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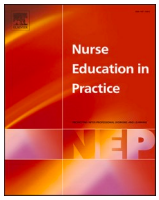

In-situ simulation for nursing students' professional competence development in postanesthesia care: A quasi-experimental study

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ABSTRACT

Aim: To evaluate the differences in professional competence development between nursing students in routine clinical practice and those who experienced four additional in-situ simulations.
Background: The amount of clinical practice time available to nursing students is limited. Occasionally, clinical settings do not provide all of the content that nursing students are expected to acquire. In high-risk clinical scenarios, such as the postanesthesia care unit, clinical practice may not provide sufficient context for students to develop the professional competence.
Design: This was a non-blinded, non-randomized, quasi-experimental study. The study was conducted in the postanesthesia care unit of a tertiary hospital in China between April 2021 and December 2022. Nursing students' self-assessed professional competence development and faculty-assessed clinical judgment were used as indicators.
Methods: A total of 30 final year undergraduate nursing students were divided into two groups according to the time they arrived at the unit for their clinical practice. Nursing students in the control group followed the routine teaching protocol of the unit. Students in the simulation group received four additional in-situ simulations during the second and third weeks of their practice in addition to the routine program. Nursing students self-assessed their postanesthesia care unit professional competence at the end of the first and fourth weeks. At the end of the fourth week, the nursing students were evaluated on their clinical judgment.
Results: Nursing students in both groups scored higher on the professional competence at the end of the fourth week than at the end of the first week and there was a trend of higher competence improvement in the simulation group than in the control group. For clinical judgment, nursing students in the simulation group scored higher than the control group.
Conclusions: In-situ simulation contributes to the development of professional competence and clinical judgment of nursing students during their clinical practice in the postanesthesia care unit.

1. Introduction

Clinical practice is a critical component for nursing students to develop their professional competence (Yang and Zang, 2022). Undergraduate nursing programs typically last four years in China nowadays. In general, nursing students spend the first three years in school with theoretical courses and the last year in clinical practice (Gao et al., 2012). Nursing students are required to rotate through different clinical departments in a teaching hospital during the last year of undergraduate education to strengthen their practice competence (He et al., 2020). Nursing students are exposed to a variety of clinical situations that may require them to make judgments. However, with limited time, the clinical practice sometimes does not provide all events, especially certain skills that students expect to acquire, such as how to respond to emergencies (Peachey, 2021). Improved professional competence for nursing students increases confidence in pursuing the nursing profession and achieves higher professional satisfaction or increased professional self-efficacy (McPherson and Wendler, 2020; Muirhead et al., 2022). Increased professional self-efficacy in nursing students contributes to their academic success and improved job performance (Bryan and Vitello-Cicciu, 2022; Bulfone et al., 2022). Clinical judgment is one of the most important professional competencies that nursing students

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should acquire in nursing education. Clinical judgment covers recognizing, observing, assessing, interpreting and responding to clinical phenomena (Uppor et al., 2022). Lasater had developed an instrument for measuring clinical judgment, called Lasater Clinical Judgment Rubric (LCJR) (Lasater, 2007). The LCJR has been widely used in nursing simulation (Calcagni et al., 2023; Callihan et al., 2023).

Emergence or recovery is a critical phase of general anesthesia(Wei et al., 2021). Patients are vulnerable and are usually medically monitored in the postanesthesia care unit (PACU) or the intensive care unit (ICU). Several unexpected events may occur to these patients, including respiratory depression, postoperative hypotension and cardiac arrest (Ayad et al., 2019; Smischney et al., 2020). These conditions may lead to serious problems or even death if not recognized and treated in a timely manner. The high-risk environment of the PACU places a greater demand on nurses' emergency response and assessment skills. How to empower nursing students to quickly recognize and manage potentially life-threatening situations is the challenge facing clinical nursing education in the PACU (Patel et al., 2022). Relying solely on clinical education under realistic conditions, nursing students may not experience critical situations.

Simulation guides students to actively explore by playing different roles and synthesizing solutions to problems (McNaughten et al., 2021). It helps to strengthen the professional skills, self-confidence and critical thinking of nurses and nursing students (Coyne et al., 2021; Üzen Cura et al., 2020). Simulation is valuable in multidisciplinary education and promotes collaboration between healthcare professionals or students (Atamanyuk et al., 2014; Sarmasoglu Kilikcier et al., 2021). Classical simulations are conducted in laboratories and serve as a bridge between theoretical learning and clinical practice (Lei et al., 2022).

