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Factors influencing patient safety competence among Chinese vocational nursing students: A mixed-methods study using COM-B model and theoretical domains framework

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ABSTRACT

Background: Although patient safety education is receiving increased attention, nursing students' patient safety competency remains moderate. As an important source of future caregivers for many primary health hospitals, the level of patient safety competence of higher vocational nursing students directly affects the delivery of nursing care, which in turn affects patient safety, the patient's disease healing process, and their outcomes. There is a lack of evidence to support the factors that influence patient safety competence among nursing students.
Objective: The aim of this research was to explore the factors that impact patient safety competency among Chinese higher vocational nursing students.
Design: An explanatory sequential mixed research design was used in this study.
Methods: The quantitative part was a cross-sectional survey. Convenient sampling was used to conduct a questionnaire survey on 523 nursing students from a vocational college in Chongqing using the general information questionnaire, The metacognition ability scale, the general self-efficacy scale, the self-directed learning skill scale, patient safety nurse competency evaluation scale. Multiple linear regression and serial mediating effect test were used to analyze the impact factors. Qualitative research was then conducted to explain the initial quantitative research results. The qualitative research part used purposive sampling to conduct semi-structured interviews with 16 higher vocational nursing students, and the data was analyzed through content analysis. Quantitative and qualitative data are mapped to the Capability, Opportunity, Motivation, Behavior (COM-B) model.
Results: The quantitative findings found that metacognition had a statistically significant indirect predictive effect on patient safety competence through general self-efficacy and self-directed learning, with an indirect effect value of 0.034 (95 % CI [0.017, -0.013]). Combining quantitative and qualitative results, The Capability, Opportunity, Motivation, Behavior (COM-B) model and theoretical domains framework captures a series of factors, including Competence

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(professional knowledge and skills); Opportunities (resources, public opinion); Motivation (metacognitive abilities, personality, roles, beliefs, goals).
Conclusions: This study provides evidence for a serial mediating role of general self-efficacy and self-directed learning in the relationship between metacognition ability and patient safety competency, contributing to a psychological understanding of the underlying mechanisms of patient safety competency. Therefore, when developing interventions, consideration should be given to promoting positive behaviours in higher vocational nursing students concerning general self-efficacy and self-directed strategies to enhance metacognition, boost patient safety competency, and safeguard patient safety.

1. Introduction

Patient safety, as an organized activity framework (WHO, 2021), is closely related to medical quality and patient rights and interests. It is a global public health priority, aiming to reduce risks, minimize harm and errors (Mitchell, 2008). Patient safety competence, which refers to the abilities and qualities of healthcare professionals in preventing and reducing avoidable medical harm, serves as a crucial factor in achieving patient safety. It is of vital importance for ensuring patient safety and improving the quality of medical services (Jang and Lee, 2017).

As future medical professionals, nursing students' patient safety competence directly affects prognoses, as well as patient safety, recovery, and the quality of nursing care. In China, higher vocational nursing education features diversified training models. Junior high school graduates follow the 5-year (3 + 2) curriculum, which encompasses secondary vocational learning, a transition examination, and an associate degree stage, with an emphasis on in-depth nursing practice (Fu et al., 2022, Yang, 2023). High school graduates who have passed the college entrance examination can enroll in 3-year or 4-year accelerated nursing courses and obtain associate degrees (Shah, 2024). Throughout the learning process, they lay stress on practice and skills, aiming to master competencies, cultivate professional ethics, and be competent in primary health care work after graduation, thus contributing to patient care.

However, currently, China faces challenges like uneven medical resources (Qin et al., 2024, Zhang et al., 2017), a large population, and diverse medical needs (Wang, 2024), posing threats to patient safety and stressing the urgency to boost higher vocational nursing students' patient safety competence (Yang et al., 2024). Ample evidence backs the importance of such competence in medical quality, risk prevention, and emergency rescue (Donaldson, 2021, Strandas et al., 2024). But most studies on nursing students' patient safety competence focus on undergraduates (Cho et al., 2022), overlooking higher vocational nursing students. This neglects how their unique backgrounds, training, and roles impact the competence (Tella et al., 2014). Thus, it's urgent to deeply study Chinese higher vocational nursing students' patient safety competence to understand its factors and enhancement methods, as inadequate preparation might harm medical outcomes.

Metacognition, defined as a reflective approach allowing people to examine their thinking (Croskerry, 2003), is closely tied to patient safety. Teaching metacognitive skills aids learners in getting adaptive knowledge and helps clinicians improve diagnosis and patient safety potential (Lowenstein et al., 2019, McFarlane et al., 2018, Royce et al., 2019). It's also vital for healthcare safety (Guraya et al., 2023, Stiegler et al., 2012). Recent research shows it directly impacts nursing interns' patient safety and indirectly affects behaviors via professional identity (Huang et al., 2024). Thus, we hypothesize that for Chinese higher vocational nursing students, metacognition directly affects their patient safety competence and may indirectly do so through other factors.

Self-efficacy, as an individual's belief in task-executing ability for expected results (Bandura, 1997, Mehdi Arabzadeh, 2012, Schunk, 2005), is closely linked to metacognition. Prior studies indicate they jointly impact cognitive and practical processes (Colthorpe et al., 2019). Metacognitive training can boost students' self-efficacy (Baernholdt et al., 2022, Harsul, 2020), and clear metacognition offers feedback to strengthen it, spurring active learning and practice (Fu et al., 2023). Meanwhile, self-efficacy is an intermediary for patient safety competence. It improves safety practices (Berdida and Alhudaib, 2024), regulates factor relationships related to safety abilities (Katsantonis, 2024), and interacts with other elements (perceived abilities and resilience) to influence patient safety (De Miguel et al., 2023). High self-efficacy nursing students are more active in learning and practice (Yang et al., 2024), while behaviors reducing it harm nursing care (Berdida, 2024). Hence, we hypothesize that in Chinese higher vocational nursing students, self-efficacy serves as an intermediary and plays a positive moderating role in patient safety competence.

Nowadays, self-directed learning ability is increasingly crucial in nursing education and practice. Learners must independently plan learning directions, set goals, arrange steps, and screen resources. This enables nursing students to keep abreast of medical knowledge updates and handle new challenges (Charokar and Dulloo, 2022). It's a fundamental modern nursing skill (Wong et al., 2021) and prerequisite for students facing severe challenges (Dogham, 2022). Research shows a positive link between metacognition and self-directed learning (Ang et al., 2018), and web-based self-directed learning can trigger a virtuous cycle in activating metacognition (Yeo and Jang, 2023). Besides, self-efficacy, a key driver and predictor of self-directed learning (Wong et al., 2021), affects task selection, effort, and perseverance, further influencing learning improvement (Grund, 2024, Park and Kim, 2023). Thus, it's speculated that among Chinese higher vocational nursing students, self-directed learning ability may bridge metacognition, self-efficacy, and patient safety competence, enhancing the latter.

Although patient safety in nursing education is widely acknowledged, existing literature leans towards undergraduate nursing students (Cho et al., 2022, Huang et al., 2020), when exploring related issues, neglecting higher vocational nursing students. Meanwhile, research on the influencing factors of patient safety competence among Chinese higher vocational nursing students lacks

comprehensiveness and depth. Hence, it's vital to introduce proper theoretical frameworks.

The Capability, Opportunity, Motivation, Behavior model (COM - B model) by Michie et al. (2011). has three elements: "capability" (linked to knowledge and skills), "opportunity" (external conditions), and "motivation" (internal drives), jointly influencing behaviors (Cane et al., 2012). It can analyze factors multidimensionally, providing a framework for exploring these students' patient safety competence. The Theoretical Domains Framework (TDF), integrating and simplifying multiple behavioral theories, contains 14 domains like knowledge and social influence (Lavallee et al., 2018, Madhani and Finlay, 2022) see Fig. 1, facilitating micro-level analysis of behavioral mechanisms and complementing the Capability, Opportunity, Motivation, Behavior model, and is highly suitable for in-depth research on issues related to the patient safety competence of Chinese higher vocational nursing students.

This study focuses on the group of Chinese higher vocational nursing students and unfolds around the following two aspects. Firstly, it delves into the impacts and interactions of metacognition, self-efficacy, and self-directed learning ability on the patient safety competence of Chinese higher vocational nursing students. In the Capability, Opportunity, Motivation, Behavior model, metacognition facilitates the development of "capability". Self-efficacy is correlated with metacognitive ability and is influenced by "opportunity" and "motivation". Self-directed learning promotes the development of "capability" and interacts with other factors; the domains of the Theoretical Domains Framework also affect these factors. Secondly, the combined influence of the elements of the two frameworks and the key factors on competence is analyzed. Foreign scholars have used similar tools for relevant research to explore the impediments and facilitators of students' health service competence (Brown et al., 2024, Cassidy et al., 2018). This study applies the Capability, Opportunity, Motivation, Behavior model and the Theoretical Domains Framework and adopts a mixed-methods approach to explore the relationships among various factors and verify the hypotheses (see Supplementary Figure 1). It aims to fill the gap in existing literature regarding in-depth research on this specific group based on such comprehensive theoretical frameworks and to provide evidence and suggestions for understanding the influencing factors of patient safety cometence.

