Enhancing Patient Safety Competence Through Virtual Simulation Training and Artificial Intelligence (ViSTA): A Quasi-Experimental Study in Samarinda

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ABSTRACT

Patient safety is a key indicator of healthcare quality, yet it remains a critical challenge in Indonesia, including in Samarinda. The high incidence of patient safety events highlights the urgent need for innovative interventions to enhance healthcare workers' competence. Virtual Simulation Training and Artificial Intelligence (ViSTA) is considered a potential solution to address this issue. This study aimed to evaluate the effectiveness of ViSTA in improving healthcare workers' competence in managing patient safety incidents. A quasi-experimental design with a pre–post test and control group was employed, involving 40 healthcare workers in Samarinda. Respondents were divided into an intervention group (n=20), who participated in ViSTA training, and a control group (n=20), who received no intervention. Competence was measured before and after the intervention. Data analysis was performed using paired t-tests and independent t-tests. The intervention group demonstrated a significant improvement in competence scores after training (p<0.001), whereas the control group showed no meaningful change. Posttest comparisons between groups also revealed a significant difference (p<0.001), underscoring the effectiveness of ViSTA in enhancing healthcare workers' skills in managing patient safety incidents. ViSTA proved to be effective in improving competence through interactive, realistic, and data-driven learning experiences. These findings support the integration of simulation technology and artificial intelligence as a sustainable training strategy, particularly in regions with limited access to face-to-face training. ViSTA holds strong potential to serve as a national training model for strengthening patient safety systems in Indonesia

Keywords: Patient Safety, Virtual Simulation Training, Artificial Intelligence, Healthcare Workers' Competence

1. INTRODUCTION

Patient safety has long been recognized as a critical benchmark for evaluating the overall quality of healthcare delivery within medical institutions, serving as an essential measure of how effectively health systems protect patients from preventable harm (Irfan et al., 2023; Moldovan & Moldovan, 2024). According to global estimates released by the World Health Organization (WHO), nearly 134 million incidents related to patient safety occur every year in low- and middle-income nations, a category that includes Indonesia (World Health Organization, 2024). These adverse events are associated with more than 2.6 million deaths annually, and a significant portion of these fatalities could be avoided if healthcare systems strengthened the competencies, training, and preparedness of their workforce (Utami et al., 2020). These numbers reinforce the notion that patient safety is not solely dependent on advanced medical technologies or clinical protocols, but rather it reflects the overall resilience and readiness of the healthcare system in preventing repeated and avoidable mistakes.

In the context of Indonesia, particularly in Samarinda, a major urban center in East Kalimantan, concerns regarding patient safety have become increasingly prominent. Reports released by the Samarinda City Health Office in 2023 highlight that incidents related to patient safety grew by 12% compared to the previous year. Alarmingly, approximately 40% of these incidents were attributed to errors in medical procedures and breakdowns in communication among healthcare personnel. These statistics not only underline weaknesses in coordination and teamwork within healthcare facilities but also reveal systemic shortcomings in the training and professional development mechanisms provided to healthcare workers. Given these challenges, the urgency to implement innovative training models that incorporate advanced technology becomes even more evident, especially as healthcare demands continue to rise.

Driven by the rapid evolution of digital health technologies, Virtual Simulation Training (ViSTA) combined with Artificial Intelligence (AI) has been identified as a highly promising approach for strengthening healthcare worker competence (Georgieva-Tsaneva et al., 2024; Mulders et al., 2024; Patel et al., 2024; Rony et al., 2024; Sezgin, 2023). Virtual simulation tools allow healthcare workers to immerse themselves in realistic clinical scenarios, enabling them to practice essential skills without putting actual patients at risk. Meanwhile, AI technologies enhance this learning experience by providing real-time feedback,

performance metrics, predictive analytics, and individualized recommendations (Banoub et al., 2024; Johan et al., 2021; Lastrucci & Giansanti, 2024). Evidence from international studies demonstrates that training using simulation-based methods can accelerate skill acquisition by up to 25% when compared with conventional approaches, such as lectures or static modules (Elendu et al., 2024; Lastrucci & Giansanti, 2024; Shahrezaei et al., 2024; Sun et al., 2024). This illustrates how technology-driven learning methods have the potential to transform the landscape of healthcare education and improve the consistency and quality of patient care.

Despite these advances, the adoption and integration of ViSTA and AI-based training in Indonesia—particularly in regions outside the main technological and educational hubs of Java—remain far from optimal. In places like Samarinda, where healthcare workers face complex caseloads but have limited access to high-quality and continuous training programs, the development of an integrated simulation and AI platform becomes not only beneficial but essential. To bridge this gap, the introduction of a locally relevant and context-sensitive ViSTA model is proposed. This platform is intended to provide efficient, interactive, and tailored training experiences that directly address the challenges healthcare workers encounter in managing patient safety incidents.