In-situ simulation is one of the most effective approaches to bridge the gap between theory and practice by directly applying nursing theories and methods in a simulated clinical setting without any risk (Coyne et al., 2021; Morineau et al., 2017). It is cost-effective and requires minimal space (Calhoun et al., 2011). In-situ simulation is conducted in the same location as the existing clinical setting, allowing nurses or nursing students to respond and manage effectively and quickly in emergency (Alsaedi et al., 2021; Bentz et al., 2022). The ultimate goal of in-situ simulation is to facilitate patient safety (Langevin et al., 2022). In addition, in-situ simulations provide a better persistence of impact on students than laboratory simulations (Connell et al., 2016).

This study hypothesized that nursing students who experienced four additional in-situ simulation scenarios would develop their professional competence better than students who received routine clinical practice in a PACU. The objective of this study was to evaluate the differences in professional competence development between nursing students in routine clinical practice and those who experienced four additional in-situ simulations. The PACU professional competence and clinical judgment were employed to measure the professional competence of nursing students practicing in the PACU.

2. Methods

2.1. Study design

This study could not be randomized and blinded due to the limitations of the study participants and intervention methods. A quasi-experimental design was adopted. Blindness was impossible because the intervention was open to faculty and nursing students. Nursing students practiced in this PACU on a rotating basis, with a possible one to three students at a time. Simple randomization could result in students in the same rotation being assigned to different groups. Between April 2021 and December 2022, final year undergraduate nursing students practicing in the PACU of a tertiary teaching hospital in Beijing, China were alternately assigned to the control and experimental groups according to the order in which they enrolled to begin practice in this PACU. Nursing students in the control group followed the routine teaching protocol of the unit. Two or more nursing students practicing in the PACU at the same time were assigned to the same group. Students in the experimental group received four additional in-situ simulation scenarios. This study followed the guidelines of the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND Statement).

2.2. Participants

Convenience sampling was employed to recruit final year nursing students in the PACU of a tertiary hospital from April 2021 to December 2022. Inclusion criteria were full-time final year undergraduate nursing students on clinical practice rotations in the PACU for four weeks or more, who voluntarily participated in this study. We approached all the 32 nursing students during this period. Two of whom declined to participate in this study. There were 30 participants in the study, 15 in the control group and 15 in the experimental or simulation group. No participants withdrew during the study period.

The two independent samples *t*-test, paired *t*-test and repeated measures analysis of variance (ANOVA) were used in this study to compare the data from the two groups of participants. The two-tailed independent samples *t*-test requires the largest sample size. The sample size was calculated using G*Power v3.1 (Faul et al., 2007). We set the effect size *d* to 0.8, the *alpha*= 0.2 and the power (1- *beta*) = 0.8. The sample size was calculated to be 30, with 15 in each of the two groups. Participants were recruited continuously for this study. Recruitment was stopped when sufficient complete data were obtained.

2.3. Study procedure

Nursing students spent at least four weeks of clinical practice in the PACU. Six hours of theoretical lectures were given on Monday, Wednesday and Thursday of the first week. The main content is shown in Table 1. On the first Friday, a questionnaire was distributed asking the students to self-assess their professional competence in the PACU. No special arrangements were made for the control group students during the second and third weeks. The nursing students in the experimental group participated in four simulation scenarios. At the end of the fourth week, nursing students in both groups were again asked to self-assess their PACU professional competencies. The students' clinical judgment based on their practice performance was also assessed at this time. The clinical judgment evaluation was conducted by three nursing faculty members who were not involved in the simulation. The study procedure is shown in Fig. 1.

Nursing students in the control group followed the routine PACU teaching protocol. This protocol had been implemented in this PACU for several years and was considered effective for the professional competence development of nursing students. They were assigned designated clinical instructors. Clinical skills were introduced by the assigned instructor.

The experimental group added in-situ simulation sessions besides the above theory and practical skills teaching.

2.4. In-situ simulation

The design and implementation of the in-situ simulation scenarios in

Table 1
Main contents of theoretical lectures.

