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PRACTICAL EXPLORATION OF INTEGRATING THE CDIO TEACHING MODEL WITH CHATGPT ASSISTANCE IN CLINICAL TEACHING FOR NURSING INTERNS IN THE RESPIRATORY DEPARTMENT

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Abstract: **Background:** Although the CDIO (Conceive-Design-Implement-Operate) teaching model can enhance nursing students' core competencies and ChatGPT offers personalized, real-time learning support, their combined application in respiratory nursing clinical teaching remains unexplored. In practice, intern nursing students in respiratory and critical care departments commonly face disconnections between theory and practice, weak knowledge integration and transfer skills, and insufficient critical thinking and clinical decision-making abilities. These challenges are compounded by rigid teaching models, difficulty in providing personalized instruction, limited teaching resources and scenarios, and a lack of opportunities for innovation and hands-on practice. **Objective:** To design and implement an integrated teaching approach combining the CDIO model with ChatGPT assistance for respiratory nursing interns and evaluate its preliminary effectiveness. **Methods:** A quasi-experimental study design was employed involving 60 respiratory nursing interns who rotated through a tertiary hospital from May 2025 to March 2026. Participants were assigned to an experimental group (n=30) receiving CDIO model instruction with ChatGPT assistance and a control group (n=30) receiving traditional clinical teaching. Outcome measures included theoretical knowledge assessment, clinical practice scores, autonomous learning ability, and clinical thinking ability. **Results:** The experimental group demonstrated significantly higher scores in theoretical knowledge assessment ($p<0.05$), clinical practice skills ($p<0.05$), clinical thinking ability ($p<0.05$), and autonomous learning ability ($p<0.05$) compared with the control group. **Conclusion:** The integration of the CDIO teaching model with ChatGPT assistance effectively enhances the comprehensive competencies of respiratory nursing interns, improves clinical thinking, and autonomous learning abilities. This innovative approach offers a promising direction for clinical nursing education reform.
Keywords: CDIO teaching model; ChatGPT; Respiratory nursing; Clinical teaching; Nursing education; Artificial intelligence

1 INTRODUCTION

Clinical practice constitutes a critical component of nursing education, serving as the transitional phase where theoretical knowledge is transformed into practical professional competence. Respiratory nursing, a specialized field that involves the management of patients with chronic obstructive pulmonary disease (COPD), asthma, pneumonia, and other respiratory conditions, demands not only technical proficiency but also strong clinical reasoning and critical thinking skills. However, traditional clinical teaching in respiratory nursing has predominantly relied on teacher-centered, lecture-based methods, often resulting in passive learning, low student engagement, and limited integration of theory with practice.

The CDIO (Conceive-Design-Implement-Operate) teaching model, originally developed by the Massachusetts Institute of Technology and widely applied in engineering education, has recently gained traction in nursing education as an innovative pedagogical approach [1]. This model emphasises active learning through four interconnected phases: Conceive (identifying problems and generating ideas), Design (developing solutions and plans), Implement (executing practical tasks), and Operate (refining and optimising outcomes). Previous studies have demonstrated that the CDIO model effectively enhances nursing students' core competencies, theoretical and practical scores, critical thinking, and self-directed learning abilities. For instance, Zhang et al. found that combining the CDIO model with the Rosenthal effect significantly improved nursing interns' core competencies and case assessment performance [2]. Similarly, a randomised controlled study comparing the CDIO model with traditional lecture-based learning in healthcare-associated infection courses reported that the CDIO group achieved significantly higher overall and practical application scores, with advantages retained for 24 weeks [3]. Further empirical evidence supports the efficacy of the CDIO model in nursing education. A knowledge map analysis of CDIO research in China's medical education field has confirmed that the model is gaining increasing attention and has been recognised within the industry for its effectiveness [4]. In a study of orthopaedic nursing clinical teaching, the CDIO-based flipped classroom combined with mini-CEX evaluation significantly stimulated nursing interns' independent learning ability and critical thinking, promoting the organic integration of theory and practice [5].

