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Nurses Knowledge of Patient Safety at Regional Hospitals in Medan City

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ABSTRACT

Background: Patient safety remains a global healthcare priority, with nurses playing a pivotal role in preventing adverse events. This study evaluated the effectiveness of a structured educational intervention in improving nurses' patient safety knowledge and explored multidimensional relationships among patient safety knowledge domains.
Methods: A randomized controlled trial was conducted among 300 registered nurses from three regional hospitals in Medan, Indonesia. Participants were randomly assigned to an intervention group (n = 150) receiving structured patient safety education or a control group (n = 150) receiving conventional module-based learning. Knowledge was assessed across five domains. Within-group differences were analysed using the Wilcoxon signed-rank test, while between-group differences were evaluated using the Mann–Whitney U test. Correlation heatmaps and a 50-node correlation network were used to examine multidimensional relationships.
Results: Both groups demonstrated significant improvements ($p < 0.001$). The intervention group improved from 11.72±1.93 to 16.44±1.46 (mean gain 4.72), whereas the control group improved from 12.21±1.74 to 14.99±1.74 (mean gain 2.79). Post-intervention scores were significantly higher in the intervention group (U = 6636.00; Z = −6.12; $p < 0.001$; r = 0.35). Stronger correlations were observed among patient safety knowledge domains in the intervention group (r = 0.87 - 0.96) than in the control group (r = 0.65 - 0.76). The correlation network further demonstrated dense intra- and inter-domain connectivity, indicating integrated knowledge development.
Conclusions: Structured patient safety education significantly improves nurses' knowledge and strengthens multidimensional competency integration, supporting its implementation to enhance patient safety and healthcare quality.

INTRODUCTION

Patient safety is recognized as a global healthcare priority because preventable adverse events remain a major cause of morbidity, mortality, prolonged hospitalization, and increased healthcare costs. The World Health Organization (WHO), through the Global Patient Safety Action Plan 2021–2030, emphasizes strengthening healthcare systems, improving workforce competencies, and fostering a culture of safety to reduce avoidable harm (Walton et al. 2010; Steven et al. 2014). Nurses, as the largest group of healthcare professionals and primary providers

of continuous patient care, play a critical role in implementing patient safety principles through effective communication, accurate patient identification, medication safety, infection prevention, and early recognition of patient deterioration (Zumhari et al. 2025; Sidabutar et al. 2025).

Therefore, strengthening nurses' patient safety knowledge through structured educational interventions is essential for improving safe clinical practice. (Cronenwett et al. 2007; Mansour 2012). In this study, nurses' patient safety knowledge was evaluated across five domains—Knowledge Score (KS), Learning Achievement (LA), Knowledge Consistency (KC), Educational Impact (EI), and Clinical Applicability (CA) (e.g. Gough et al. 2013; Steven et al. 2014)—to determine the effectiveness of educational interventions and their potential contribution to safer nursing practice and improved healthcare quality, as illustrated in Figure 1.

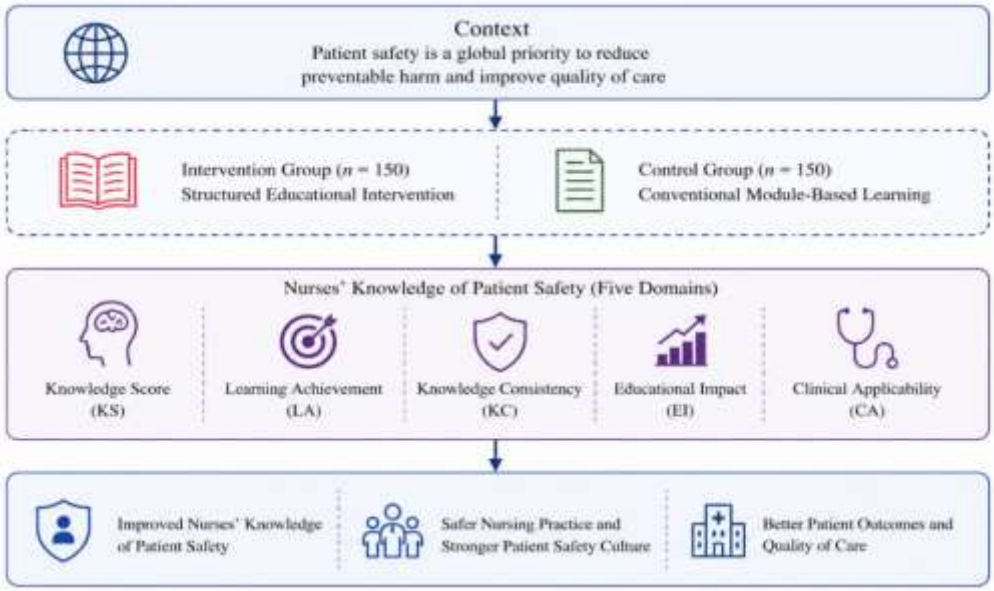

Figure 1. Conceptual framework of factors influencing nurses' knowledge of patient safety and their implications for patient safety practices and healthcare quality.

Patient safety competency among nurses is influenced by multiple interrelated factors, including knowledge deficits, ineffective communication, limited patient safety training, human errors, and inadequate integration of digital learning technologies as schemed in table 1. These challenges contribute to unsafe clinical practices and increase the risk of preventable patient safety incidents. Addressing these issues requires comprehensive educational strategies that strengthen fundamental patient safety knowledge and significantly improve communication and teamwork skills for promoting professional development.

Table 1. Major Factors Influencing Nurses' Patient Safety Competency.

