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The impact of virtual simulation technology and blended learning methods on nursing students' performance, acceptance and transition to clinical practice in higher vocational education

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ABSTRACT

In the context of China's national vocational education digitalization framework, nursing education virtual simulation (VS) is still not fully utilized as a resource to link theory and practice. The objective of this study is to compare the effects of VS-based blended learning (VS-BL) and traditional blended learning (T-BL) on nursing students' knowledge, skills, acceptance, and clinical readiness. A quasi-experimental design was employed with a sample of 79 vocational nursing students. The VS-BL group (n = 39) was exposed to a formal simulation unit prior to practical skills performance, while the T-BL group (n = 40) received traditional training. Theoretical scores (M = 86.33 ± 8.18) and OSCE performance (M = 84.38 ± 2.68) were significantly higher in the VS-BL participants than in the T-BL group ($p < 0.001$). Additionally, the percentage of VS-BL students who felt prepared for clinical experience, self-directed learning, or professional identity development increased by 84.6%. The findings indicate that incorporating virtual simulation within blended learning significantly enhances students' competencies and preparedness for clinical practice, highlighting its potential as an effective educational resource in nursing training.

Contribution/ Originality: This study contributes to the existing body of literature by empirically evaluating the implementation of virtual simulation within a nursing blended learning course. It is among a limited number of studies that examine its impact on students' clinical preparation, professional identity development, and self-directed learning. The primary finding of this research is that both theoretical knowledge and practical skills, as well as their transition into clinical practice, are significantly improved through virtual simulation-based blended learning.

1. INTRODUCTION

The accelerating growth of artificial intelligence (AI) and digital technologies has profoundly transformed educational concepts globally, making the field of vocational education (VE) enter an era characterized by a digital turning point. In China, this shift is supported by national policies that advocate for integrating high-tech technologies into vocational courses as a means of linking knowledge acquisition with practical application. This initiative is exemplified by the "Education Information 2.0 Action Plan" and the large-scale effort to promote high-quality development in modern vocational education, emphasizing practical training, education-industry integration, and educational modernization. One notable example is the 2022 "Guidance Opinions on Accelerating Scenario Innovation of High-Level AI Applications," which explicitly mandates that schools incorporate scenario-based innovation courses into AI-related programs to enhance students' ability to apply technology to real-world problems.

Conversely, virtual simulation technology remains a critical component for achieving "Double-High" status and upgrading higher vocational colleges, with significant capital investment in simulation facilities. However, the underutilization of these resources is a major concern, as the potential benefits are not fully realized, highlighting the need for empirical evidence to identify successful approaches to application.

This gap is particularly evident in nursing education, as it is the field intended to equip students with theory, practical skills, and confidence in clinical environments. The traditional didactic model presents several challenges that hinder this objective. First, the increasing number of enrollees combined with an insufficient number of teaching facilities results in limited clinical training opportunities and impedes students' acquisition of essential practical experience. Second, safety and ethical considerations prevent learners from performing high-risk procedures on real patients, leading to incomplete training in critical skills. Third, students have limited exposure to real-world healthcare settings, which complicates the transition from theory to practice, resulting in 'workplace unreadiness' and diminished confidence. This gap between theory and practice is widely acknowledged in theories such as 'Reality Shock' by Kramer [1], where one of the stages involves rejection when new nurses do not meet their expectations [1], and Duchscher's Transition Stages Model, which explains how new professionals may become overly concerned with tasks and neglect clinical judgment.

There are also pedagogical challenges that exacerbate this, such as uninteresting teaching methods which fail to motivate students, poor interactions between teachers and students in didactic lecture settings, the expense of disposable medical materials, and a lack of assessment tools for monitoring skills over time. Taken together, these issues diminish the quality of nursing education and how well graduates are prepared for life on the job. That's where virtual simulation technology enters as a solution to these complex issues. It is able to create realistic, interactive, and safe learning environments where students can practice their clinical skills repeatedly without endangering patient safety. Moreover, it improves situational awareness and clinical decision-making and decreases reliance on costly consumables. The Chinese Ministry of Education has already recognized this trend and actively advocated for virtual simulation in higher education, such as the "Notice on Construction of Demonstration Virtual Simulation Experimental Teaching Projects."

In light of this background, the aim of this study is to explore intravenous infusion, a basic nursing procedure that requires stringent aseptic procedures and has potential clinical risks such as needle stick injury and infection. We will compare the effectiveness of virtual simulation-enhanced blended learning with the traditional blended teaching model. In particular, we will examine the impact on skill acquisition, student engagement, perception of and receptivity to technology, and the translation of learning into clinical practice. This research has the potential to serve as a direct link in evidence-based implementation of virtual simulation as a system-wide strategy for safely graduating competent nurses. This research indirectly addresses policy mandates as well as the continued gap between theory and practice.