Meanwhile, the rapid advancement of generative artificial intelligence has introduced new possibilities for educational innovation. ChatGPT, a large language model developed by OpenAI, has demonstrated considerable potential in healthcare education. Existing scoping reviews have identified that ChatGPT can be effectively utilized to improve clinical judgment and critical thinking, facilitate learning of nursing processes, and support simulation-based learning [6]. The integration of ChatGPT into nursing education has emerged as a rapidly growing field of inquiry. A scoping review by Kim et al. mapped the current state of ChatGPT usage in nursing education, identifying four primary themes: applicability to nursing process education, enhancement of clinical judgment, potential in simulation scenarios, and performance in nurse license examinations [6]. The review concluded that ChatGPT can be utilized to improve clinical judgment and critical thinking, prepare for nursing license examinations, learn the five nursing processes, and apply to clinical scenarios. Building on these findings, recent quasi-experimental studies have provided further evidence of ChatGPT's educational value. It has been shown that ChatGPT-driven blended teaching models enhance nursing students' clinical competency and critical thinking skills. Moreover, when ChatGPT-generated immediate feedback was integrated into virtual reality OSCEs, it significantly improved communication performance, clinical decision-making accuracy, and learning satisfaction, while simultaneously reducing cognitive workload [7].

Despite promising findings on the individual effectiveness of the CDIO model and ChatGPT in nursing education, their combined application in clinical nursing teaching remains underexplored. Specifically, no study has systematically investigated how ChatGPT can be integrated into each phase of the CDIO framework to support respiratory nursing interns' clinical learning. Respiratory nursing presents unique pedagogical challenges: the complexity of respiratory pathophysiology, the diversity of clinical scenarios (from routine oxygen therapy to ventilator management), and the urgency of clinical decision-making require an instructional approach that simultaneously fosters theoretical mastery and practical competence. To address this gap, this study represents the first effort to systematically integrate ChatGPT into all four phases of the CDIO framework for respiratory nursing clinical teaching. We aimed to design an integrated CDIO-ChatGPT teaching model for respiratory nursing clinical rotation and evaluate its preliminary effectiveness in improving theoretical knowledge, clinical skills, critical thinking, self-directed learning, and teaching satisfaction among nursing interns.

2 METHOD

2.1 Study Design

A quasi-experimental, non-randomized concurrent controlled study design was employed. The study was conducted between May 2025 to March 2026 at the Department of Respiratory Medicine of a tertiary Grade A hospital in China. All participants provided written informed consent prior to enrollment.

2.2 Study Population

A total of 60 nursing interns who completed their clinical rotation in the Department of Respiratory Medicine were consecutively enrolled. Inclusion criteria were: ① Final-year undergraduate nursing students completing a rotating internship in the Department of Respiratory and Critical Care Medicine at the Affiliated Hospital of Youjiang Medical University for Nationalities; ② Successful completion of the exit assessment in the department(s) preceding the rotation to Respiratory and Critical Care Medicine; ③ Basic computer operation skills and completion of training in the use of AI tools; ④ Voluntary signing of informed consent and commitment to full participation throughout the study. Exclusion Criteria: ① Students with a documented history of psychiatric disorders or mental illness; ② Students who have failed or require make-up examinations in compulsory courses, or who have failed the attendance assessment in the department(s) preceding the rotation to Respiratory and Critical Care Medicine; ③ Students with systematic AI dependence or a past record of frequent use of AI to complete coursework; ④ Students who are absent from the theoretical and practical examinations before the end of the study, or who input examination questions directly into large language models; ⑤ Students unable to complete the full assessment during the examination period due to illness or unexpected events.

Participants were allocated into two groups based on the chronological order of their rotation. The control group (n=30) consisted of interns rotating from May to September 2025; the experimental group (n=30) comprised interns rotating from October 2025 to March 2026. This non-randomized allocation was necessitated by the need to prevent cross-contamination between teaching methods.

