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Nursing students' knowledge and confidence in peripheral intravenous cannulation utilizing simulation at the University of Tabuk

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ABSTRACT

Insertion and maintenance of a peripheral intravenous catheter (PIVC) are essential nursing skills used to administer medications, fluids, blood transfusions, and to perform diagnostic procedures. This study aimed to evaluate nursing students' knowledge and self-confidence regarding peripheral intravenous cannulation using simulation at the University of Tabuk. A descriptive cross-sectional study was conducted using a convenience sample of second- to fourth-year nursing students. Data were collected through a questionnaire distributed via Google Forms to assess students' knowledge and self-confidence in performing PIVC using simulation-based training. Out of 120 responses, 107 were included in the analysis. The results showed significant associations between age, frequency of practice, and knowledge scores. Most participants were male (62.6%) and aged 21–23 years (64.5%), and nearly half were in their fourth year of study (47.7%). Approximately half of the students reported exposure to both simulation and real-patient scenarios during IV cannulation training. The median knowledge score was 10.0 (IQR = 8.0–13.0), with significant differences observed according to age and the frequency of IV cannulation practice. The findings highlight the importance of tailored training programs, with high-fidelity simulation identified as an important method for improving IV cannulation training. These results emphasize the need for targeted educational strategies to enhance students' competence and confidence in IV cannulation, ultimately contributing to improved patient care and safety.

1. Introduction

The primary goal of nursing programs is to prepare competent nurses, capable of meeting the needs of the populace and prioritize public safety (Eyikara and Baykara, 2017). Over recent years, teaching methodologies have evolved significantly, thereby enhancing the teaching-learning process in nursing education (Campanati et al., 2021). The progress of nursing practice relies heavily on the preparedness of nursing students, who bring their education as the most crucial tool to the clinical setting throughout their careers (Albagawi, 2019). Simulation-based clinical education addresses these concerns by utilizing diverse pedagogical methods, allowing nursing students to engage in learning through simulated scenarios. This approach provides opportunities for students to deliver nursing care to patients while learning from their experiences, thus developing their knowledge and self-confidence (Albagawi, 2019).

Simulation serves as an approach, with applications across various fields such as healthcare, construction, molecular biology, aviation, automotive manufacturing, and industrial sectors (Eyikara and Baykara, 2017).

Simulation can be defined as a deliberate process aimed at achieving outcomes closely resembling clinical practice, involving the use of guided experiences that either substitute or supplement real-life encounters. It provides a faithful representation of the real world in an interactive manner (Koukourikos et al., 2021). Simulation offers a flexible continuum of fidelity levels, ranging from low fidelity to high fidelity, to accommodate the

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diverse learning needs of nursing students and align with the complexity of the procedures they are undertaking (Albagawi, 2019). In Norway, scenario-based simulation was reported to underscore the multifaceted benefits of simulation-based training in promoting not only technical skills but also confidence and satisfaction among nursing students. Vital elements associated with simulation include vital elements such as active learning, collaboration, high expectations, problem-solving, feedback, and clear objectives (Olaussen et al., 2020).

2. Literature review

Peripheral intravenous catheter (PIVC) and maintenance are vital nursing skills for delivering drugs, fluids, blood transfusions, and performing diagnostic tests for patients. Numerous literatures have suggested the effectiveness of simulation in improving technical proficiency in IV cannulation among student nurses. In fact, participants trained in simulation exhibited superior skill performance compared to those trained using traditional methods (İsmailoğlu and Zaybak, 2018). A randomized controlled experimental study investigated 72 nursing students divided into experimental and control groups, with the experimental group receiving simulation-based learning in addition to traditional education on PIVC. Results indicate that students in the experimental group achieved higher skill performance scores compared to those in the control group, highlighting the efficacy of simulation-based approaches in improving procedural competencies (Yilmaz and Sarı, 2021). A similar study in Turkey with two groups of students; one group utilizing a virtual simulator, while the other group watched an instructional video. Although both groups demonstrated improvement in knowledge, those trained through a virtual simulator exhibited significantly higher proficiency in performing the task, emphasizing the value of simulation-based approaches in enhancing psychomotor skills (İsmailoğlu et al., 2020). A quasi-experimental study involving two groups of students: the Hybrid Simulation (HS) group and the Low Fidelity Simulation (LFS) group (wherein the former interacted with standardized patients using moulage, while the latter worked with mannequins and visuals), reported that that the former had significantly higher satisfaction and self-confidence scores compared to the latter, highlighting the benefits of immersive and realistic simulation experiences in fostering confidence and satisfaction among nursing students (Yilmaz and Sarı, 2021). Moreover, simulation training was noted to have significantly increased students' self-confidence in their physical examination skills, reinforcing the positive impact of simulation-based approaches on self-confidence levels among nursing students (Bremner et al., 2006).

A multicenter prospective observational study involving 49 practitioners performing 1855 procedures assessed the learning curve for ultrasound-guided peripheral intravenous cannulation (US-guided PIVC) among novices highlighted that the first attempt cannulation success rate increased from 73% during the first procedure to 98% on the fortieth attempt. This study emphasizes that a mean number of 34 procedures was required to achieve competency, illustrating the importance of a fixed educational curriculum in enhancing first attempt success rates and reducing the time needed for successful procedures (van Loon et al., 2022).