The central focus of this study is the implementation of a ViSTA–AI hybrid training model as an innovative approach to healthcare education in Indonesia, with specific emphasis on its relevance for the geographic and systemic conditions of Samarinda. What makes this model particularly powerful is its dynamic, interactive, and data-driven nature. Virtual simulations immerse practitioners in real-world clinical settings, prompting them to make decisions under conditions that mimic actual emergencies. AI then supplements this by generating objective assessments related to key performance indicators such as decision-making speed, frequency of mistakes, communication patterns, and simulated patient satisfaction scores (Fahmi et al., 2024; Kang, 2024; Kaplan et al., 2021; Li & Ma, 2024; Morelli et al., 2024; Sulistyawati, 2023). Unlike traditional training frameworks—which often rely on theoretical instruction and rarely provide immediate feedback—this model allows for personalized, adaptive learning. Such characteristics make it suitable for healthcare workers in both well-resourced and resource-constrained environments, including many areas in East Kalimantan (Anggraini et al., 2024; Caffaro et al., 2020; George & Wooden, 2023; Gligorea et al., 2023; Irawati & Iwan, 2024; Ningsih et al., 2024; Sulistyo et al., 2024).

Furthermore, the implementation of this research aligns closely with national strategies aimed at modernizing the healthcare sector through digital transformation. Indonesia has increasingly emphasized the importance of optimizing technology to strengthen health system resilience, reduce medical errors, and enhance public trust in healthcare institutions. By addressing patient safety challenges through the integration of virtual training and AI-based evaluation, this study contributes not only to the local needs of Samarinda but also to broader national goals regarding the advancement of digital health ecosystems.

The outcomes expected from this research extend beyond training improvements. First, it is anticipated that the adoption of ViSTA will significantly reduce the number of preventable patient safety incidents, directly improving the quality of care received by the community. Second, health workers will gain more confidence, agility, and competence in handling emergencies and coordinating care, leading to improved teamwork and communication in clinical settings. Third, by providing a structured and measurable training system, the model can serve as a replicable framework for other regions in Indonesia that face similar challenges. Lastly, the effective use of AI-driven assessments is expected to boost transparency and accountability in the evaluation of healthcare worker performance, promoting a culture of continuous improvement.

In conclusion, the escalating rates of patient safety incidents in places like Samarinda call for immediate, innovative, and technologically enhanced interventions. The integration of Virtual Simulation Training and Artificial Intelligence offers a compelling solution to existing training limitations and systemic challenges. Through this study, the hope is to contribute to a safer healthcare environment, support national digital health initiatives, and establish a sustainable training model capable of improving patient outcomes across Indonesia.

2. SCOPE OF THE STUDY

This study focuses on the rising number of patient safety incidents occurring in Samarinda and responds to the growing demand for technology-supported training solutions aimed at improving the competence of healthcare workers. The scope of the research is specifically confined to healthcare professionals who are directly responsible for patient safety–related tasks within the Samarinda area. Competence enhancement is measured solely through pretest and posttest evaluations, meaning the study does not extend to assessing long-term retention of skills or examining broader external influences, such as institutional culture, staffing levels, or workload pressures that might also affect performance.

Given these clearly defined boundaries, the study seeks to generate concrete empirical findings regarding the effectiveness of Virtual Simulation Training combined with Artificial Intelligence (ViSTA) in elevating the competence of healthcare workers. The intention is to demonstrate how an integrated digital training model can produce measurable improvements in

the short term, even though long-term outcomes remain outside the study's focus.

By concentrating on immediate competence changes, the research provides an evidence-based rationale for the adoption of innovative digital learning platforms within healthcare settings. Furthermore, the findings are expected to serve as a scientific basis for recommending ViSTA as a feasible and sustainable approach to strengthening patient safety practices in Indonesia. Through this contribution, the study aims not only to address local challenges faced in Samarinda but also to support national efforts to improve patient safety systems through the strategic use of technology-driven training interventions.

3. MATERIALS AND METHODS

This research utilized a quasi-experimental methodology employing a pre–post test format combined with a control group to determine how effectively Virtual Simulation Training and Artificial Intelligence (ViSTA) enhances the competence of healthcare workers in handling patient safety incidents. The selected design was considered the most suitable because it enables a clear comparison between two groups—one receiving the ViSTA intervention and another functioning as a non-intervention control group. Through this structure, the study could more accurately measure differences in competence improvement, offering a stronger evaluation of the training's actual influence.

