case-based learning vs. lecture-based learning	1	101	3.37 (2.08, 4.67)
Evidence-based nursing vs. lecture-based learning	9	925	2.13 (1.01, 3.24)
Four-step cycle teaching method vs. lecture-based learning	2	110	1.03 (−1.33,3.40)
Hands-on inquiry-based learning vs. lecture-based learning	3	208	1.58 (−0.35,3.51)
Maker education vs. lecture-based learning	6	658	0.65 (−0.71, 2.00)
Microteaching vs. lecture-based learning	2	130	2.81 (0.40, 5.22)
Problem-based learning vs. lecture-based learning	9	1212	2.29 (1.18, 3.41)
Project-based learning vs. lecture-based learning	2	214	1.30 (−1.05, 3.64)
Seminar vs. lecture-based learning	3	268	0.77 (−1.15, 2.69)
3D printing models vs. lecture-based learning	1	66	2.45 (−0.90, 5.81)
CDIO vs. lecture-based learning	1	30	1.50 (−1.89, 4.89)
Heuristic education vs. lecture-based learning	1	80	0.43 (−2.89, 3.75)
Instructional system design vs. lecture-based learning	1	120	4.34 (0.98, 7.69)
Interactive teaching method vs. lecture-based learning	1	98	0.92 (−2.40, 4.24)
Mind map vs. lecture-based learning	1	60	1.62 (−1.73, 4.96)
PDCA cycle vs. lecture-based learning	1	102	0.67 (−2.64, 3.99)
Quality control circle vs. lecture-based learning	1	60	6.31 (2.78, 9.84)
Six Thinking Hats vs. lecture-based learning	1	136	5.92 (2.53, 9.30)
TDPC vs. lecture-based learning	1	136	1.28 (−2.03, 4.59)
Team-based learning vs. lecture-based learning	1	68	0.85 (−2.48, 4.18)

Abbreviations: CI = confidence interval; SMD = standardized mean difference.

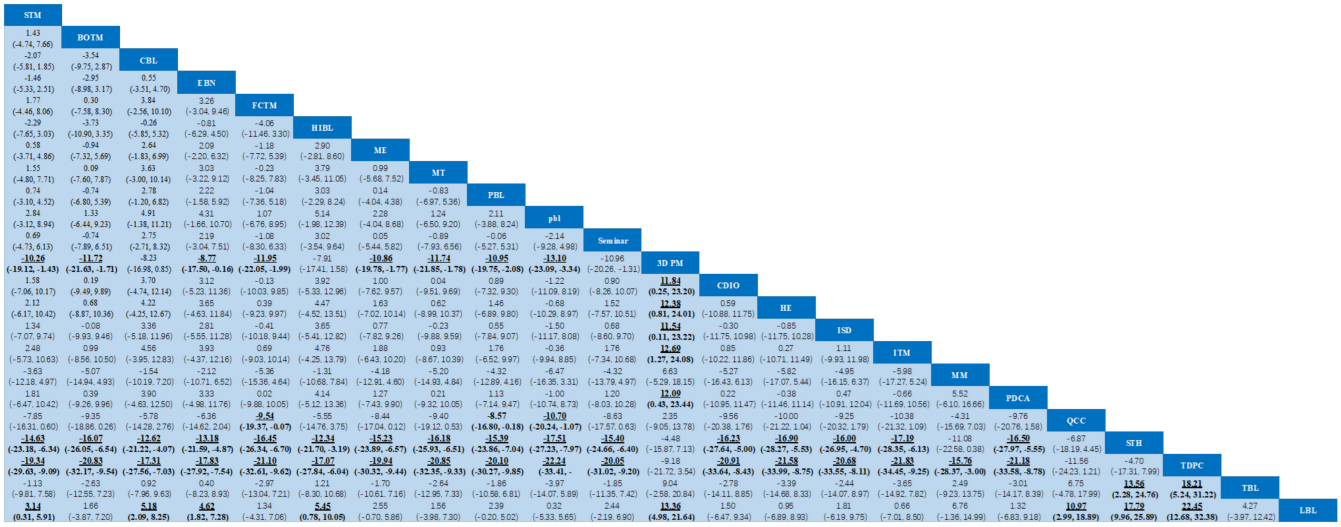

FIGURE 3 | Efficacy of the 23 teaching models. Results are the SMDs in the column-defining treatment compared with the SMDs in the row-defining treatment. For efficacy, SMDs higher than 0 favour the column-defining treatment. Significant results are in bold and underscored. 3D PM = 3D printing models; BOTM = behaviour-oriented teaching model; CBL = case-based learning; CDIO = conceive, design, implement, operate model; CI = credibility interval; EBN = evidence-based nursing; FCTM = four-step cycle teaching method; HE = heuristic education; HIBL = hands-on inquiry-based learning; ISD = instructional system design; ITM = interactive teaching method; LBL = lecture-based learning; ME = maker education; MM = mind map; MT = microteaching; PBL = problem-based learning; pbl = project-based learning; PDCA = PDCA cycle; QCC = quality control circle; SMD = standardized mean difference; STH = Six Thinking Hats; STM = situational teaching mode; TBL = team-based learning; TDPC = theory, drill, practice, combination model.

