# Development and evaluation of virtual reality cases for clinical reasoning training in primary care: A Pilot Study at Hue University of Medicine and Pharmacy

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**Abstract**

**Background:** Integrating virtual reality (VR) into medical education can revolutionize teaching and learning clinical reasoning, yet it remains relatively limited in Vietnam. This study represents the first effort to develop and evaluate VR-based clinical cases for clinical reasoning training at Hue University of Medicine and Pharmacy. **Methods:** This quasi-experimental study uses a pretest-posttest design with 298 fifth-year medical students. VR scenarios were designed to simulate clinical reasoning skills, including ordering laboratory tests, providing diagnoses, and making clinical decisions. A structured questionnaire assessed students' readiness for VR-integrated learning, while clinical reasoning skills were evaluated using a four-station OSCE format and a VR-based examination. **Results:** A VR system and cases for clinical reasoning training were developed. The majority of students showed high readiness for VR-integrated learning. The paired sample T-test revealed significant improvements in clinical reasoning skills, with a mean OSCE score increase of 4.85 ($p < 0.001$). Significant gains were observed in students' abilities to suggest medication regimens, provide diagnoses, and order diagnostic tests ($p < 0.001$) but not in health behavior management planning. **Conclusions:** Our study highlights the value of VR in enhancing clinical reasoning skills, supporting the evidence for VR-based education in healthcare. Improving VR training, incorporating an integrated curriculum design, and fostering multidisciplinary collaboration in creating VR cases are strongly recommended to optimize learning outcomes.

**Keywords:** *virtual reality; medical education; clinical reasoning education; primary care.*

## 1. INTRODUCTION

Clinical reasoning (CR) is the cornerstone of effective medical practice, involving collecting and synthesizing patient information and formulating prognosis, diagnosis, and care plans. Mastering clinical reasoning is crucial for medical students as they transition from theoretical knowledge to practical application in real-world settings [1]. Traditional CR teaching methods, such as clinical case presentations, case-based discussions, and bedside teaching, are valuable but have some limitations due to variability in patient presentations and the availability of experienced clinical instructors. Moreover, increasing medical students further promotes these challenges as clinical training opportunities become more limited and competitive.

In the evolving era of digital technology, medical education has increasingly embraced technological advancements to enhance the training of future healthcare professionals. One prominent innovation nowadays is virtual reality (VR) technology, which fosters immersive and interactive learning environments that are controlled, repeatable, and safe, tailored to specific educational objectives. VR engages students in interactive clinical scenarios on computers for learning and evaluating purposes, providing a realistic learning environment that can be adjusted in difficulty levels [2]. Many medical universities employ VR systems to train students in communication skills, medical history taking, and clinical reasoning, ensuring they are well-prepared for real patient interactions [3-5]. Previous studies have demonstrated that virtual patients and virtual

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reality environments enhance student engagement and enable repeated practice of essential skills in a realistic virtual setting before students encounter real patients [6]. Case Western Reserve University (USA) has adopted a blended learning approach that integrates traditional teaching with VR systems for early-stage medical education, refining and standardizing basic clinical skills and clinical reasoning for first-, second-, and third-year students [7].

VR-based training is particularly beneficial in primary care settings, where the diversity and volume of cases can overwhelm students. Furthermore, VR technology can offer immediate feedback, enabling students to learn from their mistakes and continuously improve their decision-making processes. However, designing and integrating VR in undergraduate medical education curricula remains challenging for low-resource settings, including Vietnam. At Hue University of Medicine and Pharmacy, this study represents a pioneering effort to integrate VR into the medical curriculum, specifically focusing on developing clinical cases for training fifth-year medical students in clinical reasoning. This initiative is a first for the university and a significant step forward in modernizing medical education in Vietnam. The primary aim of this study is to develop VR-based clinical cases and evaluate the improvement in students' learning abilities through this innovative educational approach. Using a pretest-posttest evaluation, this study measures gains in clinical reasoning competency after VR practice, providing insight into the impact and challenges of VR integration in medical education.

## 2. MATERIALS AND METHODS

### 2.1. Study population

Fifth-year medical students enrolled in the Family Medicine module at the Hue University of Medicine and Pharmacy during the 2022-2023 academic year.