In Saudi Arabia, there is still a dearth of literature tackling students' knowledge and confidence in intravenous therapy administration. A descriptive cross-sectional study in Abha revealed that among 117 third and fourth-year student nurses, moderate confidence levels in vein selection, site preparation, catheter insertion, and advancement were reported. However, confidence was notably low in areas like initiating the IV line in one or two attempts and assisting peers with challenging IV starts (Kaliyaperumal et al., 2023). Despite the existing research in Saudi Arabia, particularly in the region of Tabuk, there is still a scarcity of studies investigating on knowledge and self-confidence among nursing students regarding PIVC. While studies have been conducted in other regions, none have specifically focused on this population in Tabuk, highlighting the need for this present investigation.

This literature gap underscores the importance of current research. By addressing this gap, the study aims to contribute valuable insights into the knowledge and self-confidence levels of nursing students in Tabuk regarding PIVC, thus enhancing the understanding of educational needs and opportunities for improvement in nursing education in the region.

The problem of the study revolved around the nursing students' knowledge and self-confidence levels in IV cannulation utilizing simulation at the University of Tabuk. This aimed to evaluate the nursing students' knowledge acquisition and self-confidence levels in peripheral intravenous cannulation.

The significance of the study lies in its potential to inform educational practices and curriculum development within nursing programs. The study can contribute valuable insights into enhancing nursing education methodologies. Additionally, the findings may have implications for patient safety and quality of care, as proficient IV cannulation skills are crucial for delivering effective healthcare services. Also, research questions can be summarized as follows:

1. What is the demographic profile of the respondents regarding gender, age range, current academic level, and how do these factors relate to their IV cannulation training, experience, and practices?
2. What is the nursing students' knowledge level in IV cannulation utilizing simulation at the University of Tabuk?

3. What is the nursing students' confidence level in IV cannulation utilizing simulation at the University of Tabuk?
4. What factors affect the enhancement of the students' knowledge and self-confidence levels in IV cannulation simulation-based training at the University of Tabuk?

Research objective in this study is to determine the nursing students' knowledge and confidence in intravenous cannulation utilizing simulation at the University of Tabuk.

Kolb's (1984) Experiential Learning Theory (ELT) proposes that learning is a dynamic process driven by the transformation of experiences into knowledge. Central to this theory is a four-step cycle, which guides the learning process.

Initially, individuals embark on a concrete experience, immersing themselves in direct and tangible encounters, such as participating in simulations. These experiences serve as the foundation for learning, offering raw material for further exploration and understanding. This is followed by the next phase of reflective observation, where they engage in introspection and critical analysis, reflecting on their thoughts, feelings, and actions during the experience. Through this reflective process, individuals gain insight into their learning process and extract meaning from their experiences. The next step in the cycle is abstract conceptualization, where individuals abstractly conceptualize their experiences. Here, they synthesize observations and reflections to develop concepts or theories, deriving generalized principles or understandings from their experiences. Finally, individuals engage in active experimentation, applying the knowledge and insights gained from their experiences in new or different contexts. This stage involves testing theories, experimenting with new approaches, and integrating learning into practice. Through active experimentation, individuals refine their understanding, develop new skills, and adapt to changing circumstances.

Kolb underscores the iterative nature of learning, emphasizing the continuous engagement with experiences, reflection, conceptualization, and application. By embracing this cyclical process, individuals deepen their understanding, foster personal and professional growth, and navigate complex learning environments effectively.

Kolb's 4-stage Experiential Theory can serve as a cyclical framework showing how simulation-based learning is most effective. The actual simulation serves as the "concrete experience," where learners actively engage in a hands-on activity. This is followed by reflection on the experience, the development of abstract concepts and principles, and active experimentation to apply what was learned. The conceptual framework of this study is presented in Fig. 1.

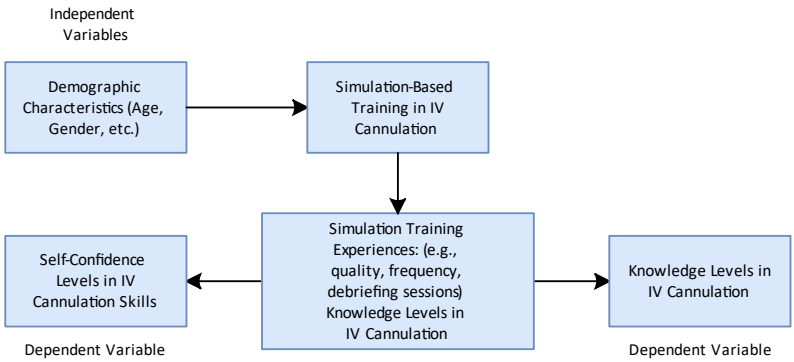

Fig. 1: The conceptual framework of the study

3. Research methods

This study utilized the descriptive, cross-sectional design to evaluate the knowledge acquisition and confidence levels in IV cannulation of the second, third, and fourth-year student-nurses at the University of Tabuk through simulation-based training.

Out of the total population of 500 student-nurses undergoing training in PIVC, convenience sampling was utilized to include 120 students; however, 13 of them did not completely answer the questionnaire, therefore, the total sample size is 107. The participants were selected based on their exposure to relevant educational content and practical experiences in this domain. The exclusion criteria include students who have not yet received training in venipuncture and PIVC, such as first-year nursing students. By targeting this specific population, the study aimed to provide insights into the competencies and educational needs of nursing students in these critical clinical skills.