No.	Title and main content
1	General information of the PACU, type of patients admitted, nurses' duties and responsibilities
2	General anesthesia and recovery
3	Drug administration and monitoring during recovery
4	Vital signs and ECG monitoring
5	Specialized assessment of anesthetic recovery
6	Postoperative airway management and emergency response

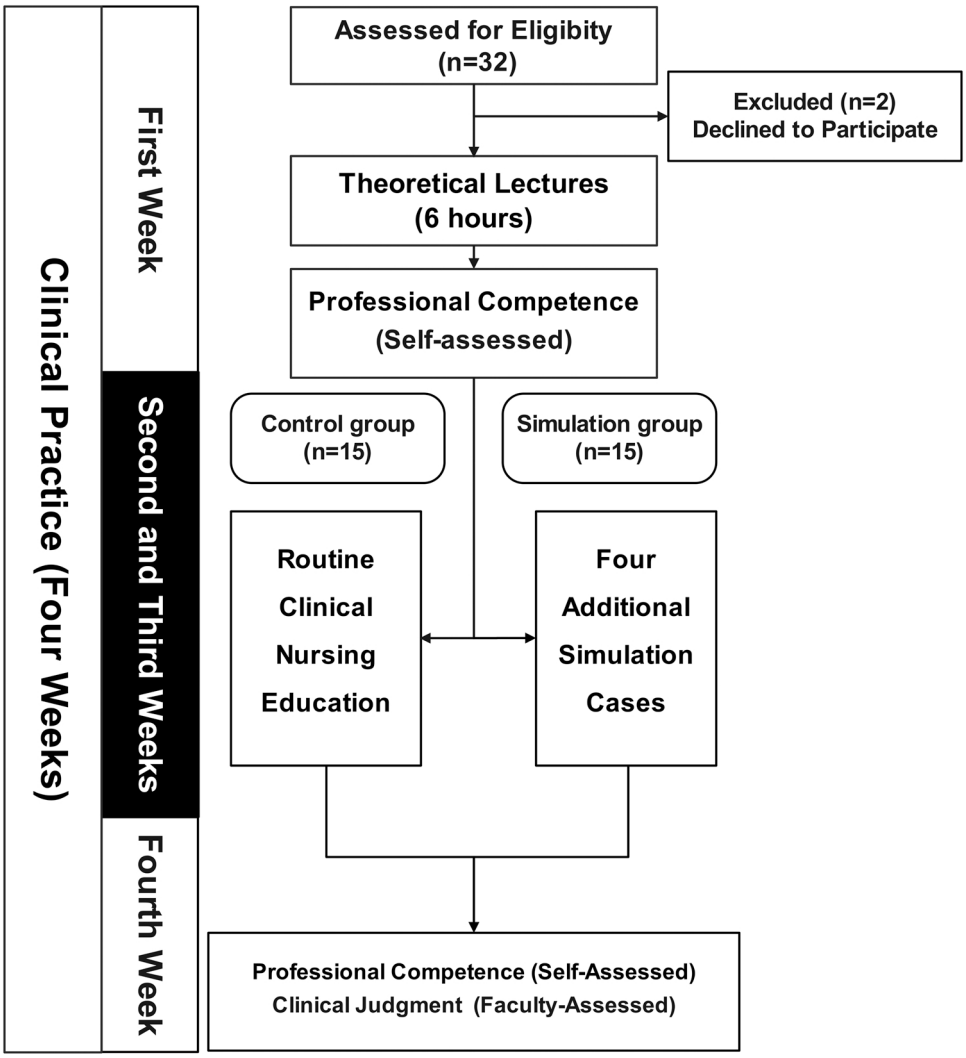

Fig. 1. Flowchart of the study.

this study followed the Healthcare Simulation Standards of Best Practice developed by the International Nursing Association for Clinical Simulation and Learning (INACSL) (Watts et al., 2021).

2.4.1. Preparation

(1) Development of simulation cases

First, a preliminary construction of the cases was performed. Case development team of seven members was formed. Three registered nurses (RNs) trained in simulation methods and with at least ten years of clinical work experience were responsible for preparing simulation cases, designing guiding questions and participating in and guiding the simulation processes. Two RNs were assigned to prepare the text, build and rehearse the process on-site and participate in the simulations. Two RNs handled other technical work such as assisting in the collection and collation of expert opinions. According to the clinical teaching objectives, the teaching conditions in this PACU and the analysis of the basic situation of nursing students, four cases were initially constructed after thorough discussion in the team. These cases were based on real-life scenarios. The cases were designed to meet the following criteria: (a) complications easily developed in PACUs and related to anesthesia or surgery; (b) condition changes could lead to rapid changes in the patient's vital signs and/or serious consequences; (c) nursing staff could play important roles in these cases, including observation, recognition and resuscitation; and (d) required nursing students to possess knowledge related to recovery care, such as drug administration, resuscitation equipment use. The study team initially constructed the case scenarios.