2. LITERATURE REVIEW

This section focused on a review of related studies on constructivist learning theory, virtual simulation technology, and blended online-offline teaching methods.

This paper is conceptually situated within constructivist learning theory, which emphasizes the central role of learners in actively forming new knowledge by situating it based on their prior knowledge rather than being mere recipients of information [2]. This view asserts that learning is a process of constructing meaning, which develops from the interaction between individual cognition and the surrounding environment. In this context, students have personal agency in their cognitive functioning as they make sense of and incorporate novel experiences. Constructivism highlights that learning only happens when people are actively engaged; the content has a meaningful context, and learners learn socially, all of which makes education less about transferring rote knowledge to impart insight than constructing understanding based on engagement with realistic activities.

Context, collaboration, dialogue, and meaning making are all fundamental features of a constructivist learning environment [3, 4]. Context is used to describe real or simulated learning situations where abstract information is rooted in actual practice. Collaboration stems from an emphasis on social interaction, and learning in collaboration is the negotiated process of representing shared knowledge among learners as a result of their group activity. Discussion serves as the mechanism for exchanging ideas that help learners to evolve and extend their views. Meaning-making is the end product of such interactions, in which learners are said to incorporate new information into pre-existing frameworks and develop coherent and applicable knowledge structures. In concert, these principles facilitate learning that is active, reflective, and socially mediated, rather than passive and isolated.

According to this theory, virtual simulation technology (VST) and blended learning are current educational models based on constructivist principles. Virtual simulation offers an immersive learning space that allows learners to take on the roles of real-life practitioners in interactive, digital worlds. Simulation-based systems in nursing education simulate clinical scenarios that students may experience in practice, such as control of IV sites [5] or emergency management. These simulations translate indirect clinical concepts depth of the needle, flow rate of the fluid, or patient's response into very concrete and intuitive experiences that engender a high level of understanding [6]. As students explore, make their own decisions, and learn from their consequences in a safe environment, this approach aligns closely with constructivist learning principles active, experiential learning. Blended learning extends the utility of virtual simulation by integrating face-to-face instruction with computer-based teaching into a cohesive framework. It is a pedagogical model rooted in constructivism and learner-centered principles, emphasizing interaction, collaboration, and reflection. In a blended learning environment, students are encouraged to collaborate and solve problems as groups, receive peer assessment feedback at various stages, and obtain verbal instructions beyond traditional classroom boundaries. Teachers act as facilitators, designing scenario-based tasks and guiding students in reflection rather than delivering didactic instruction. This combination fosters student independence, motivation, and enhances critical thinking and problem-solving skills [7, 8].

Empirical studies indicate that virtual simulation is effective in improving learning outcomes for nursing students. Studies by Liu et al. [9] and Lin et al. [10] compared students using virtual simulation and online learning with those taught through traditional methods. The experimental groups demonstrated a high level of effective independent learning, acceptance of technology, and theoretical understanding, but their results for collaborative skills were insufficient. Diao et al. [11] found higher theoretical scores and technical competence among students in the virtual simulation group compared to the traditional demonstration group. Similarly, Yang et al. [12] applied self-efficacy theory and VR simulation in a one-year randomized control trial involving 200 nursing trainees' internships; clinical training was significantly improved, including assessment accuracy and learner satisfaction, highlighting its pedagogical value. Consistent with these findings, Zhang et al. [13] found that supplementing traditional education with virtual simulation enhanced students' learning, clinical reasoning skills, and positively influenced their professional identity; however, it remains unclear whether such gains are transferable to long-term skill retention. Wang et al. [14] concluded that online teaching combined with virtual simulation could improve the theoretical knowledge and practical skills of nursing students, but standardizing the comparability of different teaching methods remains challenging. Collectively, the findings demonstrate that virtual simulation facilitates independent learning, technical skill acquisition, and clinical reasoning, making it a priority in nurse training. However, the overall heterogeneity of terminology used in studies particularly regarding collaboration, engagement levels, and long-term transfer of learning indicates the need for more rigorous research designs.

Scholars such as Fan et al. [15] and Cant et al. [6]: Many studies around the world have investigated virtual simulation in nursing, but the number of Chinese studies concerning application or evaluation is greater, while less attention has been paid to instructional design or rationale. Therefore, although the application of simulation-based pedagogy has been emerging as a trend in Chinese nursing education since the late 1990s, it is lagging behind in Western countries. Fortunately, recent developments reveal an increasing focus on effectively implementing virtual

simulation in applied training (aetiology), with initial indications of positive effects in this area but limited longitudinal evidence regarding transfer to realistic clinical settings. Figure 1 illustrates key global studies on virtual simulation and blended learning in nursing education. It visually groups the literature reviewed according to its research focus, learning outcomes, cost-effectiveness, curriculum integration, and technology acceptance, demonstrating how previous research collectively supports the educational value of simulation-based learning while also highlighting gaps in current evidence on long-term skill transfer, standardization, and instructional design.