Factor	Impact on Patient Safety	Educational Focus
Knowledge deficit (Biresaw et al. 2020)	Unsafe care	Patient safety principles
Communication (WHO, 2021)	Medical errors	Team communication
Limited training (WHO, 2021)	Low competency	Continuous education
Human error (Gong, 2022)	Safety incidents	Error prevention

Despite increasing emphasis on patient safety education, conventional educational approaches, including lectures, printed modules, and periodic in-service training, often provide limited opportunities for continuous learning and active engagement, particularly for nurses working in demanding clinical environments with rotating shifts and heavy workloads

(Schwappach & Gehring, 2014). These limitations may contribute to persistent gaps in patient safety knowledge and the consistent application of safety principles in clinical practice.

Therefore, structured educational interventions have emerged as a promising strategy to strengthen nurses' knowledge through systematic and competency-based education (Tella et al. 2014; Tregunno et al. 2014). This study evaluated the effectiveness of a structured patient safety educational intervention compared with conventional module-based learning. We hypothesized that nurses receiving the structured educational intervention would demonstrate significantly greater improvements in patient safety knowledge. The findings are expected to provide empirical evidence supporting the integration of structured patient safety education into continuing nursing professional development and healthcare quality improvement initiatives.

METHODS

Study Design

This study employed a two-arm, parallel-group randomized controlled trial (RCT) with a 1:1 allocation ratio to evaluate the effectiveness of a structured patient safety educational program in improving nurses' patient safety knowledge. Participants were randomly assigned to either the intervention group, which received the structured patient safety educational program, or the control group, which received conventional module-based learning. Pre-intervention and post-intervention assessments were conducted to evaluate changes in patient safety knowledge following the educational intervention. This study was conducted and reported in accordance with the Consolidated Standards of Reporting Trials (CONSORT) 2010 Statement.

The intervention consisted of a structured patient safety educational program delivered by the research team using PowerPoint presentations, case discussions, and printed educational materials. The program covered the International Patient Safety Goals (IPSG), effective communication, medication safety, infection prevention, patient identification, and fall prevention. The intervention was delivered in a single structured session lasting approximately 120 minutes. Participants in the control group received the standard patient safety module routinely used by the participating hospitals without additional face-to-face instruction.

Study Setting and Participants

The study was conducted in three hospitals in Medan City, North Sumatra, Indonesia, namely Murni Teguh Memorial Hospital, Rosiva Hospital, and Susanna Wesley Hospital. The study population comprised 860 registered nurses working in inpatient departments across the participating hospitals. The sample size was determined using the Slovin formula (Hwang et al. 2016; Lee et al. 2016), as presented in Equation (1), resulting in a total of 300 participants. Proportional random sampling was used to ensure adequate representation from each participating hospital.

$$n = \frac{N}{1+Ne^2} \quad (1)$$

where:
n = required sample size;
N = total population size (860 nurses);
e = margin of error (5%).

Eligible participants were registered nurses who had worked for at least six months, held the minimum required nursing qualification, were employed full-time (40 hours per week), and had no plans to resign during the study period. Nurses who did not meet the eligibility criteria or declined to participate were excluded from the study. Written informed consent was obtained from all participants before enrolment. Because of the educational nature of the intervention, allocation concealment was not implemented. Following enrolment, participants were randomly assigned in a 1:1 ratio to either the intervention group or the control group using a computer-

generated random sequence. The demographic and professional characteristics of the participants, including age, sex, educational qualification, and previous patient safety training, are presented in Table 2.

Table 2. Baseline characteristics of participants by study group.

Characteristics	n-Intervention	%	n-Control	%	Total	%
Age (years)						
<30	104	69.3	99	66.0	203	67.7
≥30	46	30.7	51	34.0	97	32.3
Sex						
Male	8	5.3	12	8.0	20	6.7
Female	142	94.7	138	92.0	280	93.3
Marital status						
Married	52	34.7	38	25.3	90	30.0
Unmarried	98	65.3	112	74.7	210	70.0
Educational qualification						
Diploma III	64	42.7	57	38.0	121	40.3
Bachelor/Ners	86	57.3	93	62.0	179	59.7
Clinical nursing level						
Pre-Nurse	51	34.0	52	34.7	103	34.3
Clinical Nurse I	49	32.7	51	34.0	100	33.3
Clinical Nurse II	24	16.0	18	12.0	42	14.0
Clinical Nurse III	17	11.3	16	10.7	33	11.0
Clinical Nurse IV	9	6.0	13	8.7	22	7.3
Previous safety training						
Yes	133	88.7	134	89.3	267	89.0
No	17	11.3	16	10.7	33	11.0

Data Collection and Instruments

Data were collected using a questionnaire with two sections. The first section was demographic and professional characteristics, including age, gender, marital status, educational background, clinical experience, and previous patient safety training. The second section assessed participants' knowledge of patient safety using a validated questionnaire. Patient safety knowledge was assessed using a structured 50-item multiple-choice questionnaire developed based on the World Health Organization (WHO) Global Patient Safety and the International Patient Safety Goals (IPSG). The questionnaire has five domains: Knowledge Score (KS), Learning Achievement (LA), Knowledge Consistency (KC), Educational Impact (EI), and Clinical Applicability (CA) (e.g. Usher et al. 2017; Mansour et al. 2018).

Each correct response was scored as 1 and incorrect responses as 0, yielding a total score ranging from 0 to 50, where higher scores indicated greater patient safety knowledge. The instrument demonstrated excellent content validity following expert review and high internal consistency (Cronbach's α = 0.91) (Mansour et al. 2018). Instrument validity was evaluated using the Pearson product–moment correlation test as shown in Eq. (2).

$$r = \frac{n\sum XY - \sum X \sum Y}{\sqrt{[n\sum X^2 - (\sum X)^2][n\sum Y^2 - (\sum Y)^2]}} \quad (2)$$

where:
r = Pearson correlation coefficient;
X = individual item score;
Y = total questionnaire score;
n = number of respondents.