Thinking Hats (MD 9.18, 95% credible interval −3.54 to 21.72; MD 4.70, 95% credible interval −7.99 to 17.31).

The study exhibits the probability distribution (Figure S3) of each treatment's ranking in the 23 available positions. TDPC, Six Thinking Hats and 3D printing models were among the most efficacious treatments. The cumulative probabilities of being among the top three most efficacious treatments were TDPC (98.3%), Six Thinking Hats (94.8%), 3D printing models (88.4%), quality control circle (83.7%), mind map (67.6%), case-based learning (67.6%), hands-on inquiry-based learning (64.5%), evidence-based nursing (60.9%), team-based learning (52.9%), maker education (42.2%), situational teaching mode (41.2%), seminar (40.8%), problem-based learning (40.4%), instructional system design (36.6%), CDIO (34.9%), behaviour-oriented teaching model (34.6%), microteaching (34.1%), PDCA cycle (32.9%), four-step cycle teaching method (32.0%), heuristic education (31.2%), interactive teaching method (29.3%), project-based learning (24.3%) and lecture-based learning (16.9%).

These results are based on 171 simultaneous comparisons, and it is likely that around three statistically significant findings would occur by chance alone. The model converged adequately. Heterogeneity (global $I^2 = 3\%$) was low for creativity. The deviance information criterion was used to compare and demonstrate the similarity in model fitting. Loop-specific heterogeneity estimates and the node-split analysis showed no significant inconsistency in the comparison of situational teaching mode versus case-based learning or lecture-based learning (IF 1.74, 95% credible interval 0.00–7.02, loop-specific heterogeneity [τ^2] 2.988).

Sensitivity analyses revealed no significant variations in the effects of the individual studies on the overall meta-analysis estimates. And scale bias was not a major factor in the metaregression analysis, as SMDs and final rankings remained largely unchanged.

4 | Discussion

Our analysis was based on 63 studies including 6287 individuals randomly assigned to 23 different teaching models. Our meta-analysis is distinct from the earlier study by (X. Ma et al. 2018), excluding (Ku et al. 2002) due to a self-created teaching model and limited application scope. *Our findings might help to choose among teaching models for improving creativity and critical thinking of nursing students.* In terms of response, TDPC, Six Thinking Hats and 3D printing models were significantly more efficacious than case-based learning, situational teaching mode, seminar, problem-based learning, evidence-based nursing, behaviour-oriented teaching model, hands-on inquiry-based learning, project-based learning, CDIO model, four-step cycle teaching method, interactive teaching method, team-based learning, mind map, PDCA cycle, seminar, heuristic education, instructional system design, maker education and lecture-based learning. Among these approaches, 3D printing models did not show statistical significance in terms of effectiveness when compared to case-based learning, hands-on inquiry-based learning and seminar. Only TDPC was found to be more effective than mind map. Direct comparisons showed situational teaching mode, case-based learning, evidence-based nursing, microteaching, problem-based learning, instructional system design, quality control circle and Six Thinking Hats to be more efficacious than lecture-based learning. Conversely, indirect comparisons revealed statistically significant differences between the 3D printing and TDPC models versus the lecture-based model.

Direct comparisons typically presume study consistency, while indirect comparisons might need adjustments for baseline differences, potentially causing biased outcomes.

With low heterogeneity across studies ($I^2 = 3\%$), the included studies demonstrated considerable homogeneity in clinical, methodological and statistical aspects. Strict inclusion/exclusion criteria in a uniform RCT design ensured similar baseline characteristics across studies. The studies concentrated on particular age ranges of nursing students, with remarkably consistent participant characteristics. At the same time, standardized outcome indicators in the included studies minimized heterogeneity stemming from differing outcome measures. Despite the low overall consistency, we still performed metaregression and sensitivity analyses to explore factors that might influence heterogeneity; however, no significant heterogeneity was found.

