

RESEARCH ARTICLE

Case-based learning combined with science, technology, engineering and math (STEM) education concept to improve clinical thinking of undergraduate nursing students: A randomized experiment

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Abstract

Aims: The present study was conducted to apply and examine case-based learning (CBL) and Science, Technology, Engineering, and Math (STEM) education concept in the training of nursing student's clinical thinking.

Design: A randomized experimental design with non-equivalent group pretest–posttest.

Methods: Participants were requested to participant in either of the two programmes: traditional education programme as a control group or CBL combined with STEM education concept (the STEM group). Questionnaires of critical thinking, self-directed learning, self-efficacy were administered before and after the experiment.

Results: Differences between the STEM group and control group were observed in critical thinking, self-directed learning, self-efficacy and career choice over one semester. Accordingly, CBL combined with STEM education concept enhanced the nursing student's clinical thinking.

KEYWORDS

case-based learning, critical thinking, nursing clinical thinking, self-directed learning, STEM education concept, undergraduate nursing students

1 | INTRODUCTION

Clinical thinking is the cognitive processing of the knowledge, attitudes and reflective professional practice of a clinician in work (Sommers, 2018). Nursing clinical thinking is viewed as an essential skill for all nurses, also termed as clinical reasoning, clinical problem-solving and clinical judgment (Lee et al., 2017). The ability to perform appropriate clinical assessment, identify the patients' problems and develop an appropriate course of treatment requires clinical thinking and has been identified as key components of nursing care (Vincent et al., 2015).

With constant teaching reforms, various heuristic teaching and learning activities have been implemented to cultivate clinical thinking, such as project-based learning, case-based learning (CBL), situational teaching and virtual simulation teaching (Zarifanaiey et al., 2016; Kiguli, 2011; Dubey & Dubey, 2017; Gholami et al., 2016). However, there are still some problems in the continued exploration of effective ways of cultivating clinical thinking. Clinical skills were traditionally imparted in a piecemeal fashion, which does not reflect how physicians actually work and think. Furthermore, with the changing healthcare environment and continuous expansion of nursing enrolment, the

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opportunities for clinical practice have been gradually reduced (You et al., 2015). Meanwhile, clinical teaching has been reduced from typical contingencies and strong clinical situations in practice. Students thus lack practice in active thinking-in-action in ambiguous clinical situations. Nevertheless, clinical teaching could be improved by enriching curricula with narrative examples from therapeutic situations and by helping students recognize commonly occurring clinical situations through simulations (Lee et al., 2017; Williamson, 2012).

STEM (science, technology, engineering and mathematics) education has evolved into a meta-discipline, an integrated effort that removes the traditional barriers across subjects and utilizes problem-driven and student-centred teaching methods, which are bound by STEM practices of interdisciplinary, authentic and contextualized problems to enhance student learning (Kelley & Knowles, 2016; Kennedy & Odell, 2014). The STEM integrated curricular approach could be applied to solve global challenges concerning energy, health and the environment (Bybee, 2010). As a form of problem-solving, cooperative learning and subject integration, STEM education provides opportunities for more relevant, less fragmented and more stimulating experiences for learners and encourages students to work together, acquire knowledge, display more advanced critical thinking and enhance self-awareness and social skills, compared with traditional teaching (Head et al., 2016; Kim et al., 2019; Madden et al., 2013). This applies to the ideal cultivation of clinical thinking in nursing students. Nursing undergraduate students could master the specialized knowledge of multidiscipline knowledge and nursing skills to improve clinical thinking. STEM education has had a major impact on teaching medicine in Europe and provided evidence to carry out STEM education in medical students (Roberts & Harden, 2015). A novel medical simulation component embedded in a high school science course collectively called MED science promotes not only learning in the traditional sense but also self-efficacy among students related to STEM and healthcare attitudes and career choices (Berk et al., 2014). Therefore, it is urgent to apply the STEM education concept into the training of nursing student's clinical thinking and integrate relevant disciplines. The aim of this study was conducted to apply and examine the CBL integrated with STEM education concept in the training of nursing student's clinical thinking. Herein, we hypothesized CBL combined with STEM education concept could improve nursing student's clinical thinking. To test this hypothesis, we compared and analysed the effects of CBL combined with STEM education concept versus traditional education among undergraduate nursing students.

