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Research

Interactive Virtual Simulation Case: A Learning Environment for the Development of Decision-Making in Nursing Students

Daniel Medel, RN, MRes, ABD[1], Aïda Bonet, RN, MRes, PhD[1], Maria Jimenez Herrera, RN, ANTP, MB, PhD[2], Francesc Sevilla, ASCP[3], Jordi Vilaplana, CSE, PhD[4], Tània Cemeli, MBM, PhD[1]*, Judith Roca, RN, MEd, PhD[5]

[1] *Department of Nursing and Physiotherapy, University of Lleida, Lleida, Spain*
[2] *Department of Nursing, University Rovira Virgili*
[3] *Fundació Universitària del Bages/Althaia (Hospital Universitari de Manresa), Manresa, Tarragona, Spain*
[4] *Department of Computer Science, Higher Polytechnic School, University of Lleida, Lleida, Spain*
[5] *Department of Nursing and Physiotherapy, Health Care Research Group (GRECS), Health Education, Nursing, Sustainability and Innovation Research Group (GREISI), University of Lleida, Biomedical Research Institute of Lleida, Lleida, Spain*

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ABSTRACT

Background: Interactive virtual clinical simulation allows students to actively engage in a learning experience by interacting with digital content.
Aim: To analyze the decision-making processes undertaken by nursing students using an interactive virtual simulation case.
Methods: Employing a cross-sectional design, this study involved 119 nursing students tasked with resolving a clinical case presented on a web platform. The case featured 11 decision points categorized into theoretical knowledge, data interpretation, and clinical management, offering multiple resolution options. Individual checklists were generated to document chosen actions and decision-making time upon completion. Additionally, students received feedback through learning capsules.
Results: Analysis of 119 checklists revealed that students achieved higher success rates in data interpretation (81.7%) and lower success rates in clinical management (58.7%). No significant differences were observed in resolution time across categories or among students with prior professional experience.
Conclusions: The interactive virtual simulation case (SAVI project) provides a conducive learning environment where students can demonstrate applied knowledge individually and within a lifelike context.
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Introduction

Health sciences education requires the cultivation of both practical and theoretical competences to prepare students for clinical practice. Among the range of pedagogical methodologies, clinical simulation has emerged as a prominent approach, underscoring its efficacy in enhancing teaching and learning. Recent research (Borg Sapiano et al., 2018; Lubbers & Rossman, 2017; Zapko et al., 2018) highlights the value of formative clinical simulations and experiences mirroring real-world scenarios within nursing education. These simulations not only enhance learning outcomes but also bolster psychomotor skills, motivation, self-efficacy, confidence, critical thinking, and overall student satisfaction. Furthermore, they contribute to elevating the quality and safety of real clinical practice by mitigating adverse events within healthcare settings (Cobbett & Snelgrove-Clarke, 2016; Padilha et al., 2019)

With advancements in technology, virtual simulation has emerged as a valuable tool for developing healthcare skills and competencies. Virtual simulation entails recreating real-life healthcare scenarios on a computer interface, enabling nursing students to actively engage in decision-making processes and consequential actions affecting simulated patients (Padilha et al., 2019). On the one hand, virtual simulation has been shown to enhance knowledge retention, clinical reasoning, and overall satisfaction with learning processes (Bogossian et al., 2015; Cobbett & Snelgrove-Clarke, 2016; Padilha et al., 2019). On the other hand, it aligns with students' expectations due to its interactive, adaptable, and digital nature, effectively preparing them for real-world clinical experiences (Tjoflåt et al., 2018). Interactive virtual simulation provides nursing students with a partially immersive and engaging learning experience, allowing them to cultivate the competencies necessary to deliver high-

*Corresponding author.
E-mail address: tania.cemeli@udl.cat (T. Cemeli).

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quality patient care. This simulation format enables dynamic, bidirectional communication between participants and digital devices or content, enriching the learning environment. Students actively engage with digital content, influencing scenario outcomes through their decisions, thus fostering a dynamic and interactive learning experience.

Clinical reasoning and clinical decision-making are foundational components of nursing practice. Clinical reasoning involves a complex process that integrates cognition, metacognition, and specialized nursing knowledge to analyze information, assess its significance, and determine potential courses of action (Simmons, 2010). Within this framework, decision making emerges as the crucial process for choosing among available options to address real or potential issues.

Multiple conceptual frameworks exist to elucidate the process of decision making. (Nibbelink & Brewer, 2018). In nursing education, clinical reasoning is essential for ensuring safe and high-quality patient care (Sim et al., 2022; Theobald et al., 2021) and enhancing nurses' professional competence (Mohammadi-Shahboulaghi et al., 2021). Virtual simulation facilitates active participation in the learning process and supports reflective practices through various feedback systems (Sim et al., 2022). It is imperative to underscore the importance of fostering reflection in students and emphasizing the responsibility of nursing faculty in guiding and promoting reflective practice and critical thinking to enhance future clinical decisions (Tutticci et al., 2022).

