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Research Article

Simulation-Based Intravenous Cannulation Training Using Peyton's Four-Step Method in Undergraduate Nursing Students: A Pilot Quasi-Experimental Study

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ABSTRACT

Introduction: Peripheral intravenous (IV) cannulation is a fundamental yet challenging skill for undergraduate nursing students. Simulation-based education provides a safe and controlled environment for practicing invasive procedures; however, its effectiveness depends on the instructional design used. Peyton's four-step method offers a structured, learner-centered approach that may enhance procedural competence.

Objectives: This study aimed to evaluate the effectiveness of simulation-based IV cannulation training using Peyton's four-step method on procedural learning outcomes among novice nursing students. Secondary outcomes included procedural efficiency (time and number of attempts), self-efficacy, and learner acceptance of the instructional method.

Methods: This pilot quasi-experimental study enrolled 16 first-semester nursing students who were randomly assigned to an intervention group (n = 8) using Peyton's four-step method (180-min simulation) or a control group (n = 7) receiving traditional instruction. The control group's traditional instruction encompassed standard didactic lectures and instructor-led demonstrations with "observe and do" approaches. Post-intervention performances were video-recorded and assessed by blinded evaluators using a validated 26-item checklist. Outcome measures included procedural time, attempts, and general/IV cannulation self-efficacy. Data were analyzed using appropriate statistical tests ($p < 0.05$).

Results: Students trained with Peyton's four-step method achieved significantly higher procedural learning scores than the control group (intervention: 16.79 ± 6.27 vs. control: 10.45 ± 2.21; p = 0.002; d = 1.32). While the intervention group showed trends towards shorter cannulation times (6.50 ± 0.53 vs. 7.00 ± 0.58 minutes) and fewer attempts (1.13 ± 0.35 vs. 1.43 ± 0.53), these differences were not statistically significant. Learner acceptance of the instructional method was significantly higher in the intervention group (48.57 ± 3.15 vs. 43.28 ± 5.58; p = 0.039; d = 1.05), reflecting strong learner approval of the structured approach.

Conclusions: This pilot study suggests that Peyton's four-step method may be a well-accepted and effective instructional strategy for teaching IV cannulation in simulation settings, with positive trends in procedural learning. However, due to the very small sample size, no definitive conclusions can be drawn regarding the overall effectiveness or generalizability of the findings. Further research with larger sample sizes is recommended to confirm these preliminary results.

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1. Introduction

Developing competence in clinical procedures is a core component of undergraduate nursing education and is essential for ensuring safe, effective patient care. Peripheral intravenous (IV) cannulation is one of the most frequently performed yet technically demanding procedures, requiring psychomotor precision, anatomical knowledge, and adherence to safety protocols (1, 2). Novice nursing students often experience anxiety, low self-efficacy, and inconsistent performance when they first attempt IV cannulation, which may negatively affect both patient safety and learning outcomes (3, 4).

Simulation-based education provides a safe and structured environment for practicing complex procedures without exposing patients to risk (5). Skills-lab simulation supports repeated practice, immediate feedback, and guided error correction, all of which enhance psychomotor learning and procedural confidence (6-8). However, the effectiveness of simulation training depends heavily on the instructional method. Traditional "observe and do" approaches often lack adequate cognitive scaffolding and may result in disorganized skill acquisition or fragmented learning, as learners must integrate disparate steps without structured guidance (9).

Peyton's four-step method offers a structured, learner-centered sequence—demonstration, deconstruction, elicitation, and independent performance—that has been shown to improve procedural accuracy, skill retention, and learner engagement (10). Although originally designed for 1:1 instruction, modified small-group applications have demonstrated feasibility in skills-lab settings (11-14).
Several studies have evaluated Peyton's four-step method across different clinical skills. Evidence shows that the method improves technical performance and procedural retention compared with conventional teaching (12, 14). Awad and Mohamed (13) demonstrated significant performance improvements among nursing students trained using Peyton's four-step method in skills labs. A recent meta-analysis by Giacomino et al. (12) also confirmed that Peyton's approach yields superior skill acquisition across health professions education.