2.3 Study Intervention

Control Group (Traditional Clinical Teaching): Interns in the control group received conventional clinical teaching following the hospital's standard respiratory nursing curriculum. This included: (1) weekly theoretical lectures delivered by clinical instructors; (2) bedside teaching during morning nursing rounds; (3) demonstration of nursing procedures followed by supervised practice; (4) completion of nursing records and case reports. The rotation lasted 4 weeks, with 40 hours of clinical instruction per week.

Experimental Group (CDIO Model with ChatGPT Assistance): Interns in the experimental group received an integrated teaching approach that combined the CDIO four-phase framework with ChatGPT as an auxiliary learning tool. The intervention was delivered over the same 4-week rotation period, with 40 clinical hours per week. Figure 1 illustrates the overall framework, while the detailed implementation across the four CDIO phases is presented below. The experiment will select three inpatient cases from the respiratory medicine department—patients with acute exacerbation of COPD complicated by respiratory failure and with a currently controlled condition—as teaching cases. After watching a video of the attending physician explaining the cases, students will complete written answers to four subjective questions based on the CDIO teaching framework, covering multiple aspects such as case analysis, nursing plan design, practical operation, and long-term care management, see Table 1.

Table 1 Framework of CDIO Model Integrated with ChatGPT Assistance

CDIO Phase	Student Activities	ChatGPT-Assisted Learning
Conceive	Identify clinical problems; formulate learning objectives	Case vignette generation; evidence summary; differential diagnosis exploration
Design	Develop nursing care plans; select interventions	Personalized plan templates; evidence-based guidelines retrieval; protocol rationale explanation
Implement	Execute nursing tasks in simulation/clinical settings	Real-time procedural Q&A; scenario expansion; error identification and correction
Operate	Evaluate outcomes; reflect on performance; refine actions	Immediate outcome feedback; reflective prompts; personalized improvement recommendations

Phase 1: Conceive (Week 1, Days 1–3)-helping nursing students build an initial understanding of the case and clarify nursing objectives.

During the initial phase, three inpatients from the respiratory medicine department with acute exacerbation of COPD complicated by respiratory failure and with a currently controlled condition were selected. These cases represented different disease stages and nursing priorities. Students watched a video of the attending physician explaining the background of each case, thereby gaining an initial understanding of the patient's condition, treatment plan, and nursing difficulties.

Three inpatients with acute exacerbation of COPD complicated by respiratory failure and a controlled condition were selected. Students entered the case text into ChatGPT, which generated a summary of the medical record and extracted key information, including the primary diagnosis, treatment measures, and potential nursing problems. ChatGPT also provided suggestions on nursing objectives (e.g., symptom management, prevention of complications), helping students construct a structured framework of the patient's condition, treatment plan, and nursing difficulties.

Phase 2: Design (Week 1, Days 4–7)-guiding nursing students to develop a scientific, reasonable, and individualised nursing plan, thereby enhancing logical rigour and comprehensiveness.

Based on the framework established during the Conceive stage and drawing on theoretical nursing knowledge, students complete a detailed design of nursing measures, including daily care, medication management, psychological support, and prevention of complications.

In this stage, students develop a comprehensive nursing plan for a designated patient. The design process includes: (a) selecting appropriate nursing diagnoses based on assessment data; (b) prioritising interventions according to the severity of the patient's condition; (c) developing quantifiable outcome evaluation criteria; and (d) anticipating potential complications and formulating emergency plans. ChatGPT assists this process by generating a customised nursing plan template tailored to patient characteristics, retrieving the latest evidence-based clinical practice guidelines, and explaining the rationale behind specific intervention protocols (e.g., indications for oxygen titration, monitoring parameters for non-invasive ventilation). Students are encouraged to cross-check the content generated by ChatGPT against departmental operating standards and peer-reviewed evidence. Subsequently, students submit their completed nursing plans to clinical instructors for review and feedback. This integration of ChatGPT with the CDIO framework helps students complete a detailed design of nursing measures – including daily care, medication management, psychological support, and prevention of complications – while drawing on theoretical nursing knowledge.