This study introduces a learning experience through interactive virtual simulation conducted within a classroom setting. Within this environment, nursing students interact with a computer interface portraying a clinical case featuring a virtual patient with acute pathology. The scenario dynamically evolves based on students' decisions during their interaction in the simulation. This innovative approach involves digital content developed by the research team, which differs from similar studies in the contemporary literature (Heyn et al., 2023; Kiegaldie & Shaw, 2023; Lee & Baek, 2023; Molloy et al., 2022; Yang et al., 2024). The digital content in the present study is structured to encompass various types of learning skills (Adams, 2015) based on Bloom's revised taxonomy (Wittrock et al., 2000), spanning three knowledge categories: 1) conceptual knowledge under Theoretical Knowledge, 2) procedural knowledge within the Data Interpretation category (theoretical-practical knowledge), and 3) cognitive and metacognitive knowledge within Clinical Management (practical knowledge). Additionally, the platform provides feedback through learning capsules to support students' learning processes and incorporates gamification elements to motivate students (van Gaalen et al., 2021). Virtual simulation fosters the development of clinical reasoning through experiential learning linked to direct patient care management (Sim et al., 2022). This enables nursing students to apply theory, interpret data to analyze information, and navigate clinical scenarios, thus acquiring critical nursing skills related to clinical reasoning and decision-making within a realistic context.

The primary objective of this study was to analyze the decision-making processes undertaken by nursing students through an interactive virtual simulation case. The secondary objectives were: 1) To determine the success rate in the decision points, based on the category of each decision and global score, 2) To identify the time spent on decision making, 3) To analyze the correlation between the “hit-rate” by category, time spent, and global score 4) To compare students with and without prior professional experience.

Methodology

Design

This educational research employed a quantitative cross-sectional methodology, following the guidelines outlined in the STROBE statement (Cuschieri, 2019; Vandenbroucke et al., 2009).

Context and Participants

A total of 135 students, all of whom were enrolled in the "Adult Nursing Care 2" course within the Nursing degree program at the Faculty of Nursing and Physiotherapy (FIF), University of Lleida (UdL), took part in this study. This course is part of the second-year curriculum, as the nursing degree program at Spain spans four academic years. The selection of this course aligns with the pedagogical elements, including competencies, teaching methodologies, and content relevant to the virtual simulation case developed (curriculum link: https://www.infermeriaigualada.udl.cat/en/pla-formatiu/pla-estudis-guies-docents/).

The participants comprised a natural class group; hence, no sampling techniques were employed. Inclusion criteria stipulated that participants must have enrolled and completed the entire course. Excluded from the study were repeating students, those who had opted for a single assessment, and students who, for various reasons, did not participate in all stages of the study or withdrew their data from the research (16 out of 135). Consequently, the final sample consisted of 119 participants.

Teaching Material and Classroom Implementation

Creation of Teaching Material

This learning experience centered on the resolution of an interactive virtual clinical case hosted on a website within the University of Lleida domain as part SAVI (*Simulación AudioVisual Interactiva*) project. This unique experience was entirely created, assembled, and recorded by an interdisciplinary research team consisting of three nurses, a physician, a biomedical scientist, and a computer engineer. The team collectively possessed expertise in both immersive clinical simulation and digital content creation. The case, set in a hospital room and involving a standardized patient and a nurse, was recorded in a high-fidelity format at the 4dH Simulation Center (simulator center: https://4dhealth.com/).

The written case underwent review by the research team and was subsequently validated by a panel of five clinical nurses for content, coherence, and realism. Upon acceptance, the research team (DM, JR, FS, JV, TC) mapped the entire clinical case into sequences in flowchart format, with each sequence independently recorded in video format. A script was developed for each sequence, delineating the scenario, participants, dialogue, and necessary materials. A total of 49 videos were recorded and assembled using Screenflow software (NCH Software) ® (see Supplementary File 1 for an example of the flowchart and scene script).

Learning Objectives

The competencies and learning outcomes are defined within the framework of the teaching guide for the “Adult Nursing Care 2” course (link to the teaching guide https://guiadocent.udl.cat/en/html/2024-25_100660). Supplementary File 2 presents the learning objectives related to the virtual simulation learning experience.

Content

A clinical case was developed using the Harvard technique (Mendoza, 2006), providing detailed case information while presenting various resolution possibilities. Created by three members of the research team (DM, JR, FS), comprising two nurses and a physician, the narrative organized the clinical situations of the case chronologically, considering elements such as:

1. Demographic aspects, medical history, and presenting symptoms of the patient: A 62-year-old ex-smoker with a history of chronic obstructive pulmonary disease, hypertension, and dyslipidemia

undergoing treatment with bronchodilators, antihypertensives, and statins.
2. Dyspnea due to an upper respiratory tract infection, a common condition observed in hospitalized patients.
3. Standard procedures included vital signs measurement and interpretation, arterial blood gas analysis, dyspnea management with selection of oxygen therapy devices, interpretation of laboratory values (renal function), drug administration based on patient's hemodynamic status, and identification and management of severe hypoglycemia.
4. Standard and current medications were used in the patient's treatment, such as paracetamol, amlodipine, salbutamol, methylprednisolone, ipratropium bromide, midazolam, glucagon, and glucose.
5. Potential complications (PC) described in the literature: PC dyspnea, PC hypoglycemia, PC hypercapnia, and PC alteration of consciousness (Carpenito, 2017; Hinkle & Cheever, 2021).
6. Eleven decision points were created, each presenting two or more resolution options, from which the student had to choose one, with only one correct option.
7. Critical scenarios necessitated autonomous decision-making by nursing students. These included selecting the most appropriate oxygen therapy device to address the patient's dyspnea (D4), as well as promptly identifying and managing the emergence of severe hypoglycemia (D10 and D11).