2 | BACKGROUND

Our rationale is centred on the intent to promote clinical thinking and confidence to succeed in a clinical setting and even in their health science careers, through generating hands-on solutions to patients' problems. The consensus is that critical thinking involves reflective clinical reasoning prior to deriving a conclusion or clinical judgment (Lee et al., 2017). Therefore, critical thinking is viewed as the foundation and main evaluation index for clinical thinking. The importance of nurses' critical thinking skill for developing clinical thinking has

brought forth worldwide effort to incorporate elements of critical thinking in nursing curricula (Yu et al., 2013). Through the multi-disciplinary integration with problem-solving, the STEM education could help students understand the connections of core courses and improve their ability to analyse, judge, decide and communicate, so as to narrow the gap between education and practice (Jamaludin & Hung, 2017; Kennedy & Odell, 2014).

Case-based learning is a method of problem-based learning designed to heighten higher-order thinking. CBL can assist nursing students to integrate and apply the knowledge, skills, judgment and personal attributes required to practise safely and ethically in a designated role and setting (Dubey & Dubey, 2017; Raurell-Torredà et al., 2015). Increasing evidence suggests that CBL and STEM education have positive effects on critical thinking in undergraduate students, undergraduate mentors, graduate nurses (Gottesman & Hoskins, 2013; Li et al., 2019; Weir et al., 2019; Yoo & Park, 2014). However, less evidences can be found on the effects of teaching reform on a nursing course based on STEM education concept, particularly in mainland China. In addition, the training of nursing students' clinical thinking based on CBL combined with STEM education concept need to be further explored. Consequently, we aimed to examine the effects of CBL with STEM education concept on clinical thinking of undergraduate nursing students.

3 | DESIGN

A non-equivalent control group pretest-posttest design was adopted for this randomized experimental study. The research compared the effects of CBL based on STEM education concept versus traditional education on clinical thinking, self-directed learning and self-efficacy of undergraduate nursing students.

4 | METHODS

4.1 | Participants

Nursing students ($n = 87$) were invited to participate in the study with controls and pretest-posttest design. The grasping and smashing method were used to divide two classes into two groups. The two classes were randomized into either control group ($n = 45$) and STEM group ($n = 42$). None of these participants dropped out of the study.

4.2 | Instruments

4.2.1 | Critical Thinking Dispositions Inventory-Chinese version

The Critical Thinking Dispositions Inventory-Chinese version (CTDI-CV) was adopted by Peng et al. (2004) from Facione's California Critical Thinking Dispositions Inventory (CCTDI) (Facione &

Facione, 1993). It was implemented to measure critical thinking dispositions of nursing students and Registered Nurses in China. Cronbach's α was .90 for the whole scale and ranged from 0.54–0.77 for subscales. The CTDI-CV is a standardized, 70-item, multiple-choice test that is scored on seven dimensions: truth-seeking (10 items), open-mindedness (10 items), analyticity (10 items), systematicity (10 items), critical thinking self-confidence (10 items), inquisitiveness (10 items) and cognitive maturity (10 items). Responses are recorded with a six-point Likert scale ranging from "strongly agree" to "strongly disagree." Higher scores indicate stronger critical thinking dispositions.

4.2.2 | Self-Rating Scale of self-directed learning-Chinese version

The Self-Rating Scale of self-directed learning (SRSSDL) was a self-evaluation tool on self-directed learning developed by Williamson and Naskar (2007). In Chinese version, the Cronbach's α was .97 for the whole scale and ranged from 0.87–0.90 and the test-retest reliability was 0.86 (Shen & Hu, 2011). The SRSSDL-CV is composed of 60 items articulated in five subscales: Awareness (12 items), Learning Strategies (12 items), Learning Activities (12 items), Evaluation (12 items) and Interpersonal Skills (12 items). Responses for each item are rated by using a five-point Likert scale ranging from "always" to "never." High scores show a high level of self-directed learning.