2. Material and methods

This study used a mixed-method study design (Burke Johnson, 2004), which was consistent with the Good Reporting of a Mixed Methods Study (GRAMMS) framework (O'Cathain et al., 2008) (see Fig. 2). The patient safety competence of higher vocational nursing students is a complex and multi-dimensional construct, involving aspects such as knowledge, skills, attitudes, values, and the ability to respond to actual situations. It is difficult to fully and deeply explore this topic by relying solely on quantitative or qualitative methods. Quantitative data were gathered via questionnaires, and path analysis was conducted to explore the relationships among self-directed learning skills, metacognitive abilities, general self-efficacy, and patient safety competence. Initially grasp the overall relationship and trend. Then, based on the quantitative results, different types of students were purposefully selected for semi-structured interviews.

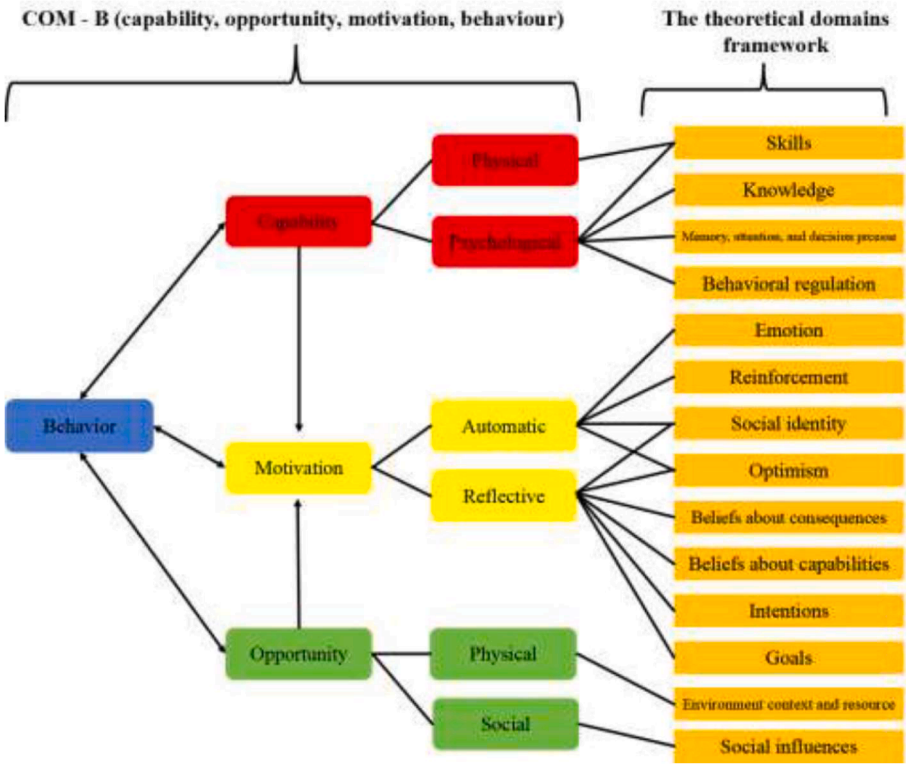

Fig. 1. Map of theoretical domains framework to COM-B model (capability, opportunity, motivation, behaviour).

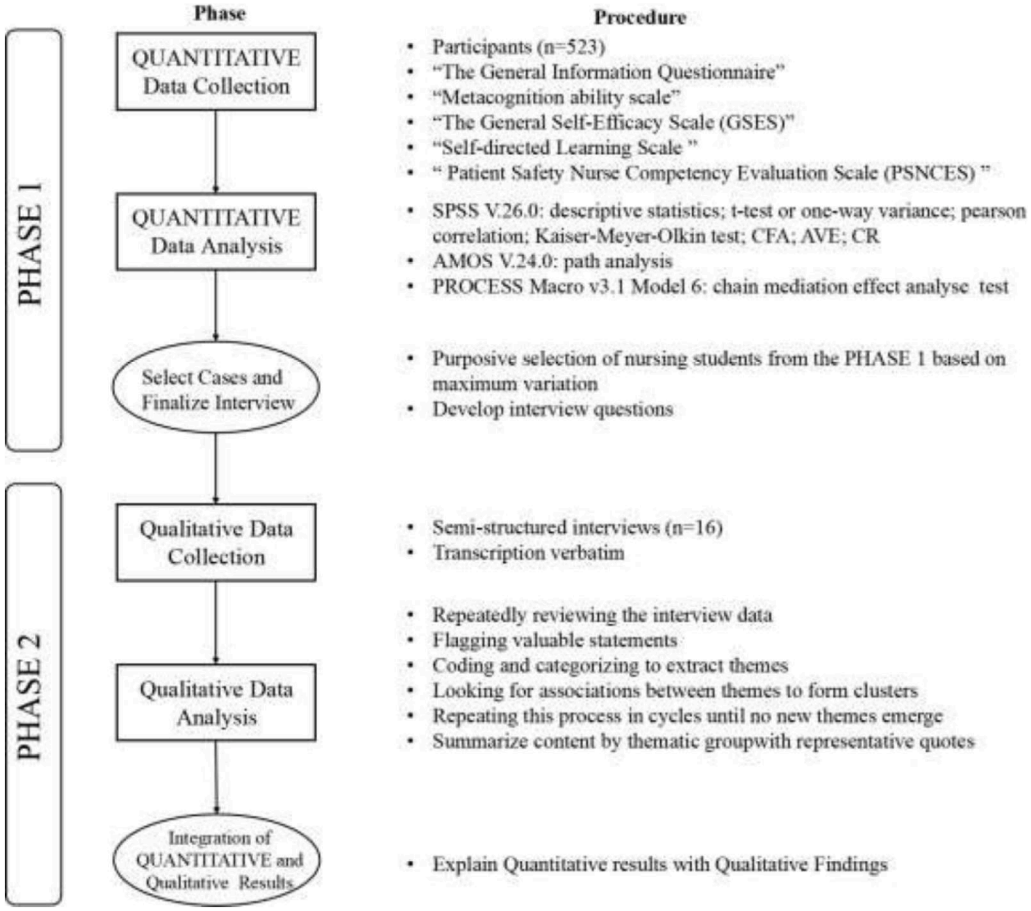

Fig. 2. Study diagram of an explanatory sequential design of a mixed methods study on self-directed learning skill, metacognition ability, general self-efficacy, and patient safety competency. The quantitative and qualitative data collection and analysis phases are shown in rectangular boxes along the left side of the diagram. The two points of interface (or mixing) of the quantitative and qualitative phases are shown and described in the ovals. The term 'QUANTITATIVE' is capitalized to indicate the study's prioritization of the quantitative phase. The study procedures for each phase are listed along the right side of the diagram. SPSS, Statistical Package for the Social Sciences. AMOS, Analyze of Moment Structures.

Specifically, those with outstanding or poor performance on the patient safety competence scale and those with relevant practical experiences (e.g., patient safety training participation or adverse event experiences) were chosen. This enabled in-depth insights into their clinical practice experiences, thought processes, behavioral decisions, and influencing factors, thereby providing a profound interpretation and verification of the quantitative findings. This design approach enables the study to not only grasp the overall trends but also deeply understand individual behaviors and concepts, thus comprehensively and thoroughly revealing the relevant situations regarding the patient safety competence of higher vocational nursing students.

2.1. Phase 1: quantitative research

2.1.1. Study participates

In November and December 2022, we selected one vocational nursing college in the XXX region by using the convenience sampling method, and then randomly chose classes through the cluster sampling method. A total of 12 classes were selected. Considering the structure and characteristics of higher vocational nursing students, we determined the proportion of students from different grades in the sample. Specifically, sophomore students accounted for 60 % of the total sample, while freshmen and junior students each accounted for 20 %. The main reason for setting such a proportion is that sophomore students in vocational nursing education have completed the first-year basic courses and are deeply engaged in learning professional knowledge and practical skills. They have already been exposed to the concepts and practices of patient safety, and their understanding and performance regarding patient safety competence are more representative than those of freshmen. Freshmen are still adapting to the environment and grasping basic knowledge, so their perception and performance of this competence are relatively limited. Secondly, junior students are more concerned with internships and job-hunting preparations, while sophomores are fully devoted to the core learning of the nursing major and can invest more time and energy in improving their professional abilities, including patient safety competence. Therefore, they can

provide richer and deeper perspectives on the factors influencing this competence. Moreover, from a practical perspective, this proportion takes into account the availability and convenience of data collection. A larger sample of sophomore students can obtain more detailed and diverse information, and it can also cover the situations of students from other grades, which helps to analyze the overall situation of patient safety competence among higher vocational nursing students of different grades. However, it should be noted that convenience sampling may introduce selection bias and thus cannot fully represent the entire population of vocational nursing students. Meanwhile, cluster sampling may result in high homogeneity within classes and overlook the differences between different classes. To mitigate these potential biases, we conducted stratified sampling among students of different grades to ensure that students from each grade were included in a certain proportion, thereby increasing the diversity of the sample. There were 105 freshmen students (distributed across three classes), 315 sophomore students (distributed across six classes), and 125 junior students (distributed across three classes).

