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## ~~DEVELOPING~~DEVELOPMENT OF A VIRTUAL REALITY HEAD-MOUNTED DISPLAY FOR TEACHING INFECTION PREVENTION AND CONTROL

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### ABSTRACT

**Introduction:** Infection prevention and control ~~requires~~is a crucial aspect of any healthcare setting. ~~To achieve this,~~ students ~~are required~~ to ~~practice following procedures.~~ ~~Serious complications can occur in individuals when the sequence of steps is not following~~follow aseptic procedures and principles. ~~This practice is essential as failure to follow the sequence of steps can result in serious complications.~~ However, the current ~~challenge in teaching~~ ~~challenge~~infection control to students is the millennial generation who were born and raised during the Fourth Industrial Revolution and digital technology. ~~Furthermore, Millennials~~These millennials are confident, innovative, committed, collaborative, multitasking, and tech-savvy. ~~Only a few study reports of head-mounted virtual reality (HMD) on Infections prevention and control devices especially for Catheter-associated Urinary Tract Infections.~~ Previous virtual reality studies have ~~only been based~~focused on haptic and computer simulation. ~~This,~~ while only a few explored the potential of virtual reality ~~head-mounted display (HMD) devices for infection prevention and control, especially for Catheter-Associated Urinary Tract Infection.~~ Therefore, this study aimed to develop a virtual reality head-mounted display ~~for~~to teaching ~~nursing students about infection prevention and control for nursing student.~~

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**Methods:** ~~The infection~~Infection prevention and control application was developed using Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model. An evaluation was conducted using ~~a user experience questionnaire~~User Experience Questionnaire (UEQ) among 65 nursing students; and ~~the data obtained were~~analyzed ~~the data~~ with UEQ Data Analysis Tool version 10.

**Results:** The results of ~~this study,~~ ~~Infection~~infection prevention, and control application, were considered very valid by medical-~~surgical~~nursing ~~expert~~and ~~very valid by the media expert.~~ The

~~User experience questionnaire experts. UEQ measurement results showed excellent ratings for attractiveness, clarity, efficiency, accuracy, stimulation, and novelty, with mean values in the means were of 2.26 (95% CI: 2.162- 2.362), 2.30 (95% CI: 2.167-2.425), 1.89 (95% CI: 1.646-2.139), 1.88 (95% CI: 1.536-2.225), 1.72 (95% CI: 1.304-2.127), and 1.61 (95% CI: 1.225-1.990), respectively, were excellent. The. Furthermore, Cronbach's alpha value was >0.7 showing consistent, indicating good consistency.~~

~~Conclusions: Infection prevention and control applications for application was found to be excellent in terms of attractiveness, clarity, efficiency, accuracy, stimulation, and novelty were excellent. It is, making it suitable for millennial nursing students.~~

~~Keywords: Teaching; Virtual Reality; Nursing Students; Infection prevention Prevention;~~

## INTRODUCTION

~~Infection prevention and control requires is a crucial aspect of any healthcare setting. To achieve this, students are required to follow aseptic procedures and principles. This practice following procedures. Serious complications can occur in individuals when is essential as failure to follow the sequence of steps can result in serious complications is not following aseptic procedures and principles(1-). Therefore, students should practice clinical skills to adequately fulfill procedural steps correctly and follow aseptic principles to prevent more severe infection infections(2) and students have). Students are also expected to apply their knowledge appropriately and provide a learning experience in a real-world atmosphere (3,4-).~~

~~Catheter-associated Urinary Tract Infections Infection (CAUTIs) are among the highest nosocomial infections infection in various hospitals (5,6) The, with an incidence rate of CAUTIs is 35% in inpatients (7) and approximately 3% to 7% per day (8-). CAUTIs are inflammation of the urinary tract acquired during hospitalization due to urinary catheter insertion (9-). Symptoms include fever, bladder pain, dysuria, pyuria, and bacteriuria (10-12) An intervention). One of the~~

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interventions to reduce the risk of CAUTIs is to clean the periurethral area of the penis or vagina before inserting a urinary catheter (13,14).

The current ~~teaching~~-challenge in teaching infection control is the millennial generation who were born and raised during the Fourth Industrial Revolution and digital technology (15). ~~the~~ These millennials-generation born in 1980 and 2005 are confident, innovative, committed, collaborative, multitasking, and tech-savvy (16,17). ~~Learning~~. Previous investigations have established that learning media suitable for millennial ~~student~~ students is virtual reality technology. This is because ~~Virtual Reality~~ virtual reality (VR) is a three-dimensional computer platform simulation that provides interactive and realistic experiences (18,19). ~~Furthermore, the~~ The lack of access for students to clinical practice before graduation which can be a challenge, as well as the existence of and mandatory pre-practice training on real patients so that can be a challenge for students. Therefore, practical learning tools are needed that must be easily accessible, interactive, and fun. ~~This will~~ are needed to help the millennial generation ~~to~~ understand laboratory practicum material more efficiently and effectively. Virtual reality head-mounted display (HMD) is a three-dimensional simulation technology that combines haptics, computer simulation, and audio with various information (20). However, ~~at present~~ Only only a few ~~study report~~ studies reported the use of virtual reality based on head-mounted display to train technical expertise in infection prevention and control, Guidelines guidelines for using sterile and non-sterile equipment, and case simulation of infection problems. ~~It is still rarely used~~ (21). Previous studies ~~of virtual reality~~ have only been based focused on haptic and computer simulation technology to practice nontechnical skills such as interpersonal and social skills, Procedural procedural skills, and anatomy (22). Haptic and computer simulation technology is unable to give not suitable for giving complex commands and handling complicated devices because they are very sensitive and require special care (23,24).

This study aimed to develop a virtual reality head-mounted display for teaching nursing students about infection prevention and control Catheter-associated Urinary Tract Infections (related to CAUTIs) for nursing student.

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## METHODS

This study was approved by Bakti Tunas Husada University, Indonesia (No. 218/ec.01/kep-kbth/IX/2022). ~~This~~ To ensure the effectiveness of the study, the evaluation was conducted using ADDIE (~~analysis, design~~ Analysis, Design, Development, Implementation, and Evaluation) development, ~~implementation, and evaluation~~ development research study model. The stages of the ADDIE ~~research~~ study model were used as follows:

### 1. Analysis

The analysis phase ~~includes~~ included needs, teaching participants, technical, and content analysis (25,26). Functional application needs and problems in the learning process were analyzed in May 2022 using literature review and interview methods. ~~The interview was conducted online using Zoom with~~ Subsequently, semi-structured interviews were conducted online using Zoom with five students, four lecturers, and nurses at the Karsa Husada Garut High School of Health, West Java Province, Indonesia. The interviews showed that ~~of~~ practicum learning media in the laboratory must be low-cost, realistic, easy-to-use, and easy-to-configure simulators ~~that to~~ reduce safety, ethical and health concerns. Furthermore, ~~The~~ the instructors ~~are~~ were not bound by time and location ~~by~~ using technology era 4.0.