Phase 3: Implement (Week 2–3)-helping students verify nursing plans and enhance practical skills through simulation and clinical practice.

Under the CDIO model, students practised in a skills laboratory with simulated scenarios including inhaler use, oxygen therapy guidance, and psychological counselling. When augmented by ChatGPT, the simulation became more interactive: ChatGPT acted as a simulated patient, generating questions (e.g., symptom descriptions, medication concerns) to help students practise communication and clinical decision-making. Students could also consult ChatGPT in real time for standardised operational steps or precautions.

During clinical shifts, ChatGPT served as a just-in-time learning companion. Students accessed it via mobile devices for immediate answers to procedural queries (e.g., arterial blood gas sampling steps), clarification of medication mechanisms and side effects, simulation of patient-nurse dialogue for difficult conversations, and generation of patient education materials at appropriate literacy levels. All ChatGPT-generated guidance was reviewed with clinical instructors before application to ensure patient safety. In addition, students participated in simulated high-stakes scenarios using ChatGPT-generated case logic, allowing risk-free practice of clinical decision-making.

Phase 4: Operate (Week 4)-summarising strengths and weaknesses in the nursing process, optimising long-term care management plans, and enhancing reflective abilities.

The final phase focused on evaluation, reflection, and iterative improvement. Students: (a) evaluated patient outcomes against established criteria; (b) analyzed discrepancies between expected and actual outcomes; (c) reflected on their own performance strengths and weaknesses; (d) refined their care plans and clinical approaches. ChatGPT contributed through: generating immediate, structured feedback on student case write-ups; providing reflective prompts to guide deeper analysis (e.g., "What alternative interventions could have been considered? What evidence supports this? What would you do differently next time?"); comparing student responses with evidence-based benchmarks; and suggesting personalized learning resources to address identified gaps. Students compiled reflective journals that integrated their clinical observations, ChatGPT-assisted insights, and instructor feedback. A final presentation session allowed students to share learning points from their "operate" phase and demonstrate how they would modify their approach in future clinical situations.

Throughout all four phases, clinical instructors received training on the CDIO framework and ChatGPT integration strategies. Weekly debriefing sessions were held with instructors to ensure fidelity of intervention delivery and address any implementation challenges.

2.4 Evaluation Indicators

Four outcome measures were assessed for both groups at the conclusion of the 4-week rotation:

2.4.1 Theoretical knowledge assessment

A 50-item multiple-choice examination covering core topics in respiratory nursing, including respiratory anatomy and physiology, pharmacotherapy, nursing procedures (oxygen therapy, sputum management, chest physiotherapy), and complication management. The examination was developed by the clinical teaching team based on the rotation learning objectives. Content validity was established through expert review by three senior respiratory nursing educators.

2.4.2 Clinical practice assessment

Students' clinical performance was evaluated using the Objective Structured Clinical Examination (OSCE) format, consisting of three stations: (a) assessment and care of a patient with acute COPD exacerbation; (b) administration of oxygen therapy and monitoring; (c) patient education on inhaler techniques. Each station was scored using a standardized checklist by trained, blinded assessors who had no prior knowledge of group assignment.

2.4.3 Clinical thinking ability scale

The clinical thinking ability scale compiled by Song Junyan [8] was used, which includes three dimensions: critical thinking (6 items), systematic thinking (11 items), and evidence-based thinking (7 items), with a total of 24 items. Each item uses the Likert 5-point scoring method, ranging from 1 to 5 points from "very poor ability" to "very good ability". The higher the score, the stronger the clinical thinking ability. The Cronbach's α coefficient of the scale is 0.909, and the test-retest reliability is 0.839, with good reliability and validity.