2.1.2. Inclusion and exclusion criteria

Inclusion criteria: Participants gave informed consent and volunteered to take part in this survey.

Exclusion criteria: Those who had been on leave for more than one month due to special circumstances such as suspension of studies due to illness or enlistment in the military were excluded. The main reason was that these students had significant differences from normal in-school students in terms of curriculum progress and even experienced interruptions in their studies. Their autonomous learning patterns and patient safety competence were not comparable to those of students who continued their studies on campus. This affected the development of their knowledge, skills, and attitudes, thus influencing the correlation of the overall data and the results of regression analysis. Therefore, they were excluded from the study to accurately identify the real relationships and experiences among variables in a regular educational environment and, to some extent, eliminate the impact of the environment on the data.

2.1.3. Sample size calculation

According to Kendall's sample estimation method, the sample size is calculated as 5–10 times the number of variables, 11 items of nursing students' general information, 24 items of "The metacognition ability scale", 10 items of "The General Self-Efficacy Scale", 8 items of the "Self-Directed Learning Skills Inventory", and 35 items of the "Patient Safety Nurse Competency Evaluation Scale". The sample size was calculated to be 440 to 880, considering 10 % of the missing samples. Due to the structural equation modelling sample size requirement being more significant than 385, 525 electronic questionnaires were distributed face-to-face, 2 invalid questionnaires were excluded (the whole questionnaire ticked the same option 2), and 523 valid questionnaires were recovered, which meets the requirements of sample size calculation.

2.1.4. Study instruments

There were five parts of the questionnaire in this study. The first part is a researcher's general information questionnaire designed by the research team after the literature study. The second to fifth are an adapted Likert-scale questionnaire accessed from an open-access journal with permission asked and granted by respective authors. The individual dimension scores are shown in Table 2. In addition, we performed the Kaiser-Meyer-Olkin test (KMO value= 0.938) and Bartlett's test of sphericity (chi-square value= 5484.361, degrees of freedom= 171,p= 0.000) on the questionnaire as a whole. The default language used is Chinese, and brief description of the questionnaire is as follows:

The general information questionnaire was composed of 2 components: demographic characteristics (age, gender, grade level, time in school, grade point average, internship department, preferred mode of teaching) and patient safety education and training (whether they know about patient safety, whether they have experience with patient safety education and training, whether they have personally experienced or heard of a patient safety incident, and whether patient safety education and training is necessary). Most items in this questionnaire were records of objective facts or subjective choice-based responses.

The metacognition ability scale was developed by (Kang, 2005) and has been widely used in China. It aims to comprehensively and deeply understand individuals' abilities in monitoring, regulating, and other aspects regarding their own cognitive activities during the process of learning and thinking. It comprised four dimensions: metacognition ability planning (with 7 items), metacognition ability monitoring (6 items), metacognition ability regulation (6 items), and metacognition ability evaluation (5 items). Each dimension was measured using a 5-point Likert scale (1= never; 5= always). The total score was obtained by adding up the scores of all items, with the score range being from 24 to 120. A higher score indicated a stronger metacognition ability. The Cronbach's α coefficient of the scale was 0.93, suggesting that the scale had good internal consistency and reliability. In this study, the Cronbach's α of the scale was 0.991, and the Cronbach's α of each dimension ranged from 0.967 to 0.977. The composite reliability (CR) was 0.824, and the average variance extracted (AVE) was 0.548.

The General Self-Efficacy Scale (GSES) was developed by (Zhang, 1995). The Chinese version was translated and revised by Zhang et al. (1995). It is used to measure individuals' self-perceptions of their overall ability to cope with challenging situations. The general self-efficacy level was represented by the total score of its 10 items, with each item measured on a 4-point Likert scale (1= completely wrong; 4= completely right). The total scale score was calculated by adding up the item scores and dividing by 10. The total scale score was calculated by adding up the item scores and dividing by 10. A higher score indicated a better sense of self-efficacy among individuals, meaning that they were more confident in their ability to handle and solve problems when facing various challenging tasks or situations. Its internal consistency coefficient Cronbach's α was 0.87, the test-retest reliability was r= 0.83 ($p < 0.001$), and the split-half reliability was r= 0.82 (n= 401, $p < 0.001$), demonstrating good reliability. In this study, the scale had good internal consistency with a Cronbach's α of 0.964.

The Self-Directed Learning (SDL) Skill Scale was designed by Yi Lin (2004). It aims to comprehensively evaluate individuals' key

abilities in self-directed learning and analyze from multiple dimensions the comprehensive ability level of nursing students to take the initiative to learn without excessive external supervision. It is composed of 8 dimensions: Competencies for identifying learning needs (with 3 items), time management competencies (3 items), learning to monitor competencies (4 items), competency for information accessibility (5 items), broadening of information channel competencies (5 items), information analysis and processing competencies (5 items), competencies for help-seeking (3 items), and communication ability (4 items). Each item was measured using a 5-point Likert scale (1= never; 5= very often). The total score was obtained by adding up the scores of all items, with the score range being from 28 to 140. A higher total score indicated a stronger self-directed learning ability among nursing students. In this study, the Cronbach's α of this questionnaire was 0.912. The composite reliability (CR) was 0.914, and the average variance extracted (AVE) was 0.571.

The Patient Safety Nurse Competency Evaluation Scale (PSNCES) was developed by Wang (2018). It plays an important role in evaluating the comprehensive competence of nursing staff in ensuring patient safety and can comprehensively examine the performance of nursing students' abilities in matters related to patient safety in actual work scenarios from multiple dimensions. It included 7 dimensions and 35 items on patient-centred care (4 items), clinical practice (10 items), continuous quality improvement (5 items), evidence-based nursing practice (4 items), patient safety culture (5 items), and safety risk management (7 items). Each item was measured using a 5-point Likert scale (1= not at all; 5= fully). The total score was obtained by adding up the scores of all items, with the score range being from 35 to 175. A higher score indicated a higher level of patient safety competence. The Cronbach's α coefficient was 0.942. In this study, this scale had a Cronbach's α of 0.990, and the Cronbach's α for each dimension ranged from 0.767 to 0.910. The composite reliability (CR) was 0.896, and the average variance extracted (AVE) was 0.589.

2.1.5. Data collection

Researchers abided by the standard process and protocol of data gathering in the college as the locale of the study. XXX communicated with school leaders, class leaders and class officials before conducting the survey to obtain permission and support to collect the data. Higher vocational nursing students are recruited as researchers for the study. Before questionnaires were issued, they were informed in detail about the purpose of the study, the data collection instrument duration of data collection, and other precautions related to questionnaire filling. The questionnaires were checked and recalled on the spot by three members of the research team.

2.1.6. Data analysis

SPSS V.26.0, AMOS V.24.0, and PROCESS Macro 3.1 model 6 are utilized to analyze the data, with a significance level of α= 0.05. A *p*-value less than 0.05 is considered statistically significant. The quantitative data collected via the Questionnaire Star platform (functioning similarly to Amazon Mechanical Turk) on www.wjx.cn was tabulated and coded in Microsoft Excel before being extracted into the SPSS V.26.0 application for computation. The specific procedures for data analysis are detailed below: During the descriptive statistics analysis, the quantitative data were represented by scores and mean ± standard deviation ('x±SD), such as students' scores on various scales. For qualitative data like students' gender, age, and grade, frequencies and percentages were used for description. Cronbach's α coefficient was employed to conduct reliability analysis, and the average variance extracted (AVE) and composite reliability (CR) were utilized to measure convergent validity, aiming to assess the reliability and validity of the measurement tools. Next, Pearson correlation analysis was applied to explore the relationships among self-directed learning skills, metacognitive abilities, general self-efficacy, and patient safety competence. The purpose was to determine whether linear associations existed among these variables, as well as their directions and strengths. By analyzing their synergistic change trends, factors that might have a impact on patient safety competence were screened out, providing a basis for subsequent analyses. Based on the previous analysis results, the maximum likelihood method was chosen for model fit testing. Indicators including the root mean square error of approximation (RMSEA), goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), root mean square residual (RMR), Tucker-Lewis index (TLI), and comparative fit index (CFI) were used for evaluation (Xia and Yang, 2019). This enabled the identification of key influencing paths and revealed how self-directed learning skills, metacognitive abilities, and general self-efficacy directly or indirectly affected patient safety competence, facilitating a deeper understanding of the internal influencing mechanism. Finally, the PROCESS v3.1 model with the Bootstrap method (a non-parametric test) was used to test the model effect analysis (Fang, 2013). The mediating effect values were used to evaluate whether self-directed learning skills and general self-efficacy played an intermediary role between metacognitive abilities and patient safety competence, as well as to determine the magnitude of the mediating effect. By combining the p-values and 95 % confidence intervals (CI), the statistical significance of the mediating effect was judged. Meanwhile, the direct effect was used to understand the direct impact degree of metacognitive abilities on patient safety competence, further clarifying the complex relationships among variables and providing more in-depth answers to the research questions.