Pedagogical Resources of the Teaching Content

The design of the clinical case incorporated eleven decision points, each offering multiple response options. Through clinical reasoning, students made decisions directly influencing the patient's condition, thereby shaping the pathology progression. These decision points were distributed across three categories and are categorized by complexity (Fig. 1), as articulated through Bloom's revised taxonomy (Adams, 2015; Wittrock et al., 2000), wherein higher-order thinking skills always encompass lower-order thinking skills.

Table 1 outlines the case and decision points categorized as theoretical knowledge (n=1), data interpretation (n=5), and clinical management (n=5). The decision to integrate more advanced skills (data interpretation and clinical management) was made to assess the competency training of the students, thus emulating real-life clinical practice situations. It is worth mentioning that objective test-type assessments or similar can be used to evaluate theoretical concepts.

The case developed according to the participant's decisions, simulating a real clinical care scenario with multiple potential outcomes. This approach enabled students to make clinical decisions, assess alternatives, and understand the consequences of their decisions (SupplementaryFile3: Evolution of Nexus Decision).

Feedback was provided through graphical and visual elements of theoretical and theoretical-practical knowledge in the form of learning capsules to bolster each decision point during the clinical case. These capsules included explanations of each decision point (theoretical knowledge and data interpretation), aiding students in comprehending both successful and unsuccessful outcomes. Upon completing the case resolution, students received an overall success rate o global score (0-100%), serving as a gamification element.

Implementation

This interactive virtual simulation took place during face-to-face classroom seminars, involving groups of 15-20 participants. Each seminar lasted 2 hours, with 7 seminars conducted.

During implementation, the three phases of clinical simulation, according to the International Nursing Association for Clinical Simulation and Learning (INACSL) standards (INACSL Standards Committee, 2021) were followed. In the *prebriefing phase,* an instructor and simulation expert presented: 1) the associated learning objectives and the clinical case details, 2) the interactive virtual simulation methodology, and 3) website instructions. Approximately 15-20 minutes were allotted for students to check internet connectivity and resolve potential technical queries. In the *scenario phase*, students individually resolved the clinical case using a computer and generated a resolution checklist in PDF format via the website. Instructors

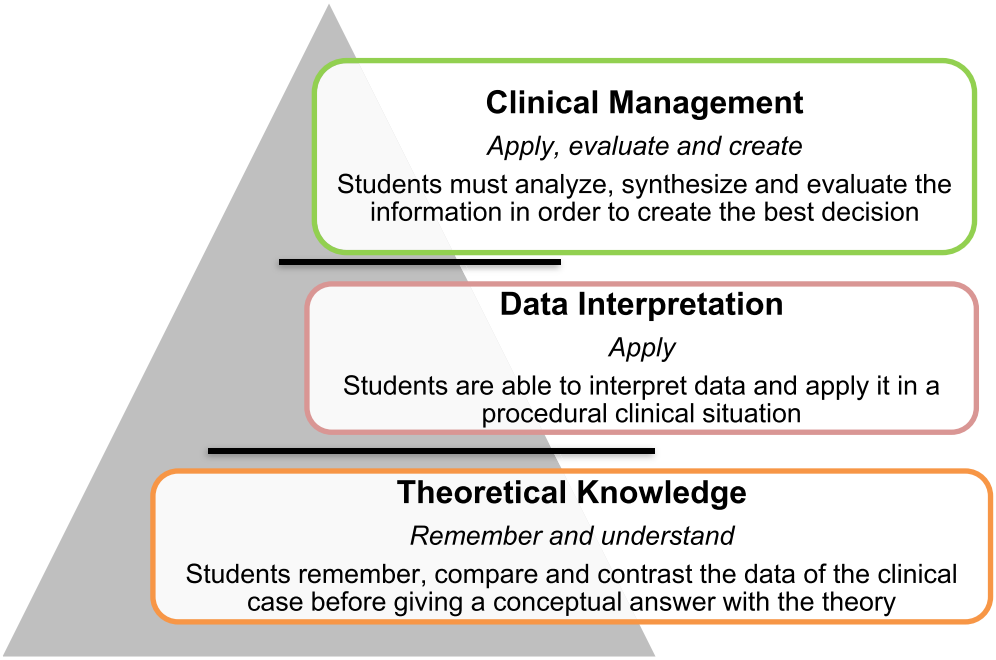

Fig. 1. Description of content categories.