~~Results of the Analysis~~ The analysis of teaching ~~Participants~~ participants showed that it ~~is~~ was necessary to have ~~Innovative~~ innovative and attractive learning, ~~improving to~~ clinical knowledge and skills, specifically in preventing CAUTIs ~~and the~~. The formation of learning flows and compiling media content ~~is~~ were also consistent with the Standard Principles of Nursing Operational Methods published by the Indonesian National Nurses Association (INNA) in 2021 (27).

The technical analysis proved that up-to-date learning methods are needed and suitable for the 4.0 era in ~~the~~ form of computer software, the internet, and the character of millennial generation students.

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## 2. Design

The ~~display~~ Display design ~~is of~~ the application was made by professional ~~application~~ developers. The ~~menu~~ concept of the menu ~~is a~~ featured a white patterned box with a white pattern and green patterned writing with a green pattern. The concept of infection, Infection treatment tools and materials ~~consists~~ consisted of 3-dimensional images of sterile and non-sterile tools with colors similar to their original shapes.

Sterile tools ~~are were~~ gloves, commas, cotton or gauze for perineal hygiene, tweezers, syringe, and clamps. ~~In contrast~~ Meanwhile, non-sterile tools ~~are were~~ complete ~~catheters~~ catheter in pure plastic according to dimensions, urine bag, antiseptic, aqua bidest, jelly, plaster, scissors, and garbage bags. A human-shaped three-dimensional animation ~~consists~~ was also included, which consisted of a male and female patient sleeping on a bed and wearing a green blanket and blue shirt. The patient also ~~has had~~ a penis or vagina that can be used interactively to insert a urinary catheter. The practice and exam plans ~~consist of~~ were presented in a white menu box display accompanied by instructions and a list of tools ~~to be used in a white menu box display and~~ written in green.

The design stage ~~requires~~ required some hardware and software to produce ~~Virtuala~~ virtual reality head-mounted display with ~~the features to bring up~~ realistic 3D depictions that look real and ~~according~~ respond to the user's perspective. ~~It can as well as~~ recognize all actions and responses ~~from the user~~, such as the movement of ~~the~~ head or eyeball (28,29). Virtual reality head-mounted display hardware ~~consists~~ consisted of glasses using Oculus Quest 2, 128 GB, with operating systems Oculus Mobile and Android 10. ~~This application development uses~~ Subsequently, software, including Visual ~~code editor~~ Code Editor ver 1.54.3, was used to develop code for ~~Virtual~~ virtual reality head-mounted display application programs. Media 3D creation was made using Unity 2021.3.21 and a lightweight 3D engine.

## 3. Development

The ~~developed~~ virtual reality head-mounted display ~~features are that was developed~~ included case simulations, -practice, and practical exams. ~~The Infection~~ When the infection prevention and

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control application ~~displays~~ was turned on, it displayed several menus ~~when turned on~~. The application ~~is~~ was made with three-dimensional animation, making it immersive and almost ~~approaching people, lifelike, depicting~~ the hospital environment, and ~~language~~ using the Indonesian. ~~Before entering language. To access~~ the menu, students ~~should~~ are required to enter their identity, starting with their name, email, and student identification number. The menu entry ~~is~~ was separated into simulations of equipment and materials, catheter insertion, a theoretical module for urinary catheter placement, ~~and~~ as well as directions for use and application.

A The simulation menu ~~of~~ provided tools and materials ~~that the~~ for students ~~can~~ to learn about sterile ~~(and non-sterile materials~~ for used in exams and exercises. In the exercise simulation, there ~~is~~ was a variety of sterile ~~(equipment such as~~ gloves, commas, cotton or gauze for perineal hygiene, tweezers, syringe, and clamps) and. Meanwhile, the non-sterile equipment ~~(catheters~~ included catheter in pure plastic according to dimensions, urine ~~bag~~ bags, antiseptic, aqua bidest, jelly, plaster, scissors, and garbage bags). ~~In this simulation, sterile or non-sterile instruments. These materials should be selected based on the on-screen text instructions. The~~ and the use of tools must be in ~~accordance~~ line with the name, type, and sequence marked with a bright yellow circle. ~~For the~~ The simulation menu ~~students can learn to install~~ also included the installation of urinary ~~catheters~~ catheter for women and men. In this simulation, students can take, store, smear, install, and wash their hands. ~~The~~ simulation starts process began with the case simulation and patient conversations, ~~inserting~~ followed by the insertion of tools, and washing hands in running water, ~~using with soap, students perform. Students also performed genital hygiene steps and insert~~ inserted a urinary catheter. Furthermore, when ~~the student is~~ students was not in order, the sign ~~will~~ continue continued to glow, and the instructions will not change. In the exam session, there ~~are~~ were time limits, scores, and the bright yellow circles indicating the order ~~in which the~~ of tools ~~are used will be~~ usage were removed during the testing phase, and instructions for ~~picking up the tools will~~ selection were not ~~be displayed~~ display.

#### 4. Implementation

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This study was carried out at ~~the~~ Karsa Husada Garut High School of ~~-~~Health, West Java Province, Indonesia. ~~Data~~The data were collected in September 2022. ~~The and the~~ application was tested on 65 nursing students who were selected by ~~Purposive~~purposive sampling. ~~This study was conducted with~~The inclusion criteria, ~~namely, were~~ students who were actively studying, ~~attended~~attending laboratory practicums, ~~studied~~studying conventionally; and did not have myopia and diplopia eye disorders. Meanwhile, the exclusion criteria were students with leave status and those who left as respondents before the study was completed. Students were given a virtual reality head-mounted display of infection prevention and control for CAUTIs, and the simulation of tools ~~and as well as~~ materials for the activity lasted for 20 minutes, ~~and virtual~~. Virtual reality head-mounted display ~~was using~~used oculus quest 2 ~~wich, which was~~ connected to an ~~android~~Android television, ~~and with the~~ application ~~must be connected to the requiring an internet-~~ connection.

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#### 4.5. Evaluation

~~Evaluation~~The evaluation in this study ~~using~~used a ~~user experience questionnaire~~User Experience Questionnaire (UEQ) and ~~the signing of~~ a consent form. The UEQ ~~has had~~ six measurement scales divided into 26 question items; and the availability of tools to perform data analysis in excel ~~form makes~~format made it easier for users to measure attractiveness, clarity, efficiency, accuracy, stimulation, and novelty (30,31). Respondents can select a circle closer to their thoughts about a product with a value range of 1-7 ~~and analyze the~~. The data were analyzed with UEQ Data Analysis Tool version 10 (32,33). ~~The data were found to be and categorized as~~ excellent (>1.60), good (1.00-1.60), and average (<1) (31). Furthermore, ~~the means were value~~mean values ranging from -3 to +3 results were all positive, and other scores ~~are were~~ negative. The confidence interval ~~in which values were all~~>1 ~~shows~~showed a good confidence level for the results, ~~and while~~ values were all <1 ~~show~~indicated a bad confidence level ~~and~~. Moreover, Cronbach's alpha value > 0.7, ~~shows~~ indicated sufficiently consistent and ~~values <0.7, shows there are not~~ showed consistent results (34).

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The validity of the infection prevention and control application was assessed by two experts, namely a media expert with a twelve-item questionnaire and a medical-surgical nursing expert with a twelve-item and a ten-item questionnaire, respectively.