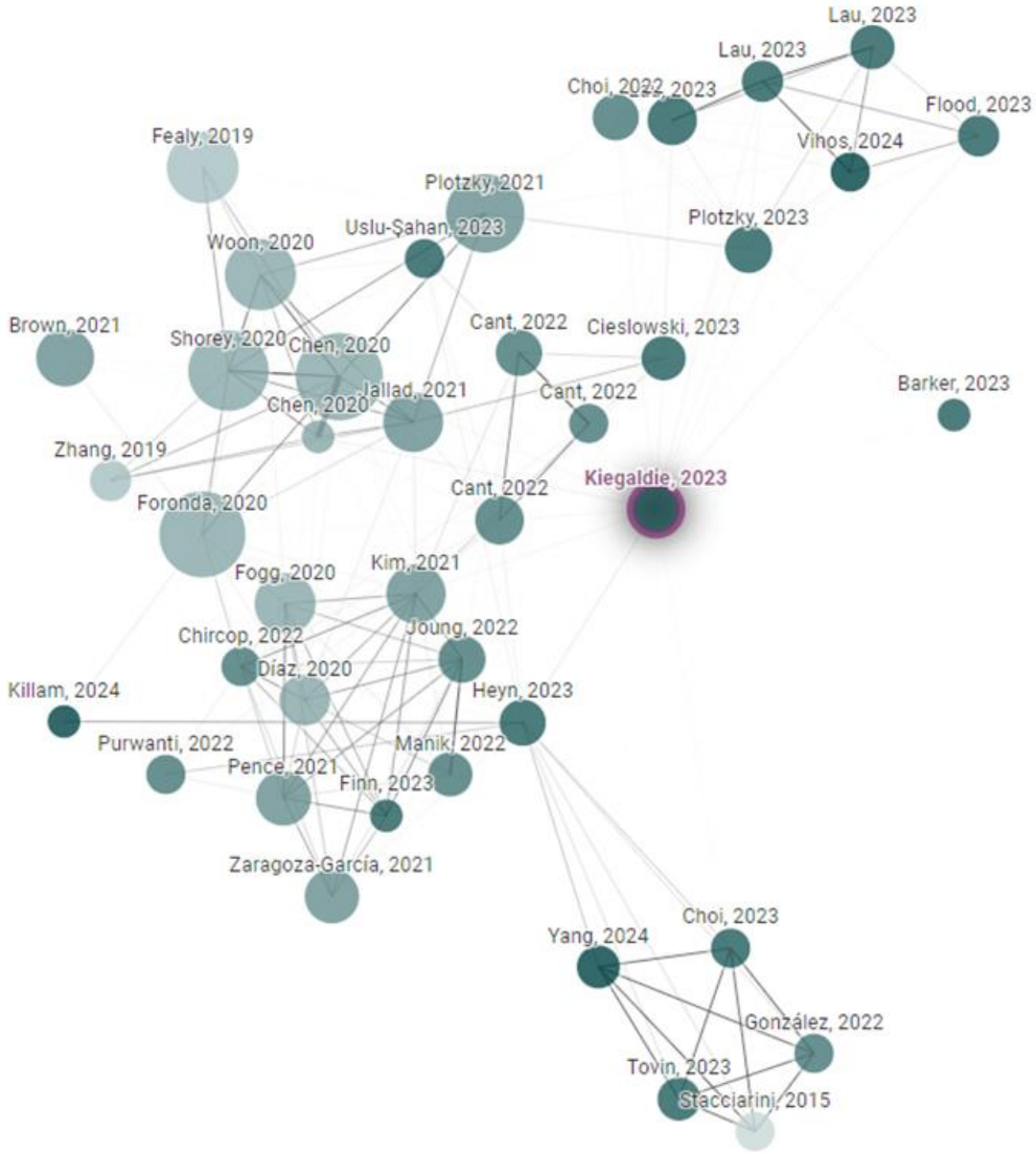

Figure 1. Related papers mapping.

Source: Brown, et al. [16]; Chen, et al. [17]; Chen, et al. [17]; Coyne, et al. [18]; El Hussein and Cuncannon [19]; Fogg, et al. [20]; Hung, et al. [21]; Kiegaldie and Shaw [22]; Kim, et al. [23]; Lee, et al. [24]; Liu, et al. [25]; Padilha, et al. [7]; Shorey and Ng [26] and Tonapa, et al. [27].

Studies on the effectiveness of virtual simulation have been conducted globally, addressing various aspects such as learning outcomes, cost-effectiveness, and curriculum integration. Padilha et al. [7] reported that knowledge retention increased by 20.4% with immersive simulation. Lee et al. [24] observed lower clinical errors and increased student satisfaction among simulation-trained trainees. Tonapa et al. [27]demonstrated that virtual simulations had

a 22% shorter development time and were 40% less expensive than high-fidelity physical simulations, with economic benefits also confirmed. Cho and Kim [28] emphasized cost reduction and savings in material usage. However, Brown et al. [16] cautioned that, although learners expect a certain level of realism, reduced authenticity can lead to limited immersion and shallower reflection levels, a concern also noted by Fogg et al. [20] and Kiegaldie and Shaw [22]. These findings suggest that there is a delicate balance between technological feasibility, pedagogical objectives, and experiential authenticity when integrating simulations into learning environments.