Second, experts reviewed the drafts. Five experts, two anesthesiologists and three senior nurses from anesthesia departments, all with more than 10 years of practice experience in other hospitals, were invited to evaluate the texts of the cases and suggest changes. They made 15 suggestions for improvement. These include four comprehensive comments and 11 detailed changes. The comprehensive comments include the following four points: (a) more detailed information should be provided to match the student's current competencies; (b) prerequisite knowledge should be taught to nursing students as early as possible; (c) the situation was so urgent that it was recommended that the student be equipped with helpers; and (d) in the case of multiple endings, nursing students should be guided to work toward a good ending to improve their self-confidence. Detailed changes included drug names, oxygen saturation values, respiratory rate values, anesthesiologist arrival times and so on.

Based on the modifications proposed by the experts, the case development team carefully discussed and modified them and formed a modified version. The team conducted a trial run and made adjustments. Three nursing students who were practicing at the time were invited to test it. After testing, a second version was

developed by discussing it with these nursing students. The final text of the simulation cases was again reviewed by experts to complete the development process.

(2) Summary of the cases

In case 1, the patient was conscious and regained respiration after surgery. The tracheal tube was removed from the operating room. After being admission to the PACU, the patient was unconscious and unable to respond to calls. Oxygen saturation was progressively decreasing, and the respiratory rate was 0. A human patient simulator is applied in this case. This case was evaluated for the resuscitation of residual skeletal muscle relaxants and general anesthetics during the recovery period.

Case 2, a patient with atrial fibrillation for more than 10 years, underwent extended maxillofacial malignant tumor resection and reconstruction with fibula osteomyocutaneous flap under general anesthesia. Oxygen saturation was continuously maintained below 92% during postoperative monitoring in the PACU. A nursing faculty member played as a standardized patient in this case. This case mainly evaluated nursing students' management and clinical thinking of the patient with decreased oxygen saturation.

In case 3, the patient was admitted to the PACU with a tracheal tube and was unconscious. Delirium developed in the PACU, and the patient was extubated unconsciously during agitation. A standardized patient was involved in this case. Some of the operations were performed on a manikin-based simulator. This case primarily evaluated the students' emergency response and method of maintaining airway patency.

In case 4, the patient received cephalosporin for the first time during surgery. The antibiotics were administered again in the PACU with a sudden onset of severe allergic reaction. Initially, blood pressure and heart rate were altered, and ventricular fibrillation occurred after a very short time. Resusci Anne™ (Laerdal Medical AS) was used as the human patient simulator in this case. This case was mainly used to assess the students' recognition of allergic reactions and the application of cardiopulmonary resuscitation techniques in emergencies.

(3) Site preparation

All simulations in this study took place in a relatively separate bed in the PACU. The bed was physically separated from the other beds by walls with windows for observation. The equipment used for the simulation was limited to that currently available in the PACU.

(4) Preparation of nursing students or pre-briefing

Before starting the first simulation, the faculty team introduced the location and schedule to the nursing students. A flyer outlining the brief process and possible knowledge to be covered in this simulation was distributed to the nursing students one day prior to each simulation and students were asked to preview. If there were two or more nursing students, one was designated as the primary person for the simulation and was responsible for evaluating and directing the work of the other personnel. Rotation would occur in subsequent simulations. To reduce anxiety among the nursing students, they should be informed that at least one member of the student team during the simulation would be an RN. However, in most cases, this member would work under the direction of the primary person. Through pre-briefing process, we hope to establish a psychologically safe environment for nursing students. A 'fiction contract' was created in this process.

2.4.2. Implementation of the in-situ simulation

The simulation was scheduled on Wednesdays and Fridays from 8:30 a.m. to 10:00 a.m., a time when there were generally no patients to care for in the PACU. Faculty members and students were able to fully engage in the simulation process. Each scene preparation and actual simulation took approximately 30–45 min, followed by a debriefing of about 30–45 min.