## RESULTS

The Infection prevention and control application was evaluated by the medical-surgical nursing expert, a media expert, and students using the user experience questionnaire (who used the UEQ). The Infection prevention and control. A total of 65 UEQs were received and the application was considered very valid and suitable for use. A total of 65 user experience questionnaire were received. Table 1 shows the characteristics Based on the characteristic of the participants most participants (in Table 1, 70%)% of them were 20-24 years, More than half of the participants (60%)% were female, and most participants (80%) were Bachelor% had a Bachelor's degree. Table 2 shows showed that the mean were all positive, the mean values were positive and  $> 1$  shows, indicating an excellent result for the Infection prevention and control application. Furthermore, shows a good confidence level for mean were all  $> 1$  for the confidence interval. Table 3 shows the six was good as all mean values had a confidence level greater than 1. The results of the six assessment components of the assessment based on the UEQ Data Analysis Tool, results show Cronbach's alpha  $> 0.7$ , indicating in Table 3 revealed that all scales were consistent, as Cronbach's alpha was  $> 0.7$ .

The media expert has also assessed the Infection infection prevention and control application and stated that the Infection prevention and control application is described it as an interactive, innovative, as well as immersive, almost hospital environment that allows students to learn with remote access, and it is. The expert suggested that the color of the image is was more pleasing to the eye.

Infection prevention and control application has also been assessed by According to the assessment of the medical-surgical nursing expert stated that, the Infection prevention and control application consists consisted of a simulation menu, exams, and quizzes. The patient case simulations in the application only focus focused on CAUTIs, and did not combined with include other

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disease complications. ~~in the simulation of tools and materials, it is.~~ Meanwhile, the expert recommended ~~to the use of~~ personal protective equipment ~~for nurses~~ such as masks, gowns, and face shields ~~but for nurses in the simulation of tools and materials, although gloves were already have~~ gloves ~~included.~~

## DISCUSSION

A nursing laboratory is a learning tool that includes active ~~student~~ students' participation, clinical skill improvement, and encouragement to practice, ~~and as well as~~ interactive learning and problem analysis (35,36). Patients ~~used in the laboratory should represent real~~ areas of hospitals ~~world hospital and clinic scenarios~~ clinics (37,38). Virtual. One example of an interactive activity in the laboratory is virtual reality head-mounted display Infection/infection prevention and control applications an interactive application. This application allows role-playing activity between medical staff and patients to obtain a medical history and physical examination, especially CAUTIs.

~~The results proved~~ This study showed that Virtual/virtual reality head-mounted display applications have application has excellent attractiveness, and Stimulation. These provide stimulation. The application also provided interactive and realistic experiences in a three-dimensional form that ~~can~~ allowed users to move, feel the atmosphere of clinic environment, touch, and act on simulated objects to give the perception of realness (immersive) (39). ~~In line with the~~. Based on these results of this study, Yeh (40) argued that audio-visual teaching ~~could~~ can increase motivation and active learning. Infection prevention and control applications can increase knowledge, reduce patient injuries, ~~reduce the risk of~~ decrease infection risk, and ~~increase the~~ enhance patient safety patients. The results are supported by. Similarly, McCarthy & Uppot (41) ~~stating~~ stated that VR ~~increases~~ virtual reality increased knowledge by providing students with experience in clinical decision-making, collaboration, communication, and problem-solving. ~~Furthermore, including~~ self-confidence and readiness for practice at a hospital or clinic ~~can be increased~~. The results are supported by. Asad et al. (42) ~~who argued~~ also reported that virtual reality is found to be ~~was~~ useful as a

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pedagogical tool ~~in the teaching learning process dan as a form of for various~~ teaching and learning models such as problem-based ~~learning~~, experiential ~~learning~~, or interactive learning. ~~Students~~Students' practice ~~had also been carried out in the laboratory is carried out~~ using patient simulations, role-playing, and mannequins as preparation before entering hospital practice (43) ~~Patients~~). The patients used in the laboratory should represent real ~~areas of hospitals world hospital~~ and ~~clinic scenarios elines~~ (37,38). Various simulation procedures ~~are were~~ used to gain experience without compromising patient safety and ~~student~~student's competence (44,45).

The ~~application use~~ of ~~head-mounted~~ virtual reality (HMD) ~~on Infections~~head-mounted display for infection prevention and control devices, especially for ~~Catheter associated Urinary Tract Infections has Excellent Perspicuity~~CAUTIs showed excellent perspicuity and novelty. ~~Another~~ According to a ~~previous study stated that~~ students ~~learn with who use a~~ virtual reality head-mounted display ~~as usually have~~ a positive practice experience (29,46). ~~Immersive~~. This is because immersive learning and a virtual reality head-mounted display ~~experiences offer offers~~ a unique experience for students who can study anywhere, ~~at any time, and have anytime, with~~ unlimited time to practice (47,48). ~~Previous research~~ Study has shown that a virtual reality head-mounted display can stimulate visual, auditory, and emotional ~~virtual reality learning~~ experiences to prepare a real environment for ~~student~~students learning ~~which comes from through the use of~~ computers (42,49). However, the use of ~~VR virtual reality~~ for more than 120 minutes ~~may can~~ cause dizziness, headache, and pain when moving the eyes (50). ~~The~~. Another limitation is that patients in the laboratory in ~~the~~ form of human-like mannequins are used when the practice requires expensive space, resources, and materials, as well as supervisory instructors, time-bound, and location (45,51).

The results ~~proved showed~~ that ~~Virtual a~~ virtual reality head-mounted ~~display applications~~ ~~have application has~~ excellent efficiency; and dependability. Previous ~~research has shown study~~ reported that instructors in a virtual reality head-mounted display are not bound by time and location (29,52). ~~In comparison, and~~ the costs of resources and materials are more affordable (49,53). Furthermore, ~~virtual reality head-mounted display the application~~ can be used in high-risk settings for

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medical education to help trainees acquire skills in a safe environment (29,54,55). The study conducted by Koivisto et al. (56) stated that using virtual reality for patient assessment simulation on patients using VR was more effective and interactive than the lecture and presentation methods.

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### Limitations of the study

#### LIMITATIONS OF THE STUDY

The sample selection was not seen from consider the class level and achievement. Furthermore, virtual reality head-mounted display was based on the Android operating system and should be developed on the IOS application. This study only assessed the user experience and needs by assessing the effectiveness of learning with infection prevention and control applications compared to conventional methods for further study.

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### CONCLUSION

This study was validated by medical-surgical nursing and media expert. Infection prevention and control Catheter-associated Urinary Tract Infections (CAUTIs) application were found to be excellent in terms of attractiveness, clarity, efficiency, accuracy, stimulation, and novelty, as confirmed by nursing students. Furthermore, it is an alternative can be used by nursing students instead of as an alternative to laboratory learning.

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Nursing students and instructors can also use the Infection prevention and control Catheter-associated Urinary Tract Infections (CAUTIs) applications as innovative application for innovative and attractive learning, improving to improve clinical knowledge and skills, specifically their prevention of CAUTIs. Therefore, this application is suitable for millennial nursing students who become more skilled when practicing in a hospital and it is suitable for millennial nursing students.

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## DECLARATION OF INTEREST

The authors declare no conflict of interest.

