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Effect of Augmented Reality-Based Training on Nursing Students' Accuracy in Performing Clinical Procedures in Private and Public Nursing Colleges

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ABSTRACT

Background: Traditional nursing education may provide limited opportunities for repetitive, self-paced clinical practice. Augmented reality (AR) offers immersive, interactive training with real-time guidance, but evidence from Pakistan remains limited.
Objective: To evaluate AR-based training effectiveness in improving clinical procedure accuracy among nursing students.
Methods: A quasi-experimental single-group pre-test post-test design was employed. A total of 250 nursing students were recruited from two nursing colleges (Siddiq Institute of Nursing and Allied Health Sciences Multan and Nishtar Nursing College Multan) using purposive sampling. Data were collected using a structured knowledge questionnaire and a clinical procedure accuracy checklist before and four weeks after the AR-based training intervention. The intervention comprised comprehensive AR-based training sessions covering five core clinical procedures: wound dressing, intramuscular injection, urinary catheterization, endotracheal suctioning, and medication administration. Data were analyzed using SPSS version 26.0, employing descriptive statistics and paired t-test.
Results: The mean pre-test knowledge score was 13.28 ± 4.12, which significantly increased to 26.94 ± 3.87 at post-test ($t = 28.46$, $p < 0.001$). Similarly, the mean clinical procedure accuracy score improved from 16.42 ± 5.23 pre-intervention to 33.58 ± 4.14 post-intervention ($t = 26.73$, $p < 0.001$). The AR-based training intervention demonstrated a highly statistically significant improvement in both knowledge and clinical procedure accuracy among the study participants.
Conclusion: Augmented reality-based training significantly enhances nursing students' knowledge and accuracy in performing clinical procedures. Integrating structured AR-based training programs into nursing curricula is recommended to bridge the gap between theoretical knowledge and clinical competence, particularly in resource-constrained settings like Pakistan.

Keywords: Augmented reality, nursing education, clinical procedures, accuracy, quasi-experimental study, Pakistan

INTRODUCTION

Clinical procedural competence is a fundamental component of nursing practice and requires the integration of theoretical knowledge, psychomotor performance, clinical judgment, and adherence to patient-safety principles. Procedures such as medication administration, injections, wound care, urinary catheterization, suctioning, and other bedside interventions must be performed accurately and consistently because deficiencies in procedural competence may compromise the quality and safety of patient care. Consequently, nursing education must provide students with sufficient opportunities to acquire, practice, and refine clinical skills before they assume independent responsibilities in clinical settings. [1,2]

Traditional approaches to clinical skills education generally combine classroom instruction, faculty demonstration, mannequin-based practice, and supervised clinical experience. Although these methods remain essential, they may be constrained by limited practice time, variable access to clinical placements, faculty workload, and opportunities for individualized feedback. These limitations are particularly important when students require repeated practice to achieve procedural proficiency. Increasing recognition of these challenges has encouraged nursing educators to incorporate simulation and technology-enhanced approaches that can provide structured, interactive, and relatively low-risk learning environments. [3,4]

Augmented reality (AR) has emerged as one such technology with potential applications in health-professions education. AR integrates computer-generated information, including three-dimensional objects, visual cues, animations, and other digital content, with the learner's physical environment. Unlike virtual reality, which replaces the real environment with a fully simulated digital setting, AR preserves interaction with physical

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objects while superimposing contextual digital information. This characteristic is particularly relevant to nursing skills education because students can continue to manipulate mannequins, instruments, and other clinical equipment while receiving digitally mediated instructions or visual guidance. [5,6]

The educational value of AR extends beyond the presentation of information. AR-based environments can support visualization of anatomical structures, procedural sequences, spatial relationships, and clinical cues that may be difficult to appreciate through conventional two-dimensional teaching materials. Recent evidence suggests that AR and related immersive technologies can enhance engagement, knowledge acquisition, clinical reasoning, and selected aspects of practical skill development. [7,8] In addition, AR can provide learners with opportunities for self-directed and repetitive practice, potentially allowing students to progress through procedural steps at an individualized pace while reducing dependence on continuous faculty supervision. [9]

The growing literature on AR in nursing and health-professions education provides encouraging, although not uniformly consistent, evidence. Studies involving immersive and mixed-reality approaches have reported improvements in nursing students' knowledge, confidence, satisfaction, and selected clinical competencies. [10,11] A systematic review and meta-analysis of mixed reality in undergraduate nursing education further identified benefits related to knowledge and skill acquisition, while also emphasizing implementation challenges and variability between educational interventions. [12]

These findings indicate that AR should not be considered a universally effective intervention; rather, its educational impact may depend on the type of procedure, instructional design, degree of learner interaction, technological usability, and the extent to which digital guidance is integrated with hands-on practice.