Items with correlation coefficients exceeding the critical value at the 95% confidence level ($p < 0.05$) were considered valid. Furthermore, internal consistency reliability was assessed using Cronbach's alpha coefficient as shown in Eq. (3) (Bedgood & Mellott, 2018). A Cronbach's alpha value of ≥ 0.70 indicated acceptable internal consistency of the instrument.

$$\propto = \frac{k}{k-1}\left(1 - \frac{\sum_{i=1}^{k}\sigma_i^2}{\sigma_t^2}\right) \quad (3)$$

where:
$\propto$ = Cronbach's alpha coefficient;
k = number of questionnaire items;
σ_i^2 = variance of each item;
σ_t^2 = variance of the total score.

Knowledge assessments were administered immediately before the educational intervention to establish baseline levels of patient safety knowledge (Gleason et al. 2019). Following completion of the intervention, the same questionnaire was administered to evaluate knowledge attributable to the educational program. The primary outcome was nurses' patient safety knowledge.

Statistical Analysis

We processed the data through editing, coding, data entry, verification, and cleaning before statistical analysis. Data normality was assessed prior to inferential analysis using the Shapiro–Wilk test. Depending on the distribution of the data, paired comparisons within groups were analysed using the Wilcoxon signed-rank test as shown in Eq. 4 (Kim et al. 2019).

$$W = \frac{\left(\sum_{i=1}^{n}\alpha_i x_{(i)}\right)^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \quad (4)$$

where:
W = Shapiro–Wilk test statistic;
$x_{(i)}$ = ordered sample observations;
α_i = constants derived from the expected values of order statistics of a normal distribution;
$\bar{x}$ = sample mean;

The Shapiro–Wilk test indicated that the knowledge scores were not normally distributed ($p < 0.05$); therefore, non-parametric tests were applied throughout the analysis. Moreover, the differences between the intervention and control groups were examined using the Mann–Whitney U test as shown in Eq. (5) (Kirkman et al. 2015). Statistical analyses were performed using IBM SPSS Statistics version 25, and statistical significance was established at a two-sided p value of less than 0.05.

$$U = n_1 n_2 + \frac{n_1\,(n_1+1)}{2} - R_1 \quad (5)$$

where:
U = Mann–Whitney test statistic;
n_1 = number of participants in the intervention group;
n_2 = number of participants in the control group;
R_1 = sum of ranks for the intervention group.

Ethical Considerations

Ethical approval for this study was obtained from the Health Research Ethics Committee under approval number 650/KEPK/FK/VI/2024. Prior to participation, all respondents received information regarding the study objectives and procedures and provided informed consent.

Participants' confidentiality and anonymity were maintained throughout the study, and all data were analyzed in aggregate form solely for research purposes.

RESULTS

Demographic and Professional Characteristics of Nurses

The total of 300 registered nurses from three regional hospitals were included and randomly assigned to the control groups. The workforce profile demonstrates that the study population consisted predominantly of nurses actively involved in direct patient care and clinical service delivery. This profile provides an appropriate foundation for evaluating educational interventions designed to strengthen patient safety knowledge because the participants represent the group primarily responsible for implementing patient safety during.

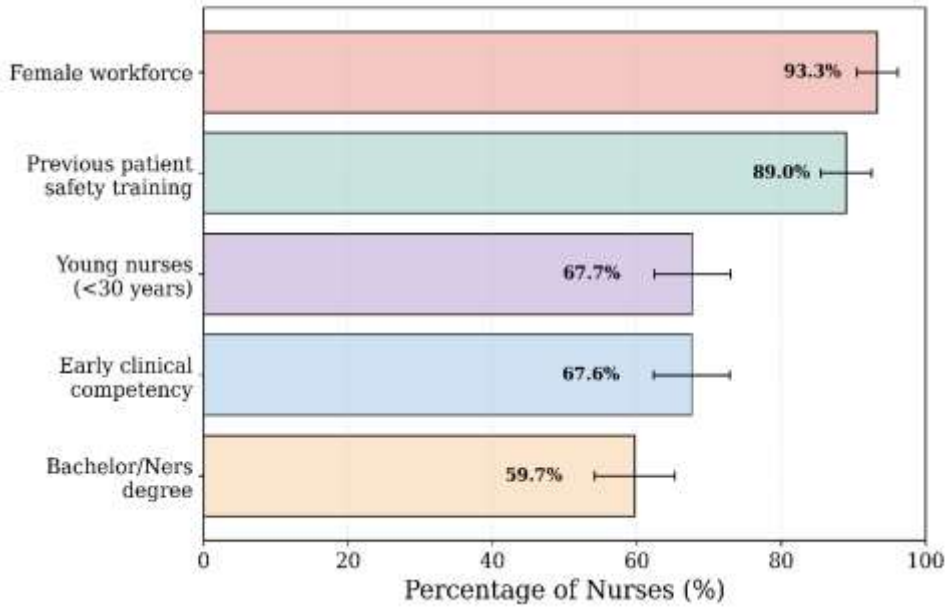

Figure 2. Baseline professional readiness for patient safety illustrating the distribution of five indicators among participating nurses. Error bars represent 95% confidence intervals.