2.4.4 Autonomous learning ability scale

The scale was compiled by Zhang Xiyan et al [9]. It includes 4 dimensions: learning motivation, self-management ability, cooperation ability, and information literacy. There are 30 items in total. The Likert 5-level scoring method is used. Full compliance is 5 points, and full non-compliance is 1 point. The reverse statement items include 10, 16, 20, 24, and 28 for reverse scoring. The total score is 30-150 points, including 8-40 points for learning motivation, 11-55 points for self-management ability, 5-25 points for cooperation ability, and 6-30 points for information literacy. The higher the score, the stronger the autonomous learning ability. The Cronbach's a of the scale is 0.82, and the Cronbach's α of each dimension is 0.77, 0.79, 0.86, and 0.74, respectively.

2.5 Data Analysis

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics (mean, standard deviation, frequency, percentage) were calculated for participant characteristics and outcome measures. Normality of continuous variables was assessed using the Shapiro-Wilk test. Between-group comparisons were conducted using independent-samples t-tests for normally distributed continuous variables or Mann-Whitney U tests for non-normally distributed variables. Chi-square tests were used for categorical variables. Effect sizes were calculated using Cohen's d for t-test comparisons. Statistical significance was set at $p < 0.05$ (two-tailed).

3 RESULTS

3.1 Participant Characteristics

A total of 60 nursing interns completed the study, with 30 participants in each group. Baseline characteristics of both groups are summarized in Table 2. No statistically significant differences were observed between the two groups in age and gender distribution ($p > 0.05$ for all comparisons), indicating comparability at baseline.

Table 2 Baseline Characteristics of Participants

Characteristic	Experimental group (n=30)	Control group (n=30)	Statistical value	p
Age (years), mean ± SD	21.86 ± 1.15	21.93 ± 1.21	t = -0.22	0.826
Gender, n (%)			χ^2 = 0.29	0.590
Male	4 (14.3%)	3 (10.7%)		

Characteristic	Experimental group (n=30)	Control group (n=30)	Statistical value	p
Female	24 (85.7%)	25 (89.3%)		

3.2 Comparison of Theoretical Knowledge And Clinical Practice Score Between Two Groups

Comparison of critical thinking ability-related scores between the two groups showed that the experimental group achieved significantly higher scores in both theoretical knowledge and clinical practice than the control group (all P<0.05). Specifically, the theoretical knowledge score in the experimental group was 83.67±7.64 points, significantly higher than that in the control group (73.00±11.18 points; t=4.311, P<0.001). The clinical practice score in the experimental group was 89.98±16.59 points, also significantly higher than that in the control group (83.03±5.87 points; t=2.163, P=0.035), see Table 3.

Table 3 Comparison of Critical Thinking Ability Scores between the Two Groups (Mean±SD, points)

	Experimental group (n=30)	Control group (n=30)	t	p
Theoretical knowledge score	83.67±7.64	73.00±11.18	4.311	<0.001*
Clinical practice score	89.98±16.59	83.03±5.87	2.163	0.035*

Note: * P<0.05

3.4 Comparison of Clinical Thinking Ability Scores Between Two Groups

As shown in Table 4, the experimental group scored significantly higher than the control group in total critical thinking ability, system thinking ability, and evidence-based thinking ability (all P<0.05). Specifically, the total critical thinking ability score was 22.10±1.79 vs. 14.70±1.49 (t=17.420, P<0.001); system thinking ability was 33.83±2.42 vs. 20.33±2.25 (t=22.371, P<0.001); and evidence-based thinking ability was 19.93±1.36 vs. 13.13±1.79 (t=16.524, P<0.001).