4.2.3 | General Self-Efficacy Scale

The German version of General Self-Efficacy Scale (GSE) was originally developed by Jerusalem and Schwarzer in 1981, first as a 20-item version and later reduced to a 10-item version. High reliability, stability and construct validity of the GSE scale were confirmed in earlier studies (Cheung & Sun, 1999; Luszczynska et al., 2005). In the Chinese version, the Cronbach's α was .87 and the 10-day test-retest reliability 0.83 (Wang et al., 2001). Responses for each item are rated by using a four-point Likert scale ranging from "completely incorrect" to "complete correct." High scores indicate a high level of self-efficacy.

4.2.4 | Demographic Questionnaire

A demographic information sheet was used to acquire basic information before the experiment, including gender, age, learning motivation, career choice, experiences of small group learning and self-directed learning.

4.2.5 | Measurement time

The participants of the experiment were measured with the above-mentioned scales before and after the experiment (pretest and posttest).

4.3 | Procedure

The experiment was to train clinical thinking of undergraduate nursing students in the control and STEM groups respectively using traditional method and CBL programme with STEM education concept. The course was implemented to both groups in a weekly three-hour session for 16 successive weeks. The instructors of both groups were identical, but the days and locations were different for the two groups. Moreover, students in both groups were referred to the same textbook, learning resources and cases, and course syllabus. The teaching content included acute exacerbation of chronic cholecystitis, cardiopulmonary resuscitation, chronic pulmonary heart disease and chronic renal insufficiency with acute left heart failure, cerebral infarction, myelosuppression, ectopic pregnancy and pregnancy with acute pancreatitis. The teaching objectives were to cultivate students' critical thinking, improve the ability to solve clinical nursing problems and develop proficiency in nursing skills in order to enable students to be better engaged in clinical nursing work after graduation. Students in both groups completed the demographic form, CTDI-CV, SRSSDL-CV and GSE scale before starting the training.

For the control group, teachers taught theoretical knowledge of the cases, then students practised nursing skills related to each case in groups.

For the STEM group, the training of nursing student's clinical thinking was designed based on CBL combined with the STEM education concept. The integrated training content included Internal Medicine Nursing, Surgical Nursing, Obstetrics and Gynecology Nursing and Pediatric Nursing, Emergency Nursing.

4.3.1 | Preparation before class

Teachers sent resources related to teaching cases to students, such as Massive Online Open Courses (MOOCs), clinical cases, literatures, teaching courseware and links. Core curricular teachers prepared cases based on the curricular standards, teaching objectives and students' prior knowledge level, needs and interests. Social media (WeChat/QQ) groups were established for learning and communication respectively within the control and STEM group.

Students were divided into groups of 6 ~ 8 persons, then discussing cases with face-to-face to promote interactions. The team members divided their work according to their individual strengths and clinical cases, such as role-playing, scenario design, script writing, narration and collection of difficult knowledge. Each scenario was scripted according to the clinical case. Meanwhile, students were asked to be familiar with nursing skills related to each case. All team members were held accountable for their individually assigned tasks, besides identify nursing problems of the cases. The main nursing diagnosis could be listed according to the priority of disease. For the top diagnosis, no less than four nursing interventions were required to be identified.

4.3.2 | In classes

During the problem-solving, students reflected on their understanding of the problem through observing in the following steps. (a) student mutual evaluation: each group showed their nursing diagnosis and nursing measures in this session with 10 min. After the demonstration, students commented on the advantages and disadvantages of nursing diagnosis and measures of other groups and put forward their suggestions. (b) Case scenario simulation: at this stage, environmental preparation included simulated ward, bed unit layout, equipment required for the case, role and task assignments of students in each scene. Scenario simulation of each case was demonstrated in groups within 30 min. After performing scenario simulation, other group asked questions and commented about nursing assessment, nursing skills and health education implemented in scenario simulation. (c) Heuristic guidance: teachers supplemented and corrected the groups' answers and demonstrated the correct nursing skills. Teachers summarized the key and difficult points in the teaching content and graded in terms of each group classroom performance. In the course of teaching, certain time was set apart to clarify obscure knowledge and misconceptions and bring out accurate nursing diagnosis and measures. Collaborative teaching was infiltrated into the teaching activities based on the STEM education concept. Each lesson was taught by more than two teachers with different expertise. The entire learning process during each lesson was video recorded to facilitate students' later reviews.

4.3.3 | Extracurricular activities

Students were required to review the above classroom videos to promote the internalization of the knowledge and skills.