Table 1
Presentation of the clinical case

Objective: To develop aspects of clinical judgment by immersing the student in a decision-making process involving the evaluation of different alternatives and the selection of the optimal option within a virtual simulated clinical context.	
Summary of the clinical case: The virtual patient, a former smoker of several years, presents with chronic obstructive pulmonary disease (COPD) characterized by an obstructive pattern. The patient also has controlled hypertension (HTA) treatment and dyslipidemia (DLP), both of which are under treatment.	
The patient experiences dyspnea during physically demanding activities and has reported experiencing dysthermia in the last 24 hours. The patient is conscious and oriented during the physical examination, with no signs of neurological focalization. Peripheral pulses are present and symmetrical. Pulmonary auscultation reveals crackles, particularly at the end of inspiration, accompanied by hypoventilation and reduced breath sounds.	
Vital signs are: BP 130/72mmHg, HR 99 bpm, SaO2 94%, and a temperature of 38.2°C.	
Category of the decision points	Decision point scheme
Data interpretation	Decision 1: Determine respiratory patterns.
	Choice of 3 possibilities: normal, obstructive, or restrictive pattern. An incorrect or correct response prompts a concise piece of educational feedback. Responses are accompanied by icons confirming the decision. The case does not evolve until the correct answer is selected.
Data interpretation	Decision 2: Assess vital signs and select a clinical diagnostic test.
	Choice of 4 options: hemogram, coagulation, arterial blood gas (ABG) analysis, and ionogram. An incorrect or correct response prompts a concise piece of educational feedback. Responses are accompanied by icons confirming the decision, and the case does not evolve until the correct answer is selected.
Data interpretation	Decision 3: Interpret ABG results.
	Choice of 4 possible results: metabolic acidosis, respiratory acidosis, metabolic alkalosis, or respiratory alkalosis. An incorrect or correct response prompts a concise piece of educational feedback. Responses are accompanied by icons confirming the decision, and the case does not evolve until the correct answer is selected.
Clinical management	Decision 4: Select the most appropriate oxygen delivery device for the patient's condition.
	Choice of 2 oxygen delivery devices: Venturi mask or reservoir mask. The case evolves regardless of the device chosen.
Clinical management	Decision 4A: If an incorrect option is chosen in Decision 4, a new decision is presented with 2 options to redirect the baseline situation and return to the correct course (Decision 5). If the student makes an incorrect decision in this section, it results in a fatal outcome for the patient, ending the simulation.
Data interpretation	Decision 5: Assess the blood test (CBC) and interpret the renal function test results (creatinine and urea).
	Choice of 2 options: true or false regarding alterations in renal function parameters. An incorrect or correct response prompts a concise piece of educational feedback. Responses are accompanied by icons confirming the decision, and the case does not evolve until the correct answer is selected.
Clinical management	Decision 6: Assess new vital signs and decide on the most appropriate drug for the patient's condition.
	Choice of 3 drug options: Paracetamol, amlodipine and salbutamol. An incorrect or correct response prompts a concise piece of educational feedback. Responses are accompanied by icons confirming the decision, and the case does not evolve until the correct answer is selected.
Theoretical knowledge	Decision 7: Assess pharmacological knowledge theory and identify the sympathomimetic drug.
	Choice of 3 drug options: methylprednisolone, ipratropium bromide, or salbutamol. An incorrect or correct response prompts a concise piece of educational feedback. Responses are accompanied by icons confirming the decision, and the case does not evolve until the correct answer is selected.
Data interpretation	Decision 8: Compare previous and current CBCs and ABGs.
	Choice of 2 options: Improved or worsened? An incorrect or correct response prompts a concise piece of educational feedback. Responses are accompanied by icons confirming the decision, and the case does not evolve until the correct answer is selected.
Clinical management	Decision 9: Assess the patient's condition and decide on the intervention.
	Choice of 3 diagnostic tests to perform on the patient: Computed axial tomography (CT), electrocardiogram, or capillary glycemia. The case evolves regardless of which diagnostic test is chosen. This decision takes the participant to Decision 10, 9A or 9B.
Clinical management	Decision 9A/9B In the event of an incorrect choice in Decision 9, the student is presented with a new decision featuring 3 treatment options to correct the situation and return to the correct path (Decision point 10): administer midazolam, administer paracetamol, or conduct a capillary blood glucose test. An incorrect decision in this section results in a fatal outcome for the patient's evolution, ending the simulation. In case of a correct decision, the student proceeds to Decision 11.
Clinical management	Decision 10: Interpret the capillary blood glucose result and select the most appropriate pharmacological treatment.
	Choice of 2 treatment options: administer 50% glucose or glucagon. The case concludes following this choice with a higher or lower degree of success in resolving the case, depending on the decision.
Clinical management	Decision 11 (only for students from 9A/9B): Interpret the capillary glucose result and select the most appropriate pharmacological treatment.
	Choice of 2 treatment options: administer 50% glucose or administer glucagon. The case concludes following this choice with a higher or lower success rate in resolving the case, depending on the decision made.

addressed technical issues only (connectivity problems, etc). Resolution time ranged from 25-35 minutes. In the *debriefing phase*, the simulation expert or facilitators conducted an approximately 50-minute group reflection.

Variables and Instruments

The study encompassed several variables, including each participant's sociodemographic data such as: age (numeric), gender (male, female, nonbinary), educational entry level to nursing school (Baccalaureate, training courses, university degree, over 25-45 years old), and prior health work experience (Yes or No) of the participants. The term "prior health work experience" pertains specifically to students who are nursing assistants or aides.

Specific study variables wertae derived from the primary measurement instrument: a checklist generated on the website during simulation. This checklist, specifically created for this learning experience by the research team, aligns with the contents of the clinical case. Structured by decision points, it reflects the student's decision-making process among a set of alternatives (SupplementaryFile4: Checklist).