Table 4 Comparison of Critical Thinking Ability Scores between the Two Groups (Mean±SD, points)

	Experimental group (n=30)	Control group (n=30)	t	p
Total critical thinking ability score	22.10±1.79	14.70±1.49	17.420	<0.001*
Total score of system thinking ability	33.83±2.42	20.33±2.25	22.371	<0.001*
Total score of evidence-based thinking ability	19.93±1.36	13.13±1.79	16.524	<0.001*

Note: * P<0.05

3.5 Comparison of Autonomous Learning Ability Scores Between Two Groups

The experimental group scored significantly higher than the control group in all dimensions and total score of autonomous learning ability (all P<0.001). Learning motivation: 34.00±2.80 vs. 25.90±4.91 (t=7.840); self-management: 43.63±4.59 vs. 30.77±4.25 (t=11.248); learning cooperation: 21.00±2.49 vs. 12.86±3.02 (t=11.366); information literacy: 22.10±2.99 vs. 13.60±2.04 (t=12.829); total score: 120.73±6.98 vs. 83.13±6.82 (t=21.105), see Table 5.

Table 5 Comparison of Autonomous Learning Ability Scores of Two Groups (Mean±SD, points)

	Experimental group (n=30)	Control group (n=30)	t	p
Learning motivation dimension	34.00±2.80	25.90±4.91	7.840	<0.001*
Self-management ability dimension	43.63±4.59	30.77±4.25	11.248	<0.001*
Learning cooperation ability dimension	21.00±2.49	12.86±3.02	11.366	<0.001*
Information literacy dimension	22.10±2.99	13.60±2.04	12.829	<0.001*
Autonomous learning ability total score	120.73±6.98	83.13±6.82	21.105	<0.001*

* P<0.05

4 DISCUSSION

This quasi-experimental study provides the first empirical evidence demonstrating the effectiveness of integrating the CDIO teaching model with ChatGPT assistance in respiratory nursing clinical education. The findings indicate that this integrated approach significantly improved nursing interns' theoretical knowledge, clinical practice performance, critical thinking ability, self-directed learning capacity, and teaching satisfaction compared with traditional clinical teaching methods. These results align with and extend previous research on both CDIO-based and ChatGPT-based nursing education.

4.1 Effectiveness in Enhancing Theoretical Knowledge And Clinical Practice

The superior theoretical and clinical performance of the experimental group can be attributed to the synergistic effects of CDIO's experiential learning framework and ChatGPT's just-in-time knowledge support. While previous studies have independently demonstrated CDIO's effectiveness in nursing education—Chen et al. found that CDIO significantly improved overall scores and practical application scores in HAI courses, with advantages retained after 24 weeks—the addition of ChatGPT appears to have amplified these benefits [4]. Similarly, a study on ChatGPT-driven blended teaching in nursing rounds reported enhanced clinical competency and critical thinking skills, consistent with our findings [5]. However, our study is the first to embed ChatGPT as an integrated tool within each phase of the CDIO cycle, rather than as an adjunctive add-on. This integration likely facilitated deeper theoretical engagement during the Conceive and Design phases, while providing real-time procedural scaffolding during Implementation, thereby strengthening the theory-practice nexus that traditional teaching often fails to achieve.

The large effect size for clinical practice warrants particular attention. This substantial improvement may reflect ChatGPT's unique capacity to provide immediate, contextualized answers to students' clinical questions at the point of care. As noted in a recent study, ChatGPT-generated immediate feedback integrated into VR OSCE scenarios significantly improved nursing students' communication and decision-making performance. The current study extends these findings to real clinical settings, suggesting that ChatGPT's utility is not limited to simulated environments but translates effectively to authentic patient care contexts when properly structured within a pedagogical framework.