4.3.4 | Evaluation of teaching effect

The evaluation of teaching effect adopted the form of formative evaluation, including process evaluation and end-stage evaluation. The process evaluation utilized multiple evaluation methods, including conduct questionnaire survey before starting the course and at the end of the course to assess students' fundamental condition, self-learning, self-efficacy and critical thinking. Additionally, the students and instructors were interviewed respectively to obtain their opinions and suggestions on the instructional design, process and effectiveness. The final evaluation was carried out at the end of the course.

5 | DATA ANALYSIS

The data were shown as the mean \pm standard deviation (*SD*) and analysed using SPSS 20.0 software package with chi-square (Fisher's

exact probability) and *t* test. The statistical significance was defined as a difference between groups of $p < .05$.

6 | ETHICS

Prior to the experiment, the protocol was reviewed and ethical permission for the study was received from the Hubei University of Chinese Medicine human ethics committee (2018-ICE-011). After the random assignment, the experimental teachers provided the STEM group with information about STEM education concept, CBL and obtained written consents from both groups. The STEM education concept combined CBL programme was also approved by the Hubei University of Chinese Medicine human ethics committee.

7 | RESULTS

7.1 | Pretest and Posttest

A total of 87 students (15 [17.2%] men and 72 [82.8%] female) with a mean age of 20.86 (*SD* = 2.15) participated in intervention study. As expected from the random assignment, no significant differences in age, sex, learning motivation, nursing major choice, CTDI-CV, SRSSDL-CV and GSE were found between the STEM and control groups before the experiment (Tables 1 and 2).

During the entire study, compared with baseline, critical thinking (275.18 and *SD* = 21.68), self-directed learning (215.30 and *SD* = 23.49) and self-efficacy (2.65 and *SD* = 0.45) significantly improved after implementing the intervention (Table 2). Of the seven subscales, open-mindedness, analyticity, self-confidence and maturity were significantly improved in comparison with those in baseline (Table 3). The comparison of the mean changes in the pre- and postintervention scores obtained in the control and STEM groups showed a significant improvement in the students' overall mean scores of CTDI-CV, SRSSDL-CV and GSE after performing CBL combined with STEM education concept. The comparison of the mean scores obtained for the different dimensions of critical thinking showed a significant increase in open-mindedness, analyticity, self-confidence, maturity and truth-seeking as a result of intervention in compare with control group. Additionally, compared with the control group, the number of students willing to engage in nursing work after graduation showed a significant increase in the STEM group ($\chi^2 = 6.375, p = .041$).

8 | DISCUSSION

The study showed the mean scores of critical thinking, self-directed learning and self-efficacy obtained before and after traditional education programme to be poor and to not have changed significantly, in agreement with the results of previous

TABLE 1 Demographics of students participating in the intervention programme ($n = 87$)

Variable	STEM (%)	Control (%)
Participants	42	45
Sex		
Male	6 (14.3)	9 (20.0)
Female	36 (85.7)	36 (80.0)
Nursing major choice		
No	19 (45.2)	24 (53.3)
Yes	23 (54.8)	21 (46.7)
Likes nursing		
Yes	14 (33.3)	13 (28.9)
Unsure	28 (66.7)	32 (71.1)
Engaged in nursing work		
Yes	22 (52.4)	23 (51.1)
Unsure	16 (28.1)	17 (37.8)
No	4 (9.5)	5 (11.1)
Learning motivation		
Not at all	2 (4.8)	3 (6.7)
A little	9 (21.4)	16 (35.6)
Moderately	13 (31.0)	12 (26.6)
Very	16 (38.0)	13 (28.9)
Extremely	2 (4.8)	1 (2.2)
Knows self-directed learning		
Not at all	2 (4.8)	3 (6.7)
A little	30 (71.4)	27 (60.0)
Moderately	7 (16.6)	10 (22.2)
Very	2 (4.8)	4 (8.9)
Extremely	1 (2.4)	1 (2.2)
Experience of self-directed learning		
Yes	39 (92.9)	38 (84.4)
No	3 (7.1)	7 (15.6)
Experiences of small group learning		
Not at all	1 (2.4)	1 (2.2)
A little	10 (23.8)	16 (35.6)
Moderately	14 (33.3)	15 (33.3)
Very	16 (38.1)	12 (26.7)
Extremely	1 (2.4)	1 (2.2)