We identified a high level of previous exposure to patient safety education. A total of 267 nurses (89.0%) reported having participated in patient safety training before enrolment in the study. This finding suggests that patient safety education had already been introduced within the participating hospitals as part of continuing professional development. Moreover, we visualize in Fig. 2 that female nurses accounted for 93.3% (95% CI: 89.8–95.6) of the study population, while 89.0% (95% CI: 84.9–92.1) had previously participated in patient safety training, representing the two highest baseline readiness indicators (Mariani et al. 2015).

Nurses younger than 30 years comprised 67.7% (95% CI: 62.1 - 72.8) of participants, and 67.6% (95% CI: 62.0 - 72.8) were classified as Pre-Clinical Nurses or Clinical Nurse I, indicating that most respondents were at the early-stage careers. Bachelor or Ners qualifications were reported by 59.7% (95% CI: 54.0 - 65.1) of respondents, representing the lowest proportion among the five readiness domains. Detailed information is shown in table 3.

Table 3. Baseline professional readiness of nurses for patient safety education.

Domain	Indicator	Finding	Interpretation
Workforce age	Nurses aged <30 years	203 (67.7%)	Workforce predominantly composed of early-career nurses
Professional qualification	Bachelor/Ners degree	179 (59.7%)	Majority possessed professional nursing qualifications

Domain	Indicator	Finding	Interpretation
Clinical competency	Pre-Clinical Nurse and Clinical Nurse I	203 (67.6%)	Most nurses were at the early stages of clinical responsibility
Previous patient safety exposure	Previous patient safety training	267 (89.0%)	High baseline exposure to patient safety education
Workforce composition	Female nurses	280 (93.3%)	Workforce reflects the nursing in participating hospitals

This information indicates that the participating nurses entered the study with relatively high baseline professional readiness and demonstrates that workforce composition and previous patient safety training were the dominant characteristics, whereas professional qualification represented the domain with the greatest opportunity for future capacity strengthening (Stevanin et al. 2015). These baseline conditions provide important contextual evidence for interpreting the subsequent effects of the patient safety educational intervention.

Patient Safety Knowledge Before Educational Intervention

Before the educational intervention, baseline patient safety knowledge scores were comparable between the intervention and control groups (Table 4). Nurses in the intervention group achieved a mean score of 11.72 ± 1.93 (95% CI: 11.41–12.03), with scores ranging from 8 to 18. In the control group, the mean score was 12.21 ± 1.74 (95% CI: 11.93–12.49), with scores ranging from 8 to 17. The mean difference between groups was 0.49 points, indicating similar baseline knowledge levels before the educational program as shown in Table 4.

Table 4. Baseline patient safety knowledge before educational intervention.

Statistic	Intervention (n = 150)	Control (n = 150)
Mean score	11.72	12.21
Standard deviation (SD)	1.93	1.74
Standard error (SE)	0.16	0.14
95% Confidence interval	11.41–12.03	11.93–12.49
Minimum	8	8
Maximum	18	17
Coefficient of variation (%)	16.47	14.25

The variability of knowledge scores was also comparable across groups. The coefficients of variation were 16.47% in the intervention group and 14.25% in the control group, suggesting a relatively homogeneous distribution of baseline patient safety knowledge among participating nurses. Standard errors were 0.16 and 0.14, respectively, while the overlapping 95% confidence intervals further demonstrated comparable baseline between the two study groups.

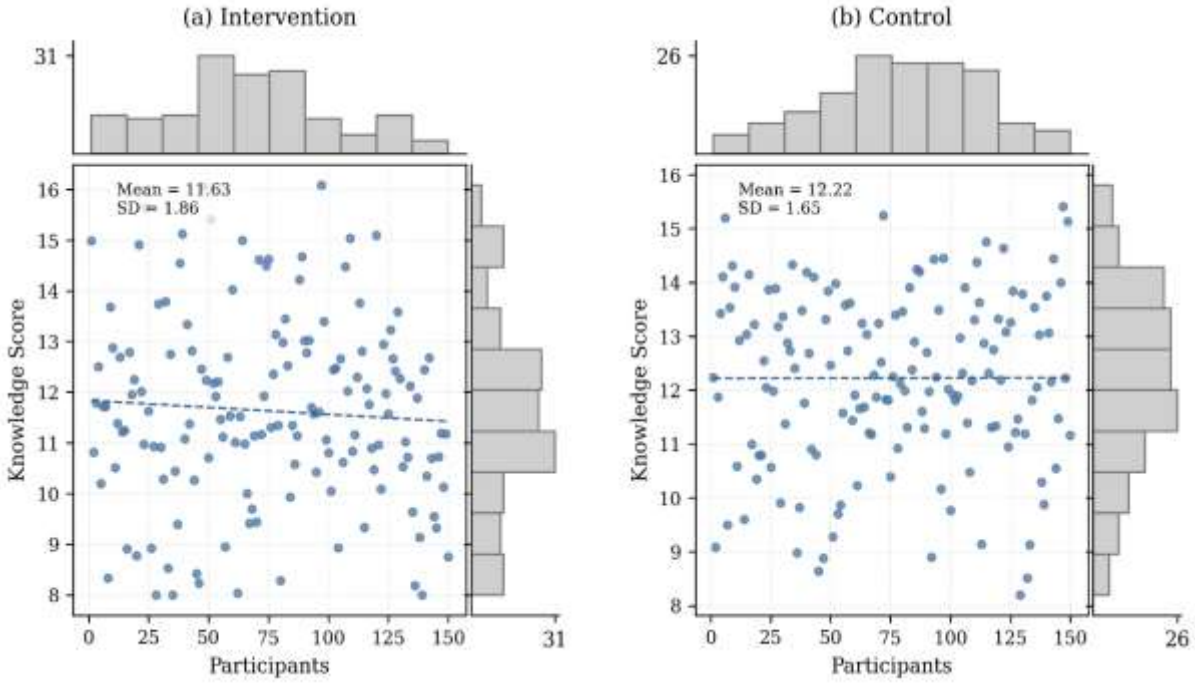

Figure 3. Joint plots of baseline patient safety knowledge scores for the intervention (a) and control (b) groups.