## ACKNOWLEDGMENT

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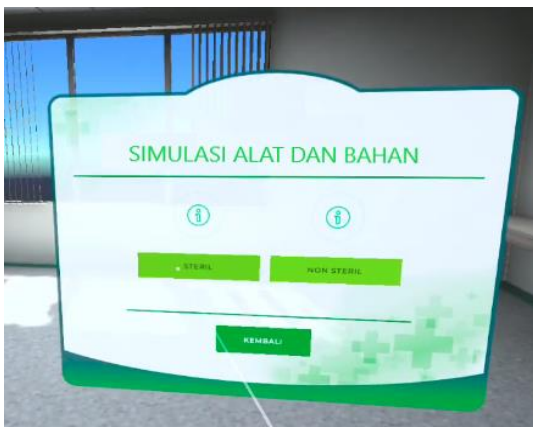
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## FIGURES AND TABLES

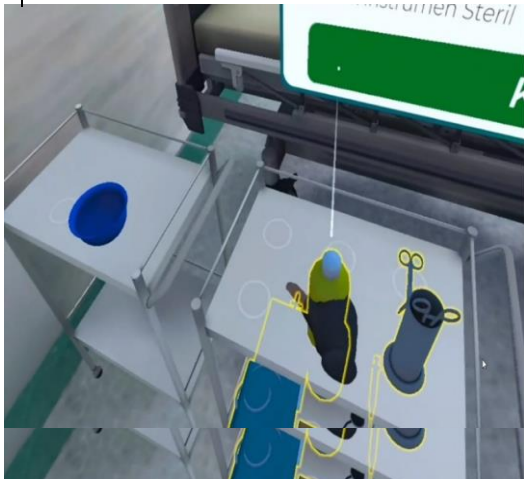
## FIGURES

**Figure 1.** Menu Simulation of Tools and Materials, 2. Simulation of Sterile or Non-Sterile Tools and Materials, 3. Simulation of Retrieval of Tools 4. Practice Test Scores

(1)



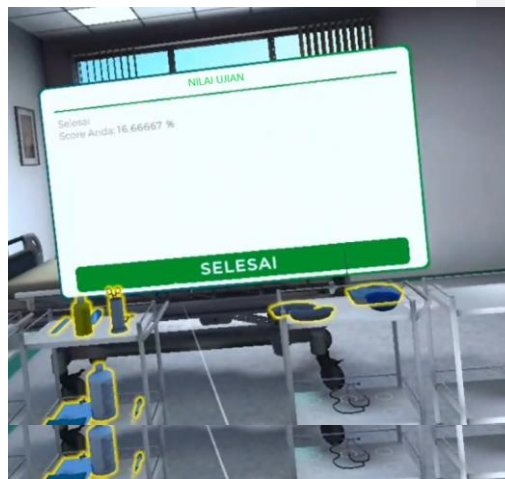
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**Figure 5.** Simulation of patient medical records, **6.** Simulation of hand washing, **7.** Simulation of genital hygiene, **8.** Simulation of urinary catheter insertion

(5)



(6)



(7)



(8)



**TABLES**

**Table 1** Characteristics of the participants

Characteristic	Category	n	%
Age	1. 15-19 years	20	30
	2. 20-24 years	45	70
Gender	1. Male	26	40
	2. Female	39	60
Degree	1. Bachelor	52	80
	2. Associate	13	20

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**Table 12** Mean and confidence interval per scale for Infection prevention and control application

Scale	Mean	Std. Dev	Confidence	Confidence Interval
Attractiveness	2.26	0.411	0.100	2.162- 2.362
Clarity	2.30	0.530	0.129	2.167- 2.425
Efficiency	1.89	1.014	0.246	1.646- 2.139
Accuracy	1.88	1.416	0.344	1.536- 2.225
Stimulation	1.72	1.692	0.411	1.304- 2.127
Novelty	1.61	1.574	0.383	1.225- 1.990

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**Table 3** Scale consistency of the UEQ from ~~the~~ Infection prevention and control application

Scale	Cronbach's <del>alpha</del> Alpha
Attractiveness	0.83
Perspiciuity	0.80
Efficiency	0.80
Dependability	0.86
Stimulation	0.82
Novelty	0.82

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## **DEVELOPMENT OF A VIRTUAL REALITY HEAD-MOUNTED DISPLAY FOR TEACHING INFECTION PREVENTION AND CONTROL**

### **ABSTRACT**

**Introduction:** Infection prevention and control is a crucial aspect of any healthcare setting. To achieve this, students are required to follow aseptic procedures and principles. This practice is essential as failure to follow the sequence of steps can result in serious complications. However, the current challenge in teaching infection control to students is the millennial generation who were born and raised during the Fourth Industrial Revolution and digital technology. These millennials are confident, innovative, committed, collaborative, multitasking, and tech-savvy. Previous virtual reality studies have focused on haptic and computer simulation, while only a few explored the potential of virtual reality head-mounted display (HMD) devices for infection prevention and control, especially for Catheter-Associated Urinary Tract Infection. Therefore, this study aimed to develop a virtual reality head-mounted display to teaching nursing students about infection prevention and control.

**Methods:** Infection prevention and control application was developed using Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model. An evaluation was conducted using User Experience Questionnaire (UEQ) among 65 nursing students and the data obtained were analyzed with UEQ Data Analysis Tool version 10.

**Results:** The results of infection prevention and control application were considered very valid by medical-surgical nursing and media experts. UEQ measurement showed excellent ratings for attractiveness, clarity, efficiency, accuracy, stimulation, and novelty, with mean values of 2.26 (95% CI: 2.162- 2.362), 2.30 (95% CI: 2.167-2.425), 1.89 (95% CI: 1.646-2.139), 1.88 (95% CI: 1.536-2.225), 1.72 (95% CI: 1.304-2.127), and 1.61 (95% CI: 1.225-1.990), respectively. Furthermore, Cronbach's alpha value was  $>0.7$ , indicating good consistency.

**Conclusions:** Infection prevention and control application was found to be excellent in terms of attractiveness, clarity, efficiency, accuracy, stimulation, and novelty, making it suitable for millennial nursing students.

**Keywords:** Teaching; Virtual Reality; Nursing Students; Infection Prevention;

## INTRODUCTION

The current challenge in teaching of infection control and prevention is currently faced with challenges caused by the millennial generation who were born and raised during the Fourth Industrial Revolution and digital technology. Millennials are different from. Compared to previous generations because they are confident, innovative, committed, collaborative, millennial possesses distinct characteristics such as confidence, innovation, commitment, collaboration, multitasking abilities, and tech-savvy [1]. Nursing lecturers face the challenge of teaching millennials in millennial the clinical skills of infection prevention and control especially specifically Catheter-associated Urinary Tract Infection (CAUTIs). This is because the process involves complex steps, strict aseptic technique, patient safety, and patient as well as education to prevent infection and injury [2]. Traditional learning methods for students in infection control and prevention, traditional learning methods such as laboratory demonstrations using manikins, are not sufficient for students to practice clinical skills and receive feedback on performance [3]. In addition, traditional learning These methods through laboratories also require a lot of significant human resources and materials, they are time-bound, so thereby preventing the campus cannot repeat the teaching of infection control and prevention repetition of skills. [4] This problem resulting leads to a deficiency in a lack of learning and practice practical experience in the laboratory, affects students' knowledge and skill development, and increases the incidence of CAUTIs [2].