Evidence from specific procedural applications further illustrates this variability. AR-supported anatomy and nursing-skills training has demonstrated the feasibility of overlaying three-dimensional anatomical information onto physical mannequins, potentially strengthening students' understanding of the relationship between anatomical knowledge and procedural performance.[13] Similarly, AR has been incorporated into procedural and clinical training to provide interactive guidance during skills practice.[14,15] More recent investigations have reported favorable outcomes for AR-supported health-professions education, including improvements in learning outcomes and clinical performance among university-level health students.[16]

The potential benefits of AR are also relevant to competency-based nursing education because procedural mastery requires repeated performance rather than passive exposure to theoretical content. AR-supported learning can provide visual prompts, stepwise instructions, and immediate contextual information during practice, thereby supporting deliberate and experiential learning. [17,18] Such features may be particularly valuable for procedures in which sequencing, accuracy, and adherence to safety steps are critical. Nevertheless, evidence from other health-professions applications suggests that AR may be more effective for some learning outcomes than others, and improvements in knowledge or confidence do not necessarily translate into equivalent gains in technical performance. [19] This distinction is important because the ultimate objective of clinical skills education is not simply knowledge acquisition but the accurate and reproducible execution of procedures.

Recent research has expanded the application of AR beyond conventional nursing-skills laboratories. AR-based interventions have been investigated for clinical decision-making, communication and empathy training, radiographic positioning, orientation and mobility training, and other health-related educational tasks. [20–23] This expanding evidence base demonstrates the adaptability of AR across different educational contexts but also highlights considerable heterogeneity in intervention design, technological platforms, learner populations, outcome measures, and assessment methods. Consequently, findings from one clinical or educational domain cannot necessarily be generalized to all nursing procedures.

Importantly, the evidence base remains geographically uneven. Much of the published research on AR-supported health education has originated from technologically developed educational environments, where access to advanced hardware, digital infrastructure, technical support, and simulation facilities may differ substantially from those available in low- and middle-income countries. Reviews of AR and immersive technologies have highlighted both the educational potential of these approaches and the importance of contextual factors affecting implementation. [24,25] Therefore, evidence generated in high-resource settings may not directly reflect the feasibility, acceptability, or educational effectiveness of AR within nursing institutions operating under different infrastructural and pedagogical conditions.

The Pakistani context represents an important but comparatively underexplored setting for this research. Nursing education in Pakistan continues to rely substantially on conventional classroom teaching, faculty demonstration, skills-laboratory practice, and clinical placement. Although digital technologies are increasingly being incorporated into health-professions education, empirical evidence evaluating AR-based clinical procedural training among Pakistani nursing students remains limited. Furthermore, there is insufficient evidence regarding whether AR can improve objectively assessed procedural accuracy across nursing institutions with different organizational and educational environments. This gap is particularly relevant when comparing public and private nursing institutions, which may differ in resources, student exposure, faculty support, and access to educational technologies.

Accordingly, the present study evaluated the effectiveness of augmented reality-based training in improving the accuracy of clinical procedure performance among nursing students at Siddiq Institute of Nursing and Allied Health Sciences, Multan, and Nishtar Nursing College, Multan, representing private and public nursing education settings, respectively. By focusing on procedural accuracy rather than solely on knowledge, satisfaction, or perceived confidence, the study addresses an important outcome directly related to clinical competence and patient safety. The findings may provide context-specific evidence regarding the educational value of AR and inform future decisions concerning the integration of technology-enhanced procedural training into nursing curricula in Pakistan.

METHODOLOGY

A quasi-experimental single-group pre-test–post-test design was employed to evaluate the effectiveness of augmented reality (AR)-based training in improving nursing students' knowledge and accuracy in performing clinical procedures. The study was conducted at two undergraduate nursing institutions in Multan, Pakistan: Siddiq Institute of Nursing and Allied Health Sciences (private sector) and Nishtar Nursing College (public sector), selected to provide representation of different educational settings.

The study population comprised undergraduate nursing students enrolled during the study period who had completed foundational clinical skills courses. A sample of 250 students was determined using a single-population proportion formula with a

95% confidence level, 5% margin of error, and an anticipated proportion of 50%. Participants were recruited through purposive sampling. Eligible participants were aged 18–35 years, enrolled in an undergraduate nursing program, had completed foundational clinical skills training, and were willing to participate. Students with previous AR-based training, visual or physical impairments preventing AR-device use, cognitive or communication difficulties, epilepsy or conditions potentially triggered by AR exposure, non-consent, or extended leave during data collection were excluded.