However, while IV cannulation is a high-frequency, high-risk nursing procedure, only a limited number of studies have focused specifically on applying Peyton's four-step method to IV cannulation training in simulation environments. Most existing research has examined general psychomotor skills (12, 14) or venipuncture-related competencies (15), and there is insufficient evidence on how Peyton's structured method influences IV cannulation performance, efficiency, self-efficacy, or learner acceptance among novice nursing students. Furthermore, gaps remain regarding the feasibility and effectiveness of implementing the method in small group, undergraduate simulation settings.
This pilot quasi-experimental study compared simulation-based IV cannulation training using Peyton's four-step method versus traditional "observe and do" instruction among first-year nursing students, evaluating procedural learning outcomes, efficiency, self-efficacy, and learner acceptance.

2. Objectives

This study aimed to evaluate whether simulation-based IV cannulation training using Peyton's four-step method improves technical performance, procedural efficiency, and learning-related outcomes compared with traditional instruction among first-year nursing students.

3. Methods

3.1 Study Design

This pilot quasi-experimental, two-group pretest–posttest study was conducted in the clinical skills laboratory of the School of Nursing and Midwifery, Islamic Azad University, Najafabad Branch, Iran, during the autumn 2024 semester. The study evaluated the effectiveness of simulation-based IV cannulation training using Peyton's four-step method on nursing students' technical performance, procedural efficiency, and learning outcomes. Although the design was not a randomized controlled trial, reporting procedures followed CONSORT-aligned principles to ensure transparency in participant flow and group allocation.

3.2 Participants

Participants were first-semester undergraduate nursing students with no prior experience in IV cannulation or paramedical training. The inclusion criteria were enrollment in the first semester, no prior experience in IV cannulation or venipuncture training, no paramedical background, and willingness to participate and provide written informed consent. The exclusion criteria included absence from any training session, refusal to participate in video recording, or withdrawal from the study during the intervention period.

A total of 16 eligible students were recruited via convenience sampling. Participants were randomly allocated to intervention and control groups (eight per group) using a computer-generated randomization list. One student in the control group withdrew during training, resulting in a final analytic sample of 15 students.

For this pilot study, a priori sample size estimation was performed using G*Power software, solely to guide feasibility and recruitment, not to ensure definitive statistical power. Based on previous studies evaluating Peyton's four-step method in procedural skill acquisition with a medium effect size (Cohen's d = 0.8) for primary performance outcomes, assuming a two-tailed alpha of 0.05 and statistical power of 0.80, a minimum of 14 participants (7 per group) was required. To account for potential attrition (estimated at 10%), a total of 16 students were enrolled (8 per group). Figure 1 shows a CONSORT-like flow diagram summarizing recruitment, allocation, follow-up, and analysis.