2.4.3. Debriefing

The debriefing process was performed according to the Gather, Analyze, Summarize (GAS) model (Decker et al., 2021). It was facilitated by one of the senior RNs on the nursing students' team. The facilitator began by describing or providing feedback to the students about their performance in the simulation, such as how the students reacted when a medical change occurred and details of how the students responded to the emergency. The feedback would be nonjudgmental. The students then described how they felt about the case. This was followed by a discussion of the key participants in the simulation. Faculty members commented on the students' performance in the simulation. The nursing students again reflected on their performance. Finally, the facilitator summarized. The nursing students were given positive feedback and their performance was moderately encouraged. They were kindly acknowledged for their errors or imperfect performance and encouraged to improve their skills in subsequent practice sessions.

2.5. Measurement instruments

This study compared the effect on the development of PACU professional competence of nursing students with and without participation in simulation during clinical practice. The general information questionnaire was used to collect general and demographic information (gender, age, previous experience in PACU practice) about the participants.

The PACU Professional Competence Scale for Nursing Students (PPCS-NS) was a self-report scale. PPCS-NS was developed for this study. It was used to assess nursing students' PACU professional competence. The items of the scale were developed according to the clinical teaching objectives of this PACU and with reference to related instruments (Dahlberg et al., 2021; Hvidberg et al., 2021). The scale consisted of 16 items corresponding to the areas of competence of the nursing students. A brief description of the items is presented in Table 2. Nursing students rated themselves on levels ranging from "unable to do" (1 point) to "fully able to do" (4 points). The total score on the scale ranged from 16 to 64. The higher the score, the better the PACU professional competence. The content validity index at the scale-level (S-CVI) and at the item-level (I-CVI) were used to measure the validity. Five experts, two anesthesiologists and three nurses, all with more than 10 years' experience in practice, were invited to evaluate the content validity of the scale after the initial draft was developed. Universal expert agreement at the scale level (S-CVI/UA) was 0.813. The average CVI (S-CVI/Ave) was 0.963. The item level CVI (I-CVI) ranged from 0.8 to 1. Before conducting this study, we invited 10 nursing students after four weeks of practice in this PACU to be tested with this scale. The internal consistency reliability Cronbach's alpha value was 0.697. This value was acceptable considering the difference in difficulty and uneven development between the competency items.

The Chinese version of the Lasater Clinical Judgment Rubric (C-LCJR) was employed to assess the clinical judgment of the nursing students (Yang et al., 2019). The scale consists of four dimensions namely noticing, interpreting, responding and reflecting, which represent Tanner's four phases of clinical judgment (Tanner, 2006). The C-LCJR consists of 11 items, rated 1–4 (totally 11–44) according to nursing students' performance. The higher the score, the better the clinical judgment. The scale can be either self-assessed by the nursing students themselves or rated by the evaluators. Evaluator ratings were used in this study. Scoring was performed by PACU nursing faculty who were not involved in the simulation. To avoid interference in the scoring by the raters, three senior nurses with more than 10 years of experience in this PACU scored it simultaneously. To ensure consistency in their scoring, a pilot assessment was conducted with five nursing students who were not involved in this study. The Kendall's W correlation coefficient value was 0.642 ($p = 0.040$), indicating a good agreement among

Table 2
Results of PACU Professional Competence Scale for Nursing Students.