As illustrated in Figure 3, the distributions of baseline patient safety knowledge scores were similar in both groups. The marginal histograms showed comparable score frequencies, with most nurses clustered around the respective group means and relatively few observations at the lower and upper score ranges. Likewise, the scatter plots demonstrated an even distribution of individual participant scores without apparent outliers or marked clustering (Mansour et al. 2015). Collectively, the numerical and graphical findings indicate that both groups began the study with comparable levels and distributions of patient safety knowledge before the nursing educational intervention.

Changes in Patient Safety Knowledge After Educational Intervention

Patient safety knowledge scores increased in both study groups (see Table 5). In the intervention group, the mean knowledge score increased from 11.72 ± 1.93 before the intervention to 16.44 ± 1.46 after the intervention, representing a mean increase of 4.72 points. The Wilcoxon signed-rank test demonstrated a statistically significant improvement in patient safety knowledge ($p < 0.001$). The control group showed an increase in mean knowledge score from 12.21 ± 1.74 to 14.99 ± 1.74, corresponding to a mean increase of 2.79 points, which was also statistically significant ($p < 0.001$).

The post-intervention distributions shifted toward higher knowledge scores in both groups. Nurses in the intervention group demonstrated a greater concentration of scores at the upper end of the assessment scale, whereas the control group showed a more moderate upward shift (Lee et al. 2020). The marginal histograms indicated an increased frequency of higher scores following the educational intervention, while the scatter plots demonstrated a consistent distribution of individual observations without marked outliers as shown in Table 5.

Table 5. Changes in patient safety knowledge following the educational intervention.

Statistic	Intervention (n = 150)		Control (n = 150)	
	Pre-test	Post-test	Pre-test	Post-test
Mean	11.72	16.44	12.21	14.99
Standard deviation (SD)	1.93	1.46	1.74	1.74
Standard error (SE)	0.16	0.12	0.14	0.14

Statistic	Intervention (n = 150)		Control (n = 150)	
	Pre-test	Post-test	Pre-test	Post-test
95% Confidence interval	11.41–12.03	16.21–16.67*	11.93–12.49	14.71–15.27*
Minimum	8	—	8	—
Maximum	18	—	17	—
Mean change	-	**+4.72**	-	**+2.79**
p-value	-	<0.001	-	<0.001

Overall, the intervention group achieved a larger absolute improvement in patient safety knowledge than the control group, with a gain of 4.72 compared with 2.79 points. These findings indicate that knowledge scores increased after the educational program in both groups, with a more pronounced improvement observed among nurses receiving the intervention.

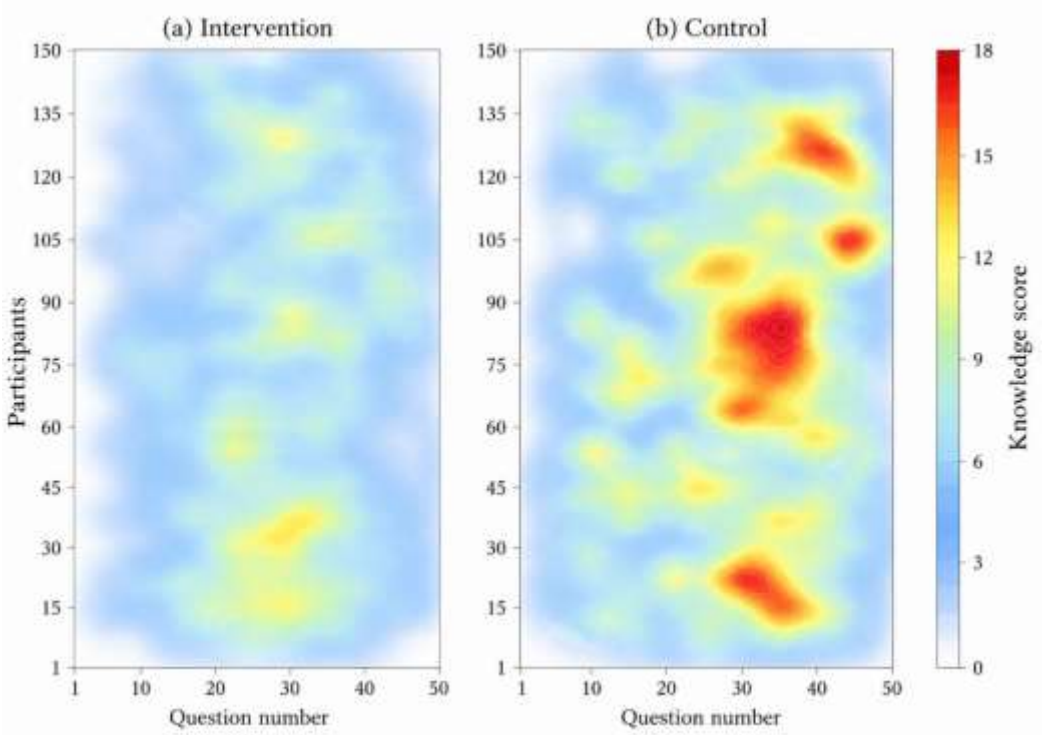

Figure 4. Contour heatmaps illustrate the distribution of participant responses across 50 questionnaire items before the educational intervention. Colour intensity corresponds to the participant knowledge score, with warmer colours indicating higher scores and cooler colours indicating lower scores.