Catheter associated Urinary Tract Infection (CAUTIs) is CAUTIs are one of the highest nosocomial infections in various hospitals [4], with an incidence rate of 35% in hospitalized patients/patient [5] and approximately 3% to 7% per day [6]. Furthermore, CAUTIs are urinary tract inflammations acquired during hospitalization due to urinary catheter insertion [7]. Symptoms include fever, bladder pain, dysuria, pyuria, and as well as bacteriuria [8]. This increases and are associated with increased morbidity, mortality, or cost of patient care [9].

Accessible, interactive, and fun clinical skills learning is needed to help millennials/millennial understand laboratory practicum materials more efficiently and effectively. To reduce the incidence of CAUTIS/CAUTIs, students are also expected to apply students' their knowledge and skills appropriately [9]. Previous research has established that According to a previous study, virtual reality

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technology is a suitable learning medium for millennial students [10]. This is because virtual reality (VR) is a three-dimensional computer platform simulation that provides an interactive and realistic experience. Virtual reality head-mounted display (VR-HMD) is a three-dimensional simulation technology that combines haptics, computer simulation, and audio with various information (Sünksen *et al.*, 2018). However, only a few studies reported there is limited information on the use of virtual reality based on head-mounted display displays to train technical expertise in infection prevention and control. This includes guidelines for using sterile and non-sterile equipment, and as well as case simulation of infection problems (Bracq *et al.*, 2019). Previous studies have only focused on haptic and computer simulation technology to practice nontechnical skills such as interpersonal and social skills, procedural skills, and anatomy (Mäkinen *et al.*, 2020). Haptic. Although haptic and computer simulation technology offers several advantages, it is not suitable for giving teaching complex commands and handling complicated devices because they are very sensitive due to its high sensitivity and required for special care (Goldsworthy *et al.*, 2020).

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Traditional learning methods for the prevention of CAUTIs for millennial nursing students have been unsuccessful in enhancing their learning potential, so there is a need for. This makes it necessary to create a technology-based learning media that allows the development of systems that are cheap, realistic, easy to use user-friendly, and easy to configure customizable to reduce safety, ethical, and health concerns. This Therefore, this study aimed to develop a virtual reality head-mounted display for teaching millennial nursing students about infection prevention and control related to CAUTIs.

## METHODS

This study was approved by Bakti Tunas Husada University, Indonesia (No. 218/ec.01/kepk-bth/IX/2022). To ensure the effectiveness of the study, the evaluation was conducted using ADDIE (Analysis, Design, Development, Implementation, and Evaluation) development study model. The stages of the ADDIE study model were used as follows:

### (A). Analysis

The analysis phase included needs, teaching participants, technical, and content analysis (25,26). Functional application needs and problems in the learning process were analyzed in May 2022 using literature review and interview methods. Subsequently, semi-structured interviews were conducted online using Zoom with five students, four lecturers, and nurses at the Karsa Husada Garut

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High School of Health, West Java Province, Indonesia. The interviews showed that practicum learning media in the laboratory must be low-cost, realistic, easy-to-use, and easy-to-configure simulators to reduce safety, ethical and health concerns. Furthermore, the instructors were not bound by time and location using technology era 4.0.

The analysis of teaching participants showed that it was necessary to have innovative and attractive learning to clinical knowledge and skills, specifically in preventing CAUTIs. The formation of learning flows and compiling media content were also consistent with the Standard Principles of Nursing Operational Methods published by the Indonesian National Nurses Association (INNA) in 2021 (27).

The technical analysis proved that up-to-date learning methods are needed and suitable for the 4.0 era in form of computer software, the internet, and the character of millennial generation students.

## 2.2. Design

Display design of the application was made by professional developers. The menu concept featured a white patterned box with green patterned writing. Infection treatment tools and materials consisted of 3-dimensional images of sterile and non-sterile tools with colors similar to their original shapes.

Sterile tools were gloves, commas, cotton or gauze for perineal hygiene, tweezers, syringe, and clamps. Meanwhile, non-sterile tools were complete catheter in pure plastic according to dimensions, urine bag, antiseptic, aqua bidest, jelly, plaster, scissors, and garbage bags. A human-shaped three-dimensional animation was also included, which consisted of a male and female patient sleeping on a bed and wearing a green blanket and blue shirt. The patient also had a penis or vagina that can be used interactively to insert a urinary catheter. The practice and exam plans were presented in a white menu box display accompanied by instructions and a list of tools written in green.

The design stage required some hardware and software to produce a virtual reality head-mounted display with realistic 3D depictions that respond to the user's perspective as well as

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recognize all actions and responses, such as the movement of head or eyeball (28,29). Virtual reality head-mounted display hardware consisted of glasses using Oculus Quest 2, 128 GB, with operating systems Oculus Mobile and Android 10. Subsequently, software, including Visual Code Editor ver 1.54.3, was used to develop code for virtual reality head-mounted display application programs. Media 3D creation was made using Unity 2021.3.21 and a lightweight 3D engine.

### 3.3. Development

The virtual reality head-mounted display that was developed included case simulations, practice, and practical exams. When the infection prevention and control application was turned on, it displayed several menus. The application was made with three-dimensional animation, making it immersive and almost lifelike, depicting the hospital environment, and using the Indonesian language. To access the menu, students are required to enter their identity, starting with their name, email, and student identification number. The menu entry was separated into simulations of equipment and materials, catheter insertion, a theoretical module for urinary catheter placement, as well as directions for use and application.

The simulation menu provided tools and materials for students to learn about sterile and non-sterile materials used in exams and exercises. In the exercise simulation, there was a variety of sterile equipment such as gloves, commas, cotton or gauze for perineal hygiene, tweezers, syringe, and clamps. Meanwhile, the non-sterile equipment included catheter in pure plastic according to dimensions, urine bags, antiseptic, aqua bidest, jelly, plaster, scissors, and garbage bags. These materials should be selected based on the on-screen text instructions and the use of tools must be in line with the name, type, and sequence marked with a bright yellow circle. The simulation menu also included the installation of urinary catheter for women and men. In this simulation, students can take, store, smear, install, and wash their hands. The process began with the case simulation and patient conversations, followed by the insertion of tools, and washing hands in running water with soap. Students also performed genital hygiene steps and inserted a urinary catheter. Furthermore, when students was not in order, the sign continued to glow, and the instructions will not change. In the

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exam session, there were time limits, scores, and the bright yellow circles indicating the order of tools usage were removed during the testing phase, and instructions for tools selection were not display.

#### ~~(4)~~4. **Implementation**

This study was carried out at Karsa Husada Garut High School of Health, West Java Province, Indonesia. The data were collected in September 2022 and the application was tested on 65 nursing students who were selected by purposive sampling. The inclusion criteria were students who were actively studying, attending laboratory practicums, studying conventionally and did not have myopia and diplopia eye disorders. Meanwhile, the exclusion criteria were students with leave status and those who left as respondents before the study was completed. Students were given a virtual reality head-mounted display of infection prevention and control for CAUTIs and the simulation of tools as well as materials for the activity lasted for 20 minutes. Virtual reality head-mounted display used oculus quest 2, which was connected to an Android television, with the application requiring an internet connection.