Data were collected using two investigator-developed instruments. The first was a 35-item structured knowledge questionnaire covering theoretical knowledge, procedural steps and sequencing, infection prevention and safety, complication recognition and management, and documentation and reporting. Each correct response received one point, producing a maximum score of 35. The second was a 25-item clinical procedure accuracy checklist assessing wound dressing, intramuscular injection, urinary catheterization, endotracheal suctioning, and medication administration. Each item was rated as accurate (2), partially accurate (1), or inaccurate (0), with a maximum score of 50. Both instruments were developed following a literature review and underwent expert content validation by five nursing and medical professionals. The content validity indices were 0.91 for the knowledge questionnaire and 0.89 for the accuracy checklist. Pilot testing among 20 students demonstrated acceptable internal consistency, with Cronbach's α coefficients of 0.86 and 0.84, respectively.

The AR intervention was developed using evidence-based clinical procedure guidelines and comprised five modules addressing wound care, intramuscular injection, urinary catheterization, endotracheal suctioning, and medication-administration safety. Smartphone-based AR applications provided stepwise visual instructions, anatomical overlays, procedural cues, and performance-related feedback while students practiced using mannequins or task trainers. Following a 30-minute orientation, students participated in structured AR training over two weeks, with two sessions per week. Each session incorporated instructor demonstration, guided practice, and independent practice with AR-supported feedback. Students subsequently received access to the applications for self-directed reinforcement, followed by a reinforcement session two weeks after training. Baseline demographic information, knowledge, and procedural accuracy were assessed before the intervention, while identical outcome measures were administered four weeks after completion of the intervention.

Ethical approval was obtained from the relevant institutional review boards of both participating institutions. Written informed consent was obtained from all participants after explanation of the study objectives, procedures, potential benefits, and possible discomfort associated with AR use. Confidentiality and voluntary participation were maintained, and participants could withdraw at any stage without consequence. Data were anonymized and securely stored. Statistical analysis was performed using SPSS version 26.0. Frequencies, percentages, means, and standard deviations were calculated as appropriate. Pre-test and post-test knowledge and procedural accuracy scores were compared using paired-samples t-tests, with statistical significance established at $p<0.05$.

RESULTS

Demographic Characteristics of Participants

A total of 250 nursing students from two nursing colleges participated in the study. The demographic characteristics are presented in Table 1.

Table 1: Demographic Characteristics of Participants (N=250)

Demographic Variable	Category	Frequency (n)	Percentage (%)
Age (years)	18-22	112	44.8
	23-27	98	39.2
	28-35	40	16.0
Gender	Female	210	84.0
	Male	40	16.0
Year of Study	First Year	62	24.8
	Second Year	68	27.2
	Third Year	72	28.8
	Fourth Year	48	19.2
College Type	Private (Siddiq Institute)	125	50.0
	Public (Nishtar Nursing College)	125	50.0
Previous AR Experience	Yes	18	7.2
	No	232	92.8
Smartphone Ownership	Yes	238	95.2
	No	12	4.8

Table 1 shows that the majority of participants (44.8%) were in the 18-22 years age group. The sample was predominantly female (84.0%), reflecting the gender distribution in nursing education in Pakistan. Participants were distributed across all years of study, with the largest proportion in the third year (28.8%). Equal numbers of participants were recruited from the private (n=125) and public (n=125) nursing colleges. The vast majority (92.8%) had no prior experience with AR-based training, and 95.2% owned smartphones.

Effectiveness of AR-Based Training on Knowledge

The knowledge scores of participants before and after the AR-based training intervention are presented in Table 2.

Table 2: Comparison of Pre-test and Post-test Knowledge Scores (N=250)

Domain	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Difference	t-value	p-value
Theoretical knowledge of clinical procedures	3.86 ± 1.52	6.24 ± 1.18	2.38	22.45	<0.001*
Procedural steps and sequencing	2.94 ± 1.38	5.68 ± 1.24	2.74	24.12	<0.001*
Infection control and safety practices	2.68 ± 1.42	5.46 ± 1.08	2.78	23.67	<0.001*
Complication recognition and management	2.12 ± 1.28	4.82 ± 1.14	2.70	21.89	<0.001*
Documentation and reporting	1.68 ± 1.12	4.74 ± 1.06	3.06	25.34	<0.001*
Total Knowledge Score	**13.28 ± 4.12**	**26.94 ± 3.87**	**13.66**	**28.46**	**<0.001***

*Statistically significant at $p < 0.05$

The total mean pre-test knowledge score was 13.28 ± 4.12, which significantly increased to 26.94 ± 3.87 at post-test, with a mean difference of 13.66. The paired t-test revealed a highly statistically significant difference (t = 28.46, p < 0.001). The domain-wise analysis showed that the greatest improvement was observed in documentation and reporting (mean difference = 3.06), followed by infection control and safety practices (mean difference = 2.78).