Evidence for virtual simulation is fragmented, although promising. Chen et al. [17]; Coyne et al. [18]; Liu et al. [25] and Cant et al. [6] noted that variation in outcomes is associated with implementation, instructional design, and learner context. Shorey and Ng [26] also found no longitudinal research investigating the transfer of simulated learning to practice, as stated by Kim et al. [23], who identified the untapped capabilities of simulations to complement reflective "what-if" learning. El Hussein and Cuncannon [19] also raised concerns over the seamless transfer of virtual skills to clinical practice. Altogether, these studies point to the need for standardization and conceptual integration as well as cultural relevance. According to Hung et al. [21], simulation is most effective for learning when it is used as a reflective practice – an opportunity for the learner to benefit from mistakes and actively redefine meaning. Nonetheless, technical, cultural, and language constraints still obscure the general usage of it [20].

Along with simulation technologies, blended learning has also become a revolutionary teaching model in nursing education. It is defined as the deliberate integration of conventional face-to-face approaches with online and technology-facilitated learning, which builds on constructivist theory to encourage active participation and learner self-responsibility [29]. Blended learning actively promotes children's critical and reflexive thinking and problem-solving, surpassing their abilities rather than passively listening to the things said or done Hong and Lee [30]. Kobicheva et al. [31] identified that information has shifted blended learning to the “new norm,” and most nursing programs are currently using some form of a hybrid approach. A well-designed blended learning model usually phases three parts, including pre-class, in-class, and post-class, to promote deep learning, which spans the lowest to highest categories of Bloom’s taxonomy [32, 33]. Examples include micro-lectures, online quizzes, and simulations that provide basic meaning. As with other topics, participants will develop practical exercises and peer assessments in class to make theoretical knowledge a matter of practice. It is also after class, through activities such as giving hints for tests, posting questions, and submitting practice videos on platforms like “Mosoteach,” that learning and procedural skills are further developed. These activities foster a continuous process of engagement, feedback, and reflection, all key features of constructivist pedagogy. One of the keys to effectiveness in blended learning is collaborative learning. Collaboration among peers in both virtual and physical spaces fosters critical skills, such as clinical reasoning, communication, and teamwork, which are applied competencies core to the field of nursing. Studies by Padilha et al. [7]; Jallad and Işık [34]; Tonapa et al. [27]; Liu et al. [25], and Stenseth et al. [8] assert that collegial, student-centered models outperform traditional didactic models in terms of skill and professionalism growth. If implemented correctly, blended learning has the potential to enhance not only conceptual development but also the interpersonal competencies essential for clinical capacity.

However, there are still difficulties in hybrid system learning and technology emulation extension. Critical to this is the informatics expertise of nursing faculty. Chen et al. [17], Coyne et al. [18], and Sim et al. [35] emphasize that poor teacher training may result in inadequate use, or even mechanical use, of simulation and online tools without pedagogical integration. The goal of the educational system and tools, compared to the technologies used, also leads to inefficient learning as well [6]. Professionals using virtual simulation may struggle to acquire specific clinical skills or knowledge if new teaching objectives are not explicitly articulated. Additionally, digital disparities in access and connectivity among students such as unequal internet connection, device possession, and varying levels of digital literacy may further exacerbate inequalities in learning outcomes [36]. These "reality checks" are local, demonstrating that we cannot expect the infusion of technology to elevate us into the next tier of pedagogical innovation without faculty development and institutional support.

Now, there is further research required regarding both virtual simulation and blended learning, but the available evidence in the literature highlights serious concerns. These comprise a lack of clarity around the development of collaborative skills and learner engagement dynamics, inconsistent findings regarding long-term retention and generalization (transfer) of skills, and a dearth of studies on cost-effectiveness and cultural adaptation. Furthermore, it is also obvious that there is a need for powerful instructional design models that blend simulation-based and blended features and are based on existing learning theories. Nevertheless, the combined evidence supports the value of integrating blended learning and virtual simulation in promoting independent learning, critical thinking, and clinical reasoning—core competencies for professional nursing practice.