### 2.2. Study design

***2.2.1. Objective 1: Developing virtual reality clinical scenario for clinical reasoning training***

*2.2.1.1. Developing Virtual Reality Clinical Scenario Simulations*

Developing VR clinical scenarios is crucial for enhancing clinical reasoning skills by providing realistic and diverse practice opportunities across various medical specialties. The process involves several key steps:

**Step 1: Analysis of Common Clinical Issues**

- The research team begins by analyzing common health issues encountered in clinical practice and consulting with experienced medical clinical skills instructors to identify challenging topics that require solid clinical reasoning skills.

- These selected topics form the basis for developing clinical scenarios reflecting outpatient consultations.

**Step 2: Scenario Development**

- Using data from clinical scenarios during routine practice and real patient case data from electronic medical records, the team develops detailed simulated clinical scenarios.

- The scenario includes the full sequence of clinical consultation: medical history taking, clinical examination results, ordering laboratory tests, diagnosis, and care plan.

- Multiple-choice questions are integrated at key points in the scenario, requiring learners to apply clinical reasoning skills to make accurate decisions.

- At the end of each scenario, a summary with key take-home messages is explained, and additional information and references are provided to help learners reflect and address the clinical problems presented.

**Step 3: Expert Review and Feedback**

- Once the scenario is developed, it is reviewed by expert instructors with extensive experience in teaching medical clinical skills. Feedback and adjustments are incorporated to ensure accuracy and realism before converting them into VR clinical cases.

*2.2.1.2. Developing Virtual Reality Clinical Case System*

Based on pre-developed clinical scenario scripts, the research team collaborates with the technical team to develop VR clinical cases by creating virtual settings, developing virtual characters, and programming character interactions.

**Step 1: Creating the Setting**:

- The Family Medicine Clinic at the Family Medicine Center, Hue University of Medicine and Pharmacy, was selected as the software's setting. The design of the consultation room was based on actual images, ensuring an accurate representation of objects and medical equipment.

- Key medical devices used in this case, such as insulin pens, blood pressure monitors, otoscopes, ophthalmoscopes, and stethoscopes, needed to be accurately represented in terms of shape and structure compared to real-life devices. The arrangement of tools and furniture in the consultation room was proportionate and correctly sized.

**Step 2: Developing Characters**:

- Characters were detailed and aligned with anthropometric indices: height, weight, chest circumference, and body part proportions. The

Advanced Skeleton tool in Maya created a skeletal system for character rigging.

- The Paint Skin Weights Tool adjusted joint influence areas to prevent deformation during movements. Once rigged, character movements depicting medical examination processes were created in separate scenes.

**Step 3: Programming Character Interactions**:

- Keyframe animation created movement sequences for the patient character, including actions such as sitting, lying down, mouth movements, and hand movements. Independent arm movements were animated according to illustrated video scripts.

- Each action was executed in different files, and the execution time in the 3D software matches the real-time scenario script.

**Step 4: Exporting the File**: After completing the character's movements, exporting the file was the final step to integrate the character into the application programming software.

***2.2.2. Objective 2: Evaluating the improvement in clinical reasoning skills and overall learning abilities of students***

***Design:***

This quasi-experimental study employed a pretest-posttest design to evaluate the VR intervention with the participation of 298 fifth-year medical students. The intervention was implemented in the first semester of the fifth year of the medical education program, aligning with a 4-week curriculum focusing on primary care, and family medicine practice in the 2022-2023 academic year.

***Intervention:***

The intervention utilized a blended learning and self-directed learning approach during clinical rotation at primary care, in which virtual patient simulation was adjunct to usual program delivery for students. One virtual reality case was utilized, covering the expected competency of clinical reasoning in primary care. The learning activities with virtual reality cases were divided into two sessions. The first session was carried out in the third week of the module. During this session, students had 2 hours working in a group of 13-14 students and experiencing a case developed in another pediatric training project to get familiar with the virtual environment. The second session was carried out during the last week of the module, with the virtual reality case developed for this project.