2.2. Phase 2: qualitative research

2.2.1. Study participates

In the quantitative research, we used purposive sampling to select 12 nursing students from those who participated in the study's first phase. We first considered intern students with experiences in patient safety training and adverse events, as well as those whose scores on the patient safety competence scale fell within the top 2 % and bottom 2 % intervals were chosen as the first-round interviewees. Since data saturation had not been achieved, another 4 students whose scores were within this interval were included. In total, 16 students were interviewed in the two rounds. They were notified and invited to participate in the study via the social media app WeChat. The sample size was determined based on information saturation, and saturation was reached after the two rounds of

interviews. At this stage, first-year higher vocational nursing students were undergoing patient safety education in the college. Second-year higher vocational nursing students had already received patient safety education and were in the stage of strengthening practical operations and preparing for internships. Third-year higher vocational nursing students were in the stages of internships and job hunting.

2.2.2. The interview guide

The research team initially drafted the interview guide through a literature review and brainstorming session. A pilot interview was conducted with two students to test the guide. The finalized interview contents were developed with an entry point of patient safety events: a. How would you describe patient safety incidents? b. What were you thinking before, during and after a potential patient safety adverse event was about to occur? c. Please share the most successful experience you had regarding preventing patient safety issues during your internship. Describe the situation, actions, outcome, and thoughts and reflections. d. Please share the most unsuccessful experience you had regarding patient safety during your internship. Describe the situation, actions, outcome, thoughts, and lessons learned.

2.2.3. Data collection

2.2.3.1. Before the interview. Experts in nursing education and qualitative research were invited to guide this research. The interview outline was determined after literature analysis and then revised by members of the research team after two rounds of pilot interviews to form the final version.

2.2.3.2. During an interview. The interview was conducted in a quiet classroom to avoid distractions from January 30, 2022, to March 26, 2023. In the interview process, the researcher used listening, appropriate follow-up, counter-questioning, clarification, repetition and response skills while not affecting the ideas and expressions of the research subjects, held a neutral attitude and encouraging them to express their genuine emotions the whole interview process. Based on the pre-test findings, it was determined that an interview duration of 20 to 30 min was appropriate. This time frame allowed higher vocational nursing students to narrate their experiences and thoughts in a relatively comprehensive and in-depth manner. Meanwhile, considering the time schedules and attention spans of these students, it could prevent fatigue and boredom within 30 min, thus ensuring the quality of the interviews and obtaining sufficiently in-depth information. The transcripts were completed within 48 hours after the interviews and then underwent checks bymembers of the research team to ensure the integrity of the texts.

2.2.4. Data analysis

For data analysis, content analysis was used, involving: Repeatedly reviewing the data, marking valuable statements, coding and classifying to extract themes, searching for associations among themes and clustering them, repeating the above steps in a cycle until no new themes emerged, summarizing by theme groups and attaching representative quotations.

2.2.5. Quality control

Before interviews, literature analysis was conducted and experts in nursing education and qualitative research, leveraging their professional knowledge and practical experience, guided the overall framework, question logic, and content depth of the interview outline. The first draft was then formulated. Two samples were selected for pilot interviews to observe the actual effects and promptly modify any issues with unclear expressions (for example, in the initial version of the outline, there was a question like "Please share an instance where you achieved success in preventing patient safety issues during your internship, along with the relevant details."). The final version was formed to ensure the validity and relevance of the questions. During interviews, neutrality was maintained. After interviews, two members of the research team independently transcribed the data back-to-back to minimize subjective influence and interference. Transcriptions were completed word for word within 48 hours. The strict time limit helped ensure the accuracy of the researchers' memories of the interview content and avoid forgetting or confusing details due to a long lapse of time. The transcribed data was checked with participants to correct misunderstandings, omissions, or recording errors, enhancing result credibility. Through the meticulous operations in each step, the rigor and scientific nature of the research results were ensured.

2.3. Integration of quantitative and qualitative data

As (Creswell, 2006) pointed out, a critical step in mixed methods research is to conduct integrated analysis and interpretation of quantitative and qualitative data. In this study, a merged analysis was carried out using the side-by-side comparison approach. The quantitative and qualitative results were tabulated side by side to facilitate the integration of different data sources (Nessle et al., 2023, Zhang et al., 2024). This technique enabled comparisons between consistent and contradictory interpretations within the two datasets and supported the conclusions by synthesizing the quantitative and qualitative findings. The integration process is shown in Supplementary Table 3.

For example, first of all, we identified the "Capability" in the COM-B domain that corresponded to "Skills" in the Theoretical domains framework. Then, we located our relevant data, such as those related to Clinical Practice abilities and Safety Risk abilities. Besides, we gathered data from qualitative studies, like the indication of "Lack of experience in dealing with emergencies and adverse events (−)". Based on the outcomes from both quantitative and qualitative data sources, we presented the consistent and discrepant

results in the Integrated result as follows:

CONFIRMATION: Higher-level nursing students generally show limited levels of patient safety competency, particularly in the practical area.

INCONSISTENT: Quantitative studies have consistently shown that senior nursing students often score lower on self-directed learning competencies. However, it should be noted that qualitative studies have not yet explored the impact of this area, which highlights a significant gap.

EXTENSION: Lower skill scores prompt academics to encourage the maintenance and improvement of students' clinical patient safety competency skills.

2.4. Ethics

The research team obtained ethical approval from the corresponding author's Medical University (Approval No.: 2022-k218) prior to collecting data and conducting interviews. Participants were informed that their participation was voluntary and would not impact their academic performance. Data was collected via anonymous online surveys and the completed questionnaires were securely stored electronically on password-protected computers. The researchers utilized the collected data solely for the purposes of this study. Moreover, no form of remuneration or compensation was provided in this study.

3. Results

3.1. Quantitative results

3.1.1. Demographic results and single factor analysis

Ninety-four percent of the 519 students surveyed were female. More than half of the students (60.03 %) had student tenure experience, most of the students' clinical internships lasted less than 4 months (57.40 %), most of the students had no internship experience (56.20 %), as detailed in the pieces in Table 1. Comparison of patient safety competency scores of nursing students of different genders and ages and whether they had training experience showed no statistically significant differences. In contrast, the differences in other items were statistically significant, as shown in Table 1($P < 0.05$). Post hoc multinomial tests were conducted to examine the factors with statistically significant differences in the one-way factors: scores by grade in the order of their mean sizes

Table 1
Summary of respondent demographics and differences in patient safety competence scores(n= 523).

Variables	Characteristic	Frequency	Percentage(%)	Mean ± SD	*t/F*	*P*
Age (Years)	<=18	81	15.48	140.66 ± 29.33	1.810	0.109
	19	215	41.11	130.9 ± 29.16		
	20	158	30.22	139.97 ± 28.31		
	21	52	9.94	133.58 ± 29.24		
	>=22	17	3.25	127.46 ± 31.26		
Gender	Male	33	6.31	127.93 ± 31.10	-0.598	0.550
	Female	490	93.69	131.42 ± 30.54		
Grade	Freshman	83	15.87	136.25 ± 31.15	4.908	0.008*
	Sophomores	303	57.93	128.39 ± 30.49		
	Junior	137	26.20	139.15 ± 28.06		
Student tenure	Yes	318	60.80	133.00 ± 30.41	2.056	0.040*
	No	205	39.20	126.76 ± 30.56		
Grade point average	Above 90	83	15.90	143.41 ± 27.02	9.555	<0.001*
	80–90 Points	296	56.60	132.45 ± 29.52		
	70–80 Points	122	23.32	123.05 ± 31.63		
	60–70 Points	21	4.02	114.38 ± 32.69		
	Under 60	1	0.16	/		
Clinical internship duration	Less than 4 months	302	57.74	125.91 ± 30.65	10.415	<0.001*
	5 to 8 months	154	29.45	137.38 ± 29.15		
	Greater than 9 months	67	12.81	140.15 ± 28.91		
Internship hospital level	Grade-a tertiary hospital	175	33.46	140.42 ± 27.06	9.128	<0.001*
	Grade-b tertiary hospital	35	6.70	135.52 ± 26.43		
	Grade-a secondary hospital	1	0.16	133.54 ± 27.57		
	Others	16	3.09	131.51 ± 36.33		
	No internship	294	56.22	125.26 ± 31.21		
Patient safety understanding	Yes	476	91.01	133.11 ± 29.92	4.541	<0.001*
	No	47	9.00	111.39 ± 30.39		
Patient safety incident experience	Yes	359	68.65	132.38 ± 30.0	5.745	<0.001*
	No	164	31.35	127.56 ± 31.9		
Training experience	Yes	395	75.53	136.49 ± 29.71	1.501	0.134
	No	128	24.47	120.11 ± 29.39		
Training attitude	Yes	494	94.55	132.50 ± 29.70	4.113	<0.001*
	No	29	5.45	107.12 ± 36.55		

were juniors> first-year students>sophomores, as shown in Supplementary Table 1.