This paper contributes to the emerging literature by reporting a study on ICT in intravenous infusion simulation training as part of a blended learning model. Hybrid educational models have been considered in other nursing settings, but data regarding the optimal mix of online simulation versus face-to-face skills practice are limited. This work, by systematically testing a range of modality ratios, provides valuable practical insights on achieving meaningful integration. Furthermore, the study enhances understanding of how blended learning with computer simulation (e.g., vSIM) affects nursing students' readiness for clinical transition over time, a relatively under-studied concept in nursing education. A second contribution is the consideration of teachers' technological readiness. As known, teachers' proficiency in simulation and online resources influences the success of blended methods; therefore, the study suggests providing teachers with inclusive training and continuous guidance. This in-service support promotes the use of technology as more than a surface tool but as a valuable educational resource. Moreover, by analyzing inequities in student access to digital learning resources, the study demonstrates that blended course design must be locally shaped for equity and inclusivity. In situations where access to infrastructure and digital literacy is uneven, targeted interventions and supporting institutional policies are necessary to ensure all learners benefit equally. Finally, this paper advances understanding of how virtual simulations and blended learning within a constructivist framework can revolutionize nursing education. Virtual simulation offers contextual and experiential framing that encourages deep learning, while blended learning provides the interactive and reflective structure necessary to maintain engagement, stimulate debate, and foster critical development. Together, they support not only retention of knowledge and skill development but also the acquisition of effective communication, collaboration, and clinical decision-making critical components for being work-ready. Despite its potential, further investigation is needed to address key questions about long-term retention and transfer of simulation-based learning, including issues related to cost-effectiveness and scalability in blended models and tailoring approaches across diverse cultural settings. The theoretical synthesis of constructivist principles must continually inform instructional design so that technology integration is grounded in solid pedagogy. Contextualizing technology within an active, contemplative, and collaborative model allows nursing education to evolve from merely providing knowledge to developing competencies necessary for effective practice in real healthcare settings. Pedagogical theory offers a robust framework for viewing and improving contemporary nursing education. Advantages of virtual simulation include enabling instructors to develop competent, learner-centered classrooms through active learning, critical thinking, and clinical competencies via virtual simulations and blended learning. The results and insights from this study provide useful directions for developing such models to enhance nursing education's progress toward richer, more contextually authentic, and technology-enriched learning environments.

3. RESEARCH METHODOLOGY

3.1. Research Design

This research employed a quasi-experimental pre-test post-test control design to evaluate the effectiveness of virtual simulation-enhanced blended learning on nursing students' performance, acceptance, and transition to clinical practice. Following the methodology outlined by Thomas [37] and Rogers and Revesz [38], this design compares

two groups: an experimental group that experienced virtual simulation technology combined with blended learning (VS-BL) and a control group that experienced traditional blended learning (TBL).

The design of the construction was.

Experimental group (EG): O1 → VS-BL → O2.

Control Group (CG) O1 → T-BL → O2.

Where O1 = Pre-test, O2 = Post-test, VS-BL = Virtual Simulated + Blended Learning… etc, and T-BL = Traditional Blended Learning… etc.

3.2. Participants

A total of 79 second-year nursing students enrolled in a 3-year full-time nursing program at Guizhou Vocational College of Industry and Commerce, Guiyang, Guizhou Province, P.R. China, constituted the study population. Participants were selected via a purposive sampling method through foundational nursing courses and had no previous exposure to intravenous infusion practice to homogenize their basic capability [39, 40].

Experimental group: 39 students (30 females, 9 males; mean age = 18.21 ± 0.34 years), including 33 from high schools and 6 from technical-vocational schools. Control group: 40 subjects (28 females, 12 males; average age 18.65 ± 0.43), students also with a matching educational level as the experimental group. Both groups studied in courses led by the same professors, having the same curriculum and conditions for evaluation and exams in order to avoid any potential bias.

3.3. Experimental Process

The intervention took place in the first semester of the academic year 2022-2023 and focused on the theme of intravenous infusion education as a fundamental nursing skill, dealing with sterile procedures and clinical applicability. The curriculum was consistent, consisting of 4 hours of classroom instruction followed by 8 hours of hands-on training for both sets. The content included pre-class online micro-lectures, in-class theoretical lectures, and practical performance.

Experimental Group: Intervention designed as interactive teaching skills simulation practice by virtual reality (VR) and traditional teaching; and the experimental group received a combined intervention. In the traditional skills teaching, a super class was organized to have students practice in a VR non-immersive simulation. Protocols: students were given traditional theory classes and an instructor demonstration on intravenous infusion first. Afterwards, they used the Unity Crash Handler 64 virtual simulation environment, with 3D environments and situations (Figure 2). Within these scenarios, students conducted step-by-step training: verifying information from virtual patients, selecting items of the correct kind from an inventory, and practicing individual steps of a procedure (e.g., following specific disinfection instructions). Once they completed the virtual practice and received real-time procedural feedback (e.g., venous anatomy and accuracy of technique), they moved to hands-on training with physical models in the laboratory. The layered practice in this progressive method was intended to strengthen mechanics and theoretical understanding.

Control Group Treatment: Students were trained according to the same configuration of muscle model training but not with virtual simulation. Ethical issues, institutional ethics approval, and participants' written consent were obtained, and the control group was given access to the virtual simulation lab after the intervention for equity.