Data collection was done over a 2-week period, following Institutional Review Board (IRB) approval, utilizing a Google form questionnaire, adapted from Hernon et al. (2024). The questionnaire included a brief description of the study, informed consent, and questions related to demographic and cannulation practice-related characteristics.

Each section had a designated point person for assistance. Students were instructed to complete the questionnaire voluntarily, ensuring anonymity and confidentiality. The collected data were organized in an Excel sheet for analysis.

The study was conducted using Knowledge, Attitudes, and Practices (KAP) survey retrieved from

Hernon et al. (2024). The said survey tool underwent rigorous validation procedures conducted by the authors. Face validity assessment involved experts in vascular access, educators, and public and patient involvement members to ensure the relevance, comprehensibility, and appropriateness of survey items. Subsequently, content validity assessment was carried out through content validity index (CVI) calculations, considering both item-level (I-CVI) and scale-level (S-CVI) indices. Only items with an I-CVI of 0.80 or higher were retained in the final scale, demonstrating robust content validation. Additionally, suggestions from an additional content expert further enhanced the survey's comprehensiveness and relevance. The rigorous validation process, including face and content validity assessments, ensured that the survey tool was robust and accurately captured relevant constructs related to knowledge and self-confidence in intravenous cannulation among nursing students. The research instrument comprises three sections:

1. Demographic profile: This included an 8-item section gathering information on participants' gender, age, academic level, training in IV cannulation, experience, and frequency of IV cannulation practice.
2. Knowledge section: This involved a 21-item section adapted from Hernon et al. (2024) to assess participants' knowledge of IV cannulation. Each correct answer receives one mark, while 12 incorrect or unanswered questions receive no marks. Scores are calculated based on the number of correct responses.
3. Self-confidence section: This part includes a 12-item section adapted from Hernon et al. (2024) to measure participants' self-confidence and attitudes toward IV cannulation. Responses were scored on a 0-10 scale, with scores of 6 or greater considered as positive responses and scores below 6 considered as negative responses.

In this study, an overall knowledge score was calculated for each participant based on their responses to the 21 items assessing knowledge of IV cannulation. Correct answers were assigned a score of 1, while incorrect or unanswered items received a score of 0. A high score indicates a better understanding of IV cannulation concepts.

The self-confidence section contained 12 items covering various aspects of IV cannulation self-confidence, including vein selection, terminology (such as phlebitis, infiltration, extravasation), procedural guidelines (disinfection protocols, flushing techniques), clinical decision-making (number of cannulation attempts, indications for referral), and opinions on the use of technology in IV cannulation assessment. A high score indicates a high confidence level.

The statistical analysis for this study utilized RStudio software, version 4.3.1. Descriptive statistics, including median with interquartile range (IQR) and frequency with percentage, were calculated to summarize the characteristics of participants' responses. For inferential analysis, Wilcoxon rank sum test and Kruskal-Wallis rank sum test were employed to assess the differences in median knowledge scores across groups. Additionally, multivariable generalized linear regression analysis was performed to identify predictors of participants' knowledge, with beta coefficients and 95% confidence intervals (95%CIs) reported. Fisher's exact test was utilized to examine associations between participants' experience in IV cannulation (simulation, patient, or both) and their responses to confidence items. Statistical significance was determined at a p-value threshold of 0.05.

4. Results

4.1. Demographic and cannulation practice-related characteristics

Out of the 120 student-respondents, 107 of them have complete responses, hence were considered for this study. Most of the participants were males (62.6%) and aged between 21 to 23 years (64.5%). The largest proportion of students was in their fourth year of academic study (47.7%). Regarding their experience with IV cannulation, nearly half of the students (49.5%) reported exposure to both simulation and real-patient scenarios, whereas 45.8% have experience with simulation, and only 4.7% have experience with patients. More than one-third of students had been taught the skill of IV cannulation for the last 6 months (39.3%). Additionally, the highest frequency was observed in students who performed IV cannulation less than once a month (34.6%). In terms of simulation experience, majority of participants (57.9%) recalled undergoing 1 to 3 simulations. Notably, hand hygiene was included in the IV cannulation teaching instruction for most of the students (97.2%, Table 1).

4.2. Knowledge regarding IV cannulation and the association factors

The median knowledge score was 10.0 (IQR = 8.0 to 13.0). The distribution of the knowledge score variable is shown in Fig. 2. It can be noted that significant differences ($p < 0.05$) were observed in participants' knowledge scores across certain categories. Specifically, with age, participants above 23 years demonstrated significantly higher median knowledge scores (median = 15.0, IQR = 14.0 to 16.0) compared to 18-to-20 years old (median = 10.0, IQR = 8.0 to 12.0) and those in 21 to 23 years age range (median = 10.0, IQR = 8.0 to 12.8, $p = 0.017$). Furthermore, frequency of performing IV cannulation also showed notable variations in knowledge scores, with participants performing the procedure weekly (median = 10.5, IQR = 10.0 to 12.0) and monthly (median = 12.0, IQR = 10.0 to 14.5) exhibiting significantly higher scores

compared to those performing it daily (median = 5.0, IQR = 4.0 to 10.0, p = 0.001, Table 2).