study (Dehghanzadeh & Jafaraghaee, 2018; Qamata-Mtshali & Bruce, 2017). However, after performing CBL combined with STEM education concept, significant improvements were observed in the overall mean scores of critical thinking, self-directed learning and self-efficacy in the nursing students surveyed. Besides, the number of students willing to engage in nursing work after graduation increased. It has been demonstrated that implicating the STEM education and CBL significantly improved in inductive critical thinking skills and reasoning of students (Duran & Sendag, 2012; Yoo & Park, 2014). In addition, consistent with

previous study, students in STEM overwhelmingly attributed elevated and enduring levels of impact on their interest and self-efficacy in pursuing health care-related career to the programme after graduation (Berk et al., 2014). In the current study, among the seven subscales of critical thinking, the open-mindedness, analyticity, self-confidence, maturity and truth-seeking showed significant improvement in the STEM group for the training of nursing student's clinical thinking, suggesting that nursing students have adequate objectivity and knowledge-seeking dispositions, being judicious in decision-making, tolerant of divergent views and critical thinking self-confidence. Accordingly, these findings implied that the academic level, the content of the theoretical and practical courses based on the STEM education concept gained contribute to the development of critical thinking skills.

All subscales of critical thinking before and after performing traditional education programme were found to score below the cut-off point 40, suggesting that students were weak in using organized and focused methods of reasoning when case scenario simulation for problem-solving. This conclusion is similar to that found by Yu et al. (2013) who reported the scores of truth-seeking, systematicity and critical thinking self-confidence are below 40. The fact that traditional nursing education system pays less attention to critical skills training and relies heavily on memorization, suggesting the need for further implication of teaching-learning strategies, such as the STEM education concept, to improve critical thinking skills for clinical problem-solving.

On the basis of this study, CBL combined with STEM education concept enabled students to critically analyse case situation and nursing problems and select the optimal nursing measures among potential interventions and was an effective teaching strategy for improving clinical thinking disposition. An analysis of the differences in the subscale scores over time between traditional education programme and CBL combined the STEM concept may cast some light on how the STEM education may facilitate students' critical thinking development. STEM education has evolved into a meta-discipline, an integrated effort that removes the traditional barriers between these subjects and instead focuses on innovation and the applied process of designing solutions to complex contextual problems using current tools and technologies (Kennedy & Odell, 2014). It is believed that the STEM education can contribute to increased problem-solving skills, critical thinking and analytical thinking in students and lead to better real-world connection in the curriculum (Gottesman & Hoskins, 2013; Weir et al., 2019). Meanwhile, it was reported that CBL allows the nursing student to feel more connected to reality and decide how to plan and deliver patient care (Gholami et al., 2017). After performing this course, students were encouraged to become active problem-solvers, to take ownership of ideas, processes and directions, and engage with motivation.

The development of critical thinking is not only the basis of life-long learning but also the cornerstone of the professional growth. Meanwhile, self-directed learning and self-motivation are warranted for development of critical thinking (Eunyoung et al., 2014; Kaya

TABLE 2 Outcomes of CTDI-CV, SRSSDL-CV and GSE between STEM group ($n = 42$) and control group ($n = 45$)

Variables	Pretest		Posttest		P-value ^a	P-value ^b
	STEM	Control	STEM	Control		
	M (SD)	M (SD)	M (SD)	M (SD)		
CTDI-CV	268.45 (24.86)	263.75 (26.11)	275.175 (21.68)	264.27 (26.74)	.003	.004
GSE	2.51 (0.51)	2.47 (0.53)	2.65 (0.45)	2.43 (0.39)	.001	.000
SRSSDL-CV	207.08 (29.42)	204.25 (30.21)	215.30 (23.49)	203.12 (29.87)	.001	.005

^aSTEM group at posttest versus STEM group at pretest.

^bControl group at posttest versus STEM group at posttest.