Each checklist (one per student) recorded:

1. The accuracy of the decision made at each of the 11 decision points, with a dichotomous value (0=incorrect, 1=correct). Each decision point had only one correct response.
2. The time taken to make each decision, expressed in minutes and seconds (mm:ss)
3. The global score was based on the outcome (0-100%) and the total time. The final score primarily depended on the decisions made in the clinical management decision points (D4, D9, D10, and D11), which were crucial in determining whether the patient ultimately received appropriate treatment. The other decision points were not scored, as students could only advance when arriving at the correct solution. The research team established the global score, based on the decisions made by the students and their implications for the patient (SupplementaryFile5: Global score description).

The checklist appeared in the upper right margin of the computer screen within the web platform alongside the clinical case. Students entered their name, and a timer was automatically activated upon starting the case. They clicked on each decision point in the checklist to input their response, and the system recorded the time it took for the student to provide an answer in minutes. Upon completing the case, the system generated a global score, and the total time taken to resolve the case. Finally, the students created a PDF with their responses and times, downloaded the document, and submitted it to the instructor. Data collection took place from March to April 2022.

Data Analysis

Descriptive statistics of the sample were conducted to analyze the sample data, including participant characteristics, the final success rate, or global score, expressed as a percentage, and the average resolution time (measured in minutes). Variables were created to calculate the mean success rate and response time taken (t) by averaging the decision points grouped by categories: theoretical knowledge (D7), data interpretation (D1, D2, D3, D5, D8), and management of clinical situations (D4, D6, D9, D10, D11). Additionally, each of the eleven decision points was individually analyzed by success rate percentage and resolution time).

Correlations were examined using Spearman's rho, as the normality assumption (Shapiro-Wilk test) was not met due to a nonrandom, medium-sized sample with dichotomous variables in most of the decision points. Correlations were explored regarding the global score, response time, and success rate concerning the three categories (theoretical knowledge, data interpretation, and clinical management). Gender and prior work experience were compared using T-tests (Welch's t-test), while educational entry levels to nursing school were analyzed using ANOVA. Effect sizes were assessed using Fisher's tests.

Statistical calculations were performed using JASP software version 0.18.2 (Department of Psychological Methods, University of Amsterdam, Amsterdam, The Netherlands), and graphs and tables were generated using Excel version 365 (Microsoft®). A significance level of $p < .05$ was applied for the analyses.

Results

The results are structured into four sections and directly related to the secondary objectives outlined as follows: 3.1) Participant description; 3.2) Decision points description (items, categories, time) (secondary objectives 1 and 2); 3.3) Relationship between variables associated with decision making (secondary objective 3); and 3.4) Comparison between students with and without prior professional experience (secondary objective 4).

Participant Description

Among the 119 participating students, 75% were female (n=89), with an average age of 20.7 years (SD=3.12). The educational entry levels of nursing students were Baccalaureate for 76.41% (n=91), followed by training courses for 18.49% (n=22), and university degrees, and over 25 years for 2.52% (n=3 each). Students with prior work experience accounted for 27.73% (n=33). It is noteworthy that 100% of students had previously undergone immersive face-to-face clinical simulation, with this being their first encounter with virtual simulation.

Decision Points Description (Items, Categories, Time)

A total of 119 checklists were analyzed. The average response time per decision was 2:18 minutes (SD=01:23), and the average total simulation development time was 25:15 minutes (SD=01:30). The overall average success rate o global score was 79.6% (SD=0.35).

The success rates varied across decision categories, with data interpretation showing the highest success rate (81.70%) and an average response time of 02:53 minutes (SD=01:47), followed by theoretical knowledge decisions (59.70%) with and an average response time of 01:37 minutes (SD=00:51), and clinical management with the lowest mean success rate of 58.70% and a resolution time of 02:09 minutes (SD=01:13).

The decisions showed varying levels of complexity, which is evident in the mean response time for each decision point and percentage of correct answers. Fig. 2 presents the accuracy percentages for each decision point by category and response time.

The fastest decisions were "Compare previous and current assess: C60 the blood test (CBCs) and arterial blood gas (ABGs)" (D8, 01:09 minutes) and "Select the most appropriate oxygen delivery device for the patient's condition "(D4, 01:16 minutes). Conversely, the most time-consuming decisions were "Determine respiratory patterns" (D1, 04:54 minutes) and D6: "Assess new vital signs and decide on the most appropriate drug" (D6, 04:49 minutes).

In the data interpretation category, less accurate decisions were "Determine respiratory patterns" (D1, 60%) and "Interpret ABG results" (D3, 68%), and more accurate responses were observed for "Assess CBC and interpret the renal function results" (D5, 100%), "Compare previous and current CBCs and ABGs" (D8, 92%), and