Figure 2. Some photos of virtual simulation scenarios for intravenous infusion.

Control Group Theoretical Training Practice Session: The control group was trained using the identical theoretical model and physical practice procedures as those of the experimental group. Ethical issues included gaining ethics approval from the institutions and participant consent, with the virtual simulation lab being opened to the control group after the end of interventions to ensure that the control group members do not feel disadvantaged.

3.4. Research Instruments

The instruments for data collection include a self-developed questionnaire and the methodological approaches outlined in a previous study [25], as well as pre- and post-tests and skill performance evaluations. The questionnaire consisted of questions on students' perceptions, expectations, and learning needs regarding the virtual simulation (VS) technology for intravenous infusion training. The survey instrument measured different dimensions of students' experiences on a 5-point Likert scale, perceived effectiveness of teaching methods, learning motivation, confidence in communication skills, and self-reported proficiency in intravenous infusion procedures. The items included in the survey were derived from prior studies in virtual simulation and nursing education. Pre- and post-tests were used to measure students' learning progression and the impact of virtual simulation technology. To assess students' procedural competence, a standardized clinical skills performance was conducted as an objective evaluation.

3.5. Data Analysis

The analysis was performed using SPSS 25.0: Results include descriptive statistics such as mean, standard deviation, and frequencies for participants' demographic information, pre-test and post-test scores, and responses on the survey. Inferential statistics involved independent samples t-tests to examine post-test differences between groups with pre-test performance covaried. Within-group comparisons from pre- to post-testing were conducted using paired

samples t-tests. A p-value of less than 0.05 was considered statistically significant. To assess the magnitude of group differences, effect sizes (Cohen's d) were also calculated.

4. RESULTS

4.1. Introduction

This chapter presents findings from the quasi-experimental study investigating the impact of virtual simulation-enhanced blended learning on vocational nursing students' intravenous infusion performance, technology acceptance, and clinical transition. Data analysis integrated descriptive and inferential statistics to address the research questions, with significance set at $p < 0.05$.

4.2. Findings by Research Question

4.2.1. Impact on Student Performance

Table 1 Comparison between pre- and post-test of EG and CG in intravenous infusion theory knowledge. Descriptive statistics revealed that there were no significant differences in pre-test scores between EG (n=39; 59.77±14.47) and CG (n=40; 54.30±14.57) (t=1.675, p=0.098), suggesting that both groups had similar baseline levels of knowledge before the intervention.

However, post-test scores were found to be statistically significantly different (t=8.692, p=0.000), with the experimental group (EG) obtaining a significantly higher mean score of 86.33±8.18 compared to the control group (CG) with 70.83±7.68. This remarkable enhancement in EG's performance, along with the pre-test equivalent level, indicates that incorporating virtual simulation technology into the blended learning model has a significantly positive effect on increasing college nursing students' theoretical knowledge about the IVI. The results support that this teaching strategy promotes the effective achievement of theoretical praxis content on parenteral therapy more effectively than traditional blended learning.

Table 1. Comparison of pre-test and post-test results between the two groups ($\bar{x}\pm s$).

Assessment stage	Group	Sample size	Mean ± SD	t	p
Pre-test	Experimental	39	59.77 ± 14.47	1.675	0.098
	Control	40	54.30 ± 14.57		
Post-test	Experimental	39	86.33 ± 8.18	8.692	0．000
	Control	40	70.83 ± 7.68		

From Table 2, it is shown that for the Control Group, the mean and standard deviation of the Nursing Etiquette score are 7.13±1.29; Communication Skills score, 7.73±0.76; Nursing Skills score, 51.88±1.24; Nursing Documentation score, 7.23±0.75; Humanistic Care score, 7.52±1.33; and Total Score, 78.77±2.56. For the Experimental Group, the mean and standard deviation of the Nursing Etiquette score are 7.87±0.67; Communication Skills score, 8.42±0.43; Nursing Skills score, 54.20±2.23; Nursing Documentation score, 7.68±0.86; Humanistic Care score, 7.75±0.65; and Total Score, 84.38±2.68.

Table 2. Comparison of performance assessment results for two groups of operations.

Groups	Sample size	Nursing etiquette	Communication skills	Nursing skills	Nursing documentation	Humanistic care	Total score
Control group	40	7.13± 1.29	7.73± 0.76	51.88± 1.24	7.23± 0.75	7.52± 1.33	78.77± 2.56
Experimental group	39	7.87± 0.67	8.42± 0.43	54.20± 2.23	7.68± 0.86	7.75± 0.65	84.38± 2.68
F		0.157	1.249	11.753	4.546	0.361	15.371
p		0.869	0.002	0.001	0.010	0.671	0.000

More specifically, the mean scores of the Experimental Group in Communication Skills (8.42 vs. 7.73), Nursing Skills (54.20 vs. 51.88), and Nursing Documentation (7.68 vs. 7.23) are significantly higher than those of the Control Group, with corresponding p-values (0.02, 0.001, 0.01) indicating statistical significance. The total score of the Experimental Group (84.38) is also notably higher than that of the Control Group (78.77), with an F-value of 15.371 and a p-value of 0.000, suggesting that the experimental teaching method integrating virtual simulation technology has a significant positive impact on improving students' overall operational performance in intravenous infusion skills. However, there is no significant difference in Nursing Etiquette and Humanistic Care between the two groups.