The target population consisted of all healthcare professionals working across various healthcare facilities in Samarinda, including hospitals, community health centers (puskesmas), and private clinics. Several inclusion criteria were established to ensure participant relevance: individuals had to reside in Samarinda, be actively involved in work related to patient safety responsibilities, express willingness to participate throughout the study duration, and have no prior history of joining ViST-based training programs. Meanwhile, exclusion criteria were applied to healthcare workers currently on leave and those with under one year of professional experience, as these factors could potentially affect the accuracy and consistency of competence measurement.

Altogether, 40 participants were recruited for the study, with 20 assigned to the intervention group and 20 to the control group. This distribution strategy was intentionally designed to ensure adequate representation while also managing the possibility of sample reduction

due to dropout or unforeseen circumstances occurring over the course of the research. Maintaining equal group size allowed the comparative analysis to remain balanced and scientifically robust.

The study took place in Samarinda, East Kalimantan, throughout the year 2025. The overall procedure began with an initial screening phase, during which all prospective participants were evaluated based on the predetermined inclusion and exclusion criteria. After confirming eligibility, participants were assigned to either the intervention or control group through a simple allocation method. Prior to any exposure to the ViSTA program, both groups were required to complete a pretest aimed at capturing their baseline level of competence in managing patient safety incidents. This baseline data served as a crucial reference point for later comparison.

Following completion of the pretest, the intervention group underwent the structured ViSTA training module. This module provided virtual simulation sessions integrated with artificial intelligence–based feedback mechanisms designed to enhance clinical decision-making and competence. In contrast, the control group did not receive any form of training or exposure to ViSTA during the same period, ensuring that any observed improvement could be attributed specifically to the intervention rather than external factors.

After the intervention phase concluded, all participants—including those in the control group—completed a posttest using the same instrument as the pretest. The posttest served to identify changes in competence levels and to evaluate whether the ViSTA training produced measurable improvements compared to the control group. The design and systematic sequence of activities enabled the research to accurately determine the effectiveness of ViSTA as a training tool for improving patient safety–related competencies among healthcare workers in Samarinda.

4. DISCUSSION

A total of 40 healthcare workers participated in this study, comprising 20 respondents in the intervention group and 20 respondents in the control group. All respondents met the inclusion criteria, and no dropout occurred during the study period. Data analysis was conducted to describe respondents' baseline characteristics, compare pre- and post-training competence scores, and evaluate the effectiveness of the ViSTA intervention in enhancing healthcare workers' ability to manage patient safety incidents in Samarinda

Table 1. Baseline Characteristics of Respondents (n = 40)

Variable	Intervention (n=20)	Control (n=20)	p-value
Age (Years) (mean ± SD)	32,4 ± 4,5	31,8 ± 4,2	0,68
Gener (Male / Female)	6 / 14	7 / 13	0,74
Education (Diploma/Bachelor's/Master's)	8 / 10 / 2	7 / 11 / 2	0,89
Years of ezperience (mean ± SD)	6,2 ± 2,1	6,5 ± 2,4	0,71

Table 1 presents the baseline characteristics of respondents in both groups, showing a relatively balanced distribution. The mean age of participants was approximately 32 years, with a higher proportion of females compared to males. Most respondents held a Diploma (D3) or Bachelor's degree, while a smaller proportion had a Master's degree. The average length of work experience among healthcare workers was around six years. Statistical testing indicated no significant differences between the intervention and control groups ($p > 0.05$), confirming that both groups were comparable for analyzing the effectiveness of the ViSTA intervention.

Table 2. Comparison of Competence Scores Pretest and Posttest Within Groups

Group	Pretest (mean ± SD)	Posttest (mean ± SD)	p-value
Intervention (n=20)	55,8 ± 6,2	78,9 ± 5,8	<0,001
Control (n=20)	56,1 ± 5,9	59,3 ± 6,1	0,08

Table 2 presents the analysis results showing that the intervention group, which received ViSTA training, experienced a significant increase in competence scores, rising from 55.8 ± 6.2 at pretest to 78.9 ± 5.8 at posttest ($p < 0.001$). In contrast, the control group showed no significant difference, with scores increasing only from 56.1 ± 5.9 at pretest to 59.3 ± 6.1 at posttest ($p = 0.08$). These findings indicate that the virtual simulation and artificial intelligence–based intervention substantially improved healthcare workers' skills compared to those who did not receive the training. The relatively small improvement observed in the control group was likely attributable to routine work experience rather than structured intervention

Table 3. Comparison of Posttest Competence Scores Between Groups

Variable	Intervention (n=20)	Control (n=20)	p-value
Posttest (mean+SD)	78,9 ± 5,8	59,3 ± 6,1	<0,001

Table 3 demonstrates that the comparison of posttest scores between groups revealed a highly significant difference. The mean competence score in the intervention group (78.9 ± 5.8) was substantially higher than in the control group (59.3 ± 6.1), with $p < 0.001$. These findings provide robust evidence that the implementation of ViSTA produced a meaningful improvement in healthcare workers' competence in managing patient safety incidents. The effectiveness of ViSTA can be attributed to its interactive, realistic, and real-time feedback features, which offer a more intensive and applicable learning experience. This aligns with international reports indicating that virtual simulation training can accelerate skill acquisition by up to 25% compared with conventional methods.