3.1.2. Self-directed learning skill, metacognition ability, general self-efficacy, and patient safety competency results

According to the data in Table 2, higher vocational nursing students had the highest monitoring scores in metacognition (3.00 ± 1.117), the best performance in self-directed learning competencies,time management competencies (3.02 ± 1.023), and the highest scores in continuous quality improvement (3.04 ± 1.136) in patient safety nurse competency and a moderate general self-efficacy score (2.98 ± 1.101).

3.1.3. Correlation of scale sub-dimensions

This analysis explored the correlations between the variables using Pearson correlation. According to Supplementary Table 2, there is a new primary correlation between all the variables in this analysis. According to the results of the correlation coefficient, it can be seen that the correlation coefficient r between each variable is greater than 0. All of them are statistically significant at a 99 % level of significance.

3.1.4. Model validation

For model effect testing, after controlling for demographic factors like gender, age, GPA, and clinical internship duration, a structural equation model was built. In this model, metacognitive ability served as the antecedent variable, patient safety as the outcome variable, while general self-efficacy and self-directed learning skill were the middle variables. The model fit values were:$\chi^2/df = 2.723$, RMSEA = 0.057, RMR = 0.048, GFI = 0.925, AGFI = 0.903, TLI = 0.945, CFI = 0.953 (See Fig. 3 for the serial mediation model analysis results). Table 3 outlined this study examined the chain mediating roles of general self-efficacy and self-directed learning on metacognition and patient safety competency. In this chain - mediating model, metacognition has significant positive effects on general self - efficacy, self - directed learning skills, and patient safety competency, with coefficients of 0.531, 0.396, and 0.422 respectively, and all the corresponding *P* - values are less than 0.001. General self - efficacy also has a significant positive effect on self - directed learning skills, with a coefficient of 0.259 and a *P* - value less than 0.001. In addition, the R^2 values of the model for general self - efficacy, self - directed learning skills, and patient safety competency are 0.177, 0.41, and 0.166 respectively, and the *P* - values corresponding to the F - values of each model are all less than 0.001, indicating that the model has good explanatory power. The PROCESS Macro v3.1 model 6, combined with the non-parametric percentile bootstrap method using 5000 replicate samples, was employed to rigorously test the chain mediating effect and determine the mediating significance level. Results are in Table 4: a. Direct effect: Metacognition on patient safety competency, direct effect value 0.422 (95 % CI [0.341, 0.503]); b. Indirect effect through general self-efficacy: 0.137 (95 % CI [0.093, 0.173]); c. Indirect effect through self-directed learning: 0.099 (95 % CI [0.057, 0.135]); and d. Indirect effect through general self-efficacy and self-directed learning: 0.034 (95 % CI [0.017, -0.053]). These statistically significantly correlated variables were modeled as chain mediators.

3.2. Qualitative results

A total of 16 participants were interviewed to reach data saturation, comprising 12 females (75.00 %), with an average age of 20.46 years. From these interviews, 23 common themes affecting the patient safety competence of higher vocational nursing students were identified and mapped into the theoretical domains framework. Themes are arranged in descending order of frequency. Including: In Skill & Knowledge, lack of emergency skills negatively impacts responses and patient safety, limited safety knowledge may cause care errors, while active knowledge helps in applying safety knowledge. For Cognition, lack of assessment leads to initial decision biases

Table 2
Individual dimension scores (n = 523).

Variables	Content of items	Min	Max	Mean	SD
Metacognition ability	Metacognitive planning	7	35	2.86	1.053
	Metacognitive monitoring	6	30	3.00	1.117
	Metacognitive regulation	6	30	2.94	1.062
	Metacognitive evaluation	5	25	2.90	1.076
General self-efficacy	General self-efficacy	10	50	2.98	1.101
Self-directed learning skill	Time management competencies	3	15	3.02	1.023
	Learning to monitor competencies	4	20	2.89	1.056
	Competencies for information accessibility	3	15	2.82	1.091
	Broadening of information channel competencies	10	50	2.96	1.126
	Information analysis and processing competencies	4	20	2.80	1.021
	Competencies for help-seeking	3	15	2.88	1.056
	Communication ability	3	15	2.91	0.998
	Competencies for identifying learning needs	11	55	2.88	1.036
Patient safety nurse competency	Patient-centred care	4	20	2.97	1.054
	Clinical practice	10	50	2.85	1.103
	Continuous quality improvement	5	25	3.04	1.136
	Evidence-based nursing practice	4	20	2.86	1.146
	Patient safety culture	5	25	2.96	1.142
	Safety risk management	7	35	3.12	1.096

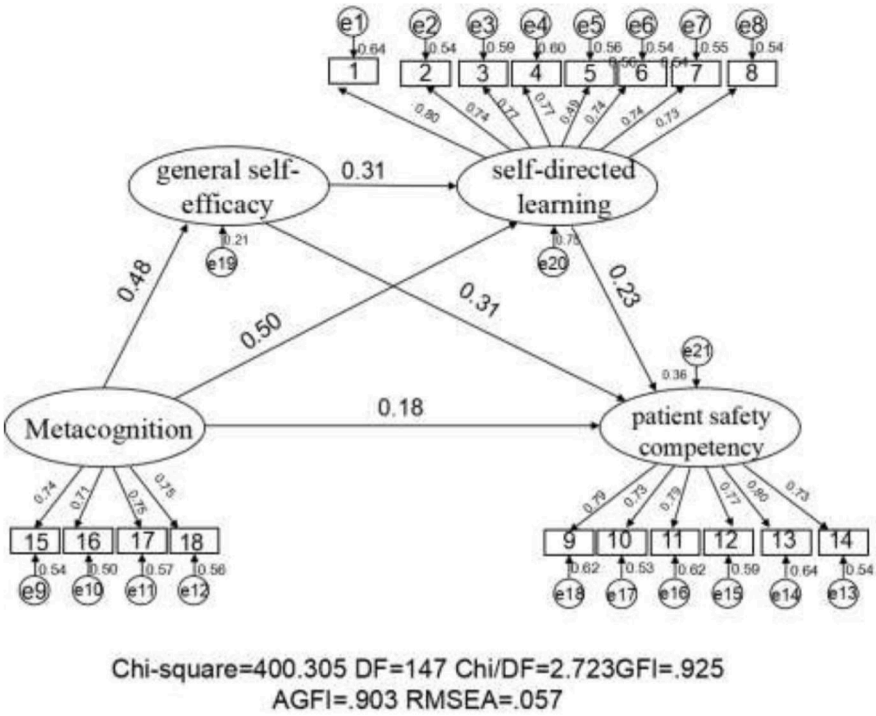

Fig. 3. The structural equation model of the study (There is a path relationship among the 4 main observation variables: Metacognition (including 4 dimensions), general self-efficacy, self-directed learning skills(including 8 dimensions), and patient safety competency (including 6 dimensions)). General self-efficacy and self-directed learning play a mediating role between metacognition and patient safety competency (IBM SPSS Amos 26.0). The numbers on the arrows represent standardized regression coefficients (path coefficients), and e1～e19 represent unobserved variables,and 1 to 19 represent the connotations with the same notes as in Supplementary Table 2.

and clinical sensitivity enables them to identify risks to safeguard patients. Social Factors involve peer pressure which can either motivate or stress students and affect safety work, patient pressure affects mood and may result in errors, family stress distracts from safety tasks, and optimism helps learn from mistakes to boost safety ability. Beliefs & Intentions cover self-doubt hindering safety efforts, irresponsibility overlooking safety hazards, and perfectionism masking errors and influencing decisions. In Goals & Environment, focusing on self limits safety skills, yet good teacher-student ties, diverse learning, learning from mistakes, big data learning and enjoyable learning respectively contribute to enhancing safety competence. Social Influences include negative views weakening safety confidence, gossip harming emotional state for safety, and criticism affecting focus on safety. Detailed information can be found in Table 5.