4.2.2. Impact on Student Acceptance

Pre-intervention surveys indicated that 92.31% of students had prior exposure to virtual simulation, with 74.36% expressing enthusiasm for its integration.

From Table 3, for the Control Group (n = 40) and Experimental Group (n = 39), pre-intervention baseline data showed no extreme disparities. Post-intervention, in terms of teaching satisfaction items:

The Experimental Group outperformed the Control Group significantly in "Enhance Self-Directed Learning Ability" (2.02 ± 0.72 vs. 1.72 ± 0.61; F = 3.852, p = 0.023), "Improve Clinical Reasoning Skills" (2.36 ± 0.79 vs. 1.75 ± 0.55; F = 9.743, p = 0.001), "Strengthen Professional Identity" (2.65 ± 0.48 vs. 2.23 ± 0.57; F = 3.524, p = 0.032), and "Total Score" (12.48 ± 2.33 vs. 12.07 ± 1.52; F = 8.652, p = 0.002).

For "Improve Teamwork and Collaboration Skills," "Clarify Classroom Teaching Objectives," and "Enhance Interpersonal Communication Skills," there was no statistically significant difference between the two groups (p > 0.05).

In summary, the experimental teaching approach (likely integrating virtual simulation as per the study context) effectively boosted students' self-directed learning, clinical reasoning, and professional identity, driving higher overall teaching satisfaction compared to the control method.

Table 3. Comparison of teaching satisfaction among two groups ($\bar{x}\pm s$).

Item	Control group (n=40)	Experimental Group (n=39)	F	p
Enhance self-directed learning ability	1.72± 0.61	2.02± 0.72	3.852	0.023
Improve teamwork and collaboration skills	2.10± 0.68	2.43± 0.65	0.582	0.457
Clarify classroom teaching objectives	2.12± 0.58	2.38± 0.58	1.914	0.151
Enhance interpersonal communication skills	2.23± 0.46	2.37± 0.51	0.173	0.732
Improve clinical reasoning skills	1.75± 0.55	2.36± 0.79	9.743	0.001
Strengthen professional identity	2.23± 0.57	2.65± 0.48	3.524	0.032
Total score	12.07± 1.52	12.48± 2.33	8.652	0.002

4.2.3. Impact on Clinical Transition

Table 4 presents student evaluations of virtual simulation platforms (n = 39) following the integration of virtual simulation blended learning for intravenous infusion training.

For the item "Facilitates Transition to Clinical Practice," 33 students (84.6%) responded "Yes," 4 (10.3%) chose "Neutral," and only 2 (5.1%) said "No." This high proportion of positive responses, especially when considered alongside two-month post-internship questionnaire feedback, indicates that the virtual simulation-blended learning approach effectively accelerates students' transition to clinical practice.

Other items also reflect positive impacts: high "Yes" rates for "Can Assist Learning" (84.6%), "Improves Operational Proficiency" (89.7%), and "Helps Stimulate Learning Interest" (89.7%) suggest that the method enhances learning outcomes. Overall, these data support that virtual simulation blended learning not only boosts skill acquisition but also facilitates the transition to clinical settings for nursing students.

Table 4. Student evaluations of virtual simulation platforms (n=39) [n (%)].

Item	Yes	Neutral	No
Can assist learning	33(84.6)	4(10.3)	2(5.1)
Helps cultivate clinical reasoning skills.	30 (76.9)	6(15.4)	3 (7.7)
Improves operational proficiency	35 (89.7)	3 (7.7)	1 (0.8)
Enhances hands-on skills	35 (89.7)	3 (7.7)	1 (0.8)
Improve communication skills	30 (76.9)	6(15.4)	3 (7.7)
Enhances analytical and problem-solving skills.	26 (66.7)	10 (25.6)	3 (7.7)
Facilitates transition to clinical practice.	33(84.6)	4(10.3)	2(5.1)
Helps stimulate learning interest.	35 (89.7)	3 (7.7)	1 (0.8)
Prefer virtual simulation-based teaching.	34 (87.2)	3 (7.7)	2(5.1)

4.3. Summary of Key Findings

VS-assisted BLSA remarkably enhanced the theoretical and practical performance of intravenous infusion, particularly in technical skills and documentation. There was good buy-in from the students and significant improvement related to self-directed learning, clinical reasoning, and professional identity. The intervention supported the transition to practice by increasing skill retention and confidence, but there are still gaps in communication skill development.