#### ~~(5)~~5. **Evaluation**

The evaluation in this study used a User Experience Questionnaire (UEQ) and the signing of a consent form. The UEQ had six measurement scales divided into 26 question items and the availability of tools to perform data analysis in excel format made it easier for users to measure attractiveness, clarity, efficiency, accuracy, stimulation, and novelty (30,31). Respondents can select a circle closer to their thoughts about a product with a value range of 1-7. The data were analyzed with UEQ Data Analysis Tool version 10 (32,33) and categorized as excellent (>1.60), good (1.00-1.60), and average (<1) (31). Furthermore, mean values ranging from -3 to +3 results were all positive, and other scores were negative. The confidence interval values >1 showed a good confidence level for the results, while values <1 indicated a bad confidence level. Moreover, Cronbach's alpha value >0.7 indicated sufficiently consistent and values <0.7 showed consistent results (34).

The validity of infection prevention and control application was assessed by a media and a medical-surgical nursing expert with a twelve-item and a ten-item questionnaire, respectively.

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## RESULTS

Infection prevention and control application was evaluated by a medical-surgical nursing expert, a media expert, and students who used the UEQ. A total of 65 UEQs were received and the application was considered very valid and suitable for use. Based on the characteristic of the participants in Table 1, 70% of them were 20-24 years, 60% were female, and 80% had a Bachelor's degree. Table 2 showed that all the mean values were positive and  $> 1$ , indicating an excellent result for the application. Furthermore, the confidence interval was good as all mean values had a confidence level greater than 1. The results of the six assessment components of the UEQ Data Analysis Tool in Table 3 revealed that all scales were consistent, as Cronbach's alpha was  $>0.7$ .

The media expert also assessed infection prevention and control application and described it as an interactive, innovative, as well as immersive hospital environment that allows students to learn with remote access. The expert suggested that the color of the image was more pleasing to the eye.

According to the assessment of the medical-surgical nursing expert, the application consisted of a simulation menu, exams, and quizzes. The patient case simulations in the application only focused on CAUTIs and did not include other disease complications. Meanwhile, the expert recommended the use of personal protective equipment such as masks, gowns, and face shields for nurses in the simulation of tools and materials, although gloves were already included.

## DISCUSSION

The results of this study indicated that VR-HMD applications have virtual reality head-mounted display application possessed excellent attractiveness and stimulation. The results of this study are, which was also supported by McCarthy and Uppot [28]. VR-HMD applications provide This application provided interactive and realistic experiences in three-dimensional form that allow users to move, feel the clinic environment, touch, and act on simulated objects so as to provide, thereby providing real perception (immersive) and interesting engaging experience [26]. The results of this study are supported by Similarly, Yeh [27] who argues suggested that audio-visual teaching can increase increased motivation and active learning, thereby increasing knowledge and patient safety, reducing patient injury, reducing the and risk of infection, and improving patient safety. Compared

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Traditional learning methods in nursing education usually involve lectures, textbooks, and as well as hands-on clinical and laboratory experiences so that, which often resulted in students feel bored boredom and saturated saturation [20]. On the other hand Meanwhile, virtual reality learning utilises used immersive technology to create simulated environments that replicate real-life scenarios for students to practice and improve their skills. Similarly, McCarthy and Uppot [28] stated that virtual reality enhances enhanced knowledge by providing students with enjoyable experiences in clinical decision-making, collaboration, communication, and problem-solving, including confidence and readiness for practice in hospitals or clinics.

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The use of VR-HMD virtual reality head-mounted display for infection prevention and control devices, especially specifically for CAUTIs shows an showed excellent Novelty and Perspicuity. According to previous studies, students who use used virtual reality head-mounted displays usually have display had a positive practical experience [20]. The results of this study are in line with the research of Ferszt et al., [20] showing that virtual reality head-mounted displays can stimulate visual, auditory, and emotional experiences to prepare a real environment for students who learn through the use of computers with easy to use and configure [28]. Compared to Traditional! Meanwhile, traditional learning methods in nursing education are often had been limited by physical constraints, such as the availability of simulation rooms, real-life clinical experiences, expensive resources, and materials, as well as supervising, time- and location-bound instructors making. These limitations made it challenging for nursing students who may did not have adequate access to certain clinical settings or specialised specialized procedures [5]. Immersive To overcome these problems, immersive learning with virtual reality head-mounted displays offers a unique experience for students who can learn anywhere, anytime any time, with unlimited time to practice [31]. However, the use of virtual reality for more than 120 minutes can cause dizziness, headaches, and pain when moving the eyes eye strain [32].

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The results showed that VR-HMD applications have virtual reality head-mounted display application has excellent efficiency and dependability. the results of this Similarly, a previous study are supported by [31] virtual reality head-mounted display applications can be used virtual reality head-mounted display in high-risk settings in medical education to help trainees acquire skills in a safe environment [20]. Using The use of virtual reality for simulated patient assessment is more effective and interactive than compared to lecture and presentation methods [36]. Asad et al. also reported that virtual reality is was useful as a pedagogical tool for various teaching and learning models such as problem-based, experiential, or interactive learning [29]. Compared to the traditional Traditional clinical teaching approach still plays an important role in nursing education, as it allows direct interaction with instructors and peers, real-world clinical experience, and hands-on

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practice [31]. However, ~~VR HMD applications have Various~~ virtual reality head-mounted display application has various simulation procedures ~~are used~~ that enable students to gain experience without compromising patient safety and ~~student~~ students' competence [30].

## **LIMITATIONS OF THE STUDY**

The sample selection did not consider the class level and achievement. Furthermore, virtual reality head-mounted display was based on the Android operating system and should be developed on the IOS application. This study only assessed the user experience and needs by assessing the effectiveness of learning with infection prevention and control applications compared to conventional methods for further study.

## **CONCLUSION**

This study was validated by medical-surgical nursing and media expert. Infection prevention and control CAUTIs application was found to be excellent in terms of attractiveness, clarity, efficiency, accuracy, stimulation, and novelty, as confirmed by nursing students. Furthermore, it can be used by nursing students as an alternative to laboratory learning.

Nursing students and instructors can also use the application for innovative and attractive learning, to improve clinical knowledge and skills, specifically in prevention of CAUTIs. Therefore, this application is suitable for millennial nursing students who become more skilled when practicing in a hospital.

## **DECLARATION OF INTEREST**

The authors declare no conflict of interest.