In TDPC education model, T refers to theory, D refers to drill, P refers to practice and C refers to combine. Nursing students experiences evolve from traditional classroom to social practice and related activities. The support of 'Society–School' system, the use of Internet means to create an academic atmosphere of innovation and entrepreneurship, exposes nursing students to the field of entrepreneurship, and promote the improvement of the psychological quality of innovation and entrepreneurship, innovation knowledge and the innovation ability level of nursing students (D. Li, Lu, et al. 2019). The TDPC model, in line with constructivist learning theory, fosters active knowledge building in students through contextually relevant learning experiences that emphasize learner initiative. Specifically, the application of the TDPC model to obstetrics and gynaecology education resulted in increased student interest and improved performance in teamwork and self-directed learning (D. Li, Lu, et al. 2019). To promote creative thinking in nursing students, educators should balance course freedom and guidance to allow students to develop constructive and useful ideas (Chan 2013). Six thinking cap is Edward de Bono put forward a thinking tool, the six colours of the hat represents a parallel six kinds of thinking, students as the main body of thinking, active learning, active thinking, the white thinking cap guides nursing students to carry out comprehensive nursing assessment, the green thinking cap guides nursing students to make accurate nursing diagnosis, the yellow and black thinking caps guide nursing students to make feasible nursing goals and reasonable nursing measures and the red thinking cap guides nursing students to put forward constructive nursing evaluations, which makes their thinking orderly and creative and effectively improves the inquiry-based learning ability and innovative thinking ability of nursing students (F. Yan et al. 2019). Beyond medical education, the Six Thinking Hats improves clinical management, providing a more comprehensive perspective (both theoretically and practically) compared to other thinking tools. Have staff walk around the room several times, gathering input by asking each person to describe the problem from an opposing viewpoint (Snow 2019), this creative thinking strategy was used by nurse leaders to inspiring creativity and innovativeness among staff. Visualization and interactivity in 3D-printed models significantly boost student engagement and creativity. Unlike traditional flat resources like books and presentations, 3D-printed models offer a hands-on approach for students to understand abstract concepts more intuitively. For example, 3D-printed human organ models help biology students learn more about the human body (Xia 2019).

Despite the significant role creativity plays in nursing education and practice, there is a notable lack of research exploring the creative capacities of nurses and nursing students. In response to the dynamic nature of healthcare, nursing faculty and preceptors must actively incorporate creative methods into both their teaching and practical training to foster the development of creative thinking and problem-solving abilities among their students. In order to foster personal growth, students and nurses should be encouraged to incorporate creative strategies and actions into their daily routines, thereby cultivating creativity as a natural and essential aspect of their development.

The meaning of creativity extends to various activities like creating, making, designing and producing goods. However, the implementation of creativity in nursing education and nursing clinical settings is of particular importance. In most health systems worldwide, the provision of primary healthcare is up to 80% reliant on nurses; providing a nurturing environment conducive to creative thinking by nursing educators, nursing and hospital administrators has a significant impact on nursing practice, quality of care and organizational performance (Shahsavari Isfahani et al. 2015). As noted, innovative teaching models can provide nursing students with creative vision, creative sensitivity and creative thinking, the ability to generate new ideas or reconstruction of old ideas and the ability to link ideas to the selection of new ways of care that lead to successful decision-making in clinical settings (Cheraghi et al. 2021). It is an educational guide for future nursing students and nurses to implement creativity in practice.

National organizations view creativity and innovation as vital for organizational change. Since 2015, the American Nurses Association (ANA 2025) has presented awards for nurse-led initiatives that enhance positive patient outcomes (1). The ANA helps nurses and nurse-led teams develop device prototypes by linking them with engineers and designers and providing resources. Essential to a design thinking transformation is access to the knowledge and tools that spark creativity and innovation. Innovation empowers today's nurses to move beyond traditional roles, investigating internal and external influences on patients and the healthcare systems they are part of (Snow 2019). Published research reveals a significant discrepancy between nursing students' and leaders' beliefs about the importance of creativity and their self-reported innovation skills (White et al. 2016). Building creative and imaginative problem-solving skills through innovative teaching models is one way.

There is evidence indicating the presence of scale bias in different teaching modes, leading to concerns regarding the potential impact of scale standards on teaching publications. Because most studies comparing teaching models have used a widely used scale to assess outcome indicators, this study does not do so; this might be a source of bias (X. Ma et al. 2018; Z. Zhang et al. 2016). Some discrepancies existed between some of the results of the multiple-treatment meta-analysis and those in the direct comparisons (microteaching, problem-based learning, instructional system design, 3D printing models, TDPC, hands-on inquiry-based learning vs. lecture-based learning). The results

highlight the potential benefit of incorporating indirect and direct comparisons in this analysis, thereby minimizing the risk of potential scale bias. Therefore, it is suggested that the scale that has been widely used to evaluate creativity should be adopted in future studies to ensure the reliability of the results.