Item		Simulation group				Control group			
		First weekend		Fourth weekend		First weekend		Fourth weekend	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	Vital signs assessment	2.27	0.46	3.40	0.51	2.20	0.41	3.40	0.51
2	Identify risks / complications during recovery	1.47	0.52	3.20	0.41	1.27	0.46	3.07	0.59
3	Knowledge and use of anesthetics and antagonists	1.67	0.62	2.87	0.52	1.33	0.49	2.60	0.51
4	Sedation assessment and treatment	1.60	0.51	3.33	0.62	1.67	0.62	2.87	0.35
5	Pain assessment & comfort care	1.47	0.52	3.00	0.38	1.27	0.46	2.93	0.70
6	Management of postoperative nausea and vomiting	1.53	0.52	3.13	0.52	1.47	0.52	2.60	0.51
7	Thermoregulation and care	1.33	0.49	3.27	0.46	1.47	0.52	3.20	0.41
8	Airway management	1.13	0.35	3.40	0.51	1.20	0.41	2.87	0.52
9	Basic life support & practice	1.20	0.41	3.13	0.35	1.20	0.41	3.07	0.59
10	ECG identification and intervention	1.13	0.35	3.07	0.46	1.07	0.26	2.53	0.64
11	Defibrillator operation	1.13	0.35	3.20	0.41	1.27	0.46	2.80	0.56
12	Hemodynamic monitoring	1.07	0.26	2.60	0.51	1.27	0.46	2.53	0.52
13	Fluid imbalance judgment analysis	1.67	0.49	3.07	0.59	1.40	0.51	2.93	0.46
14	Post-operative care for different surgical specialties in PACU	1.40	0.51	3.27	0.59	1.40	0.51	2.67	0.49
15	Patient care for all ages in PACU	1.27	0.46	3.40	0.51	1.33	0.49	2.87	0.52
16	Safety & nosocomial infection control	1.13	0.35	3.33	0.49	1.27	0.46	2.80	0.56
	Total	**22.47**	**1.89**	**50.67**	**2.64**	**22.07**	**1.16**	**45.73**	**2.74**

Abbreviations: ECG, Electrocardiogram; PACU, Postanesthesia Care Unit; SD, Standard deviation
PPCS-NS total score *t*-tests:
Simulation group first weekend (S-1) vs Control group first weekend (C-1) (two independent samples *t*-test) $t = 0.70$, $P = 0.49$, Cohen's $d = 0.26$
Simulation group fourth weekend (S-4) vs Control group fourth weekend (C-4) (two independent samples *t*-test) $t = 5.03$, $P < 0.001$, Cohen's $d = 1.84$
S-1 vs S-4 (paired *t*-test) $t = 39.62$, $P < 0.001$, Cohen's $d = 10.23$
C-1 vs C-4 (paired *t*-test) $t = 30.64$, $P < 0.001$, Cohen's $d = 7.91$

the three raters. To avoid anomalies due to student's accidental errors, each student was expected to care for three patients. The mean of these nine scores was taken as the final score.

The clinical judgment of all nursing students participating in this study was assessed using standardized patients. The standardized patients were set based on the postoperative patients admitted to the PACU on the same day. Therefore, their surgical situations and concerns that nursing students should focus on were different. The patients selected for simulation were those with tracheal tubes and unconscious after maxillofacial surgery. Cases with better general condition and relatively uncomplicated surgery were selected to reduce the difficulty of the test.

2.6. Data analysis

Statistical analysis of all data was performed using SPSS Statistics 26.0 (IBM Corporation, Armonk, New York, USA). General participant information was presented as number of cases and percentage, or mean and standard deviation (SD). The PPCS-NS and C-LCJR scores were presented as means and SDs. PPCS-NS scores at two time points were compared between groups and different time points by using two independent samples *t*-tests, paired *t*-tests and repeated measures ANOVA. C-LCJR scores of the two groups were compared using two independent samples t-tests. The effect sizes of *t*-test and repeated measures ANOVA were presented as Cohen's *d* and *partial* η^2, respectively. Correlation between the PPCS-NS and C-LCJR scores was examined using Pearson correlation coefficient. *P*-values less than 0.05 were considered statistically significant.

2.7. Ethical considerations

The protocol was reviewed and approved by the Institutional Review Board of Peking University School and Hospital of Stomatology (PKUSSIRB-202272019). All participating students were verbally informed of the study and signed an informed consent form. Nursing students were informed that their participation in this study was unrelated to their clinical practice evaluation, and they would be treated equally regardless of their participation in this study. They had the right to withdraw at any time during the study.

3. Results

3.1. General information about the nursing students

All 30 undergraduate nursing students were female (100%). Their ages ranged from 20 to 23 years, with a mean age of 20.87 years (SD 0.78). The mean age of the experimental group was 20.93 years (SD 0.70) and the mean age of the control group was 20.80 years (SD 0.86), $t = 0.464$, $P = 0.65$. None of them had any PACU-related practice experience before this clinical practice.