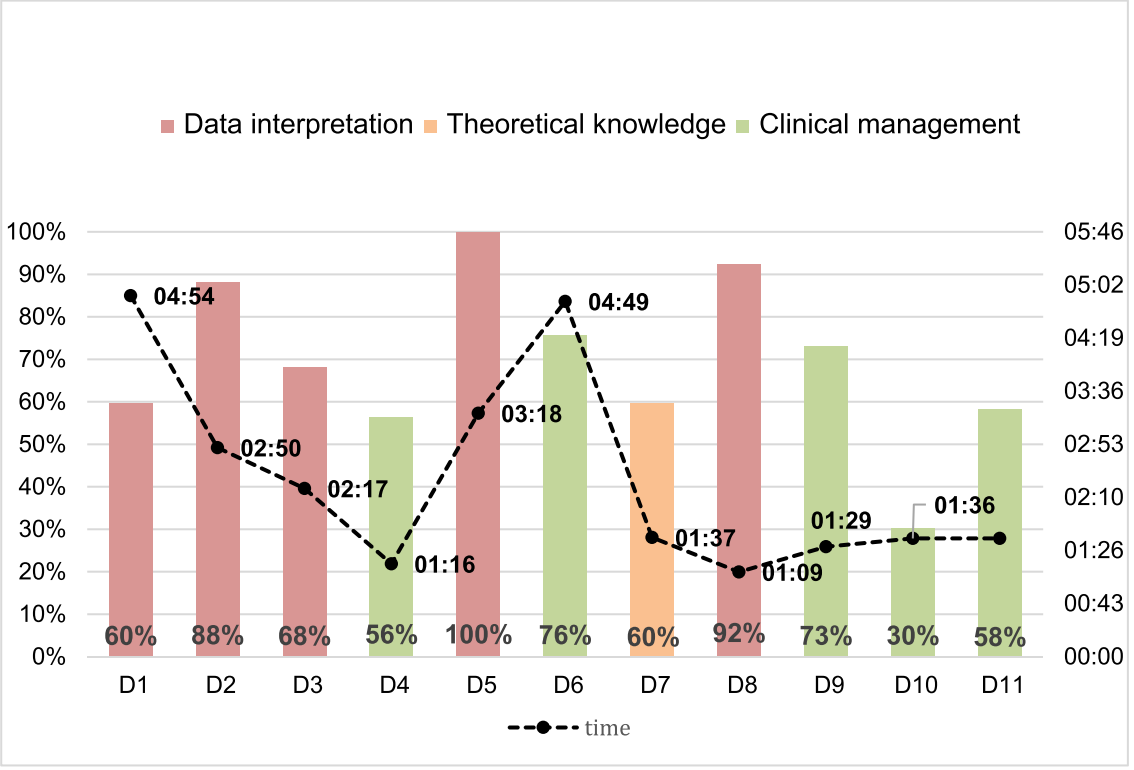

Fig. 2. Accuracy percentage and response time.

"Assess new vital signs and decide on a clinical diagnostic test" (D2, 88%).

There was only one decision point in the theoretical knowledge category: "Assess pharmacological knowledge theory and identify the sympathomimetic drug" (D7). This decision had a success rate of 60% and was resolved in the third fastest time (01:37).

In the clinical management category, the least successful decisions made were: "Select the most appropriate oxygen delivery device" (D4, 56%) and "Interpret the capillary glucose result and choose the most appropriate pharmacological treatment" (D10, 30% and D11, 58%). The most successful were: "Assess vital signs and decide on the appropriate drug" (D6, 76%) and "Assess the patient's condition and decide on the intervention" (D9, 73%).

Relationship Between Variables Associated With Decision-Making

Correlations were explored between the global score and ordinal sociodemographic variables (educational entry level, work experience) and sociodemographic variables (age). As anticipated, positive and significant correlations ($p < .001$) were found among these variables, with age correlating positively with work experience ($r = .542$), age correlating positively with educational entry level ($r = .628$), and work experience correlating positively with educational entry level ($r = .575$).

Subsequently, correlations between the overall mean number of correct decisions, response time per decision point, and the 3 categories (theoretical knowledge, data interpretation, and clinical management) were analyzed for the entire sample (N=119) (Table 2). A mean correlation ($r = .565$, $p < .001$) was observed between the global score and the average decision-making success rate (prom Ds: average accuracy achieved in decision points). However, decisions in the clinical management category had a highly positive correlation ($r = .760$, $p < .001$) and a very high effect size (.995) with the student's global score. At the same time, theoretical knowledge and data interpretation decisions do not correlate with the global score. Finally, Table 2 shows that the response time for each decision is not related to the quality of the decisions or the global score. There was also no significant correlation among the three categories of decisions.

A review of the correlation between the score, response time (t), and the type of decisions revealed a correlation only in clinical management decisions, where a negative correlation ($r = -.206$ $p < .05$) was observed. This indicates that students who made more accurate decisions tended to take less time to respond.

Comparison Between Students With And Without Prior Professional Experience

Tests were conducted to compare the students' work experience variable concerning the global score and the 3 categories (theoretical knowledge, data interpretation, and clinical management). However, no significant differences were found between students with and without prior work experience (Table 3).

Discussion

The findings of this study demonstrate the efficacy of interactive virtual simulation (SAVI project) in cultivating all types of knowledge essential to clinical decision-making, including theoretical, theoretical-practical, and practical. These results align with previous studies (Kiegaldie & Shaw, 2023; Lee & Baek, 2023), highlighting the effectiveness of this approach when used with other instruments or platforms for developing knowledge and skills among nursing students. Virtual simulation allows for individualized and self-paced learning, facilitating extensive active participation (Kiegaldie & Shaw, 2023) and repetitive learning (Lee & Baek, 2023).