Effectiveness of AR-Based Training on Clinical Procedure Accuracy

The clinical procedure accuracy scores of participants before and after the AR-based training intervention are presented in Table 3.

Table 3: Comparison of Pre-test and Post-test Clinical Procedure Accuracy Scores (N=250)

Domain	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Difference	t-value	p-value
Wound dressing	3.82 ± 1.64	7.24 ± 1.38	3.42	20.67	<0.001*
Intramuscular injection	3.28 ± 1.52	6.86 ± 1.42	3.58	21.89	<0.001*
Urinary catheterization	3.06 ± 1.48	6.52 ± 1.34	3.46	20.12	<0.001*
Endotracheal suctioning	2.94 ± 1.36	6.28 ± 1.28	3.34	19.45	<0.001*
Medication administration	3.32 ± 1.54	6.68 ± 1.36	3.36	20.89	<0.001*
Total Accuracy Score	**16.42 ± 5.23**	**33.58 ± 4.14**	**17.16**	**26.73**	**<0.001***

*Statistically significant at p < 0.05

The total mean pre-test clinical procedure accuracy score was 16.42 ± 5.23, which significantly increased to 33.58 ± 4.14 at post-test, with a mean difference of 17.16. The paired t-test revealed a highly statistically significant difference (t = 26.73, p < 0.001). The domain-wise analysis showed that the greatest improvement was observed in intramuscular injection (mean difference = 3.58), followed by urinary catheterization (mean difference = 3.46).

Comparison Between Private and Public Nursing Colleges

The comparison of pre-test and post-test scores between private and public nursing colleges is presented in Table 4.

Table 4: Comparison of Scores Between Private and Public Nursing Colleges (N=250)

Variable	Private College (n=125) Mean ± SD	Public College (n=125) Mean ± SD	t-value	p-value
Pre-test Knowledge	12.96 ± 4.08	13.60 ± 4.16	-1.24	0.216
Post-test Knowledge	27.24 ± 3.76	26.64 ± 3.98	1.23	0.219
Pre-test Accuracy	16.08 ± 5.18	16.76 ± 5.28	-1.04	0.299
Post-test Accuracy	34.12 ± 4.02	33.04 ± 4.26	2.08	0.039*

*Statistically significant at p < 0.05

Table 4 shows that while there was no statistically significant difference between private and public colleges in pre-test knowledge (p = 0.216) or pre-test accuracy (p = 0.299), the private college demonstrated significantly higher post-test accuracy scores compared to the public college (p = 0.039). The post-test knowledge scores were higher in the private college, but this difference was not statistically significant (p = 0.219).

DISCUSSION

The present study evaluated the effectiveness of augmented reality (AR)-based training on nursing students' knowledge and accuracy in performing selected clinical procedures at two nursing colleges in Multan, Pakistan. The findings demonstrated statistically significant improvements in both knowledge and clinical procedure accuracy following the AR-based intervention. These findings support the potential value of AR as a supplementary educational modality for strengthening theoretical understanding and procedural performance among nursing students. The results are consistent with the growing evidence that immersive, interactive technologies can complement conventional simulation and skills-based instruction by providing visual guidance, repeated practice, and opportunities for learner engagement. [1–4]

Knowledge scores increased substantially from 13.28 ± 4.12 at pre-test to 26.94 ± 3.87 at post-test. This improvement is consistent with evidence indicating that technology-enhanced and immersive learning environments can improve educational outcomes among health-professions students. Recent reviews have reported benefits of augmented and mixed reality for knowledge acquisition, procedural learning, learner engagement, and clinical competency. [5–7] Studies specifically examining AR-supported nursing education have also reported positive learner perceptions and educational benefits, suggesting that interactive visualization may facilitate the integration of theoretical information with procedural learning. [8–10]