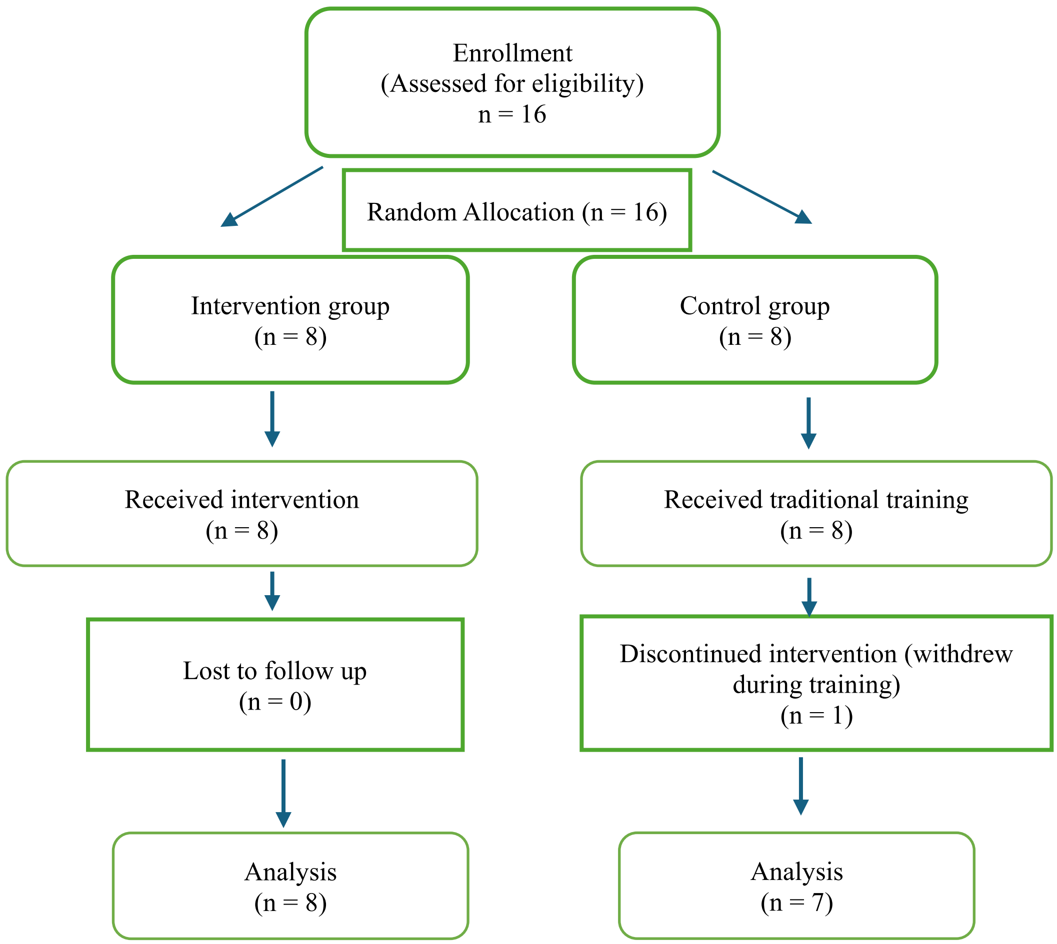

Figure 1: CONSORT Flow Diagram of Participant Allocation and Follow-up

3.3 Scales

3.3.1 Technical performance:

Technical performance was assessed using a validated 26-item procedural checklist for IV catheterization. This checklist, adapted from the "Manual of Clinical Skills Nursing" edited by the faculty members of the Nursing and Midwifery College, Islamic Azad University, Najafabad Branch, Iran (developed by the research team based on clinical guidelines), awarded one point for each correctly completed step. Inter-rater reliability for the checklist was high (intraclass correlation coefficient [ICC] = 0.91).

3.3.2 Procedural efficiency:

Procedural efficiency was measured as follows:

-Total time to successful cannulation: Recorded from the moment the student picked up the catheter to the point of successful venous entry.

-Number of attempts: The number of attempts required for correct catheter placement. The inter-rater reliability for these measures was high (intraclass correlation coefficient [ICC] = 0.91).

-Intravenous (IV) Cannulation Self-efficacy: Measured using the Cannulation Self-efficacy Questionnaire, a 5-item questionnaire assessing students' confidence in performing specific steps of the

IV cannulation procedure (α = 0.88). The questionnaire used a 6-point Likert scale (1 = strongly disagree, 6 = strongly agree). The items assessed awareness of anatomical structures, familiarity with equipment, knowledge of procedural steps, and the ability to insert into a simulator vein and a patient's vein.

3.3.3 Acceptance of the Instructional Method:

A 9-item "Teaching Method Acceptance Scale" was administered immediately after the intervention. This scale assessed learners' perceptions of clarity, usefulness, engagement, repetition, opportunities for independent performance, and overall educational value (α = 0.90). Responses were rated on a 6-point Likert scale (1 = strongly agree 6 = strongly disagree), with higher scores indicating greater acceptance.

3.3.4 General Self-efficacy Scale (GSES):

General self-efficacy was assessed using the GSES developed by Scherer et al. (1982). This 17-item instrument measures general confidence in executing tasks and coping with life challenges, using a 5-point Likert scale (total score range: 17–85). The scale demonstrated good internal consistency (Cronbach's α = 0.85).