The intervention and control were visually characterized by color gradients with scattered regions of moderate intensity, indicating that knowledge scores were largely distributed within the lower-to-moderate range across most questionnaire items. Warmer color regions appeared only in limited localized areas, suggesting relatively few participants achieved higher scores. Several distinct high-score clusters were observed, represented by orange-to-red contour regions surrounded by smooth density contours.

These clusters indicated a greater concentration of participants with relatively higher baseline knowledge scores compared with the intervention group, while lower-score regions remained distributed throughout the remaining questionnaire items (Lee et al. 2022). Overall, the contour heatmaps revealed heterogeneous participant-level score distributions in both groups, with visually distinguishable differences in the concentration and spatial distribution of higher knowledge scores (e.g. Budak et al. 2025).

Comparison of Patient Safety Knowledge After Educational Intervention

We performed a between-group comparison to evaluate the effectiveness of the educational intervention on nurses' patient safety knowledge. We found that nurses in the intervention group achieved significantly higher post-intervention knowledge scores than those in the control group. The statistical comparison demonstrated a separation in knowledge performance between the two groups, indicating that the educational intervention produced greater improvements than conventional module-based learning.

Table 6. Mann–Whitney U test comparing post-intervention patient safety knowledge between intervention and control groups

Statistics	Intervention	Control	Implication
Mann–Whitney U	6,636.00	6,636.00	Validates the effectiveness of patient safety for nurses.
Wilcoxon W	27,189.00	17,961.00	Indicates consistently knowledge among nurses.
Z statistic	−6.12	−6.12	Demonstrates an educational effect beyond module-based learning.
Asymptotic significance (2-tailed)	<0.001	<0.001	Provides supporting implementation of the nursing education.
Effect size (r)	0.35	0.35	Demonstrates clinically improvement and patient safety initiatives.

We further assessed the statistical significance of the observed differences using the Mann–Whitney U test. The analysis yielded a Mann-Whitney *U* value of 6,636.00, a Wilcoxon statistic of 27,189.00, and a standardized *Z* value of -6.12, with a two-tailed significance level of $p < 0.001$ (Table 6). These findings confirm that the higher patient safety knowledge achieved by nurses in the intervention group was statistically significant and unlikely to have occurred by chance. Nurses in the intervention group achieved a higher mean post-test knowledge score (16.44 ± 1.46) than those in the control group (14.99 ± 1.74). The intervention group also demonstrated a narrower score dispersion, as reflected by a lower standard deviation (1.46 vs. 1.74), smaller coefficient of variation (8.88% vs. 11.61%), and a narrower 95% confidence interval.

We further evaluated the interrelationships among the patient safety knowledge domains using correlation matrices and score distributions (Fig. 5). In the intervention group, strong positive correlations were observed among knowledge score, learning achievement, educational impact, and clinical applicability, with Pearson's correlation coefficients ranging from $r = 0.87$ to 0.96. The highest correlation was found between Educational Impact and Clinical Applicability ($r = 0.96$), followed by Learning Achievement and Educational Impact ($r = 0.94$), indicating a high level of consistency in educational outcomes. Conversely, Knowledge Consistency exhibited moderate negative correlations with the remaining parameters ($r = -0.35$ to -0.45).