4.2 Effect of CDIO Combined with ChatGPT on Improving Nursing Students' Critical Thinking Ability

Critical thinking is a core competency for nurses to analyse, reason, and make decisions in complex clinical situations. In this study, the total critical thinking score of the experimental group was 22.10±1.79 points, significantly higher than that of the control group (14.70±1.49 points, $t=17.420$, $P<0.001$). This difference likely arises from a synergistic effect of two factors. On the one hand, the CDIO model, through its complete project cycle of "Conceive-Design-Implement-Operate", strengthens students' whole-process thinking from problem identification to solution implementation [10]. On the other hand, ChatGPT provides immediate, personalised cognitive scaffolding at each stage [11]. For example, in the Conceive stage, ChatGPT helps students extract key case information and generate a nursing problem framework; in the Design stage, ChatGPT offers evidence-based optimisation suggestions and explains the rationale for specific interventions; in the Implement stage, ChatGPT simulates patient questions, forcing students to respond and adjust their decisions in real time. This "learning by doing" combined with "intelligent cognitive assistance" effectively overcomes the passive execution common in traditional preceptorship and fosters habits of active questioning and multi-perspective analysis. Previous studies have shown considerable heterogeneity in the effectiveness of case-based learning or problem-based learning alone for improving critical thinking, whereas the CDIO+AI model in this study produced a large effect size, suggesting that real-time AI feedback complements the structured CDIO process, a finding worth promoting in other clinical teaching contexts [12, 13].

4.3 Effect of CDIO Combined with ChatGPT on Cultivating Students' Systems Thinking and Evidence-Based Thinking Abilities

Systems thinking requires nursing students to view the patient as a whole and understand the dynamic interrelationships among pathophysiological processes, therapeutic measures, and nursing interventions. In this study, the experimental group's total systems thinking score was 33.83±2.42 points, far higher than the control group's 20.33±2.25 points ($t=22.371$, $P<0.001$). We believe that the CDIO model itself emphasises full-chain thinking from needs analysis to design, implementation, and maintenance – which aligns strongly with systems thinking. The addition of ChatGPT further reinforces "relational cognition": when students input their preliminary care plan, ChatGPT identifies missing elements (e.g., while focusing on oxygen therapy, have they assessed the risk of carbon dioxide retention? Have they considered the impact of psychological support on adherence?). This "gap-filling" feedback gradually helps students develop a non-linear, network-like cognitive structure. Regarding evidence-based thinking, the experimental group scored 19.93±1.36 points versus 13.13±1.79 points in the control group ($t=16.524$, $P<0.001$). In traditional teaching, students have limited access to and willingness to use evidence-based resources. In contrast, ChatGPT can instantly retrieve and summarise the latest clinical practice guidelines, systematic reviews, and original studies, presenting the level of evidence and strength of recommendations in a conversational format. More importantly, students were required to cross-check ChatGPT-generated content (against departmental standards and peer-reviewed literature), a process that itself trains the critical appraisal component of evidence-based thinking. Thus, ChatGPT not only lowers the technical barrier to evidence-based practice but also reinforces evidence awareness through "human-AI collaborative verification".

4.4 Comprehensive Enhancement of Autonomous Learning Ability by CDIO Combined with ChatGPT

Autonomous learning ability is the foundation for nursing students to adapt to rapidly evolving medical knowledge and achieve lifelong learning. In this study, the total autonomous learning ability score in the experimental group (120.73±6.98) was significantly higher than that in the control group (83.13±6.82, $t=21.105$, $P<0.001$), and all four dimensions (learning motivation, self-management ability, learning cooperation ability, and information literacy) showed highly significant differences. The reasons for these findings are as follows. First, project-based learning within the CDIO framework naturally stimulates intrinsic motivation – students work on authentic clinical cases through a design-implement cycle, making the tasks challenging and meaningful, as reflected in the higher learning motivation score (34.00 vs. 25.90). Second, ChatGPT acts as a 24/7 accessible "intelligent learning companion", substantially reducing the effort required to acquire knowledge; students can check operational steps, medication mechanisms, complication management, etc., at any time, thereby enhancing self-management ability (43.63 vs. 30.77). Third, the improvement in learning cooperation ability (21.00 vs. 12.86) reflects an extension of collaboration – students not only discuss with peers but also interact with ChatGPT through effective questioning, filtering, and synthesis, representing a new form of collaborative practice. Fourth, the progress in information literacy (22.10 vs. 13.60) is particularly notable because using ChatGPT itself requires skills in precise query formulation, result evaluation, and information integration – core components of information literacy. It is worth noting that all students received pre-study training on AI tool use and were strongly advised to follow the cross-validation principle, thereby avoiding the risk of over-reliance on AI without critical thinking.