Table 2
Correlation of global score and categories of decisions

Variable	Global score		Prom Ds		Prom Ds(t)	Theoretical knowledge	Data interpretation	Clinical Management
Prom Ds	0.565	***	–					
	−0.64		–					
Prom Ds(t)	-0.025		-0.047		–			
	-0.025		*-0.047*		–			
Theoretical knowledge	−0.01		0.387	***	0.143	–		
	−0.01		*0.409*		*0.144*	–		
Data interpretation	0.103		0.673	***	−0.031	0.129	–	
	0.104		*0.815*		*−0.031*	*0.13*	–	
Clinical management	0.760	***	0.702	***	−0.095	−0.023	0.089	
	0.995		*0.87*		*−0.095*	*−0.023*	*0.089*	

Spearman's Correlations (***p < .001). Effect size (Fisher's z). Prom Ds (batting average). Prom Ds(t) (average time at decision points).

The integration of conceptual or theoretical knowledge with procedural and practical insights posited by this research underpins the importance of this learning experience within competency-based assessment frameworks. Here, students demonstrate knowledge applied to practical or clinical contexts. Hence, it offers a learning environment tailored to nursing students, entailing an individualized experience grounded in authentic practice and self-assessment (Scott, 2008). Although the definition of competence remains challenging in nursing and other professions, educational programs have integrated this concept (Mrayyan et al., 2023), recognizing it as the ability to execute actions ensuring safe, effective, and quality care for individuals. Consequently, students who resolve virtual case scenarios must navigate decision-making processes and select appropriate actions to address presented challenges. The analysis of the overall success rate, or global score, on the checklist, reveals that students effectively navigate the virtual case, achieving a satisfactory rate of 79.6%. This level of achievement indicates a clinically sound resolution within the simulated environment.

Notably, Students exhibit the highest accuracy in decisions associated with the data interpretation category (81.70%), followed by the theoretical knowledge category (59.70%), and finally, the clinical management category (58.70%). Clinical management decisions, being more intricate, demand the integration of both theoretical and theoretical-practical knowledge to understand, analyze, and interpret data accurately and make informed clinical decisions. The lower success rates observed in clinical management decisions may stem from potential knowledge gaps or lack of experience among students (Mohammadi-Shahboulaghi et al., 2021). Bridging these gaps necessitates the activation of discipline-specific knowledge, cognitive perception, intuitive ability, critical thinking, and learning experiences (Mohammadi-Shahboulaghi et al., 2021). Hence, nursing education must incorporate teaching methodologies to cultivate clinical reasoning and foster attitudes conducive to critical thinking. These attitudes, comprising cognitive and metacognitive processes intertwined within the fabric of clinical reasoning, encompass independence of thought, fairness, perspicacity, humility, spiritual courage, integrity, perseverance, self-confidence, research interest, and curiosity (Papathanasiou et al., 2014). Critical thinking as a cognitive and metacognitive process is vital to clinical reasoning for effective clinical management.

Table 3
T-Test grouping by work experience variable

	T	df	p
Theoretical knowledge	−0.283	57.01	.778
Data interpretation	0.851	59.908	.398
Clinical management	0.659	68.778	.512
Global score	0.842	65.747	.403

Welch's t-test.

Thus, virtual simulation has a pivotal role in the future of healthcare training (Borg Sapiano et al., 2018; Foronda et al., 2017). This educational investigation underscores the potential for students to engage in virtual clinical practice scenarios within a safe and realistic environment, allowing them to enhance their theoretical knowledge and skills of data interpretation and clinical management on virtual patients. This approach aligns with the findings of Foronda et al. 2020. Furthermore, in agreement with previous research (Bogossian et al., 2015; Zaragoza-García et al., 2021), interactive virtual simulation facilitates the development and application of clinical reasoning and decision-making skills among students, directly impacting patient outcomes and mitigating healthcare-related risks. Thus, this project fosters learning through trial and error within a controlled environment (Bogossian et al., 2015; Padilha et al., 2019).

Students can evaluate the consequences of their decisions and the process of generating alternative solutions. In doing so, this approach contributes to patient safety, allowing participants to experience interventions that patients in healthcare facilities do not directly encounter (Johnsen et al., 2016; Kim et al., 2016). Students can subsequently transfer this knowledge and experience to real clinical practice.

One of the most noteworthy findings was students' ability to rectify and improve their decisions throughout the simulation. The case offered various response options, and nursing students did not receive real-time feedback in the clinical management sections of the simulation, mirroring a professional practice approach. This aspect represents an improvement compared to other virtual simulation experiences (Kiegaldie & Shaw, 2023) where some students expressed a preference for multiple correct responses in patient management. This phenomenon was particularly evident in complex and critical decisions, such as D4 (Select the most appropriate oxygen delivery device), D5 (Assess the blood test (CBC) and interpret the renal function test results), D10 and D11 (Interpret capillary blood glucose results and select the most appropriate pharmacological treatment). Despite potential errors in their initial decisions, students demonstrated the capacity to correct and enhance their choices in subsequent stages, utilizing their own resources or benefiting from feedback provided in the learning capsules in the categories of data interpretation and theoretical knowledge. This is evident from the results, where there is no absolute correlation between the global score and the number of times students make correct decisions. The educational experience presented enables students to rectify situations across all categories, including theoretical knowledge and data interpretation, and reinforce their knowledge through the learning capsules. These elements facilitate success in the practical phase (Tutticci et al., 2022).