***Instruments and data collection:***

Data collection was implemented between September 2022 and January 2023 using a structured questionnaire including demographic characteristics, prior experience with VR, prior experience of learning with VR, and VR-integrated learning readiness measured by the Online Learning Readiness Scale (OLRS). Readiness was categorized as poor if ORLS < 3, and high if ORLS ≥ 3 [10]. To evaluate the improvement of students in clinical reasoning competency, pre-and-post-tests were conducted using a four-station OSCE format, with each station lasting for 5 minutes. At the end of the intervention, students also participated in an examination featuring one virtual reality case lasting 20 minutes, using the same clinical template to evaluate students' proficiency in ordering appropriate diagnostic tests and providing relevant primary diagnoses, medication regimens, and health behavior management plans.

***Ethical statement***

All sections of the study were performed following the guidelines in the Declaration of Helsinki. The Ethical Committee in Biomedical Research of Hue University of Medicine and Pharmacy, Hue University, Vietnam approved all procedures. All participants provided written informed consent before participation.

## 3. RESULTS

### 3.1. Develop Clinical Cases Using Virtual Reality

#### *3.1.1. Overview of the Software*

The virtual reality-based software aims to enhance learners' clinical reasoning skills through practical application. The software features:

- **Target Users**: With two main modes - practice and assessment - the software primarily targets students engaged in research and study at the school.

- **Clinical Case Scenario**: The software develops an interactive scenario for a clinical case of a 40-year-old patient with diabetes, based on a pre-developed scenario, which includes:

+ **General Information**: Personal details of the patient, the reason for the visit, and the patient's medical history.

+ **Self-Monitoring Blood Glucose Chart**: Home blood glucose monitoring records (mmol/l).

+ **Medical History**: The patient's and family's medical history.

+ **Test History**: Records of previous laboratory tests.

**Achieved Results**

- **Login Interface Component**: The login screen interactions are developed based on the initial interface sketch. When the user clicks "login," the software reads the entered user data, checks the conditions, standardizes it, and sends it to the server for verification.


**Figure 1.** Virtual Reality (AR-VR) Software Interface

#### *3.1.2. Examination Module*

The Examination module encompasses numerous continuous actions consolidated into a single module for efficiency. The specific interface for the Examination module will be outlined below. Each option in the interface corresponds to a real-life examination procedure. The procedures that can be implemented include:

- Cardiovascular Examination
- Respiratory System Examination
- Ear Examination
- Eye Examination
- Throat Examination
- Digestive System Examination


**Figure 2.** Interface for Examination in the Virtual Reality (AR-VR)

***3.1.3. Clinical Decision-making Component:***

This is the stage where learners must apply their clinical reasoning skills to make decisions, including ordering laboratory tests, making a diagnosis, and devising a treatment plan. This involves selecting the most appropriate answer from multiple-choice questions that reflect real-life scenarios.