Based on the multivariable regression analysis, age emerged as a significant predictor, with participants aged above 23 years exhibiting a higher beta coefficient (beta = 4.25, 95% CI = 1.11 to 7.40, p = 0.010) compared to those aged 18 to 20 years, serving as the reference category. Additionally, the frequency of performing IV cannulation also influenced knowledge scores significantly. Participants who performed the procedure weekly had a higher beta coefficient (beta = 3.75, 95% CI = 0.52 to 6.98, p = 0.025), as did those who performed it monthly (beta = 4.01, 95% CI = 0.86 to 7.16, p = 0.015), compared to those performing it daily, which served as the reference category (Table 2).

In participants' training for IV cannulation, the most frequently utilized learning technologies/equipment were videos (89.7%), high-fidelity simulation (70.1%), and e-learning (28.0%, Fig. 3A). In participants' assessment of the most helpful learning technology for IV cannulation, high-fidelity simulation was identified as the most beneficial, with 64.5% of respondents selecting it. Following closely behind was the use of videos, chosen by 56.1% of participants. Additionally, social media was cited as helpful by 17.8% of respondents (Fig. 3B).

Table 1: Demographic and cannulation practice-related characteristics (N = 107)

Characteristic		n (%)
Gender	Male	67 (62.6%)
	Female	40 (37.4%)
Age (year)	18 to 2	33 (30.8%)
	21 to 23	69 (64.5%)
	Above 23	5 (4.7%)
Academic level	Second Year	26 (24.3%)
	Third Year	30 (28.0%)
	Fourth Year	51 (47.7%)
Time since IV cannulation training	Last 6 months	42 (39.3%)
	Last year	31 (29.0%)
	1 to 3 years ago	27 (25.2%)
	Over 3 years ago	2 (1.9%)
	Cannot recall	5 (4.7%)
	Did not receive training	0 (0.0%)
IV cannulation experience	Simulation	49 (45.8%)
	Patient	5 (4.7%)
	Both	53 (49.5%)
Frequency of IV cannulation	Daily	13 (12.1%)
	Weekly	23 (21.5%)
	Monthly	27 (25.2%)
	< once a month	37 (34.60%)
	Not on clinical placement yet	7 (6.5%)
Number of IV cannulation simulations	Cannot recall	9 (8.4%)
	1 to 3	62 (57.9%)
	4 to 6	23 (21.5%)
	7 to 9	13 (1214%)
Hand hygiene included in training	Yes	104 (97.2%)
	No	3 (2.8%)

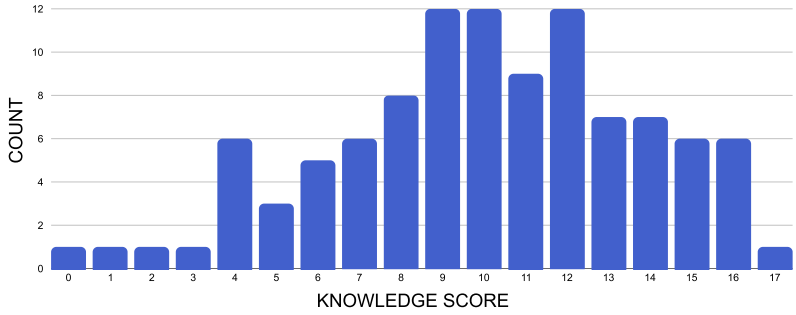

Fig. 2: A histogram depicting the frequency distribution of the knowledge score

4.3. Participants' responses to self-confidence items

Students' self-confidence in identifying the difference between arteries and veins by palpation, locating a patient's vein correctly, choosing an appropriate PIVC site, recognizing infiltration, recognizing phlebitis, the importance of performing IV cannulation successfully on the first attempt, the ability to insert a PIVC, and the ability to perform venipuncture all garnered positive responses from 72.0% to 74.8% of participants. Additionally, the importance of correct securement of a cannula and confidence in the ability to perform venipuncture on the first attempt received positive responses from 72.0% and 71.0% of participants, respectively. However, confidence in recognizing extravasation had a slightly lower percentage of positive responses, with 59.8% of participants expressing confidence in this aspect. Participants expressed concern regarding the ability to insert a PIVC and perform venipuncture on the first attempt, with 71.0% indicating significant risk associated with these tasks (Table 3).

Table 2: Factors and predictors of participants' knowledge

Characteristic	Median (IQR)	p-value	β	95% CI	p-value
Gender			**0.142**		
Male	10.5 (9.0, 13.0)				
Female	9.0 (7.0, 12.0)				
Age (years)			**0.017**		
18–20	10.0 (8.0, 12.0)		Reference	Reference	
21–23	10.0 (8.0, 12.8)		1.28	−0.22, 2.78	0.098
>23	15.0 (14.0, 16.0)		4.25	1.11, 7.40	0.010
Academic level			**0.383**		
Second year	10.0 (8.0, 12.0)				
Third year	10.0 (9.0, 12.0)				
Fourth year	10.0 (7.3, 14.0)				
Time since IV cannulation training			**0.779**		
Last 6 months	10.0 (8.0, 12.0)				
Last year	10.0 (8.0, 12.0)				
1–3 years ago	10.5 (8.3, 13.0)				
Over 3 years ago	12.5 (12.3, 12.8)				
Cannot recall	10.0 (8.0, 12.0)				
IV cannulation experience			**0.244**		
Simulation	10.0 (8.0, 12.0)				
Patient	4.0 (4.0, 7.5)				
Both	10.0 (8.0, 14.0)				
Frequency of IV cannulation			**0.001**		
Daily	5.0 (4.0, 10.0)		Reference	Reference	
Weekly	10.5 (10.0, 12.0)		3.75	0.52, 6.98	0.025
Monthly	12.0 (10.0, 14.5)		4.01	0.86, 7.16	0.015
Less than once a month	10.0 (8.0, 12.0)		2.07	−1.00, 5.14	0.190
Not on clinical placement yet	6.0 (4.0, 6.5)		−1.96	−5.72, 1.80	0.310
Number of IV cannulation simulations			**0.417**		
Cannot recall	10.0 (9.0, 10.0)				
1–3	10.0 (8.0, 13.0)				
4–6	9.0 (7.5, 12.0)				
7–9	11.0 (8.0, 14.0)				
Hand hygiene included in training			**0.073**		
No	2.0 (1.0, 6.5)				
Yes	10.0 (8.0, 13.0)				