5. DISCUSSION OF FINDINGS

Ghanbari et al. [41] compared the effects of virtual simulation-enhanced blended learning (VS-BL; a combination of face-to-face and self-regulated learning, web-based learning, and instruction in a simulation center) with traditional blended learning (T-BL) on vocational nursing students' learning of intravenous infusion skills, including theoretical knowledge, clinical performance, social professional identity, and transition to practice. The findings indicate striking similarities and are consistent with or depart from prior work and theoretical models.

5.1. Skill Acquisition and Theoretical Mastery

Consistent with the constructivist theory of learning [42], VS - BL was the best-performing group. The data in Table 1 show that their post-test theoretical scores were significantly higher than their pre-test scores (e.g., 86.33 ± 8.18 vs. 70.83 ± 7.68; $p < 0.05$). This deviates from the constructivist focus on social collaboration in learning (Weeks et al.). Existing VS modules are highly technical and lack interpersonal components. As Rouleau et al. [43] noted, simulation alone might not be sufficient to foster relational competencies, thus suggesting that more patient-centered communication scenarios be included in VS.

5.2. Professional Identity and Clinical Transition

The results presented in Table 3 indicate that the VS - BL group had a stronger professional identity (2.65 ± 0.48 vs. 2.23 ± 0.57; $p = 0.032$) and higher perceived readiness for clinical practice. This is consistent with the constructivist view on role enactment and social interaction in identity formation [44]. In virtual scenarios, students assume the role of care providers, which helps in building a sense of professional responsibility. Tonapa et al. [27] found that VS replicates real-world clinical contexts, reducing the so-called "reality shock" [1] and facilitating a smoother transition to clinical practice.

5.3. Limitation in Communication Skills

However, as the data in Table 3 shows, communication skills improvement was not significant in the VS - BL group ($p > 0.05$). This is a departure from the constructivist emphasis on social interaction in learning [3]. Current VS modules mainly focus on technical procedures rather than interpersonal dynamics. As Rouleau et al. [43] pointed

out, simulation alone may not be sufficient to develop relational competencies, indicating the need to incorporate more patient-centered communication scenarios in VS.

5.4. Alignment with Prior Research and Theoretical Contributions

Our data corroborate the prior study by Cant et al. [6] conducted an umbrella review on the use and effectiveness of virtual simulations in nursing student education, evidencing the positive effect of using VS in nursing education. Furthermore, our finding that increased mastery of theory is associated with increased motivation also goes beyond Bandura's self-efficacy theory, since the immersive nature and instant feedback offered by VS augment advanced mastery and thus confidence [45]. The current results also confirm [46] model of simulation, with VS manipulability being highly associated with VS skill internalization, as Rouleau et al. [43] found.

5.5. Educational Implications

These findings, obtained from the extensive database analysis, highlight the importance of incorporating VS into the curriculum of licensed vocational nursing. Educators will need to create blended approaches that integrate pre-class VS rehearsal with in-person VS practice. Additionally, more communication scenarios should be included in VS to address the existing gap. VS platforms with AI-based feedback for personalized learning should be incorporated, including the purchase of adaptive VS platforms with AI [47], in accordance with the national policy on digital transformation in VET. Finally, VS-BL is an effective means of improving technical and cognitive skills among nursing students, but it also requires reinforcement of social interaction aspects. The results contribute to the growing body of evidence supporting technology-enriched learning in the theoretical-practical dichotomy.

5.6. Limitations

The current study demonstrates limitations in the research subjects. Subject: The study sample included 79 nursing students who were all second-year nursing students recruited from one vocational college, and the sample size was small and the delimited site was small (limited to one institution). It did not cover nursing students from different vocational colleges of different grades in different areas, let alone students of different grades and backgrounds. The early phase also limits the generalizability and external validity of the results, which would make it hard to express completely the effect of virtual simulation-enhanced blended learning at vocational nursing education in various educational contexts.

6. CONCLUSION AND RECOMMENDATIONS

This research compared traditional blended learning (T-BL) with virtual simulation-enhanced blended learning (VS-BL) and the impact of VS-BL in a nursing education program. One hundred ninety-eight students were randomized into two groups to compare the two learning interventions on the effects of intravenous infusion skills and to assess theoretical knowledge, objective structured clinical examination (OSCE) scores, simulated clinical readiness/clinical judgment, and the professional identity domain of the Readiness for Hospital Practice Scale Ver1 2. The results of this study showed that the VS-BL group had significantly higher theoretical scores (86.33±8.18 vs. 70.83±7.68, $p<0.05$). These results align within a constructivist paradigm that VS-BL can bridge theory and practice gaps. Firefighter conclusions include educators embedding sequenced VS-BL in a communication-rich case and institution investment in adaptive VS infrastructure and faculty development, and future investigation of long-term skill retention and extension of VS to high-risk procedures.

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Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
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