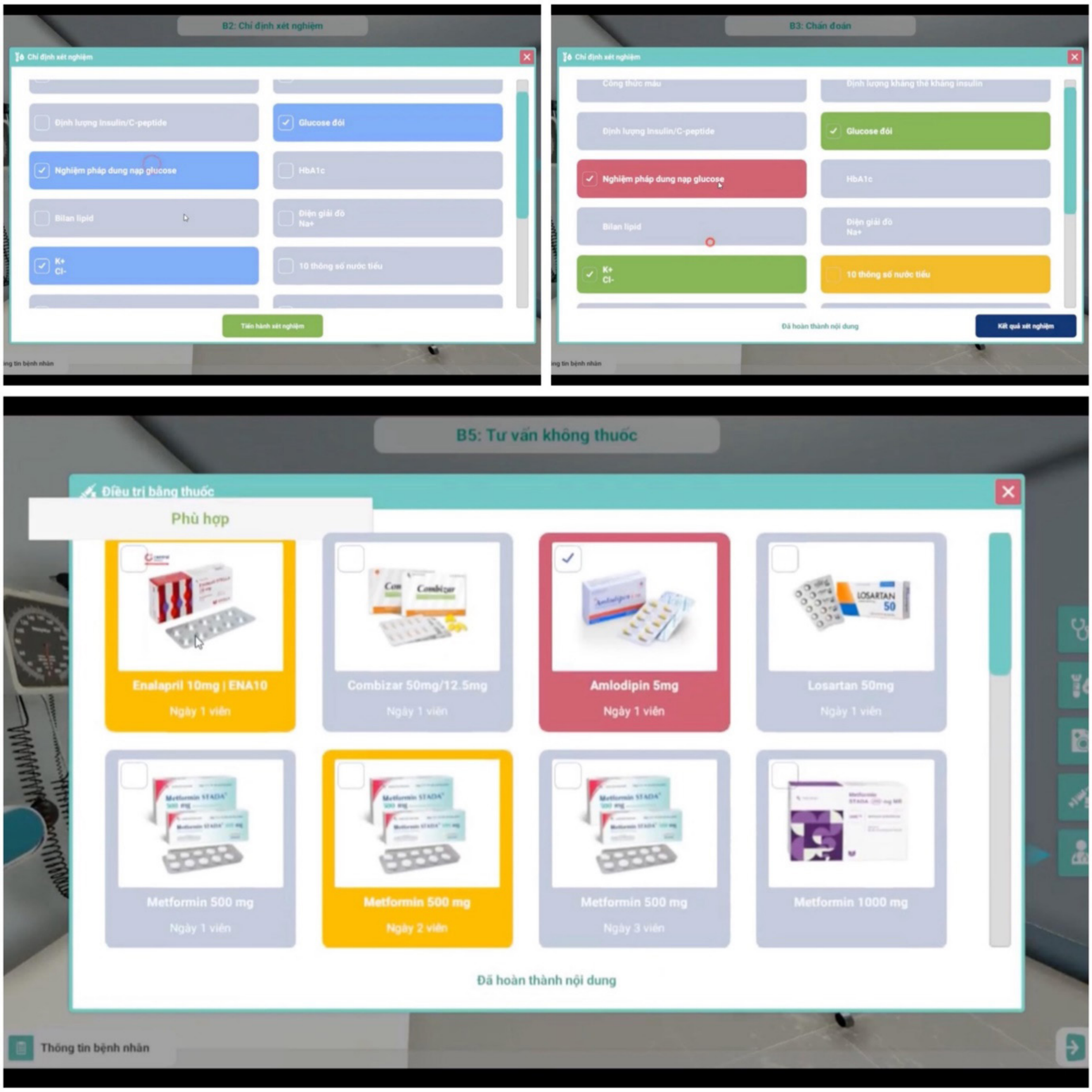


**Figure 3.** Interface Image for Ordering Laboratory Tests and Prescription in the Software

***3.1.4. Implementation***

After installing the logic and accompanying Oculus tools, export the software into an Oculus-readable file format.

Software Requirements:

- Utilizes Oculus Quest headset.
- Uses Internet connectivity to send assessment results to a teacher grading or result aggregation server.

There are two methods for using the software:

- Method 1: Directly run the .exe file on a PC.
- Method 2: Build an Android file (.apk) and use Oculus Developer Hub to download the software onto the headset. Cast from PC to install, then wear the headset and open the application.

Once completed, the software application will be uploaded to the Oculus Store for learners to download and use.

Deployment Details:

- Estimated deployment of around five headsets per session in a 30 m² clinic setting.
- Device requirements include Oculus VR headsets supporting 6 Degrees of Freedom (6DoF) motion tracking and equipped with Touch Controllers for interactive use.

**3.2. Evaluating the improvement in students' learning abilities**

**Table 1.** General characteristics of the students in this study

| **Categorical variable (n=298)** | | **Frequency (n)** | **Percentage (%)** |
|---|---|---|---|
| **Gender** | Male | 146 | 49.0 |
| | Female | 152 | 51.0 |
| **Grade Point Average (GPA) of the previous school year** | Good and under (< 3.2/4.0) | 245 | 82.2 |
| | Very good (3.2 - 3.6/4.0) | 55 | 14.8 |
| | Excellent (3.6 - 4.0) | 9 | 3.0 |
| **Duration for E-learning before classroom learning** | ≤ 30 minutes | 228 | 76.5 |
| | > 30 minutes | 70 | 23.5 |
| **Rating on the learning environment in medical school** | Overload | 68 | 22.8 |
| | Appropriate | 230 | 77.2 |
| **Stress during medical studying** | Extremely stressful | 33 | 11.1 |
| | Stressful | 188 | 63.1 |
| | Normal | 77 | 25.8 |
| **Having Ocular conditions** | Yes | 215 | 72.1 |
| | No | 83 | 27.9 |
| **Prior Exposure to V applications** | Yes | 76 | 25.5 |
| | No | 222 | 74.5 |
| **Prior involvement in VR-based learning** | Yes | 140 | 47.0 |
| | No | 158 | 53.0 |