3.2. The scores of the PPCS-NS

The scores of each item and the total score of the PPCS-NS for both groups at the end of the first and fourth weeks of clinical practice are shown in Table 2. The mean scores of the professional competence self-assessment of the simulation group and control group at the end of the first week were 22.47 and 22.07, respectively. At the end of the fourth week, these two numbers were 50.67 and 45.73 respectively. The results of the two independent samples *t*-test showed that there was no statistically significant difference between the PPCS-NS scores of the simulation and control groups at the end of the first week ($t = 0.70$, $P = 0.49$). At the end of the fourth week, the simulation group scored higher than the control group ($t = 5.03$, $P < 0.001$). Paired *t*-tests showed that students in both groups scored higher at the end of the fourth week than at the end of the first week (simulation group, $t = 39.62$, $P < 0.001$; control group, $t = 30.64$, $P < 0.001$).

The nursing students' PPCS-NS total scores at two time points were analyzed using repeated measures ANOVA. Grouping was considered a between-group factor and the two time points were treated as repeated measures variables. Box's test of equality of covariance matrices showed that the M value was 2.543, $P = 0.504$, which met the requirements of multivariate analysis. The results are shown in Table 3. As shown in the results, nursing students' PACU professional competence increased at the end of the fourth week compared with the end of the first week (time factor, F=2693.83, $P < 0.001$). There was an interaction effect between the time factor and the grouping (F=19.83, $P < 0.001$), indicating that the trend of increasing PACU professional competence differed between

Table 3
Repeated measures ANOVA of nursing students' PACU professional competence (Multivariate Tests).

Effect	Pillai's Trace Value	*F*	*P*	*Partial* η^2
Time	0.99	2693.83	< 0.001	0.99
Time * Group	0.42	19.83	< 0.001	0.42

the groups. As seen in Fig. 2, the nursing students in the simulation group scored higher than the control group.

3.3. The scores of the C-LCJR

The C-LCJR was scored simultaneously by three faculty members. Each student was assigned to care for three patients. The student's final score was the mean of these nine scores. The scores of the 30 nursing students ranged from 31.14 to 38.03. The comparison of performance scores between the two groups is shown in Table 4. C-LCJR scores were higher in the simulation group than in the control group ($t = 7.24$, $P < 0.001$). The Pearson correlation coefficient between PPCS-NS and C-LCJR for the same time period (fourth weekend) was 0.60 ($P = 0.001$).

4. Discussion

We believe that in-situ simulation contributed to the professional competence development of nursing students in the PACU. The aim of this study was to investigate the effect of in-situ simulation on the development of PACU professional competence and clinical judgment of nursing students. The results showed that the competence development in the simulation group was better than that of the control group.

Emergency recognition and management is one of the key competencies that nursing students should acquire in their clinical practice (Peachey, 2021). However, it is often difficult for nursing students to learn emergency recognition and management in a natural situation in a hospital setting (Goldsworthy et al., 2022). In-situ simulation helps nursing students to improve their patient care skills, especially in emergency situations, under current conditions. The result is similar to the results of studies where the subjects were novice nurses and the settings were pediatric PACU or ICU (Guo et al., 2022; Kurosawa et al., 2014; Patel et al., 2022). This may be explained by the fact that the visual, auditory and psychological impressions given to the nursing students in the in-situ simulation were closer to the real situation.

Table 4
Nursing students' scores of clinical judgment (C-LCJR).

Group	Mean	SD	*t*	*P*	*Cohen's d*
Simulation	35.62	0.99	7.24	< 0.001	2.63
Control	32.68	1.23			

In a real clinical situation, nursing students may appear overwhelmed if they experience an unexpected event (Bentz et al., 2022; Bhurtun et al., 2019). The application of in-situ simulation allows nursing students to experience the feeling of decision-making under conditions of better theoretical and psychological preparation, which facilitates the establishment and maintenance of nursing students' enthusiasm and confidence in learning (Generoso et al., 2016).

We provided simulation cases that reflected clinical reality. All cases were taken from classic cases in this PACU or other publicly available PACUs. These cases were carefully organized to help nursing students develop a better understanding of the complexity of the clinical environment and the important role of nurses in patient care (Bentz et al., 2022). These cases used in this study may also be applied to the education and assessment of novice nurses. The availability of senior nurses in the student teams, who provided appropriate prompts when the nursing students were overwhelmed, partially reduced the stress of the complex cases for the nursing students and allowed them to complete the cases more smoothly.

A combination of self- and other-assessment was used to evaluate the professional competence of nursing students. The results showed a strong correlation between self- and other-assessment scores, which is consistent with the findings of related studies(Unsworth et al., 2020). This reflects the sound basis of the measurement instruments and the consistency of nursing students' professional competence in terms of subjective impressions and objective performance (Burden et al., 2018).