Two notable aspects of the results were the success rate/time ratio and students' prior work experience. Regarding the first aspect,

students with higher accuracy scores resolved the case more quickly, a trend particularly noticeable in the clinical management category. In essence, students who achieved more accurate answers responded more rapidly, presumably due to their more consolidated knowledge, allowing them to apply it more confidently. This finding is consistent with other authors (Levett-Jones et al., 2020) who underscore the foundational role of effective and safe nursing practice. As for students' work experience, age, or educational entry level does not seem to be a decisive factor.

In light of these findings, instructors should emphasize the development of these competencies within the academic context and, more importantly, in the practical setting, in collaboration with the clinical tutors and/or care practicing nurses responsible for student learning. Inadequate or weak clinical reasoning can lead to adverse events (Jessee, 2018). Such events can occur when baseline data are not adequately identified, clinical situations are not effectively managed, and nursing interventions are not implemented in a timely or accurate manner (Mohammadi-Shahboulaghi et al., 2021). Such challenges are not exclusive to professionals, as Stevanin et al. (2015) have demonstrated that nursing students also encounter adverse events and perceive environments as unsafe. Interactive virtual simulation provides a safe learning environment where students can learn from their mistakes. Finally, one of the principal strengths of this educational innovation is its competency-based student assessment. The decision-making processes required in this simulated environment necessitate the activation of knowledge, skills, and attitudes within a context resembling real-life nursing care. This preparation is crucial for equipping future nurses to confront real clinical challenges (Mohammadi-Shahboulaghi et al., 2021).

Limitations and Future Directions

The study has several limitations that should be acknowledged. First, its descriptive cross-sectional design restricts the generalizability of the findings. Moreover, the participant sample consisted of a unique natural group of nursing students, limiting broader applicability. The simulation was a compulsory educational activity within the course, ensuring equal participation among students. Future research could address these limitations by incorporating quasi-experimental designs with control groups, and by examining internal and external factors influencing students' decision-making processes. Another limitation is the checklist used, which was developed ad hoc by the researchers and lacked formal parametric testing. Additionally, the study did not account for the time students spent reading the learning capsules, which could have influenced their decision-making processes. Future studies could explore the impact of time allocated to comprehending information on the quality of subsequent decisions, offering a more comprehensive understanding of how students use available resources in interactive virtual simulation scenarios.

Further investigation into the root causes of errors students make, particularly in the clinical management domain, warrants attention. Understanding these reasons can shed light on areas for improvement in nursing education and enhance patient safety by fostering a more profound comprehension of decision consequences and alternative generation processes, ultimately enhancing healthcare quality. To gain a deeper understanding of theoretical knowledge acquisition, future research should expand the range of decision points in the simulations. This broader scope would better reflect real-world application scenarios, providing a more comprehensive assessment of students' abilities and skills. Lastly, due to the unique nature of the study results, direct comparisons with other studies are challenging. Therefore, there are no cutoff points in either time or scores that can guarantee the validity of the study.

This study establishes a crucial foundation for future research in student nursing education and assessment, with profound implications for the design of clinical education and simulation programs. Furthermore, this format can be applied at different educational levels, across various academic and practical contexts, and to health science students or professionals dealing with clinical cases.

Implications for Nursing Education

Interactive virtual clinical simulation offers a powerful tool for assessing competencies and enhancing decision making. By bridging the gap between theory and practice, it effectively prepares future nurses to deliver safe healthcare in real-world settings. The learning experience presented, addressing the limitations outlined, can be used in the classroom to assess practical competency in nursing. Students are presented with individual scenarios where they can be evaluated by teachers and engage in self-assessment within a safe and realistic learning environment conducive to learning from mistakes.

Conclusions

The interactive virtual simulation case developed through the SAVI project represents a novel approach to nursing education. Its original digital content created specifically for this experience integrates various knowledge domains organized into three categories: theoretical knowledge, data interpretation, and clinical management. Presented in decision points, nursing students must choose from various options. The progression of the case depends on their responses or management of the situation, constituting an innovative element where nursing students can demonstrate individually applied knowledge within a lifelike context. As there is no single correct response at every decision point, not all students achieve the same outcome; they can evaluate the consequences of their actions. By addressing different knowledge categories, the competency assessment of students is facilitated.

Although students exhibit more shortcomings in the clinical management category, involving the most complex decision points, they demonstrate an ability to rectify errors throughout the case. This is particularly evident in data interpretation, where learning capsules provide valuable explanations and justifications that support reasoned decision-making. Finally, the implementation of teaching strategies that promote the development of decision-making and clinical reasoning skills is crucial in nursing education. By facilitating the transfer of knowledge to clinical practice, these strategies contribute to enhancing the quality and safety of patient care provided by future nurses.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Daniel Medel: Conceptualization, Methodology, Writing – original draft, Data curation, Formal analysis, Investigation. **Aïda Bonet:** Writing – review & editing. **Maria Jimenez Herrera:** Conceptualization, Writing – review & editing. **Francesc Sevilla:** Conceptualization, Software, Writing – review & editing. **Jordi Vilaplana:** Software, Writing – review & editing. **Tània Cemeli:** Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **Judith Roca:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Ethical Aspects

This project received support from the Study Committee of the Faculty of Nursing and Physiotherapy (FIF) of the University of Lleida (UdL) for data collection. It also obtained approval for teaching innovation from UdL and FIF and received a positive evaluation from the Research and Transfer Ethics Committee (CERT) of the UdL and the data protection officer of the UdL Data Protection Delegate.

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Supplementary materials

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