3.3. Integration of quantitative and qualitative results

The integration was founded on the Capability, Opportunity, Motivation and Behaviour Model with regard to capability, opportunity, and motivation. The combined quantitative and qualitative findings, which were integrated based on the Capability, Opportunity, Motivation and Behaviour Model as well as the Theoretical Domains Framework, are presented in Table 6. Regarding integrating the qualitative and quantitative research results within this study, the principal outcomes are including: Skills: As shown in Table 6, the average score for clinical practical skills was 2.97 ± 1.054, and that for clinical risk management skills was 3.12 ± 1.096. However, students were relatively inexperienced in handling emergency incidents, which is consistent with the observation of lack of experience in dealing with emergencies and adverse events in Table 6. Moreover, students still needed to improve in some skills such as information acquisition. Despite this, they demonstrated certain abilities in time management (Time Management Competencies in Table 6 with a score of 3.02 ± 1.023) and learning monitoring (Learning To Monitor Competencies in Table 6 with a score of 2.89 ± 1.056). Knowledge: According to Table 6, the average score for evidence - based nursing practice knowledge was 2.86 ± 1.146. Students were rather deficient in their knowledge regarding the benefits of patient safety and its clinical applications. Nevertheless, there was a positive tendency among them to acquire relevant knowledge. Memory, Attention, and Decision - making Processes: From the analysis of the data in Table 6, it can be concluded that students lacked comprehensive assessment and reflection abilities. However, they possessed a certain level of clinical sensitivity.

Table 3
The chain mediating model of general self-efficacy, self-directed learning skills, metacognition and patient safety competency (n=523).

Variables	General self-efficacy					Self-directed learning skills					Patient safety competency				
	B	**SE**	***t***	***P***	**β**	**B**	**SE**	***t***	***P***	**β**	**B**	**SE**	***t***	***P***	**β**
Constant	1.427**	0.153	9.30	0	–	0.965**	0.106	9.122	0	–	1.736**	0.126	13.73	0	–
Metacognition	0.531**	0.05	10.58	0	0.421	0.396**	0.035	11.20	0	0.416	0.422**	0.041	10.19	0	0.408
General self-efficacy						0.259**	0.028	9.245	0	0.343					
Self-directed learning															
R^2	0.177					0.41					0.166				
$\triangle R^2$	0.175					0.408					0.165				
F	F (1521) = 111.933, p = 0.000					F (2520) = 181.008, p = 0.000					F (1521) = 103.846, p = 0.000				

* $p < 0.05$ ** $p < 0.01$

Table 4
The analysis of the chain mediating effect of general self-efficacy, self-directed learning skills, metacognition and patient safety competency (n = 523).

Pathways	Effect	BootSE	*t/Z*	*P*	*95% CI*	
					LLCI	ULCI
Metacognition ⇒ general self-efficacy	0.531	0.050	10.58	0	0.433	0.630
Metacognition ⇒ self-directed learning	0.396	0.035	11.2	0	0.327	0.465
Metacognition ⇒general self-efficacy ⇒ patient safety competency	0.137	0.021	6.667	0	0.093	0.173
Metacognition ⇒self-directed learning skills ⇒ patient safety competency	0.099	0.020	4.968	0	0.057	0.135
Metacognition ⇒general self-efficacy ⇒ self-directed learning skills ⇒ patient safety competency	0.034	0.009	3.775	0	0.017	0.053
Metacognition ⇒ patient safety competency	0.422	0.041	10.19	0	0.341	0.503
Total mediating effect	0.270	0.033	8.132	0	0.195	0.327

Table 5
Mapping of facilitators and barriers to the theoretical domains framework.

Theoretical domains framework	Theme	Representative quotations
Skills	Lack of experience in dealing with emergencies and adverse events (−)	Things are always different in the emergency department. I feel overwhelmed. While there is a variety of clinical experiences that can be gained through practicum, the perspective is too narrow in an academic setting.
Knowledge	Limited knowledge of the benefits of patient safety and how to apply it in the clinical setting (−)	There are some procedures I forget.
	Active knowledge (+)	For me, studying is not just about exams, it's about providing better care. Whether I succeed or fail, I learn from the experience.
Memory, attention, and decision prcesse	Lack of comprehensive assessment and reflection (−, +)	Sometimes I rely too much on my subjective opinion. I will write down the mistakes I made today in my little notebook. Afterward, I'll ask my classmates first, or just ask the teacher what to do.
	Some clinical sensitivity (+)	I know that being involved and maintaining patient safety is vital for both myself and my patients. I also report any safety concerns to the medical staff if I become aware of them. I understand the need to remain vigilant.
Reinforcement	Time and enthusiasm invested cycles positively with competence (+)	The more I learn, the deeper my understanding becomes and the more interested I become.
Social identity	Peer pressure (−, +)	It's exhausting, but I'm more afraid of becoming a filler. Whenever I see the enthusiasm of my classmates in their work, it always ignites the fuel in my heart.
	Patient pressure (−)	Some patients are annoying; I just want to explode. Some patients look down on trainee nurses. He says: Sister, call your teacher; I don't want you to operate.
	Envisioning an ideal self-image (+)	Proud of a sense of responsibility and mission. I always think of myself as a pickup artist.
	Family stress (−)	There are still some family problems that bother me.
Optimism	Optimistic students adjust more quickly from mistakes (+)	I believe every mistake is an opportunity to grow.
Beliefs about capabilities	Self-doubt (−)	When working with more educated students, I may feel inadequate and afraid to say too much.
	Irresponsible traits may reduce enthusiasm for ensuring safety (−)	I may lack sufficient motivation or awareness to maintain patient safety.
Intentions	Perfectionist tendencies may mask errors and influence clinical decision making (−)	I may expect too much of myself and begin to fear making mistakes.
Goals	Excessive focus on individual needs prevents adequate fulfillment of patient needs (−)	I have to prepare for graduate school exams, so I know relatively little about the clinic. I don't plan to continue this career.
Environment context and resource	Positive relationships between faculty and students build more trust and collaboration (+)	The teacher is also tolerant and caring. The charm of gentleness and patience is important. She not only teaches me how to operate, but they also care about my health.
	Diversification of IOT learning pathways (+)	The school often has a variety of nursing skills competitions. The classroom teacher gave us the opportunity to participate.
	Providing opportunities to learn from mistakes (+)	The head nurse will facilitate discussions in the morning meeting and think together about ways to solve problems.
	Ease of learning in the age of big data (+)	I have learned a lot from bilibili University (a Chinese video sharing site).
	An enjoyable learning experience (+)	Her teaching style allowed knowledge to be incorporated effortlessly and I was particularly interested in the class.
Social influences	Negative social perceptions and media opinion (−)	We all think that nurses have a low social status. Just humble beatniks in the hospital.
	Gossip may hurt vulnerable students (−)	When I made a mistake, they were whispering.
	Harsh criticism (−)	I didn't even want to eat that day, let alone work or study.

Note: (+): facilitator; (−): barrier; (+, −): viewed as facilitator by some participants and barrier by others.

Table 6
Quantitative and qualitative results of the capability, opportunity, motivation and behaviour model and theoretical domains framework were compared side by side.

COM-B domain	Theoretical domains framework	Summary of quantitative findings	Summary of qualitative findings	Integrated result
Capability	Skills	Clinical Practice (2.97 ± 1.054) Safety Risk Management (3.12 ± 1.096) Time Management Competencies (3.02 ± 1.023) Learning To Monitor Competencies (2.89 ± 1.056) Competencies For Information Accessibility (2.82 ± 1.056) Information Analysis And Processing Competencies (2.80 ± 1.021) Competencies For Help-Seeking (2.88 ± 1.056) Communication Ability (2.91 ± 0.998) Competencies For Identifying Learning Needs (2.88 ± 1.036)	Lack of experience in dealing with emergencies and adverse events (−)	CONFIRMATION: Higher-level nursing students tend to demonstrate limited levels of patient safety competency, particularly in the area of practice. INCONSISTENT: Quantitative studies have consistently shown that senior nursing students tend to score lower on self-directed learning competencies. However, it is worth noting that qualitative studies have not yet delved into the impact of this area, representing a large gap. EXTENSION: Lower skill scores remind academics to promote the maintenance of students' clinical patient safety competency skills and improve confidence.
	Knowledge	Evidence-Based Nursing Practice (2.86 ± 1.146)	Limited knowledge of the benefits of patient safety and how to apply it in the clinical setting (−) Active knowledge (+)	
	Memory, attention, aud decision prcesse	Patient-Centred Care (3.97 ± 1.054)	Lack of comprehensive assessment and reflection (-, +)	
		Metacognition ⇒ patient safety competency (95 % CI [0.062, 0.242])	Some clinical sensitivity (+)	
Motivation	Reinforcement	Continuous Quality Improvement (3.04 ± 1.136) Broadening Of Information Channel Competencies (2.96 ± 1.126)	Time and enthusiasm invested cycles positively with competence.	CONFIRMATION: Both qualitative and quantitative studies confirm that metacognition plays a contributory role in competence, but it is particularly lacking in motivation among senior nursing students. INCONSISTENCY: Impeding factors have not yet been highlighted in quantitative research. EXTRAORDINARY: Qualitative studies provide additional insights, emphasizing that some students' peer pressures, psychological burdens imposed by patients, and lack of family support reduce self-efficacy and make students lack self-confidence, hindering competence development. On the other hand, barriers to patient safety competence often include a lack of moral support and poor psychological qualities.
	Social identity	Metacognitive Monitoring Metacognitive Regulation Metacognition ⇒general self-efficacy ⇒ self-directed learning ⇒ patient safety competency(95 % CI [0.017, −0.013])	Peer pressure (−, +) Patient pressure (−) Envisioning an ideal self-image (+) Family stress (−)	
	Optimism	General Self-Efficacy (2.98 1.101)	Optimistic students adjust more quickly from mistakes (+)	
	Beliefs about capabilities	Metacognition ⇒general self-efficacy ⇒ patient safety competency (95 % CI [0.093, 0.173])	Self-doubt (-) Irresponsible traits may reduce enthusiasm for ensuring safety (−)	
	Intentions	Metacognitive Planning	Perfectionist tendencies may mask errors and influence clinical decision making (−)	
	Goals	Metacognitive Evaluation	Excessive focus on individual needs prevents adequate fulfillment of patient needs (−)	
Opportunity	Environment context and resource	scores by Clinical Internship Duration (more than 8 months > 4–8 > less than 4 months)	Positive relationships between faculty and students build more trust and collaboration (+)	CONFIRMED: The larger environment's provision of a variety of rich resources facilitates patient safety competence and often serves as a driving force. In contrast, social influences such as strong adverse public opinion were clear impediments. EXTRAORDINARY: Qualitative research provided additional insights suggesting that social opinion, gossip, etc., became a hindrance
		scores by Internship Hospital Level (Grade-A Tertiary Hospital >Grade-A Secondary Hospital >Others >No Internship)	Diversification of IOT learning pathways (+)	