3.3.5 Learning Styles Assessment:

Learning styles were assessed using the validated Kolb Learning Styles Inventory (LSI). The 12-item Kolb LSI evaluates four learning modes—concrete experience, reflective observation, abstract conceptualization, and active experimentation—using a 4-point Likert scale. The instrument has demonstrated reliability (Cronbach's α = 0.85; split-half = 0.92).

3.4 Data Collection

-Intervention Group: The intervention group received simulation-based IV cannulation training employing Peyton's four-step method. Training was delivered in two 90-minute sessions. The instructor–student ratio was maintained at 1:4 within small groups. The training followed four sequential steps: (1) Demonstration – the instructor performed the procedure without verbal commentary; (2) Deconstruction – the instructor re-demonstrated with step-by-step verbal explanations and rationale; (3) Elicitation – the students verbally guided the instructor through each step; and (4) Independent performance – each student independently performed IV cannulation on a high-fidelity simulator (ARM model P50, ERIMED, Germany). During the elicitation and independent performance phases, the instructor provided immediate, task-specific, corrective feedback. Each student engaged in approximately 10–15 minutes of supervised hands-on practice. Peer observation and informal feedback were encouraged.

-Control Group: The control group received traditional "observe and do" instruction over two 90-minute sessions. The session began with an instructor demonstration including standardized step-by-step verbal narration with rationale. Following the demonstration, students engaged in individual practice sessions on the same task trainer. Each student was allocated approximately 10–15 minutes of supervised practice time. The instructor circulated and provided real-time direct feedback. The instructor-to-student ratio during practice was effectively 1:7. This instructional method did not include structured deconstruction or elicitation phases. The control group received an equivalent total training duration (180 minutes) to that of the intervention group.

-Outcome Assessment: To minimize assessment bias, all post-intervention performances were video recorded using fixed CCTV cameras. The recordings were independently evaluated by two blinded assessors unaware of the group allocation. Students were reminded not to disclose their training method during assessment.

-Timing of Assessments: Baseline demographic data, learning styles (Kolb LSI), and pre-intervention self-efficacy scores were collected prior to training. Post-intervention assessments were conducted immediately after the second session.

3.5 Data Analysis

Data were analyzed using SPSS (version 20). The normality of the data distribution was assessed using the Shapiro–Wilk test, which indicated that reflective observation ($p = 0.048$), pre-intervention IV cannulation self-efficacy ($p = 0.036$), and number of attempts ($p = 0.042$) were non-normally distributed. These variables were analyzed using non-parametric tests (Mann-Whitney U). For variables meeting normality assumptions, independent t-tests were conducted to compare means between groups. Non-normal variables were analyzed using the Mann–Whitney U test. Analysis of covariance (ANCOVA) was performed to compare post-intervention self-efficacy scores while controlling for baseline (pre-intervention) values to isolate the effect of the training intervention on self-efficacy. For t tests, Cohen's d was reported; for Mann Whitney U tests, rank-biserial correlation (r) was calculated; for ANCOVA, partial eta squared (η^2) was reported. A significance level of $p < 0.05$ was set for all statistical tests.

3.6 Ethical consideration

Ethical approval was obtained from the Research Ethics Committee of Islamic Azad University, Najafabad Branch, Iran (IR.IAU.NAJAFABAD.REC.1402.224). Written informed consent was obtained from all participants prior to enrollment. Confidentiality and anonymity were ensured throughout the study. Participants were informed of their right to withdraw at any time without penalty.

4. Results

A total of 15 first-semester nursing students completed the study (intervention: n = 8; control: n = 7). The baseline demographic and educational characteristics are presented in Table 1. No statistically significant differences were observed between the two groups in age, gender, place of residence, socioeconomic status, or predominant learning style (all $p > 0.05$), indicating that the groups were comparable at baseline.