The findings of this study demonstrate clearly that the implementation of ViSTA—an integrated model combining Virtual Simulation Training with Artificial Intelligence—successfully elevates the competence of healthcare workers. This improvement aligns with the foundational principles of experiential learning theory, which argues that clinical abilities grow more effectively when learners engage directly with lifelike scenarios and obtain immediate, structured feedback. Through this mechanism, ViSTA strengthens the learning process by providing simulations that closely resemble actual clinical environments and by generating instant performance insights that guide users toward better decision-making.

The effectiveness of ViSTA observed in this study is also in harmony with global evidence supporting simulation-based learning. Numerous international studies have shown that simulation enhances clinical confidence, increases procedural accuracy, and sharpens the ability to make timely and correct decisions. What distinguishes ViSTA from traditional training approaches is the integration of artificial intelligence, which contributes an additional layer of precision and personalization. Unlike conventional instructor-led methods that may offer limited or generalized feedback, AI-supported evaluations within ViSTA allow each participant to receive objective, individualized assessments based on real-time performance data. This feature ensures that learning becomes more tailored, adaptive, and responsive to each healthcare worker's needs.

From an implementation standpoint, ViSTA carries particular relevance for the healthcare context in Samarinda. In many areas of East Kalimantan, access to high-quality, face-to-face clinical training is restricted due to infrastructure limitations, uneven distribution of educators, and budget constraints. Digital training platforms such as ViSTA present a practical solution to these challenges by expanding the reach of competence-building programs. With virtual modules that can be

accessed regardless of location, ViSTA helps narrow the gap between healthcare professionals working in urban facilities and those working in more remote settings. This contributes to reducing disparities in clinical preparedness and reinforces equity in training opportunities across the healthcare system.

The successful application of ViSTA also aligns with the broader direction of Indonesia's national digital health transformation. Current health policies emphasize the importance of efficiency, improved patient safety, and high-quality service delivery. The results of this study indicate that ViSTA has strong potential to be incorporated into larger-scale training initiatives designed to decrease preventable patient safety incidents nationwide. Nevertheless, to ensure long-term sustainability, several enabling factors—such as supportive institutional policies, adequate digital infrastructure, and managerial commitment—must be strengthened. Without these elements, the full impact of ViSTA may not be realized.

In terms of academic contribution, this research adds valuable insights to the growing body of literature on technology-driven health education in Indonesia. By introducing a hybrid training approach that merges simulation with AI-based personalization, the study provides a new framework for future investigations. Potential directions include assessing the long-term influence of ViSTA on healthcare service quality, evaluating its cost-effectiveness, or applying the model to more complex and high-risk medical procedures.

In summary, the study reinforces the proposition that digital innovation in health education can serve as a strategic pathway to enhance healthcare workers' competence and promote safer patient care. ViSTA proves to be a relevant, scalable, and impactful training solution for Samarinda and holds substantial promise for replication across other regions in Indonesia as part of efforts to strengthen the national healthcare system.

5. CONCLUSION

This study demonstrates that the implementation of ViSTA, which integrates Virtual Simulation Training and Artificial Intelligence, significantly enhances healthcare workers' competence in managing patient safety incidents. The intervention proved more effective than conventional training by providing interactive and realistic learning experiences supported by data-driven feedback.

The findings confirm that ViSTA is not only academically relevant but also carries important practical implications for healthcare delivery. Its application offers solutions to training access limitations in resource-constrained areas, strengthens healthcare workers' preparedness for critical clinical situations, and aligns with the national agenda for digital health transformation. ViSTA therefore holds strong potential as a sustainable training model that can be replicated across Indonesia to reinforce the patient safety system.

Beyond its immediate contribution to healthcare workers' competence, this study also opens opportunities for further research on its long-term effectiveness, multidisciplinary engagement, and integration into health policy. These findings emphasize the importance of technology-driven innovation as a key pillar for improving healthcare quality and patient safety in Indonesia.

6. RECOMENDATIONS

Future implementation of ViSTA should be expanded across healthcare facilities with strengthened digital infrastructure to ensure equitable access. Regular refresher training, policy support, and integration into national patient safety programs are essential to maintain competence. Further research is recommended to assess long-term impacts and applicability in broader clinical settings.

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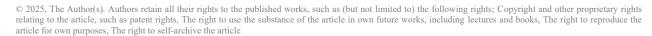
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