IQR: Interquartile range; CI: Confidence interval

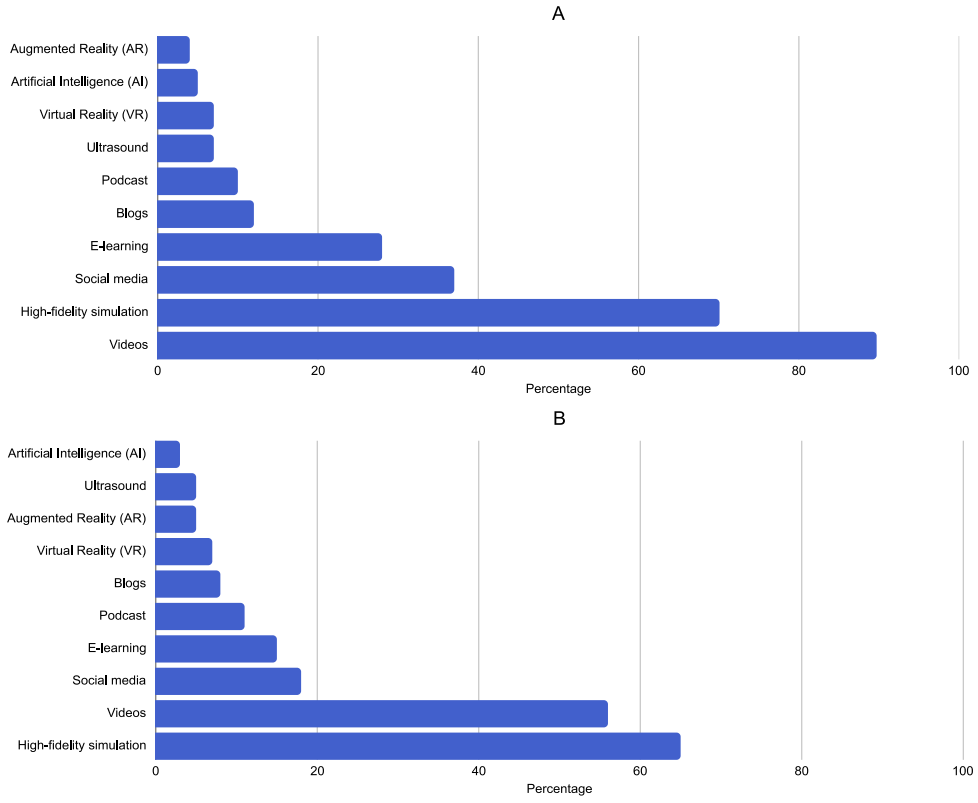

Fig. 3: The proportions of participants responses regarding learning technology/equipment that was used in the training in IV cannulation (A) their perceptions regarding the most helpful learning technology (B)

Significant associations ($p < 0.05$) were observed between participants' experience in IV cannulation and their responses to certain confidence items. Notably, participants who had experience with both simulation and patient scenarios (83.0%) and simulation only (63.3%) had significantly higher

proportions of positive responses to confidence compared to those with experience with patients only in terms of the importance of correct securement of a cannula (83.0%, 63.3% and 40.0%, p = 0.013), confidence in identifying the difference between arteries and veins by palpation (81.1%, 63.3% and 40.0%, p = 0.032), confidence in locating a patient's vein correctly (83.0%, 65.3% and 40.0%, p = 0.024), confidence in choosing an appropriate PIVC site (84.9%, 69.4% and 40.0%, p = 0.034), confidence in recognizing infiltration (92.5%, 59.2% and 40.0%, p<0.001), importance of performing IV cannulation successfully on the first attempt (81.1%, 61.2% and 40.0%, p = 0.043), confidence in the ability to insert a PIVC (84.9%, 67.3% and 40.0%, p = 0.020) and confidence in the ability to perform venipuncture on the first attempt (83.0%, 61.2% and 40.0%, p = 0.010, (Table 3).