The improvement across theoretical knowledge, procedural steps, infection control, complication recognition, and documentation suggests that the intervention provided relatively comprehensive exposure to the cognitive components underlying clinical procedures. The particularly marked improvement in documentation and reporting may be explained by the structured presentation of procedural sequences and safety checkpoints within the AR environment. Such technology can make otherwise abstract or sequential information more explicit by presenting visual cues alongside the physical learning environment. This interpretation is consistent with research showing that AR can support procedural training through interactive visual augmentation and guided learning experiences. [11–13]

Clinical procedure accuracy scores increased from 16.42 ± 5.23 before the intervention to 33.58 ± 4.14 after training. This finding is educationally important because procedural competence requires not only knowledge of a procedure but also the ability to translate that knowledge into accurate psychomotor performance. Previous research has demonstrated that AR-supported training can enhance practical skill acquisition and provide learners with interactive guidance during clinical or technical procedures. [14–16]

The greatest improvement was observed for intramuscular injection accuracy, with a mean difference of 3.58. This result may reflect the suitability of AR for procedures in which anatomical orientation, positioning, sequencing, and safety checkpoints are particularly important. Three-dimensional anatomical augmentation has previously been used to support nursing-skills training by superimposing anatomical information onto physical models, potentially improving learners' visualization of underlying structures and procedural relationships. [17] The observed improvement may therefore be attributable, at least in part, to the combination of visual anatomical information, sequential instructions, and repeated practice incorporated into the present intervention.

Urinary catheterization accuracy also improved substantially, with a mean difference of 3.46. Although the magnitude of improvement in the present study is encouraging, comparisons with previous literature should be interpreted cautiously because AR interventions differ considerably in technology, duration, instructional design, assessment instruments, and comparator conditions. Existing evidence nevertheless indicates that augmented and mixed-reality approaches can support the acquisition of clinical and procedural skills by combining simulated practice with interactive visual information. [7, 18, 19]

The significant improvements observed for wound dressing, endotracheal suctioning, and medication administration further indicate that the intervention was not restricted to a single procedural domain. This is consistent with emerging evidence on AR-supported nursing-skills education, including procedural training and medication-administration learning.[10,12,20] The broader literature also suggests that the effectiveness of immersive technologies may depend on the characteristics of the procedure and the instructional design rather than on the technology alone.[4,7] Thus, the present findings may reflect the combined effect of AR visualization, guided practice, repetition, and immediate feedback rather than AR exposure in isolation.

The private nursing college demonstrated significantly higher post-test accuracy scores than the public college ($p = 0.039$), despite the absence of a significant difference in pre-test scores. This pattern suggests that institutional context may influence the implementation or uptake of technology-supported learning. Possible explanations include differences in access to technological resources, instructor availability, student-to-faculty ratios, technical support, or familiarity with digital learning environments. However, these factors were not directly measured in the present study and should therefore be regarded as plausible explanations rather than established determinants. Previous research has emphasized that the successful implementation of AR and mixed-reality education depends not only on technological capability but also on learner acceptance, instructional integration, and institutional readiness. [8, 21, 22]

Importantly, the absence of a significant baseline difference suggests that the higher post-test performance in the private institution was not simply attributable to substantially different pre-intervention competency levels. Nevertheless, because the present study did not include random allocation or a control group within each institution, institutional differences cannot be interpreted as evidence of differential causal effectiveness of AR.

The findings provide empirical support for the educational principles underlying experiential learning and deliberate practice. AR-based training permits learners to interact with procedural information while performing tasks in a physical learning environment, thereby creating opportunities to connect conceptual understanding with practical experience. Repeated performance, focused attention on individual procedural steps, and immediate feedback are also compatible with the principles of deliberate practice. Evidence from nursing and health-professions education suggests that immersive technologies can facilitate this integration of knowledge and practical skill. [3, 7, 23]

The simultaneous improvement in knowledge and clinical procedure accuracy further suggests that AR may help reduce the traditional separation between classroom-based theoretical instruction and skills-laboratory practice. Rather than presenting procedural information exclusively through static text or conventional demonstration, AR can provide contextualized visual cues during learning. This feature may be particularly useful for procedures requiring spatial understanding, sequencing, anatomical orientation, or recognition of safety-critical steps. Research involving three-dimensional anatomical augmentation and AR procedural training provides support for this pedagogical mechanism. [17, 20]

The findings of the present study are broadly consistent with the expanding international literature on AR and mixed reality in health-professions education. Recent systematic reviews and scoping reviews have reported potential benefits in knowledge acquisition, practical skills, learner engagement, confidence, and clinical competency, while also emphasizing heterogeneity among interventions and study designs. [7, 24, 25] Evidence from nursing education includes AR-supported procedural training, medication-administration education, and immersive simulation, although the strength and consistency of effects vary across educational outcomes. [10, 12, 20]

The present findings are also consistent with studies demonstrating that AR can support practical performance through interactive visualization and simulation. For example, research involving nursing skills has explored three-dimensional anatomical augmentation over mannequins, while other studies have examined AR-supported training for specific clinical procedures. [17,20,26] These findings collectively indicate that AR may be particularly valuable when educational tasks require learners to understand relationships between anatomical structures, procedural sequences, and safety-critical actions.