Our analysis suggests that TDPC, Six Thinking Hats and 3D printing models are better than other new-generation teaching models in terms of efficacy and could be used as a standard comparator in teaching experiment research to increase the real-world applicability of the results. By incorporating aspects from the traditional 'theory + exercise + practice' trinity model, three-dimensional model, ubiquitous learning model and small and microenterprise business model, the TDPC model establishes a robust academic environment that nurtures innovation and entrepreneurship among nursing students, leading to an enhanced overall quality (D. Li, Lu, et al. 2019). The six thinking hats revolve around creative thinking, showcasing new perspectives through the various coloured hats (Cui and Shi 2010; F. Yan et al. 2019). The focus of advancements in 3D printing education in medicine lies in maker spaces, which utilize digital tools and resources to address programmes and ideas for innovative experiments (J. Sun et al. 2015). Due to the limited scope of our study's reported outcome indicator, we plan to conduct future studies to gather additional data that will enhance the guidance of instructional applications.

4.1 | Limitations

The limitations outlined below should be considered when interpreting the results of our meta-analysis. First and foremost, a meta-analysis elucidates the limitations of the studies incorporated. To mitigate this inevitable limitation, only randomized controlled trials were incorporated. The majority of studies included in our analysis did not provide sufficient information on randomization and allocation concealment, potentially compromising the credibility of the overall findings. Nevertheless, the qualitative bias assessment did not reveal any significant causes for concern. Additionally, all studies on teaching models included in this meta-analysis demonstrated a high degree of similarity in terms of design and conduct. The limited information available for quality assessment may be more attributable to reporting shortcomings in the text rather than actual deficiencies in the study design. Furthermore, 49 studies relied on self-administered questionnaires, incorporating diverse scales with varying degrees of reliability and validity and employing inconsistent measures and scoring criteria across these scales, potentially compromising the comparability and overall reliability of the reported results.

The study's limitations included the absence of long-term follow-up because of participant time constraints and limited resources; investigation periods also varied across studies. There is insufficient data on teaching outcomes several years after deploying teaching models, and the only study in our meta-analysis provided information beyond 12 months. We will monitor data over time to study how nursing students' creativity changes in the future. Finally, the use of only Chinese language literature in our meta-analysis may introduce language bias. Variations in study population and cultural background may affect the educational model's results, thus limiting the study's generalizability. Although the adjusted funnel plots (Figure S1) did not exhibit significant publication bias, it is advisable to approach the generalization of these teaching models to other countries with caution. Further research will also investigate the long-term effects, cross-cultural validity and curriculum integration of these models.

Despite limited resources and teachers, educators can enhance teaching quality and student development using these methods. We propose a phased introduction of superior teaching models into the curriculum, starting with pilot courses before full implementation. Employ the available shared network resource classes to develop a multifaceted approach to teaching. Crucially, schools must establish comprehensive support systems—including resources, tech support and collaborative platforms—and foster teacher collaboration to ensure successful model implementation.

5 | Conclusion

This study provides evidence on the effectiveness of the TDPC, Six Thinking Hats and 3D printing models in enhancing the creativity of nursing students compared with other new-generation teaching models. Despite the primary analysis indicating comparable effectiveness among TDPC, Six Thinking Hats and 3D printing models, an exploratory analysis revealed a tendency towards a greater likelihood of achieving higher creativity scores with TDPC. Nursing students lack the time and energy to engage in innovation and entrepreneurship. Utilizing TDPC, the study identified that fragmenting nursing students' time for systematic innovation and entrepreneurship education, integrating the 3-in-1 model of 'theory + exercise + practice', three-dimensional learning, ubiquitous learning and small and medium enterprises business models can enhance traditional lecturing with Internet-driven engagement while maintaining professional relevance. The sensitivity analysis and metaregression yielded no discernible differences.

Advocate for the adoption of standardized creativity assessment tools in future research to enhance comparability and reduce scale bias. Meanwhile, lengthen the follow-up assessment period and perform more research internationally to improve their integration into nursing education.

Author Contributions

Z.J.: conceptualization, design and initial manuscript writing. S.J., C.Y. and S.X.: methodology and data curation. X.C.: supervision. P.M.: revision and editing of the final manuscript.

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Ethics Statement

The authors have nothing to report.

Consent

All authors gave their final approval of this version to be published and agree to be accountable for all aspects of the work.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The authors have nothing to report.

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