Table 3: Characteristics of participants' responses to confidence items

Characteristic	Median (IQR)	N (%)	Experience in IV cannulation			p-value
			Simulation N = 49	Patient N = 5	Both N = 53	
Importance of correct securement of a cannula	8.00 (4.50 - 10.00)					0.013
Negative responses		30 (28.0%)	18 (36.7%)	3 (60.0%)	9 (17.0%)	
Positive responses		77 (72.0%)	31 (63.3%)	2 (40.0%)	44 (83.0%)	
Confidence in identifying the difference between arteries and veins by palpation	8.00 (4.00 - 10.00)					0.032
Negative responses		31 (29.0%)	18 (36.7%)	3 (60.0%)	10 (18.9%)	
Positive responses		76 (71.0%)	31 (63.3%)	2 (40.0%)	43 (81.1%)	
Confidence in locating a patient's vein correctly	8.00 (5.00 - 9.00)					0.024
Negative responses		29 (27.1%)	17 (34.7%)	3 (60.0%)	9 (17.0%)	
Positive responses		78 (72.9%)	32 (65.3%)	2 (40.0%)	44 (83.0%)	
Confidence in choosing an appropriate PIVC site	8.00 (6.00 - 9.00)					0.034
Negative responses		26 (24.3%)	15 (30.6%)	3 (60.0%)	8 (15.1%)	
Positive responses		81 (75.7%)	34 (69.4%)	2 (40.0%)	45 (84.9%)	
Confidence in recognizing extravasation	6.00 (4.50 - 9.00)					0.008
Negative responses		43 (40.2%)	27 (55.1%)	2 (40.0%)	14 (26.4%)	
Positive responses		64 (59.8%)	22 (44.9%)	3 (60.0%)	39 (73.6%)	
Confidence in recognizing infiltration	7.00 (5.50 - 9.00)					< 0.001
Negative responses		27 (25.2%)	20 (40.8%)	3 (60.0%)	4 (7.5%)	
Positive responses		80 (74.8%)	29 (59.2%)	2 (40.0%)	49 (92.5%)	
Confidence in recognizing phlebitis	8.00 (5.00 - 9.00)					0.018
Negative responses		32 (29.9%)	19 (38.8%)	3 (60.0%)	10 (18.9%)	
Positive responses		75 (70.1%)	30 (61.2%)	2 (40.0%)	43 (81.1%)	
Importance of performing IV cannulation successfully on the first attempt	8.00 (5.00 - 9.00)					0.043
Negative responses		28 (26.2%)	16 (32.7%)	3 (60.0%)	9 (17.0%)	
Positive responses		79 (73.8%)	33 (67.3%)	2 (40.0%)	44 (83.0%)	
Confidence in the ability to insert a PIVC	8.00 (5.50 - 9.00)					0.020
Negative responses		27 (25.2%)	16 (32.7%)	3 (60.0%)	8 (15.1%)	
Positive responses		80 (74.8%)	33 (67.3%)	2 (40.0%)	45 (84.9%)	
Confidence in the ability to perform venipuncture	8.00 (5.00 - 9.00)					0.132
Negative responses		29 (27.1%)	17 (34.7%)	2 (40.0%)	10 (18.9%)	
Positive responses		78 (72.9%)	32 (65.3%)	3 (60.0%)	43 (81.1%)	

4.4. Participants' practice regarding IV cannulation (supplemental)

Regarding the location where most IV cannulas are observed to be placed in professional experience, the back of the hand (39.3%) and the antecubital fossa (37.4%) were the most reported sites. Concerning the use of technology in IV cannulation practice, 47.7% of participants reported using technology, with mannequins (33.3%) and simulations (33.3%) being the primary forms. Moreover, in documenting IV cannulation practice, 43.9% of participants reported using technology. Regarding the necessity of regular re-training, a vast majority of participants (93.5%) expressed agreement that it should be provided (Table 4).

Regarding the difference between students with experience in IV cannulation, results revealed significant difference among those who had ever used technologies in documenting IV cannulation practice, with 34.7%, 40.0% and 52.8% of IV technology users among experienced participants with simulation, patients and both forms, respectively (p = 0.012, Table 4).

5. Discussion

This study aimed to evaluate the participants' knowledge and self-confidence levels in PIVC, involving 107 student nurses. Most participants were males, aged 21-23 years, and in their fourth year of study. Nearly half have exposure to both simulation and real-patient scenarios. Hand hygiene was emphasized during instruction for most participants (Table 1). The median knowledge score among participants was 10.0 (IQR = 8.0 to 13.0) (Fig. 2).

The study result suggests areas to prioritize during education or training to be more beneficial to enhance participants' comprehension. Interestingly, these findings are parallel with those of Khairunniza et al. (2019), who assessed medical students' knowledge of PIVC at a private university in Seremban, Negeri Sembilan, Malaysia following teaching sessions and found a high level of knowledge among participants. While a difference in population exists between this study and Khairunniza et al.'s (2019) both have underscored the importance of ongoing education and training to

ensure proficiency in IV cannulation practices among healthcare professionals.

5.1. Knowledge levels and associated factors

This study reported that age and frequency of performing IV cannulation significantly influenced participants' knowledge scores. Specifically, participants aged above 23 years and those performing IV cannulation weekly or monthly exhibited higher median knowledge scores compared to younger age groups and daily performers, respectively. Multivariable regression analysis confirmed age and frequency of practice as significant predictors of knowledge scores (Table 2).

It is noteworthy that older students scored higher than their younger counterparts, a phenomenon often referred to as the "relative age effect" (RAE) in academic settings. This underscores the influence of better-developed metacognitive skills, increased maturity, better self-regulation of learning, accumulated work or life experience, and enhanced time management skills on academic success (Hukkelberg et al., 2026; Ramasaco, 2024).