Table 2 summarizes baseline learning characteristics and self-efficacy measures. Although the control group demonstrated slightly higher mean scores in reflective observation and abstract conceptualization, and the intervention group showed higher scores in active experimentation, none of these differences were statistically significant (all $p > 0.05$). Pre-intervention general self-efficacy scores were also similar between groups, suggesting comparable readiness for learning prior to the intervention.

Table 1: Baseline Demographic and Educational Characteristics of Participants (Intervention vs. Control)

Variable	Intervention (n = 8) Mean ± SD	Control (n = 7) Mean ± SD	p value
Age (y)[a]	19.25 ± 1.04	19.86 ± 1.07	0.322
Gender[b]	No. (%)	No. (%)	
Female	8 (100)	5 (71.4)	0.182
Male	0 (0)	2 (28.6)	
Place of residence[b]			
Esfahan	4 (57.1) *	2 (28.6)	0.608
County	3 (42.9) *	5 (71.4)	
Socioeconomic Status[b]			
High	1 (16.7)	2 (28.6)	0.571
Medium	5 (83.3)	5 (71.4)	
Low	0 (0)	0 (0)	
Learning style[b]			
Innovator	0 (0)	1 (14.3)	0.284
Pragmatist	1 (16.7)	0 (0)	
Decision-maker	5 (83.3)	4 (57.1)	
Planner	0 (0)	2 (28.6)	

* Total sample size for analysis was N=15 (Intervention: n=8, Control: n=7). However, for some variables in the intervention group, data were missing: Place of Residence (n=7 valid responses), Socioeconomic Status (n=6 valid responses), Learning Style (n=6 valid responses). Percentages for these variables are based on valid responses. The statistical test used for each variable is indicated. A p-value < 0.05 was considered statistically significant. No participants were excluded from the study due to missing demographic data; all 15 participants completed the intervention and post-intervention assessments
a: Independent t-test
b: Chi-square test

Table 3 presents post-intervention outcomes. Students trained using Peyton's four-step method achieved significantly higher procedural learning scores than those trained using the traditional method (mean difference = 6.34; 95% CI: 2.41–10.27; $p = 0.002$). The effect size was large (Cohen's $d = 1.32$).

Although the intervention group completed IV cannulation in less time on average, the difference in procedural time did not reach statistical significance (mean difference = –0.50 minutes; 95% CI: –1.12 to 0.12; $p = 0.189$), corresponding to a moderate effect size (Cohen's $d = 0.62$). Similarly, the intervention group required fewer attempts to achieve successful cannulation, but the difference was not statistically significant (mean difference = –0.30; 95% CI: –0.78 to 0.18; $p = 0.336$; Cohen's $d = 0.48$).

The analysis of self-efficacy outcomes showed no statistically significant difference in general self-efficacy between groups after adjusting for baseline values using ANCOVA ($F (1,12) = 0.70$; $p = 0.419$; $\eta^2 = 0.055$). However, the intervention group demonstrated a higher adjusted mean score, suggesting a potentially meaningful trend that may become more pronounced with a larger sample or extended follow-up. IV cannulation self-efficacy demonstrated a similar pattern, with greater improvement in the intervention group, though not statistically significant.

The acceptance of the instructional method differed significantly between the groups. Students in the intervention group reported higher acceptance scores compared with the control group (mean difference = 5.29; 95% CI: 0.41–10.17; p = 0.039), with a large effect size (Cohen's d = 1.05). This finding reflects strong pedagogical acceptability of Peyton's four-step method structured, stepwise instructional approach.

5. Discussion

This pilot study explored the comparative effectiveness of Peyton's four-step method against a traditional "observe and do" approach for procedural learning in a simulated IV cannulation setting. Our key findings indicate that Peyton's four-step method was associated with higher learner acceptance and demonstrated trends toward improved procedural performance, specifically reduced cannulation time and fewer attempts, though these did not reach statistical significance. These preliminary results suggest that a structured, simulation-based pedagogical framework may offer advantages for acquiring complex psychomotor skills.