(*continued on next page*)

Table 6 (*continued*)

COM-B domain	Theoretical domains framework	Summary of quantitative findings	Summary of qualitative findings	Integrated result
			Providing opportunities to learn from mistakes (+) Ease of learning in the age of big data (+) An enjoyable learning experience (+)	by contributing to the formation of a poor patient safety culture.
	Social influences	Patient Safety Culture (2.96 ± 1.142)	Negative social perceptions and media opinion (−) Gossip may hurt vulnerable students (−) Harsh criticism (−)	

4. Discussion

Results from this study identify many factors impacting a higher vocational nursing students' patient safety competence in the care environment. Moreover, testing a serial-multiple mediation model using bootstrapping methods, we sought to reveal the potential mechanism of the relationship between mate and patient safety competency among nursing students. The results of our study also verified our hypothesis. We found metacognition not only had a direct effect on patient safety competency in nursing students, but it also had an indirect influence on patient safety competency via mediation by general self-efficacy and self-directed learning skills. In addition, these findings also found deeper reasons in the interviews.

In this study, we investigated the relationship between metacognitive ability and patient safety competency among higher vocational nursing students. We found that metacognitive ability can directly influence patient safety competency, with a positive correlation such that the higher the level of metacognition, the better the patient safety competency. This finding aligns with (Huang et al., 2024), our study has delved deeper into the specific manifestations of these advantages in the assessment of patient safety competency. Qualitative methods were employed to supplement and verify the results of the quantitative research. Higher vocational nursing students with high metacognition possess certain advantages. As indicated by Royce et al. (2019), Song et al. (2022), they are equipped with critical thinking skills, which enable them to better perceive the culture of patient safety. In our interviews, it was revealed that some students indeed already had a degree of clinical awareness. However, when it came to the assessment process related to patient safety, issues arose. They often struggled to consider all aspects comprehensively, and sometimes the assessment methods themselves were less than optimal. These shortcomings frequently led to wrong judgments. Some studies (Asadzandi et al., 2022, Wang et al., 2024) have also emphasized how metacognitive skills contribute to a more comprehensive understanding of patient care scenarios among nursing students. Our study delved deeper into the specific manifestation of these advantages in the context of patient safety competency assessment. Metacognitive awareness plays a crucial role here. We fond that through this awareness, students can detect when their assessments are inadequate or incorrect. Once aware of these issues, they will actively seek ways to solve the problems. But developing metacognitive competence isn't without difficulties. As O'Sullivan and Schofield (2018) reported, students need to invest more time and effort to understand the critical types of cognitive errors in the clinical setting. This is similar to the observations in other studies (Le Lagadec et al., 2024, Peixoto, 2017) that have investigated the complexity of developing higher-order cognitive skills among nursing students in clinical environments. Yet, our research expanded on this by highlighting the specific implications for patient safety competency and how these difficulties directly impact the students' ability to make accurate assessments and decisions in ensuring patient safety. Overall, awareness, cognition, and behavioural response to a patient safety event is a process, and as a caregiver, understanding the event should include awareness of one's behavioural plan. This is further supported by Aloufi et al. (2021), which found that improved cognitive control could help caregivers maintain focus even in occupationally stressful environments. While this general concept is well-established in the literature on healthcare practices and patient safety, our study contributes by emphasizing its significance specifically for higher vocational nursing students. We demonstrated through our findings that these students, facing unique challenges and stressors, rely heavily on optimizing such cognitive aspects to enhance their patient safety competency. Given the various stressful influences that higher vocational nursing students face, such as those from family, peers, patients, stress, clinical unknowns, and educational level, the students themselves, as revealed in our interviews, expressed a clear need to optimize their metacognitive abilities. In contrast to some earlier research that might have overlooked or underestimated the impact of these specific stressors on metacognitive ability optimization among this particular group of students, our study shines a spotlight on these factors. By optimizing these abilities, they aim to maintain focused practice and enhance their performance in ensuring patient safety.

The acquisition of competencies related to patient safety is deeply rooted in the development of a specific sense of self-efficacy. Self-efficacy, as defined by Grau et al. (2002). In the context of nursing students, it implies their confidence in fulfilling the role of a student as they train to become fully qualified nurses, as elaborated by Pierazzo (2014). Our study has uncovered that higher vocational nursing students with high metacognitive abilities are more likely to develop high levels of general self-efficacy, which subsequently leads to improved patient safety. This finding aligns with the study conducted by Norouzi et al. (2023), which also emphasized how such students are motivated to utilize cognitive strategies more actively to guide their learning. However, while there is this similarity in the general trend, it is important to note the differences in our research contexts. Our study focused on higher vocational nursing

students, a specific group with its own characteristics in terms of educational background and practical training experiences. In contrast, Norouzi et al.'s research have encompassed a broader range of nursing students. Numerous studies, such as those by Bandansin et al. (2022), Harsul et al. (2020), have analyzed the role of general self-efficacy in acquiring nursing competencies. Similar to these investigations, our study also delved into this aspect and found through interviews that general self-efficacy serves as the driving force behind carrying out patient safety cognition and patient safety actions, thereby contributing to the achievement of patient safety productivity. Our research provides a more detailed perspective on how this role manifests specifically among higher vocational nursing students. For instance, we qulitative study outcome discovered that lack of experience can significantly reduce their general self-efficacy. This lack of experience leads to difficulties in promptly recognizing risks and errors, creating a situation in which students might have a strong sense of responsibility but struggle to provide care because of a mismatch between their competencies and patients' needs. Such a situation can further impact their initiative to deal with safety incidents. In comparison, previous studies might not have focused as closely on these specific challenges faced by this particular group of students in relation to general self-efficacy and its implications for patient safety. Moreover, an interesting contrast emerged regarding students' behavior towards reporting errors. Our interviews revealed a different scenario compared to the findings of (Huang et al., 2020). While Huang et al. found that students were often afraid to report errors, our study, through in-depth interviews with higher vocational nursing students, uncovered that factors such as the inability to obtain timely feedback or facing various kinds of gossip played a crucial role in influencing their confidence in their actions and, consequently, their general self-efficacy. These differences could potentially stem from variations in the research settings, including the types of nursing students, the cultural of the study areas, or the specific questions posed in the investigations.

When it comes to the influence of safety culture on the patient safety competency of higher vocational nursing students, our study's interviews demonstrated a more substantial influence than previously documented. The concept of patient safety climate, which aims to measure and describe individuals' perceptions of safety (Neal and Griffin, 2002) within specific areas/units of the healthcare system (Ortiz de Elguea et al., 2019) and is part of the subgroup of safety culture (Alsalem et al., 2018), has been explored in prior research. However, our study, focusing on students in the learning phase (Soósová, 2020), revealed that a poor safety climate has a particularly adverse effect on their general self-efficacy. While schools may not have direct control over the culture of the clinical site, our findings suggest that faculty can play an important role in teaching students to speak up for patient safety and support them when they witness errors. This is an aspect that might not have been as prominently highlighted in earlier studies on safety culture and its impact on students.