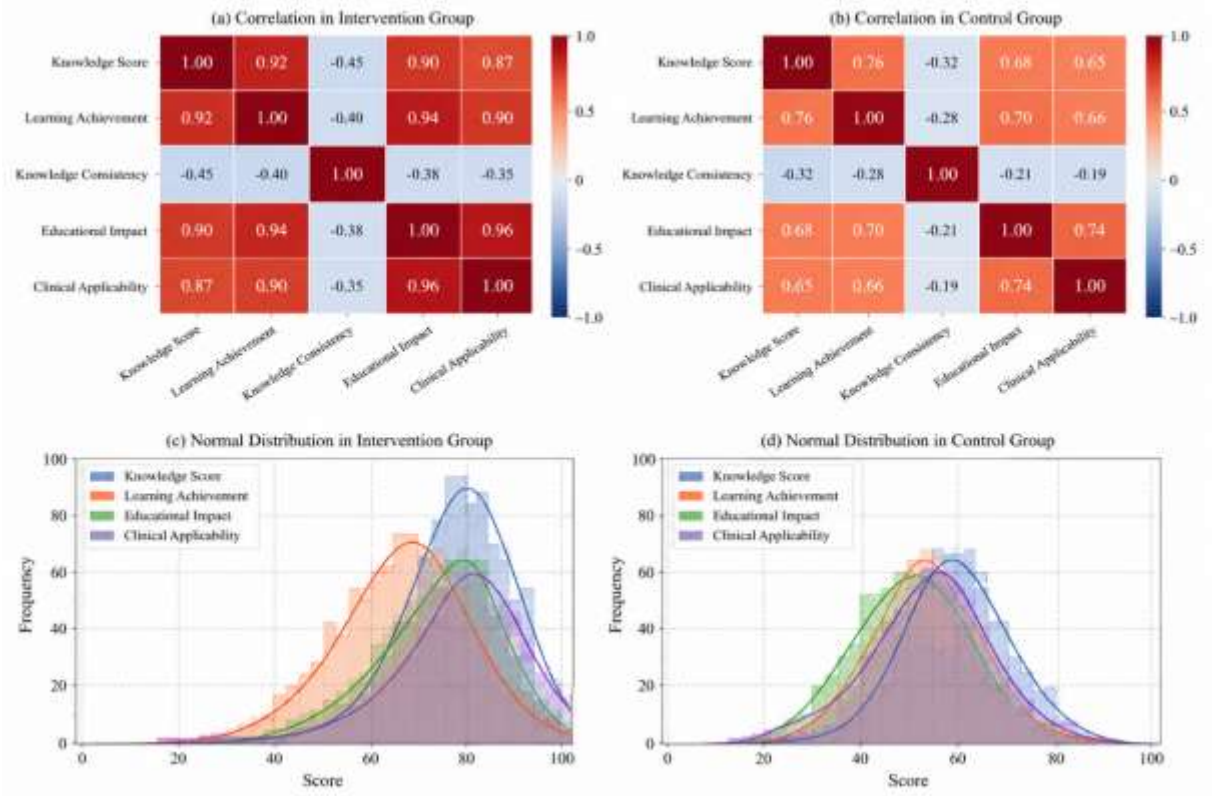

Figure 5. Correlation heatmaps and normal distribution plots of patient safety knowledge parameters in the intervention and control groups. (a) Correlation in the intervention group. (b) Correlation in the control group. (c) Normal distribution in the intervention group. (d) Normal distribution in the control group.

In the control group, positive correlations remained evident but were generally weaker, ranging from r = 0.65 to 0.76, whereas negative correlations involving Knowledge Consistency were less pronounced (r = -0.19 to -0.32). The normal distribution demonstrated that participant scores in the intervention group were shifted toward higher values (approximately 70-90) compared with the control group (approximately 50-70), reflecting improved learning performance and patient safety knowledge following the educational intervention. These findings are consistent with the Mann–Whitney test, which demonstrated a statistically significant difference between groups (U = 6636.00, Z = −6.12, p < 0.001).

We further visualized the multidimensional relationships among patient safety knowledge domains using a correlation network (see Fig. 6). We designed the correlation network illustrating the relationships among five patient safety knowledge domains, including Knowledge Score (KS), Learning Achievement (LA), Knowledge Consistency (KC), Educational Impact (EI), and Clinical Applicability (CA). We further designed the network using 10 indicator nodes for each domain (KS1–KS10, LA1–LA10, KC1–KC10, EI1–EI10, and CA1–CA10) to represent the multidimensional nature of each construct and to provide a denser visualization of the underlying correlation structure. Each domain was represented by 10 indicator nodes to provide balanced visual representation across domains and to facilitate visualization of dense intra- and inter-domain correlation patterns. Rather than depicting each domain as a single variable, the indicator-based network better reflects the complexity of patient safety knowledge and visualization of both intra-domain and inter-domain interactions (Tella et al. 2014; Lee et al. 2022).

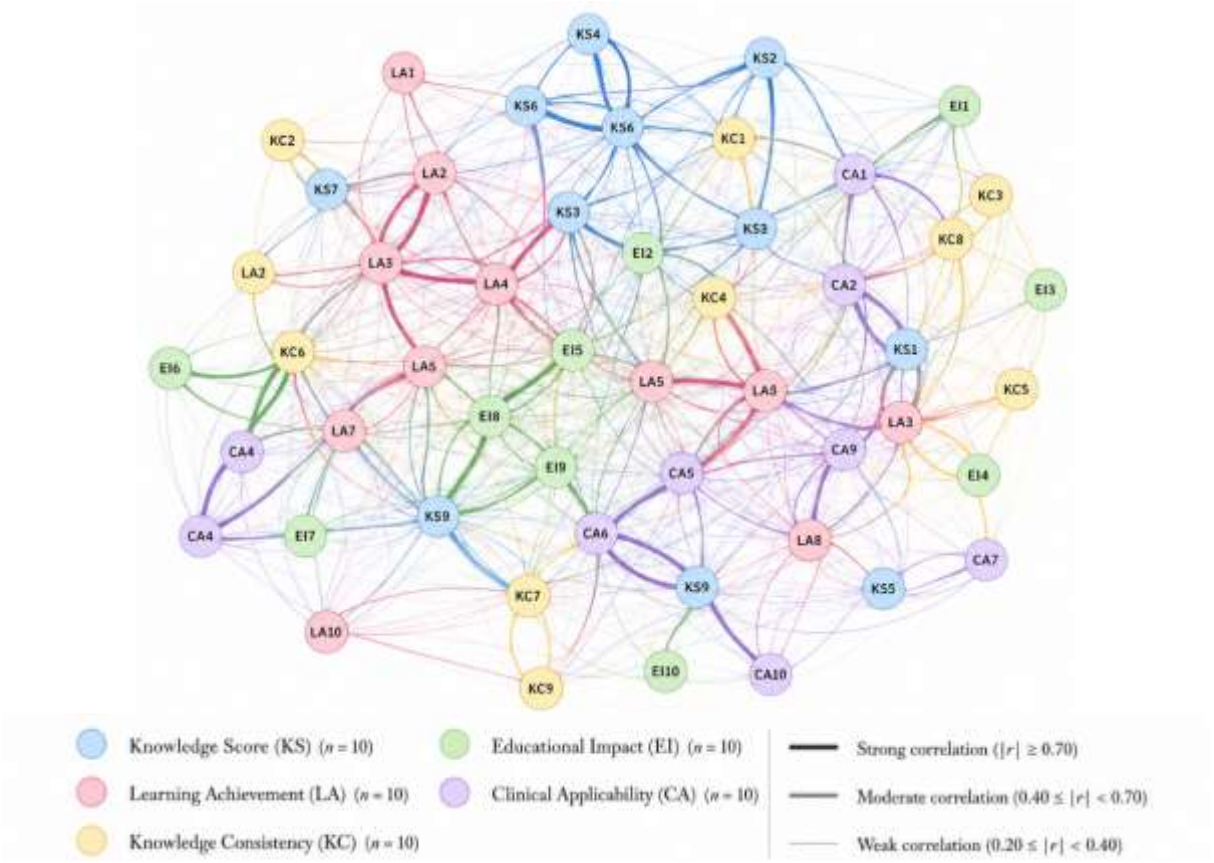

Figure 6. Correlation network of patient safety knowledge parameters showing the interactions among Knowledge Score (KS), Learning Achievement (LA), Knowledge Consistency (KC), Educational Impact (EI), and Clinical Applicability (CA). Node colours represent the five parameter categories, while edge thickness indicates the strength of the correlation.