Table 2. Baseline Learning Characteristics and Self-efficacy Scores

Variable	Intervention (n = 8) Mean ± SD	Control (n = 7) Mean ± SD	p value
Learning styles			
concrete experience[a]	33.75 ± 5.68	36.14 ± 4.81	0.398
Reflective observation[b]	38.75 ± 5.73	47.71 ± 15.27	0.146
Abstract conceptualization[a]	37.13 ± 6.22	40.43 ± 6.19	0.322
Active experimentation[a]	44.00 ± 4.69	42.00 ± 3.65	0.379
Self-efficacy measures			
IV cannulation self-efficacy (Pre)[b]	24.88 ± 7.18	29.86 ± 0.38	0.397
General self-efficacy (Pre)[a]	65.13 ± 7.97	72.00 ± 6.95	0.419

The statistical test used for each variable is indicated in the "statistical test used" column. The choice between independent t test and Mann-Whitney U test was based on the Shapiro-Wilk test for normality.
a: Independent t-test
b: Mann-Whitney U test

The observed trends favoring Peyton's four-step method in procedural efficiency and learning scores align with a growing body of evidence supporting structured instructional strategies in healthcare education (6, 13, 16, 17). Specifically, the deconstruction and elicitation phases inherent in Peyton's four-step method approach likely facilitate cognitive organization and deliberate practice by explicitly breaking down complex tasks and requiring active recall and application (10, 12, 18). This structured guidance may help to reduce extraneous cognitive load, thereby enhancing the efficiency of skill acquisition (12, 18). Simulation-based education is a well-established modality for improving clinical competence, reducing learner anxiety, and fostering confidence (6, 7, 19). Our study adds to this literature by providing preliminary evidence that even a short training period utilizing Peyton's four-step method can yield positive outcomes in procedural learning.

The tendency towards faster cannulation times and fewer attempts in the Peyton's four-step method group, while not statistically significant, is noteworthy given the persistent challenges associated with peripheral IV catheter failure and the critical importance of first-attempt success in clinical practice (1, 2, 20). These observed trends, though preliminary, are consistent with broader research indicating that structured, simulation-based training can enhance procedural efficiency and minimize errors (1, 15). Therefore, educational strategies, such as Peyton's four-step method, warrant further investigation to confirm their impact on first-attempt success rates. The decline in self-efficacy observed in both groups, although seemingly counterintuitive, has been documented in other simulation studies where learners recalibrate their perceived competence upon encountering procedural complexity. This phenomenon underscores the need for robust self-efficacy development, particularly for invasive procedures, which may require repeated practice, progressive reinforcement, and consistent, supportive feedback throughout the learning process (3, 4, 16, 21).

Learners reported significantly higher acceptance of Peyton's four-step method, valuing its inherent clarity, structured progression, and opportunities for active engagement. This finding resonates strongly with previous research highlighting enhanced learner satisfaction and active participation associated with this method (10, 13). The emphasis on guided practice followed by independent performance within the framework of Peyton's four-step method also aligns with contemporary clinical teaching principles that prioritize active learning methodologies and the cultivation of learner autonomy (13, 21, 22). Furthermore, this study contributes to the emerging literature on adaptations of Peyton's four-step method for small-group instruction, reinforcing its feasibility and educational value, particularly in contexts with limited instructor-to-student ratios, which is a common challenge in many clinical training environments (11).

Given the pilot nature and small sample size of this study, future research is crucial. To overcome these limitations, subsequent investigations should prioritize recruiting larger and more diverse participant groups to achieve adequate statistical power. Further studies are also needed to rigorously evaluate the long-term impact of Peyton's method on skill retention and its direct transferability to clinical practice. Exploring the optimal adaptations of this method across a wider range of procedural skills and diverse learner populations is essential. Additionally, a deeper examination of self-efficacy trajectories throughout the learning process is needed. Addressing these critical areas will enable the refinement of simulation-based curricula, ultimately enhancing procedural skill development and optimizing patient care among healthcare professionals.