For nursing students practicing in clinical settings, in-situ simulation offers the outstanding advantages described above. However, there are several disadvantages to this approach. First, it requires more robust simulation cases, which is a challenge for nurse faculty. Second, in-situ simulation requires a higher quality of nurse faculty. Faculty training is required prior to simulation implementation. Unlike the "one-on-one"

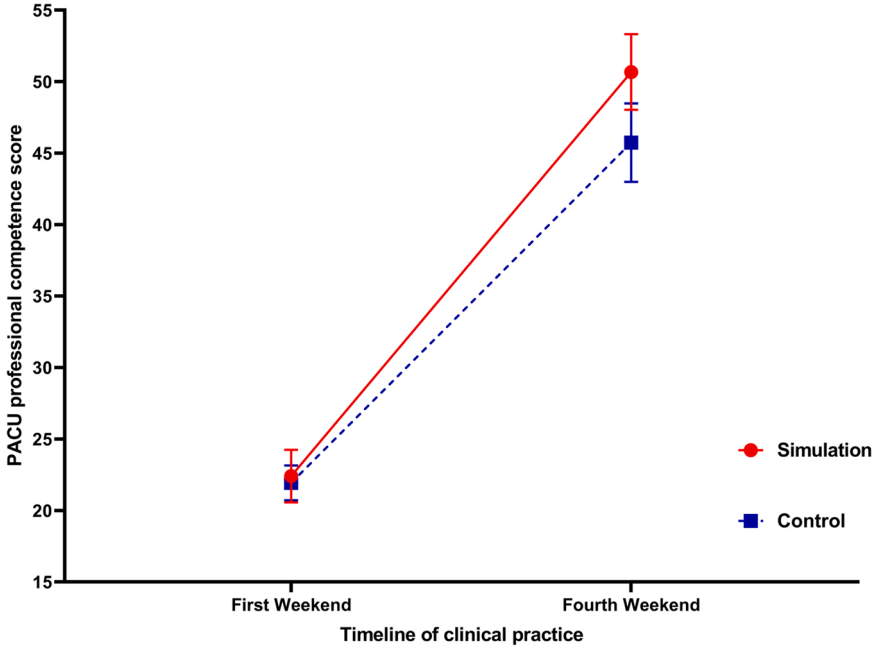

Fig. 2. Nursing students' PACU professional competence trends.

interaction between nurse faculty and nursing students in a typical clinical practice, in-situ simulations require 1.5–2 h of direct involvement of several nurses in the process. In addition, the first few simulations may present unintended problems, so nurse faculty should run the simulation without nursing students prior to scheduled sessions.

4.1. Limitations

Due to limitations of the study design, this study could not be blinded. Despite attempts to control for human factors in faculty evaluations, their influence may not be eliminated. Further follow-up of this study, which would have explored a longer range of trend in competence development of nursing students over time, was not possible due to time constraints. The professional competence we measured only considered the PACU-related competence component and did not address the combined professional competence. Other potentially relevant psychological characteristics, such as professional attitudes and critical thinking, were not addressed. In addition, because this was a single-center, small-sample study, the findings of this paper may be limited in their generalizability.

5. Conclusion

Nurses need to recognize and manage medical changes earlier. In this study, in-situ simulation cases of unexpected changes in patients recovering from general anesthesia were constructed and implemented in a PACU. The results showed that the professional competence of nursing students improved during their practice in the PACU. In-situ simulation contributed to the improvement of nursing students' professional competence. This suggests that in-situ simulation is an appropriate method for nursing students during their clinical practice. Appropriate simulation cases can be constructed according to the characteristics of individual clinical units. However, nurse educators should be concerned about the quality of the cases as well as the labor and time costs. Clinical nurse-led in-situ simulation should be rehearsed in advance to improve simulation quality.

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CRediT authorship contribution statement

Ping Bai: Data curation, Writing – original draft, Project administration. **Xianxian Zang:** Methodology, Validation, Formal analysis, Writing – review & editing. **Ruili Liu:** Data curation, Resources, Project administration, Writing – original draft. **Lu Wang:** Data curation, Resources, Writing – original draft. **Chao Dai:** Data curation, Resources, Project administration. **Guoyong Yang:** Conceptualization, Methodology, Formal analysis, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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