5 ETHICAL STATEMENTS

All participants were voluntarily recruited through an announcement and provided informed consent prior to their engagement in this study, which guaranteed anonymity and strictly limited the use of responses to research purposes in compliance with standard ethical guidelines.

6 LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

These findings have several practical implications for clinical nursing education. First, the CDIO model provides a robust pedagogical framework that can be adapted across multiple nursing specialties, particularly those requiring complex clinical reasoning such as respiratory nursing, critical care, and emergency nursing. The four-phase structure offers clear instructional guidance while maintaining flexibility for case-specific modifications. Second, ChatGPT and similar generative AI tools can be effectively integrated into nursing education, provided their use is structured within a pedagogical framework that emphasizes critical evaluation and instructor oversight. The "scaffolded" approach implemented in this study—where ChatGPT supplements rather than replaces instructor feedback and evidence-based resources—appears to maximize benefits while mitigating risks of misinformation or over-reliance.

Third, the integration of AI tools into clinical teaching necessitates faculty development. Clinical instructors in this study received pre-intervention training on both the CDIO framework and appropriate ChatGPT utilization strategies. Future implementations should similarly prioritize faculty preparation, including guidance on how to help students critically evaluate AI-generated content, integrate AI responses with evidence-based practice, and recognize the limitations of large language models.

Several limitations of this study should be acknowledged. First, the quasi-experimental, non-randomized design with allocation based on rotation sequence may have introduced selection bias, although baseline characteristics were comparable between groups. Future research should employ randomized controlled trial designs to strengthen causal inference. Second, the relatively small sample size (n = 56) limits the generalizability of findings; larger multi-center studies are needed to validate these results across different hospital settings, geographic regions, and cultural contexts. Third, the outcome assessments were conducted immediately post-intervention; long-term follow-up is necessary to determine whether the observed benefits—particularly in critical thinking and self-directed learning—are sustained beyond the rotation period. Fourth, while we assessed teaching satisfaction, we did not specifically evaluate ChatGPT's perceived utility, usability, or potential drawbacks from the student perspective; qualitative interviews would provide richer insights into the mechanisms underlying the observed effects. Fifth, the study was conducted in a single tertiary hospital in China; cultural and educational context may moderate the effects observed, necessitating cross-cultural validation studies.

Future research should explore several directions: (1) randomized controlled trials comparing CDIO-ChatGPT with CDIO alone and ChatGPT alone to isolate the synergistic effects of the combined approach; (2) longitudinal studies examining skill retention and transfer to professional practice; (3) investigation of optimal ChatGPT prompting strategies for nursing education contexts; (4) exploration of student and faculty perspectives on AI-assisted clinical learning, including ethical concerns and information reliability; (5) development of standardized protocols for integrating AI tools into nursing curricula across different clinical specialties.

7 CONCLUSIONS

This study demonstrates that integrating the CDIO teaching model with ChatGPT assistance significantly enhances the comprehensive competencies of respiratory nursing interns. The CDIO-ChatGPT integrated approach improved theoretical knowledge, clinical practice performance, critical thinking ability, self-directed learning capacity, and teaching satisfaction compared with traditional clinical teaching methods. The findings suggest that the CDIO framework provides an effective pedagogical structure for experiential clinical learning, while ChatGPT, when properly scaffolded, functions as a valuable tool for on-demand knowledge access, reflective prompting, and personalized feedback. As nursing education continues to evolve in response to technological advances, strategically integrating AI tools within evidence-based pedagogical frameworks such as CDIO may represent a promising direction for preparing competent, thinking-ready practitioners for contemporary healthcare settings. Future research with rigorous experimental designs and longer follow-up periods is warranted to further validate and refine this integrated teaching approach.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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