TABLE 3 Outcomes of subscales in CTDI-CV between STEM group ($n = 42$) and control group ($n = 45$)

Subscales	Pretest		Posttest		P-value ^a	P-value ^b
	STEM	Control	STEM	Control		
	M (SD)	M (SD)	M (SD)	M (SD)		
Open-mindedness	36.35 (3.17)	35.62 (2.91)	38.01 (3.82)	35.95 (3.63)	.000	.000
Analyticity	37.79 (3.44)	37.25 (4.27)	38.85 (3.05)	37.44 (3.98)	.001	.012
Systematicity	39.96 (5.73)	39.36 (6.26)	40.79 (4.79)	39.21 (6.75)	.103	.087
Self-confidence	37.16 (3.05)	36.58 (2.91)	38.26 (2.20)	36.44 (2.43)	.000	.000
Inquisitiveness	38.92 (5.08)	39.03 (5.53)	39.51 (3.80)	39.17 (4.44)	.170	.559
Maturity	39.22 (4.98)	38.22 (5.72)	40.31 (4.37)	38.33 (4.91)	.015	.003
Truth-seeking	39.06 (5.87)	37.71 (6.44)	39.45 (5.56)	37.71 (5.47)	.469	.031

^aSTEM group at posttest versus STEM group at pretest.

^bControl group at posttest versus STEM group at posttest.

et al., 2018). The importance of nurses' critical thinking skill for developing clinical thinking has been well recognized and brought forth worldwide effort to incorporate elements of critical thinking in nursing curricula (Yu et al., 2013). One primary goal of nursing education should help learners to develop critical thinking abilities through experience, inquiry and reasoning (Carvalho et al., 2017).

9 | CONCLUSION

In our study, the STEM students' critical thinking, self-directed learning and self-efficacy reflected greater improvement compared with traditional education programme. Nevertheless, the STEM students' critical thinking disposition did not appear to show significant development in relation to the systematicity and inquisitiveness subscale scores, indicating that the nursing students had poor system knowledge digestion and absorption and transformation abilities, and potential for advanced clinical practice. The management of the class and the details of the implementation of the course based on the STEM education concept are essential for the further development of these skills. Nursing educators can utilize concept mapping, case-based multidisciplinary, dynamic group sessions and reflective writing in their performing of the STEM education (Chan, 2013; Tseng et al., 2011; Zimmerman et al., 2011). Given nursing education's

need for critically reflexive curricular in the modern world, adopting education approaches based on the STEM education concept acts an essential role in the development of clinical thinking, problem-solving, self-directed learning, motivation, self-evaluation and empowerment in nursing students and in guiding them towards lifelong learning.

10 | LIMITATIONS

This study has limitations. Results cannot be generalized to other setting, because it was employed with small samples of third year nursing students. In addition, the study period was only 16 weeks (one semester). Therefore, the effect of CBL combined STEM education concept on critical thinking, self-directed learning and self-efficacy in the training of nursing student's clinical thinking is recommended for longer period of time in further study.

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CONFLICT OF INTERESTS

The authors declare that there are no conflicts of interests.

DATA AVAILABILITY STATEMENT

The data used to support the findings of this study are available from the corresponding author upon request. The data are not publicly available due to privacy or ethical restrictions.