Regarding the GPA of the previous school year, most students fell within the range of 2.5 - < 3.2 (82.2%). Most students (76.5%) spent 30 minutes or less on E-learning before classroom sessions. Nearly three-quarters of our students reported having ocular conditions. Approximately 22.8% of participants felt overwhelmed by the workload in medical school. A significant proportion of students reported experiencing stress, with 11.1% finding it extremely stressful and 63.1% finding it stressful. Prior exposure to VR technology is relatively low, with only about a quarter having used VR applications before and slightly less than half having any experience with VR-based learning.

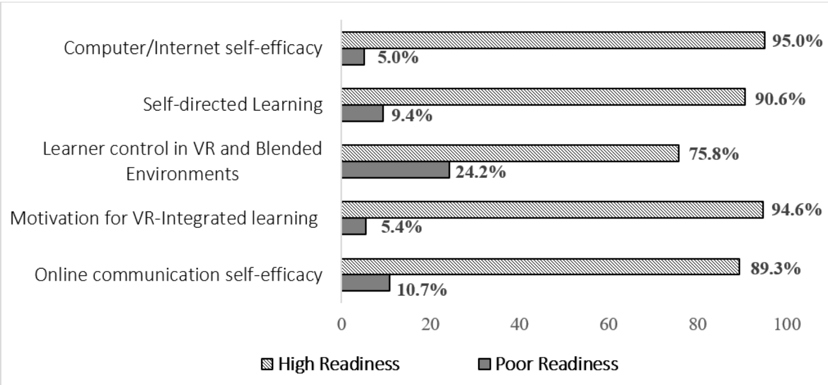


**Figure 4.** Readiness for VR-integrated blended learning among students

Figure 4 indicates a generally high level of readiness among students for VR-integrated blended learning, particularly in Computer/internet self-efficacy, motivation for learning with VR, and self-directed learning. However, there is a notable gap in learner control within VR and blended environments, where a significant proportion of students struggle compared to other domains.

**Table 2.** Assessment of students' improvement in scores of pre and post-test

| Items (n = 298) | Range | Pretest (1) Mean (SD) | Postest (2) Mean (SD | Mean different (2)-(1) | p |
|---|---|---|---|---|---|
| 4-station OSCE score | 0 - 10 | 4.85 (0.95) | 7.37 (1.04) | 2.52 | < 0.001 |
| Laboratory test proficiency | 0 - 100% | 31.51 (22.27) | 49.53 (23.65) | 18.02 | < 0.001 |
| Diagnosis proficiency | 0 - 100% | 64.04 (22.24) | 85.46 (22.62) | 21.41 | < 0.001 |
| Medication treatment proficiency | 0 - 100% | 29.43 (28.08) | 59.52 (49.17) | 30.03 | < 0.001 |
| Health behavior management plans proficiency | 0 - 100% | 69.46 (22.26) | 61.20 (27.69) | - 8.26 | < 0.001 |
| Clinical Reasoning proficiency | 0 - 100% | 30.68 (24.92) | 49.31 (36.44) | 18.63 | < 0.001 |
| Decision-making proficiency | 0 - 100% | 39.90 (31.06) | 38.92 (34.72) | -0.98 | 0.44 |

The paired sample T-test revealed a significant improvement in clinical reasoning skills after the course, with a mean difference in OSCE performance scores of 4.85 between the pre-test and post-test ($p < 0.001$) (Table 2). Additionally, there were significant improvements in students' abilities to suggest medication regimens, provide appropriate diagnoses, and order diagnostic/laboratory tests ($p < 0.001$). However, proficiency in health behavior management plans decreased, with lower scores after the course.