The results indicated that higher vocational nursing students with higher metacognitive abilities were more likely to demonstrate more vital self-directed learning skills, which increased patient safety competency, a finding consistent with previous research. Prior studies such as those by Goolsarran et al. (2018), Jin and Ji (2021) have also shown that nurses' metacognition positively relates to self-directed learning skills and that more excellent self-directed learning increases patient safety competence. However, when comparing our study found that within this particular group, the impact of metacognitive ability on promoting self-directed learning skills and ultimately enhancing patient safety competency might have unique characteristics. In exploring the aspect of self-directed learning skills, our study uncovered some new insights in the era of big data. Interviews revealed that higher vocational nursing students nowadays find solutions through independent thinking and flexibly utilize online tools for learning. The ease of access to resources and the convenience of conditions also positively affect their self-directed learning. While previous research has mainly focused on traditional learning environments or general factors influencing self-directed learning, our findings shed light on the contemporary context where digital resources play a significant role. Compared to studies that did not consider the impact of the digital age, we were able to observe how the availability of online databases, virtual learning platforms, and other digital resources enabled these students to develop their self-directed learning skills in ways that were not previously documented. Our study not only corroborates the findings of previous research regarding the relationship between metacognitive ability, self-directed learning skills, and patient safety competency but also enriches the understanding of this relationship by highlighting unique aspects specific to higher vocational nursing students and uncovering new phenomena in the modern learning environment.

We tested serial multiple mediation models between metacognition, general self-efficacy, self-directed learning skills, and patient safety competency in higher vocational nursing students to identify potential mechanisms between meta and patient safety competency. The results of this study indicated that high metacognition was first associated with increased general self-efficacy and then with increased self-directed learning skills, which in turn was associated with increased patient safety competency, and that metacognition, self-efficacy, and self-directed learning skills constitute an intrinsic mechanism of patient safety competence. Metacognition positively impacts self-efficacy, and metacognition influences the formation of self-efficacy by monitoring and evaluating individual cognitive processes and outcomes. In addition, numerous studies have shown that self-efficacy is positively correlated with self-directed learning (Chen et al., 2023) and that enhanced self-efficacy promotes self-directed learning skills(Hwang and Oh, 2021); individuals with higher self-efficacy are likely to learn more efficiently and, therefore, be more self-directed (Park and Kim, 2023). Additionally, self-directed learning is a predictor of academic self-efficacy (Karatas et al., 2023); as described by the interviewer, the convenience of learning tools and resources makes learning effortless, a sentiment that enhances self-efficacy. In a correlational study (Chen et al., 2019) found a positive correlation between SRL ability, metacognitive ability, and general self-efficacy, with results supporting Self-regulated Learning (SRL) theory (Kuiper and Pesut, 2004, Zimmerman, 2002). Finally, a qualitative study describing nurses with lower levels of self-directed learning tended to be less prone to patient safety competency (Lin et al., 2014) Nursing curriculum standards are shifting toward competency-based education, with a heavy emphasis on demonstrating the ability to apply knowledge and skills, with feedback provided throughout to assess the level of competency (Mossburg, 2023). One of the most challenging parts of nurse education is translating theory learned in the classroom into work practice in the clinical setting. To better introduce patient safety competency competencies in the dynamic and unpredictable realities of the clinical setting, schools can help students bridge the

gap by ensuring that safety competencies are an explicit part of clinical rotation curricula and communicating the expected safety competencies to students and faculty. Interviews revealed that individuals' initial perceptions of safety risks may only allow for a partial assessment of the situation, leading to imperfect metacognition and unintentional error generation. Only by considering human factors and constraints, assessing the situation comprehensively from multiple perspectives, and refining the cognitive process through reflection can correct insights and decisions be made to prevent negative consequences. Metacognition, self-efficacy, and self-directed learning skills work together to facilitate the formation of an individual's ability to identify, analyze, and solve patient safety problems, ultimately building patient safety competence.

5. Practical implications for nursing education

Enhancement of metacognitive abilities: Given the significant impact of metacognition on patient safety competence, nursing education should incorporate strategies for cultivating metacognitive skills (Norris, 2013). This involves teaching students how to reflect on their clinical experiences (Artioli et al., 2021, Mlinar Reljic et al., 2019), analyze their decision-making processes, and identify areas for improvement (Greenbank, 2010). Educators could introduce reflective journaling or case-based discussions to encourage students to critically evaluate their behaviors and thought processes in patient care scenarios (Ahmed, 2019, Horton et al., 2021). Building general self-efficacy: Schools and clinical institutions should collaborate to provide more practice opportunities, simulation scenarios and timely feedback, so as to increase students' opportunities for general self-efficacy. Through virtual reality technology, students can be exposed to various real-life situations in a controlled environment and provided with constructive feedback, enabling them to build confidence in handling patient safety issues (Alden, 2008). Moreover, it is recommended that teachers actively create a positive safety culture where students can feel supported (Tu, 2021). They should encourage students to voice their safety concerns, as a poor safety climate has been found to negatively affect self-efficacy, whether in the hospital environment (Heckemann et al., 2019, Seo and Lee, 2022)or in the school environment (Heckemann et al., 2019). Development of self-directed learning skills:To assist students in developing self-directed learning skills, educational institutions are advised to integrate digital learning resources and encourage independent exploration (Medina, 2017). Access to online databases and virtual learning platforms could be provided (Li, 2023), and students could be encouraged to conduct self-directed learning projects related to patient safety. This will enable students to keep up with the latest knowledge and adapt to the ever-changing demands of the healthcare field, ultimately enhancing their patient safety competence.

6. Limitations

Our study has several limitations that should be acknowledged, and discussing these aspects will offer a more balanced perspective on the contributions of our research. Sample selection bias: We used convenience sampling, drawing participants from just one Chongqing nursing vocational college. This may cause bias as the sample might not represent all vocational nursing students. Differences in teaching, local culture, or admission criteria could limit generalizability. Future studies should involve multicenter samples for better generalization and international comparison. Study duration: The short study period restricted our ability to observe long-term effects. It is recommended that future studies consider conducting cohort studies, tracking students from the start of receiving patient safety competency education or training until they become familiar with clinical work, to comprehensively observe changes in patient safety competency over time. This would provide a more comprehensive understanding of how these factors evolve and interact in the long run and help to capture any potential delayed or cumulative effects that were not observable within the scope of our current study. Incomplete factors: While we explored certain relationships related to patient safety competency, other factors like social support, occupational environment, and training quality could also influence it. Future research should explore these and analyze their combined effects for a more comprehensive model. Self-report bias: Our reliance on self-report questionnaires and interviews might lead to biases due to subjective memory and recall. Participants might overemphasize their positive behaviors or abilities due to social desirability bias, or misremember things. Future studies should use more objective tools like direct observation or triangulate data from multiple sources (e.g., combining self-reports with supervisor evaluations or objective performance metrics) could enhance the reliability and objectivity of the findings. By recognizing these limitations, we hope to provide a more comprehensive and accurate understanding of our study's findings and guide future research efforts in this area.

7. Implications

The current study has important implications for nursing practice. The patient safety competency level of higher vocational nursing students is moderate (Yan et al., 2021). For higher vocational nursing students and future healthcare professionals who will provide a large number of healthcare services in all types of healthcare organizations, it is essential to improve the patient safety competency of higher vocational nursing students. Educators must know practical ways to improve students' patient safety competency and prevent healthcare risks. Policymakers need to be aware of the impact of self-directed learning on this competency and provide education, support and opportunities for students.

8. Conclusions

The present study provides empirical evidence for a serial mediating role of general self-efficacy and self-directed learning in the relationship between metacognition and patient safety competency, contributing to a psychological understanding of the underlying

mechanisms of patient safety competency. This study found that general self-efficacy and self-directed learning may enhance meta-induced patient safety competency enhancement. Therefore, when developing interventions, consider: for metacognitive abilities, integrate strategies like teaching students to reflect on clinical experiences and decision-making. Use tools like reflective journaling or case discussions. For general self-efficacy, schools and clinics should collaborate to provide more practice, simulations, and feedback. Teachers should create a positive safety culture and encourage students to voice concerns as poor climate affects self-efficacy. For self-directed learning, institutions should integrate digital resources and encourage exploration. Provide access to online platforms and promote patient safety-related projects. Future research should explore the long-term effectiveness and scalability of these strategies. Examine how to optimize integration across settings and study factors like individual differences that may influence these relationships, building on current findings to improve nursing education and patient safety.

9. Relevance for clinical practice

Based on the findings of this study, we recommend that nursing and patient safety educators look at the psychological aspects of students' metacognitive abilities, self-directed learning, and self-efficacy in order to effectively enhance their patient safety competency and more fluidly adapt to future job content. We also recommend the development of innovative teaching strategies that incorporate psychological theories, influences found in this study, and opportunities for students to create best practices.

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Ethics statement

This study complies with the Declaration of Helsinki and was performed according to The First Affiliated Hospital of Chongqing Medical University (approval number: 2022-k218)

CRediT authorship contribution statement

Lu Zhou: Writing – original draft, Visualization, Validation, Investigation, Formal analysis, Data curation. **Yinsong Sun:** Writing – original draft, Validation, Software, Methodology, Formal analysis, Data curation. **Mingzhao Xiao:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **Runli Yang:** Methodology, Investigation, Data curation. **Shuang Zheng:** Investigation, Data curation. **Jun Shen:** Visualization, Methodology, Conceptualization. **Qinghua Zhao:** Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary materials

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