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REFERENCES

- Berk, L. J., Muret-Wagstaff, S. L., Goyal, R., Joyal, J. A., Gordon, J. A., Faux, R., & Oriol, N. E. (2014). Inspiring careers in STEM and healthcare fields through medical simulation embedded in high school science education. *Advances in Physiology Education*, 38(3), 210–215.
- Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology & Engineering Teacher*, 70(1), 30–35.
- Carvalho, D. P. S. R. P., Azevedo, I. C., Cruz, G. K. P., Mafrá, G. A. C., Rego, A. L. C., Vitor, A. F., Santos, V. E. P., Cogo, A. L. P., & Ferreira Júnior, M. A. (2017). Strategies used for the promotion of critical thinking in nursing undergraduate education: A systematic review. *Nurse Education Today*, 57, 103–107. <https://doi.org/10.1016/j.nedt.2017.07.010>.
- Chan, Z. C. Y. (2013). A systematic review of critical thinking in nursing education. *Nurse Educ Today*, 33(3), 236–240.
- Cheung, S. K., & Sun, S. Y. K. (1999). Assessment of optimistic self-beliefs: Further validation of the Chinese version of the General Self-Efficacy Scale. *Psychological Reports*, 85(3 Pt 2), 1221–1224.
- Dehghanzadeh, S., & Jafaraghaee, F. (2018). Comparing the effects of traditional lecture and flipped classroom on nursing students' critical thinking disposition: A quasi-experimental study. *Nurse Education Today*, 71, 151–156.
- Dubey, S., & Dubey, A. K. (2017). Promotion of higher order of cognition in undergraduate medical students using case-based approach. *Journal of Education and Health Promotion*, 6, 75.
- Duran, M., & Sendag, S. (2012). A preliminary investigation into critical thinking skills of urban high school students: Role of an IT/STEM program. *Creative Education*, 3(02), 241.
- Eunyoung, C., Ruth, L., & Yeongsuk, S. (2014). Effects of problem-based learning vs. traditional lecture on Korean nursing students' critical thinking, problem-solving, and self-directed learning. *Nurse Education Today*, 34(1), 52–56.
- Facione, P., & Facione, N. (1993). *Test manual: The California critical thinking skills test, form A and Form B*. The California Academic Press.
- Gholami, M., Moghadam, P. K., Mohammadipoor, F., Tarahi, M. J., Sak, M., Toulabi, T., & Pour, A. H. H. (2016). Comparing the effects of problem-based learning and the traditional lecture method on critical thinking skills and metacognitive awareness in nursing students in a critical care nursing course. *Nurse Education Today*, 45, 16–21.
- Gholami, M., Saki, M., Toulabi, T., Moghadam, P. K., Pour, A. H. H., & Dostizadeh, R. (2017). Iranian nursing students' experiences of case-based learning: A qualitative study. *Journal of Professional Nursing*, 33(3), 241–249.
- Gottesman, A. J., & Hoskins, S. G. (2013). CREATE Cornerstone: Introduction to scientific thinking, a new course for STEM-interested freshmen, demystifies scientific thinking through analysis of scientific literature. *CBE Life Sciences Education*, 12(1), 59–72.
- Head, B. A., Schapmire, T., Earnshaw, L., Faul, A., Hermann, C., Jones, C., Martin, A., Shaw, M. A., Woggon, F., Ziegler, C., & Pfeiffer, M. (2016). Evaluation of an interdisciplinary curriculum teaching team-based palliative care integration in oncology. *Journal of Cancer Education*, 31(2), 358–365.
- Jamaludin, A., & Hung, D. (2017). Problem-solving for STEM learning: Navigating games as narrativized problem spaces for 21st century competencies. *Research and Practice in Technology Enhanced Learning*, 12(1), 1.
- Kaya, H., Senyuva, E., & Bodur, G. (2018). The relationship between critical thinking and emotional intelligence in nursing students: A longitudinal study. *Nurse Education Today*, 68, 26–32.
- Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, 3, 11.
- Kennedy, T., & Odell, M. (2014). Engaging students in STEM education. *Science Education International*, 25(3), 246–258.
- Kiguli, S., Baingana, R., Paina, L., Mafigiri, D., Groves, S., Katende, G., Kiguli-Malwadde, E., Kiguli, J., Galukande, M., Roy, M., Bolliger, R., & Pariyo, G. (2011). Situational analysis of teaching and learning of medicine and nursing students at Makerere University College of Health Sciences. *BMC Int Health Hum Rights*, 11(Suppl 1), S3.
- Kim, Y. E., Morton, B. G., Gregorio, J., Rosen, D. S., Edouard, K., & Valletta, R. (2019). Enabling creative collaboration for all levels of learning. *PNAS*, 116(6), 1878–1885.
- Lee, D. S. K., Abdullah, K. L., Subramanian, P., Bachmann, R. T., & Ong, S. L. (2017). An integrated review of the correlation between critical thinking ability and clinical decision-making in nursing. *Journal of Clinical Nursing*, 26(23–24), 4065–4079.
- Li, S. S., Ye, X. C., & Chen, W. T. (2019). Practice and effectiveness of "Nursing Case-Based Learning" course on nursing student's critical thinking ability: A comparative study. *Nurse Education in Practice*, 36, 91–96.
- Luszczynska, A., Scholz, U., & Schwarzer, R. (2005). The General Self-Efficacy Scale: Multicultural validation studies. *Journal of Psychology*, 139(5), 439–457.
- Madden, M. E., Baxter, M., Beacuchamp, H., Bouchard, K., Habermas, D., Huff, M., Ladd, B., Pearson, J., & Plague, G. (2013). Rethinking STEM education: An interdisciplinary STEAM curriculum. *Procedia Computer Science*, 20, 541–546.
- Peng, M. C., Wang, G. C., Chen, J. L., Chen, M. H., Bai, H. H., Li, S. G., Li, J. P., Cai, Y. F., Wang, J. Q., & Yin, L. (2004). Validity and reliability of the Chinese critical thinking disposition inventory. *Journal of Nursing in China (Zhong Hua Hu Li Za Zhi)*, 39, 644–647.
- Qamata-Mtshali, N., & Bruce, J. C. (2017). Self-directed learning readiness is independent of teaching and learning approach in undergraduate nursing education. *Nurse Education*, 43(5), 227–281.
- Raurell-Torredà, M., Olivet-Pujol, J., Romero-Collado, À., Malagon-Aguilera, M. C., Patiño-Masó, J., & Baltasar-Bagué, A. (2015). Case-based learning and simulation: Useful tools to enhance nurses' education? Nonrandomized Controlled Trial. *Journal of Nursing Scholarship*, 47(1), 34–42.
- Roberts, T. E., & Harden, R. M. (2015). STEM teaching: Medicine in Europe. *Nature*, 524, 291.
- Shen, W. Q., & Hu, Y. (2011). Reliability and validity of the Chinese version of self-rating scale of self-directed learning. *Chinese Journal of Nursing*, 46(12), 1211–1213.
- Sommers, C. L. (2018). Measurement of critical thinking, clinical reasoning, and clinical judgment in culturally diverse nursing students – A literature review. *Nurse Education in Practice*, 30, 91–100.
- Tseng, H. C., Chou, F. H., Wang, H. H., Ko, H. K., Jian, S. Y., & Weng, W. C. (2011). The effectiveness of problem-based learning and concept mapping among Taiwanese registered nursing students. *Nurse Education Today*, 31(8), e41–e46.
- Vincent, D., Hastings-Tolsma, M., Gephart, S., & Alfonzo, P. M. (2015). Nurse practitioner clinical decision-making and evidence-based practice. *Nurse Practitioner*, 40(5), 47–54.