## 4. DISCUSSION

The results from our study demonstrate the potential and challenges of integrating VR into medical education, particularly in a blended learning environment. This innovative approach aligns with the increasing integration of digital technologies in medical education, as highlighted by previous research [9-10]. Our study highlights key design considerations for an ideal VR system, consistent with literature and previous studies. The simulation should use real case study scenarios [11] and provide a controlled, low-risk environment that ensures the safety of all participants [12-13]. The VR cases were carefully developed to cover various aspects of clinical reasoning, including patient history taking, physical examination, diagnosis, and management. The design process was informed by educational theories and best practices in simulation-based learning, ensuring the scenarios were pedagogically sound and relevant to primary care settings. By incorporating elements such as immediate feedback and adjustable difficulty levels, the VR cases were tailored to meet the diverse needs of students and enhance their learning experience. One of the advantages of the blended learning approach using VR cases is creating an interactive and engaging learning environment. Students engage in real-life scenarios, applying knowledge practically and developing communication, argumentation, and patient management skills. Furthermore, this method enables students to encounter various cases, thereby expanding their knowledge and understanding and enhancing their ability to apply theoretical knowledge in clinical practice. The ability to track the decisions taken by the learner in solving the case scenario can be used to identify areas of learning requiring reinforcement [14].

Developing VR-based educational tools posed several challenges. First, the technical complexity of creating immersive and interactive scenarios required significant expertise and resources. Collaboration with technology experts and iterative testing were crucial to overcoming these challenges. Additionally, ensuring the educational validity of the VR cases necessitated input from experienced clinicians and educators to align the scenarios with real-world clinical practice. Despite these challenges, the successful implementation of VR cases in our curriculum demonstrates the feasibility and potential of this approach. Our findings indicate that students responded positively to the VR cases, as evidenced by their high readiness levels in various domains, such as motivation and self-directed learning. This readiness suggests they are well-equipped with the necessary skills for engaging in virtual reality-integrated courses, which leverage technologies such as simulations and interactive scenarios to enhance learning experiences. However, the notable gap in learner control within VR environments suggests a need for further refinement and support to help students navigate and manage their learning experiences more effectively.

Our results indicate a significant improvement in students' scores before and after the course. Specifically, our study shows a significant enhancement in the clinical reasoning proficiency of students in laboratory test proficiency, diagnosis proficiency, and medication treatment. Our findings align with similar studies conducted previously. A systematic review identified the effectiveness of VR simulations in enhancing clinical reasoning skills among medical students and healthcare professionals [15]. Smith et al. (2002) conducted a comprehensive review of the literature on the use of virtual reality in medical education and found that VR simulations enhance student engagement and motivation, stimulate critical thinking skills, and provide realistic clinical experiences [16]. Virtual simulations create conditions for developing clinical reasoning abilities, as students can practice and refine diagnostic skills and decision-making in a controlled, realistic environment [17]. Contrary to the improvements seen in other areas, proficiency in health behavior management plans decreased after the course, with students scoring lower than before. This finding suggests that while VR is effective in teaching technical and cognitive skills, it may be less effective for clinical practice aspects involving complex patient interactions and behavior change strategies. The decrease in scores indicates a need to supplement VR-based learning with additional training methods focusing on these crucial aspects of patient care.

Training in clinical reasoning skills as a core competency is crucial in competency-based medical education programs, aiming to ensure the delivery of safe and quality patient care services. Combining online modules, case-based discussions, virtual clinical simulations, and real-world clinical practice experiences provides a comprehensive and engaging learning environment that bridges the gap between theoretical knowledge and real-world application. Research by Forsberg et al. (2014) [18] demonstrated high student acceptance of using VR to enhance clinical reasoning skills. According to Edelbring et al., 2013 [19], optimizing learning experiences based on experiential learning during the development and application of virtual reality simulations in teaching is essential.

## 5. CONCLUSION

Our study demonstrates a significant improvement in clinical reasoning proficiency achieved by integrating VR within a blended learning course. Integrating VR technology provides a dynamic, immersive learning experience that resembles real-life patient interactions. Faculty development and multidisciplinary collaborations can further enhance the successful development and implementation of VR cases in clinical reasoning and other clinical skills training.

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