## **ACKNOWLEDGMENT**

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## **FIGURES AND TABLES**

### **FIGURES**

**Figure 1.** Menu Simulation of Tools and Materials, **2.** Simulation of Sterile or Non-Sterile Tools and Materials, **3.** Simulation of Retrieval of Tools **4.** Practice Test Scores

1(1)



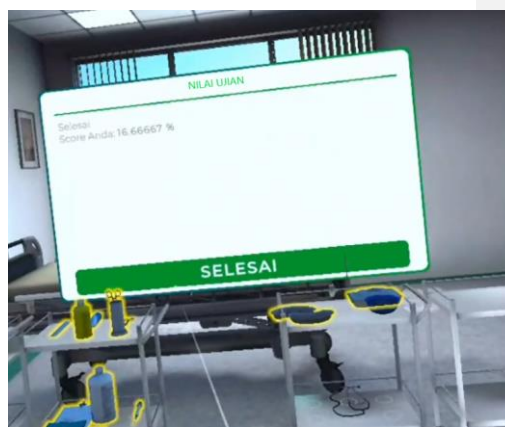
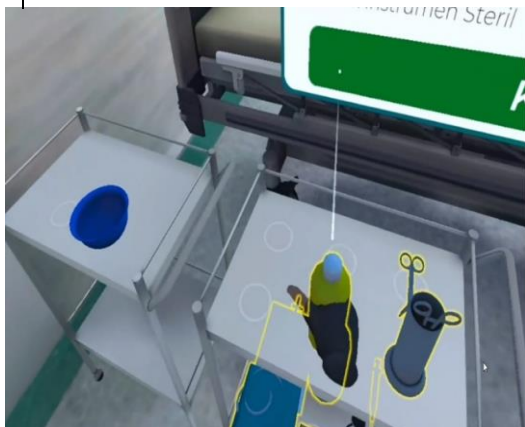
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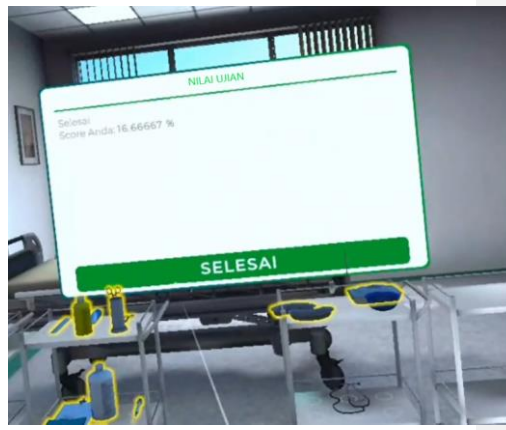
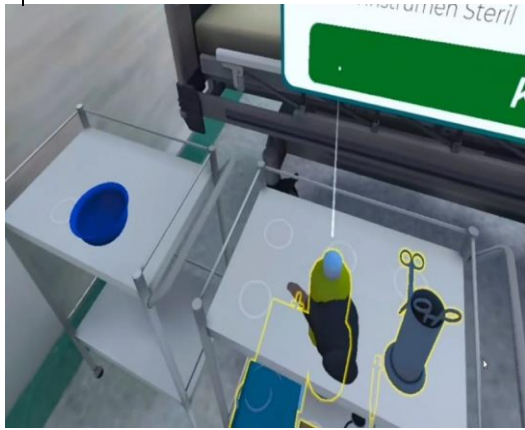
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**Figure 5.** Simulation of patient medical records, **6.** Simulation of hand washing, **7.** Simulation of genital hygiene, **8.** Simulation of urinary catheter insertion

(5)

(6)



(7)



(8)



## TABLES

**Table 1** Characteristics of the participants

Characteristic	Category	n	%
Age	1. 15-19 years	20	30
	2. 20-24 years	45	70
Gender	1. Male	26	40
	2. Female	39	60
Degree	1. Bachelor	52	80
	2. Associate	13	20

**Table 2** Mean and confidence interval per scale for Infection prevention and control application

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Scale	Mean	Std. Dev	Confidence	Confidence Interval
Attractiveness	2.26	0.411	0.100	2.162- 2.362
Clarity	2.30	0.530	0.129	2.167- 2.425
Efficiency	1.89	1.014	0.246	1.646- 2.139
Accuracy	1.88	1.416	0.344	1.536- 2.225
Stimulation	1.72	1.692	0.411	1.304- 2.127
Novelty	1.61	1.574	0.383	1.225- 1.990

**Table 3** Scale consistency of the UEQ from Infection prevention and control application

Scale	Cronbach's Alpha
Attractiveness	0.83
Perspicuity	0.80
Efficiency	0.80
Dependability	0.86
Stimulation	0.82
Novelty	0.82



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Development of Virtual Reality Head-Mounted Display : Teaching Infection Prevention and Control to Millennial Nursing Students

## Author(s)

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**Health Education and Health Promotion**

**Editor-in-Chief: Prof. Fazlollah Ghofranipour**

Dear **Prof. Fazlollah Ghofranipour**

We submit an original research article entitled “**Development Of Virtual Reality Head-Mounted Display: Teaching Infection Prevention And Control To Millennial Nursing Students** ” for your consideration to be published in your esteemed journal. All the listed authors have participated in this manuscript; the manuscript has been revised and approved by all authors. Neither the entire paper nor a part of its content has been published or currently under the review of any other journal and the authors declare no conflict of interest.

We believe the findings would be of interest to your readers who are concerned about learning media that is suitable for millennial nursing students and the industrial era 4.0 which combines technology from haptics and computer simulations and the research conducted is still limited.

We would appreciate it very much if the manuscript could be published for possible publication in your journal.

Yours sincerely,

**Andri Nugraha, S.Kep., Ners., M.Kep**

STIKes Karsa Husada Garut, Indonesia,

Jln. Nusa Indah No.24, Garut, West Java, Indonesia

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Reviewers Comments

1. The introduction is very weak and must be improved.

I have corrected the research and novelty issues. the text is attached below and has been highlighted in yellow in the main article for the corrected sections.

Teaching to millennials born and raised in the midst of the Fourth Industrial Revolution and digital technology is a challenge compared to previous generations <sup>[1]</sup>. Millennial possesses distinct characteristics such as confidence, innovation, commitment, collaboration, multitasking abilities, and tech-savvy <sup>[2]</sup>. Lecturers face the challenge of teaching millennial nursing students the clinical skills of infection prevention and control specifically Catheter-associated Urinary Tract Infections (CAUTIs), because the process involves complex steps, strict aseptic technique, patient safety, as well as education to prevent infection and injury <sup>[3]</sup>. In infection control and prevention, traditional learning methods such as laboratory demonstrations using manikins are not sufficient for students to practice clinical skills and receive feedback on performance <sup>[4]</sup>. These methods also require significant human resources and materials, time-bound, thereby preventing the repetition of skills and leads to a deficiency in learning and practical experience in the laboratory, affects students' knowledge and skill development, which will increases the incidence of CAUTIs <sup>[5]</sup>. CAUTIs are one of the highest nosocomial infections in various hospitals <sup>[6]</sup>, with an incidence rate of 35% in hospitalized patient <sup>[7]</sup> and approximately 3% to 7% per day <sup>[8]</sup>. Furthermore, CAUTIs are urinary tract inflammations acquired during hospitalization due to urinary catheter

insertion<sup>[9]</sup>. Symptoms include fever, bladder pain, dysuria, pyuria, as well as bacteriuria<sup>[10]</sup> and are associated with increased morbidity, mortality, or cost of patient care<sup>[6,11]</sup>.

Students are expected to apply their knowledge and skills appropriately to reduce the incidence of CAUTIs<sup>[12]</sup>. Accessible, interactive, and fun clinical skills learning is needed to help millennial understand laboratory practicum materials more efficiently and effectively<sup>[13]</sup>.