The network topology was consistent with the correlation heatmaps presented in Figure 5, where Knowledge Score, Learning Achievement, Educational Impact, and Clinical Applicability exhibited the strongest positive relationships. The resulting network comprises 50 nodes connected by weighted edges, where node colours distinguish the five domains and edge thickness represents the relative strength of the correlations (e.g Lamonge et al. 2024; Kadir et al. 2026). Strong correlations ($|r| \geq 0.70$) were predominantly observed within the Knowledge Score, Learning Achievement, Educational Impact, and Clinical Applicability domains, whereas Knowledge Consistency exhibited comparatively fewer strong connections while maintaining multiple moderate associations with the remaining domains (Hwang et al. 2016; Kim et al. 2019). The dense interconnections among domains indicate that improvements in knowledge acquisition are closely associated with enhanced learning performance, greater educational impact, and stronger clinical applicability, supporting the multidimensional effectiveness of the educational intervention.

DISCUSSION

The present study with 300 registered nurses demonstrated a significant educational intervention that can improve patient safety knowledge compared with conventional module-based learning. Nurses in the intervention group increased their mean knowledge score from 11.72 ± 1.93 to 16.44 ± 1.46, corresponding to a mean improvement of 4.72 points, whereas the control group improved by only 2.79 points (from 12.21 ± 1.74 to 14.99 ± 1.74). The intervention group also exhibited lower score variability (SD = 1.46 vs. 1.74) and a statistically significant between-group difference (U = 6636.00, Z = −6.12, p < 0.001, r = 0.35), indicating that the

educational intervention produced a moderate but clinically meaningful effect on nurses' patient safety knowledge (Lee et al. 2022; Budak et al. 2025).

These findings are consistent with those reported by Lee et al. (2022), who demonstrated that structured patient safety education significantly improves nurses' knowledge and competency through active learning approaches. Similarly, Jamshidi et al. (2021) found that problem-based patient safety education resulted in greater improvements in nurses' knowledge and perceptions than conventional teaching methods. Furthermore, Mansour et al. (2015) emphasized that continuous patient safety education is essential for strengthening nurses' competencies and reducing preventable clinical errors. Collectively, these findings reinforce the effectiveness of structured educational interventions in promoting patient safety competencies among nursing professionals (Bedgood & Mellott, 2018; Banjarnahor et al. 2025).

Beyond improving overall knowledge scores, the present study demonstrated that patient safety knowledge functions as a multidimensional competency rather than an isolated educational outcome. Correlation analysis revealed strong positive relationships among Knowledge Score, Learning Achievement, Educational Impact, and Clinical Applicability (r = 0.87–0.96), whereas the control group exhibited comparatively weaker correlations (r = 0.65–0.76). The strongest association was observed between Educational Impact and Clinical Applicability (r = 0.96), indicating that improvements in educational outcomes were closely associated with nurses' readiness to implement patient safety principles in clinical practice (Hwang et al. 2016; Gleason et al. 2019; Lee et al. 2022; Anggriani et al. 2024).

Moreover, the correlation network consisting of 50 indicator nodes distributed across five knowledge domains illustrated dense intra-domain and inter-domain interactions, suggesting that educational gains occurred as an integrated learning process rather than as isolated improvements (Stevanin et al. 2015; Mansour et al. 2015; Lee et al. 2020; Budak et al. 2025). These findings extend previous studies by Walton et al. (2010) and Lee et al. (2022), which primarily evaluated patient safety knowledge using conventional statistical approaches without examining multidimensional relationships among knowledge domains. By integrating inferential statistics, correlation heatmaps, and network analysis, the present study provides a more comprehensive understanding of how educational interventions strengthen nurses' patient safety knowledge and its potential contribution to safer clinical practice and improved healthcare quality.

CONCLUSION

We successfully demonstrated that the educational intervention effectively improved nurses' knowledge of patient safety in regional hospitals in Medan City. Both the intervention and control groups showed statistically significant improvements following the educational program; however, nurses receiving the intervention achieved significantly higher post-intervention knowledge scores than those receiving conventional module-based learning. Comparable baseline knowledge between groups strengthened the validity of the observed intervention effect. Participant-level contour heatmaps further illustrated a broader distribution of higher knowledge scores among nurses in the intervention group, supporting the statistical findings. These results indicate that structured educational interventions can enhance nurses' understanding of patient safety principles and contribute to safer clinical practice. Integrating innovative educational approaches into continuing nursing education may strengthen professional competencies, foster a stronger patient safety culture, and improve healthcare quality. Future research should examine the long-term retention of knowledge, assess behavioural changes in clinical practice, and determine whether these educational gains translate into measurable improvements in patient safety outcomes and patient care quality.

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performed data analysis, contributed to data interpretation and visualization. T.A. supervised the study, validated the findings, and critically reviewed the manuscript.

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