This study also highlighted that weekly/monthly practice (known as "spaced" or "distributed" practice) is superior to daily, intensive practice ("massed practice" or cramming) for long-term retention and memory consolidation. The primary benefits include deeper encoding into long-term memory, improved recall efficiency, and enhanced skill acquisition. Spaced learning improves long-term memory by increasing retrieval effort and enhancing the pattern reinstatement of prior neural representations, which may be achieved by reducing the momentary retrieval strength as the extended repetition lags might help to eliminate the residual representation in working memory (Feng et al., 2019; Yuan, 2022). This implies that we take these factors into consideration to tailor-fit educational approaches and hands-on experience in enhancing students' understanding of IV cannulation concepts.

Moreover, this study revealed that participants predominantly utilized videos, high-fidelity simulation (HFS), and e-learning for IV cannulation training (Fig. 3A). HFS emerged as the most beneficial learning technology, followed by videos (Fig. 3B).

HFS is widely acknowledged as highly beneficial because it streamlines the entire learning cycle, effectively bridging the gap between theoretical knowledge and practical application. This integration is crucial for fostering deeper comprehension and facilitating the transfer of skills to real-world scenarios. HFS can simulate practical experiences that reinforce theoretical understanding, thereby enhancing learning outcomes (Yu et al., 2025; Abdulhussain et al., 2022; Salameh et al., 2021).

Table 4: Participants' practice regarding IV cannulation (Supplemental)

Characteristic	Experience in IV cannulation					
	Missing	Overall, N = 107	Simulation N = 49	Patient N = 5	Both N = 53	p-value
In your professional experience (not to be confused with television) where have you observed most IV cannulas to be placed?	0 (0%)					0.636
Back of the hand		42 (39.3%)	23 (46.9%)	1 (20.0%)	18 (34.0%)	
Forearm		19 (17.8%)	7 (14.3%)	2 (40.0%)	10 (18.9%)	
Antecubital Fossa		40 (37.4%)	16 (32.7%)	2 (40.0%)	22 (41.5%)	
Do not know		6 (5.6%)	3 (6.1%)	0 (0.0%)	3 (5.7%)	
Have you ever used technology in your practice of IV Cannulation?	0 (0%)					0.075
No		56 (52.3%)	31 (63.3%)	1 (20.0%)	24 (45.3%)	
Yes		51 (47.7%)	18 (36.7%)	4 (80.0%)	29 (54.7%)	
If you have used technology in your practice of IV Cannulation, what technology do/did you use? If you have not, please note N/A	39 (76%)					0.588
Do not know		1 (8.3%)	0 (0.0%)	0 (0.0%)	1 (12.5%)	
Mannequin		4 (33.3%)	2 (66.7%)	1 (100.0%)	1 (12.5%)	
Simulation		4 (33.3%)	1 (33.3%)	0 (0.0%)	3 (37.5%)	
Video		3 (25.0%)	0 (0.0%)	0 (0.0%)	3 (37.5%)	
Have you ever used technology in documenting your practice of IV Cannulation?	0 (0%)					0.012
No		38 (35.5%)	15 (30.6%)	3 (60.0%)	20 (37.7%)	
Yes		47 (43.9%)	17 (34.7%)	2 (40.0%)	28 (52.8%)	
NA		22 (20.6%)	17 (34.7%)	0 (0.0%)	5 (9.4%)	
Do you think regular re-training should be provided on IV cannulation?	0 (0%)					0.069
No		7 (6.5%)	5 (10.2%)	1 (20.0%)	1 (1.9%)	
Yes		100 (93.5%)	44 (89.8%)	4 (80.0%)	52 (98.1%)	

n (%)

These findings emphasize the importance of interactive and immersive learning experiences in IV cannulation training programs. Aligning with our study, Yilmaz and Sari (2021) conducted a randomized controlled quasi-experimental study to assess the impact of simulation-based learning on

first-year nursing students' knowledge, performance, and clinical assessment skills related to IV therapy administration. Their findings showed that students who underwent hybrid simulation training demonstrated better knowledge, performance, clinical assessment skills, satisfaction, and self-confidence compared to those who received low-fidelity simulation training. Similarly, this study evaluated participants' knowledge, self-confidence, and practices regarding IV cannulation, suggesting that age and frequency of IV cannulation practice significantly influenced knowledge scores (Table 2). Additionally, it is noteworthy that participants who predominantly utilized high-fidelity simulation, have identified it as the most beneficial learning technology for IV cannulation training.

The perceived benefit of HFS aligns with Kolb's Experiential Theory because it inherently incorporates all four stages of the learning cycle, providing a platform for learners to progress through each stage of Kolb's cycle in a structured and effective manner: In concrete experience, simulation provides a realistic, hands-on opportunity to engage in complex, real-world scenarios in a safe environment. The crucial debriefing sessions after HFS sessions encourage students to critically reflect on their actions, decisions, and outcomes, which is the reflective observation stage. Through reflection and discussion, students develop new clinical reasoning and decision-making skills (abstract conceptualization) which they can then apply to future real-world clinical practice (active experimentation). Thus, HFS is perceived as highly beneficial because it facilitates movement through the entire learning cycle, directly linking theory to practice and promoting deeper learning and the transfer of skills (Wall, 2017; Aldolaim et al., 2025; Wijnen-Meijer, 2022). This has been highlighted by van Loon et al. (2022) in a multicenter prospective observational study to assess the learning curve for ultrasound-guided peripheral intravenous cannulation (US-guided PIVC) among novices reporting that the first attempt cannulation success rate increased from 73% during the first procedure to 98% on the fortieth attempt, requiring a mean of 34 procedures to achieve competency. This study illustrates the importance of a structured educational curriculum in improving first attempt success rates and reducing the time needed for successful procedures. These findings further support the effectiveness of high-fidelity simulation and structured training programs in enhancing the technical skills and confidence of nursing students in IV cannulation. Their findings align with our results, emphasizing the significance of structured and immersive educational approaches in enhancing proficiency and confidence in IV cannulation.