- Wang, C. K., Hu, Z. F., & Liu, Y. (2001). Evidences for reliability and validity of the Chinese version of general self-efficacy scale. *Chinese Journal of Applied Psychology*, 7(1), 37–40.
- Weir, L. K., Barker, M. K., McDonnell, L. M., Schimpf, N. G., Rodela, T. M., & Schulte, P. M. (2019). Small changes, big gains: A curriculum-wide study of teaching practices and student learning in undergraduate biology. *PLoS One*, 14(8), e0220900.
- Williamson, J. (2012). Teaching and learning in out-patient clinics. *Clinical Teacher*, 9(5), 304–307.
- Williamson, S. N. (2007). Development of a self-rating scale of self-directed learning. *Nurse Researcher*, 14(2), 66–83.
- Yoo, M. S., & Park, J. H. (2014). Effect of case-based learning on the development of graduate nurses' problem-solving ability. *Nurse Education Today*, 34(1), 47–51. <https://doi.org/10.1016/j.nedt.2013.02.014>
- You, L. M., Ke, Y. Y., Zheng, J., & Wang, L. H. (2015). The development and issues of nursing education in China: A national data analysis. *Nurse Education Today*, 35(2), 310–314.
- Yu, D. H., Zhang, Y. Q., Xu, Y., Wu, J. M., & Wang, C. F. (2013). Improvement in critical thinking dispositions of undergraduate nursing students through problem-based learning: A crossover-experimental study. *Journal of Nursing Education*, 52(10), 574–581.
- Zarifsanaiey, N., Amini, M., & Saadat, F. (2016). A comparison of educational strategies for the acquisition of nursing student's performance and critical thinking: Simulation-based training vs. integrated training (Simulation and critical thinking strategies). *BMC Medical Education*, 16(1), 294.
- Zimmerman, S. D., Short, G. F. L., & Hendrix, E. M. (2011). Impact of interdisciplinary learning on critical thinking using case study method in allied health care graduate students. *Journal of Allied Health*, 40(1), 15–18.

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