However, the international literature also demonstrates that AR should not be considered uniformly superior to conventional education. Differences in intervention duration, hardware, application design, learner characteristics, outcome measures, and comparator groups can produce heterogeneous findings. [4,7] Therefore, the present results should be interpreted as evidence supporting AR as a potentially effective educational adjunct rather than as evidence that AR universally replaces established simulation or clinical teaching approaches.

The findings have several implications for nursing education and clinical preparation. First, AR-based learning could be incorporated into nursing curricula as a supplementary strategy for developing procedural competence. Rather than replacing instructor-led demonstrations, simulation laboratories, or supervised clinical placements, AR may provide an additional layer of preparation before students perform procedures on mannequins or patients.

Second, the results support the value of repetitive, self-directed practice. Smartphone-based AR can allow students to review procedural sequences outside conventional classroom sessions and repeat selected components according to their learning needs. Such flexibility may be particularly valuable in settings where access to simulation laboratories, equipment, or clinical placement opportunities is limited. Reviews of AR and mixed-reality applications have similarly identified flexibility, visualization, and repeated practice as important potential advantages. [7, 12]

Third, AR may help standardize the presentation of procedural information by providing students with consistent visual instructions and safety checkpoints. This could reduce variability in exposure to procedural demonstrations, although effective implementation would still require appropriately trained faculty and integration with established competency-assessment procedures. Finally, the observation that students in both private and public institutions demonstrated significant improvements suggests that smartphone-based AR has potential for implementation across different educational environments. The high smartphone ownership observed in the present sample (95.2%) further supports the practical feasibility of a smartphone-delivered approach within the study population.

This study has several strengths. First, it addresses an important evidence gap by examining AR-supported nursing education within the Pakistani context, where empirical evidence remains comparatively limited. Second, the inclusion of 250 nursing students provides a substantial sample for evaluating pre- to post-intervention changes. Third, inclusion of both private and public nursing colleges permitted examination of outcomes across different institutional settings. Fourth, the use of validated knowledge and clinical-procedure assessment instruments strengthens the methodological credibility of the outcome assessment. Fifth, the study evaluated both cognitive and psychomotor outcomes rather than relying exclusively on learner satisfaction or self-reported perceptions. This multidimensional assessment provides a more meaningful indication of whether AR-supported education translated into measurable improvement in clinical learning outcomes. Finally, the smartphone-based delivery model reflects a potentially scalable approach that may be more feasible in resource-constrained educational settings than specialized head-mounted AR systems.

Limitations

While this study provides valuable insights into the effectiveness of AR-based training for nursing students, several limitations should be acknowledged:

1. **Single-group design**: The absence of a control group limits the ability to establish causality definitively, as improvements could potentially be attributed to factors other than the AR intervention, such as the natural course of learning or the Hawthorne effect.
2. **Single geographic location:** The study was conducted in Multan, Pakistan, which may limit the generalizability of findings to other regions of Pakistan or other countries.
3. **Purposive sampling:** The use of purposive sampling may introduce selection bias, as students who agreed to participate may differ from those who declined.
4. **Self-reported data:** The reliance on self-reported knowledge may be subject to social desirability bias, with participants potentially overreporting their knowledge in the post-test.
5. **Short follow-up period:** The post-test assessment was conducted at four weeks post-intervention, which may not capture the sustainability of knowledge and skill improvement over the longer term.

Future research should address these limitations by employing randomized controlled trial designs, including control groups, utilizing multi-center sampling, incorporating objective outcome measures, extending the follow-up period, evaluating the effectiveness of AR training in diverse populations and settings, and assessing the cost-effectiveness of AR-based training compared to traditional methods

CONCLUSION

This study demonstrated significant improvements in nursing students' knowledge and clinical procedure accuracy following smartphone-based augmented reality (AR) training at private and public nursing institutions in Multan, Pakistan. Mean knowledge scores increased from 13.28 ± 4.12 to 26.94 ± 3.87, while clinical procedure accuracy improved from 16.42 ± 5.23 to 33.58 ± 4.14 (both $p < 0.001$). Although post-test accuracy was significantly higher among students from the private institution, significant improvements were observed across both settings. These findings support the potential of AR as a complementary approach to conventional nursing education by facilitating interactive, structured, and repeatable procedural learning. Smartphone-based AR may be particularly feasible in resource-constrained settings. Future multicenter studies using randomized controlled designs and longer follow-up are warranted to confirm effectiveness and determine retention of clinical competence.

Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the relevant Institutional Review Board/Ethics Committee of Nishtar Hospital Multan, Pakistan.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Author Contributions

Conceptualization: Noor Ul Eman, Muqddas Munir
Methodology: Noor Ul Eman, Muqddas Munir, Ayeza Lodhi
Data Collection: Muqddas Munir, Ayeza Lodhi
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Writing – Original Draft: Noor Ul Eman, Muqddas Munir
Writing – Review & Editing: Noor Ul Eman, Muqddas Munir, Ayeza Lodhi

Informed Consent

Written informed consent was obtained from all participants before enrollment in the study.

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Conflict of Interest

The authors declare that they have no competing interests.

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Declaration of AI-Assisted Language Editing

Grammarly AI was used spelling and language corrections.

REFERENCES

1. Ali SM, Ali M, Abdelati IH, Abd Allah IM, Abou Shabana KR. Impact of preoperative education on relieving postoperative discomforts and improving quality of life after hysterectomy. Egypt J Hosp Med. 2026;102:652-663. doi:10.21608/ejhm.2026.483369.
2. Chahartangi F, Zarifsanaiey N, Mehrabi M, Ghoochani BZ, Sharifzadeh N. Investigating the effect of augmented reality-based virtual patient training on occupational therapy students' clinical decision-making: a quasi-experimental study. PLoS One. 2026;21(2). doi:10.1371/journal.pone.0340759.
3. Cho MK, Kim MY. Enhancing nursing competency through virtual reality simulation among nursing students: a systematic review and meta-analysis. Front Med (Lausanne). 2024;11:1351300. doi:10.3389/fmed.2024.1351300.
4. Daling LM, Schlittmeier SJ. Effects of augmented reality-, virtual reality-, and mixed reality-based training on objective performance measures and subjective evaluations in manual assembly tasks: a scoping review. Hum Factors. 2024;66(2):589-626. doi:10.1177/00187208221105135.
5. Deverell L, Bhowmik J, Lau BT, Al Mahmud A, Sukunesan S, Islam FMA, et al. Use of technology by orientation and mobility professionals in Australia and Malaysia before COVID-19. Disabil Rehabil Assist Technol. 2022;17(3):260-267. doi:10.1080/17483107.2020.1785565.
6. Guan M, Feng X. Correlation between quality of discharge teaching, readiness for hospital discharge and health