5.2. Self-confidence and experience

This study reported that participants exhibited confidence in various aspects of IV cannulation, reflecting the importance of nursing students' proficiency in peripheral intravenous catheter (PIVC) insertion and management (Table 3). This aligns well with the background and aim of Indarwati and Primanda's (2021) study, which underscored the crucial role of PIVCs in patient care and the necessity for nursing students to be competent in PIVC procedures. Our findings highlight the significance of ensuring nursing students' confidence in IV cannulation, emphasizing the importance of hands-on experience and interactive learning methods, as supported by Indarwati and Primanda's (2021) findings. Additionally, Marchionni et al.'s (2024) study addresses a critical gap in nursing education by developing and validating the Nursing Hoskinal Student Peripheral Intravenous Catheter Insertion Self-Confidence Scale. This standardized tool aims to measure nursing students' confidence in learning and performing PIVC insertions, crucial for predicting PIVC insertion success. These study findings resonate with the need for such a scale, as they revealed varying levels of confidence among participants in different aspects of IV cannulation. Specifically, the identification of slightly lower confidence levels in recognizing extravasation underscores the importance of targeted training and education to address specific areas where students may lack confidence.

Furthermore, this study's findings regarding the significant influence of experience in IV cannulation on confidence levels, particularly exposure to both simulation and patient scenarios, emphasize the importance of hands-on experience and interactive learning methods in nursing education. This aligns with the aim of Marchionni et al.'s (2024) study to assess students' confidence in both learning about and performing PIVC insertions. Overall, these studies collectively highlight the importance of confidence in IV cannulation among nursing students and underscore the significance of tailored educational interventions to enhance students' competence and confidence in this critical area of patient care.

5.3. Practices

This study suggested that the common sites for IV cannula placement included the back of the hand and the antecubital fossa, which aligns with the standard practice observed in clinical settings. Additionally, this study reported that nearly half of the participants reported using technology, particularly mannequins and simulations, in IV cannulation practice (Table 4). This finding resonates with the structured simulation-based training implemented in the study by Hassanein et al. (2021), indicating the effectiveness of such training methods in real-world practice. Furthermore, both studies emphasized the importance of regular re-training in IV cannulation practice. Hassanein et al. (2021) recommended continuous education, feedback, assessment, and monitoring to retain the gained improvement in

attitudes, knowledge, and skills. Similarly, this study reported a high proportion of participants recognizing the necessity of regular re-training in IV cannulation practice, highlighting the ongoing commitment to professional development among healthcare providers (Table 4).

5.4. Implications and recommendations

The study highlights the importance of age and frequency of practice in predicting knowledge levels in IV cannulation. It underscores the effectiveness of high-fidelity simulation and interactive learning technologies in enhancing learning outcomes. The findings emphasize the need for ongoing re-training and support for confidence-building initiatives, particularly among less-experienced practitioners. Likewise, a correlational study can be done and comparative hypotheses can be utilized to directly test the effectiveness of simulation-based training against other methods.

5.5. Limitations

Limitations of the study include the reliance on self-reported data, use of convenience sampling method, single-institution setting, the lack of a control group, and the use of cross-sectional design preventing causal inference. Future research could explore longitudinal outcomes of IV cannulation training programs and assess the impact of innovative educational interventions on knowledge retention and clinical competence.

6. Conclusions

This study provides valuable insights into the factors influencing development of PIVC knowledge and self-confidence among health professions students. A course design anchored on Kolb's Experiential learning cycle integrating experience, theory and simulation, is a valuable addition to the existing pedagogy in medical education providing hands-on experience and critical reflection. To further gain insights into the learning effects, it is recommended to further explore this approach in a different setting or context.

List of abbreviations

AI	Artificial intelligence
AR	Augmented reality
CI	Confidence interval
CVI	Content validity index
ELT	Experiential learning theory
HFS	High-fidelity simulation
HS	Hybrid simulation
I-CVI	Item-level content validity index
IQR	Interquartile range
IRB	Institutional Review Board
IV	Intravenous
KAP	Knowledge, attitudes, and practices
LFS	Low-fidelity simulation
N/A	Not applicable
PIVC	Peripheral intravenous catheter
RAE	Relative age effect
S-CVI	Scale-level content validity index
US-guided	Ultrasound-guided
VR	Virtual reality

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Compliance with ethical standards

Ethical considerations

This study was approved by the Research Ethics Committee of the University of Tabuk (Approval No. UT-383-210-2024). Written electronic informed consent was obtained from all participants prior to data collection. Participation was voluntary, and all data were anonymized and treated confidentially in accordance with the Declaration of Helsinki.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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