Table 3: Post-Intervention Outcomes: Performance, Efficiency, Self-Efficacy, and Acceptance

Outcome Variable	Intervention (n = 8) mean ± SD	Control (n = 7) mean ± SD	Mean difference (95% CI)	p value	Effect size
Learning score[a]	16.79 ± 6.27	10.45 ± 2.21	6.34 (2.41–10.27)	0.002*	d = 1.32 (large)
Procedural time[a] (min)	6.50 ± 0.53	7.00 ± 0.58	–0.50 (–1.12 to 0.12)	0.189	d = 0.62 (moderate)
Number of Attempts[b]	1.00 ± 0.35	1.30 ± 0.53	–0.30 (–0.78 to 0.18)	0.336	d = 0.48 (Small– moderate)
General self-efficacy (adjusted)[c]	32.4 ± 4.00	30.7 ± 3.80	—	0.419	η^2 = 0.055 (small)
IV cannulation self-efficacy (post)[b]	7.9 ± 1.10	7.2 ± 1.00	—	0.395	r = 0.21 (small)
Acceptance score[a]	48.57 ± 3.15	43.28 ± 5.58	5.29 (0.41–10.17)	0.039*	d = 1.05 (large)

Cohen's d was reported for independent t tests; r (Spearman's rho) was calculated for Mann-Whitney U tests when appropriate for the specific calculation of effect size; and partial eta squared (η^2) was reported for ANCOVA. The choice of statistical test was guided by the normality assessment. A dash (—) indicates that mean difference was not applicable for adjusted or non-parametric comparisons.
a: Independent t-test
b: Mann-Whitney U test
c: ANCOVA
*Statistically significant

Peyton's four-step method shows promise for peripheral IV training due to positive learner feedback; however, larger studies are needed to confirm its effectiveness and long-term benefits.

5.1 Limitation

This study had several strengths that enhanced the credibility of its findings. These include the use of blinded, video-based assessments for procedural performance, the application of validated instruments (Kolb LSI and GSES) with established psychometric properties, and the standardization of the instructional module and simulation environment. These methodological choices aimed to minimize bias and ensure controlled comparisons.

However, the interpretation and generalizability of these findings are significantly constrained by the study's limitations. The primary limitation is the small sample size in both the intervention (n = 8) and control (n = 7) groups. This inherently limits statistical power, making it challenging to detect statistically significant differences and draw definitive conclusions about the magnitude of treatment effects. Consequently, the observed trends, while promising, should be interpreted with caution. The short follow-up period and single-site design also limit the ability to assess long-term skill retention or the broader applicability of the findings across different educational settings. Finally, although simulation models offer a controlled environment, they may not fully replicate the multifaceted complexities and pressures of real-world clinical practice.

5.2 Conclusion

This pilot study explored the utility of Peyton's four-step method for peripheral IV cannulation training within a simulated setting. We observed a strong learner preference for the method's structured approach, coupled with high acceptance and perceived clarity. While preliminary trends suggested improvements in procedural efficiency and learning outcomes, these did not reach statistical significance, likely due to our limited sample size. Consequently, definitive conclusions regarding superiority of Peyton's method over traditional training cannot be established. Nevertheless, this investigation highlights the potential of structured, simulation-based instruction for acquiring psychomotor skills in nursing education. The positive learner reception and engagement provide a robust rationale for further, more extensive research.

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Statements

AI Use: Artificial intelligence tools were used solely for language editing and grammar checking. No AI tools were used for content generation, data analysis, or scientific writing. The authors take full responsibility for the originality and accuracy of all content presented in this manuscript.

Authors' Contribution: FY contributed to conceptualization, design, analysis, writing, supervision, and final approval of the manuscript. NT contributed to data collection. All authors read and approved the final manuscript.

Conflict of Interests Statement: The authors declare no conflicts of interest regarding this study.

Data Availability: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request due to ethical and privacy restrictions.

Ethical Approval: This study was approved by the Research Ethics Committee of the Islamic Azad University, Najafabad Branch (IR.IAU.NAJAFABAD.REC.1402.224). All procedures were in accordance with the 1964 Helsinki Declaration and its later amendments.

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Informed Consent: Written informed consent was obtained from all individual participants included in the study prior to their enrollment. Participants were informed of their right to withdraw at any time without penalty.

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