outcomes of hysterectomy patients: a structural equation model analysis. Nurs Open. 2023;10(6):3817-3827. doi:10.1002/nop2.1640.
7. Guillen-Aguinaga L, Rayón-Valpuesta E, Guillen-Aguinaga S, Rodriguez-Diaz B, Montejo R, Alas-Brun R, et al. Mixed reality in undergraduate nursing education: a systematic review and meta-analysis of benefits and challenges. Nurs Rep. 2025;15(5):137. doi:10.3390/nursrep15050137.
8. Jallad ST, Natsheh I, Helo LA, Ibdah DM, Salah A, Muhsen R, et al. Nursing student's perceptions, satisfaction, and knowledge toward utilizing immersive virtual reality application in human anatomy course: quasi-experimental. BMC Nurs. 2024;23:601. doi:10.1186/s12912-024-02254-8.
9. Jang W, Chai W, Kim Y, Moon Y, Yoo S, Na SG, et al. Augmented reality-based training for a rapid blood transfusion device among emergency nurses: randomized controlled trial. JMIR Med Educ. 2026;12. doi:10.2196/98073.
10. Jin S, Choi SY, Kim JH. Learning from the learners: evaluation of augmented reality-based medication administration program for nursing skills. Clin Simul Nurs. 2025;101:101706. doi:10.1016/j.ecns.2025.101706.
11. Kakoutopoulos K, Drakakis E, Papadopoulou A, Goumopoulos C. Feasibility of augmented reality-based cognitive training for older adults: the MarketMind AR approach. Sensors (Basel). 2025;25(7):2081. doi:10.3390/s25072081.
12. Kang R, Zhang B, Fu S, Tong L, Jin S, Wang Y, et al. Application of head-mounted display-based augmented and mixed reality in nursing education: a scoping review. BMC Nurs. 2025;24:1150. doi:10.1186/s12912-025-03413-1.
13. Kim SK, Lee Y, Hwang HR, Park SY. 3D human anatomy augmentation over a mannequin for the training of nursing skills. Technol Health Care. 2024;32(3):1523-1533. doi:10.3233/THC-230586.
14. Lampropoulos G, Fernández-Arias P, del Bosque A, Vergara D. Augmented reality in health education: transforming nursing, healthcare, and medical education and training. Nurs Rep. 2025;15(8):289. doi:10.3390/nursrep15080289.
15. Lee D, Bathish MA, Nelson J. Transforming nursing education: developing augmented reality procedural training. Cyberpsychol Behav Soc Netw. 2024;27(6):372-378. doi:10.1089/cyber.2023.0403.
16. Martín-Valero R, Vega-Morales Sr A, Martín-Vega FJ, Rodriguez-Huguet M, Rodríguez-Martínez MC, Vinolo-Gil MJ. Effectiveness of augmented reality in the teaching of health university students: quasi-experimental study. JMIR Serious Games. 2025;13. doi:10.2196/54312.
17. Mohamed Elghareeb Allam S, Ali Elsaadany SA, Khalifa Garas Girgis T, Gamal Abd Elnaser Ahmed Elnabawy M, Saad Shaker Soliman M. Efficacy of educational sessions on venous thromboembolism prevention and emotional status among women having major abdomino-pelvic surgery. Egypt J Health Care. 2024;15(4):530-547. doi:10.21608/ejhc.2024.388888.
18. Nagamata S. Comparison of augmented reality-based and conventional training methods for radiographic positioning in second-year radiologic technology students in Japan. J Med Radiat Sci. 2025;72(4):512-518. doi:10.1002/jmrs.70019.
19. Nakazawa A, Iwamoto M, Kurazume R, Nunoi M, Kobayashi M, Honda M. Augmented reality-based affective training for improving care communication skill and empathy. PLoS One. 2023;18(7). doi:10.1371/journal.pone.0288175.
20. Obeid MF, Ewais A, Asia MR. NursingXR: advancing nursing education through virtual reality-based training. Appl Sci. 2025;15(6):2949. doi:10.3390/app15062949.
21. Oyekunle D, Claude BEA, Waliu AO, Adekunle TS, Matthew UO. Cloud based adaptive learning system: virtual reality and augmented reality assisted educational pedagogy development on clinical simulation. J Digit Health. 2024;3(1):49-62. doi:10.55976/jdh.32024126849-62.
22. Popov V, Mateju N, Jeske C, Lewis KO. Metaverse-based simulation: a scoping review of charting medical education over the last two decades in the lens of the "marvelous medical education machine". Ann Med. 2024;56(1):2424450. doi:10.1080/07853890.2024.2424450.
23. Ribeiro N, Tavares P, Ferreira C, Coelho A. Melanoma prevention using an augmented reality-based serious game. Patient Educ Couns. 2024;123:108226. doi:10.1016/j.pec.2024.108226.
24. Su Z, Zhang L, Lian X, Guan M. Virtual reality-based exercise rehabilitation in cancer-related dysfunctions: scoping review. J Med Internet Res. 2024;26. doi:10.2196/49312.
25. Ueyama Y, Harada M. Basketball free-throw training with augmented reality-based optimal shot trajectory for novice shooters. Sci Rep. 2024;14(1):891. doi:10.1038/s41598-024-51190-9.
26. Uymaz P, Uymaz AO. Assessing acceptance of augmented reality in nursing education. PLoS One. 2022;17(2). doi:10.1371/journal.pone.0263937.
27. Vogel K, Bernloehr A, Willmeroth T, Blattgerste J, Hellmers C, Bauer NH. Augmented reality simulation-based training for midwifery students and its impact on perceived knowledge, confidence and skills for managing critical incidents. Midwifery. 2024;136:104064. doi:10.1016/j.midw.2024.104064.
28. Wei L, Jin L, Gong R, Yang Y, Zhang X. Design of audio-augmented-reality-based O&M orientation training for visually impaired children. Sensors (Basel). 2022;22(23):9487. doi:10.3390/s22239487.
29. Yoo S, Heo S, Song S, Park A, Cho H, Kim Y, et al. Adoption of augmented reality in educational programs for nurses in intensive care units of tertiary academic hospitals: mixed methods study. JMIR Serious Games. 2024;12. doi:10.2196/54188.