According to a previous study, virtual reality technology is a suitable learning medium for millennial students<sup>[14]</sup>. This is because virtual reality (VR) is a three-dimensional computer platform simulation that provides an interactive and realistic experience<sup>[15]</sup>. Virtual reality head-mounted display (VR HMD) is a three-dimensional simulation technology that combines haptics, computer simulation, and audio with various information<sup>[16]</sup>. However, there is limited information on the use of virtual reality based on head-mounted displays to train technical expertise in infection prevention and control,

includes guidelines for using sterile and non-sterile equipment, as well as case simulation of infection problems<sup>[17]</sup>. Previous studies only focused on haptic and computer simulation technology to practice nontechnical skills such as interpersonal and social, procedural, and anatomy<sup>[18]</sup>. Although haptic and computer simulation technology offers several advantages, it is not suitable for teaching complex commands and handling complicated devices due to its high sensitivity and need for special care<sup>[19]</sup>.

Traditional learning methods for the prevention of CAUTIs for millennial nursing students have been unsuccessful in enhancing their learning potential. This makes it necessary to create a technology-based learning media that are cheap, realistic, user-friendly, and customizable to reduce safety, ethical and health concerns. Therefore, this study aimed to develop a virtual reality head-mounted display (VR HMD) for teaching millennial nursing students about infection prevention and control related to CAUTIs.

Reviewers Comments :

2- Remove Figures 1 and 2.

I've removed Figures 1 and 2.

Reviewers Comments :

3- The discussion should be improved with more comparisons.

I have added a discussion section with a comparison of the research results and Traditional learning methods in nursing education. The text is attached below and has been highlighted in yellow in the main article for the corrected section.

The results showed that VR HMD application possessed excellent attractiveness and stimulation, which was also supported by Bayram & Caliskan, (2020). This application provided interactive and realistic experiences in three-dimensional form that allow users to move, feel the clinic environment, touch, and act on simulated objects, thereby providing real perception (immersive) and engaging experience<sup>[25]</sup>. Traditional learning methods in nursing education usually involve lectures, textbooks, as well as hands-on clinical and laboratory experiences, which often resulted in students boredom and saturation<sup>[26]</sup>. However, virtual reality enhanced knowledge by providing students with enjoyable experiences in clinical decision-making, collaboration, communication, and problem-solving, including confidence and readiness for practice in hospitals or clinics<sup>[27]</sup>.

The use of VR HMD for infection prevention and control devices, specifically for CAUTIs showed excellent Novelty and Perspicuity. The results of this study are in line with the research of<sup>[12]</sup> showing that VR HMD can stimulate visual, auditory, and emotional experiences to prepare a real environment for students who learn through the use of computers with easy to use and configure<sup>[12]</sup>. Meanwhile, traditional learning methods in nursing education had been limited by physical constraints, such as the availability of simulation rooms, real-life clinical experiences, expensive resources, and materials, as well as supervising, time- and location-bound instructors. To overcome these problems, immersive learning with VR HMD offers a unique experience for students who can learn anywhere, any time, with unlimited time to practice<sup>[28]</sup>. However, the use of virtual reality for more than 120 minutes can cause dizziness, headaches, and eye strain<sup>[29]</sup>.

The results showed that VR HMD application has excellent efficiency and dependability. Similarly, a previous study used virtual reality head-mounted display in high-risk settings in medical education to help trainees acquire skills in a safe environment<sup>[21]</sup>. The use of virtual reality for simulated patient assessment is more effective and interactive compared to lecture

and presentation methods <sup>[30]</sup>. Traditional clinical teaching approach still plays an important role in nursing education, as it allows direct interaction with instructors and peers, real-world clinical experience, and hands-on practice <sup>[31]</sup>. However, VR HMD has various simulation procedures that enable students to gain experience without compromising patient safety and students' competence <sup>[5]</sup>.

## **DEVELOPMENT OF VIRTUAL REALITY HEAD-MOUNTED DISPLAY: TEACHING INFECTION PREVENTION AND CONTROL TO MILLENNIAL NURSING STUDENTS**

### **Abstract**

**Aims:** Teaching infection prevention and control to millennial nursing students is a challenge. This study aimed to develop a virtual reality head-mounted display to teaching millennial nursing students about infection prevention and control related to Catheter-associated Urinary Tract Infection.

**Methods:** The study design was Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model. An evaluation was conducted using User Experience Questionnaire (UEQ) among 115 nursing students at College of Health Sciences Karsa Husada Garut, West Java Province, Indonesia were selected using purposive sampling. The data obtained were analyzed with UEQ Data Analysis Tool version 10.

**Findings:** excellent ratings for attractiveness, Perspicuity, efficiency, Dependability, stimulation, and novelty, with mean values of 2.26 (95% CI: 2.162- 2.362), 2.30 (95% CI: 2.167-2.425), 1.89 (95% CI: 1.646-2.139), 1.88 (95% CI: 1.536-2.225), 1.72 (95% CI: 1.304-2.127), and 1.61 (95% CI: 1.225-1.990), respectively.

**Conclusions:** virtual reality head-mounted display Infection prevention and control application was found to be excellent in terms of attractiveness, clarity, efficiency, accuracy, stimulation, and novelty, making it suitable for millennial nursing students.

**Keywords:** Teaching; Virtual Reality; Nursing Students; Infection Prevention

## INTRODUCTION

Teaching to millennials born and raised in the midst of the Fourth Industrial Revolution and digital technology is a challenge compared to previous generations <sup>[1]</sup>. Millennial possesses distinct characteristics such as confidence, innovation, commitment, collaboration, multitasking abilities, and tech-savvy <sup>[2]</sup>. Lecturers face the challenge of teaching millennial nursing students the clinical skills of infection prevention and control specifically Catheter-associated Urinary Tract Infections (CAUTIs), because the process involves complex steps, strict aseptic technique, patient safety, as well as education to prevent infection and injury <sup>[3]</sup>. In infection control and prevention, traditional learning methods such as laboratory demonstrations using manikins are not sufficient for students to practice clinical skills and receive feedback on performance <sup>[4]</sup>. These methods also require significant human resources and materials, time-bound, thereby preventing the repetition of skills and leads to a deficiency in learning and practical experience in the laboratory, affects students' knowledge and skill development, which will increase the incidence of CAUTIs <sup>[5]</sup>.

CAUTIs are one of the highest nosocomial infections in various hospitals <sup>[6]</sup>, with an incidence rate of 35% in hospitalized patient <sup>[7]</sup> and approximately 3% to 7% per day <sup>[8]</sup>. Furthermore, CAUTIs are urinary tract inflammations acquired during hospitalization due to urinary catheter insertion <sup>[9]</sup>. Symptoms include fever, bladder pain, dysuria, pyuria, as well as bacteriuria <sup>[10]</sup> and are associated with increased morbidity, mortality, or cost of patient care <sup>[6,11]</sup>.

Students are expected to apply their knowledge and skills appropriately to reduce the incidence of CAUTIs <sup>[12]</sup>. Accessible, interactive, and fun clinical skills learning is needed to help millennial understand laboratory practicum materials more efficiently and effectively <sup>[13]</sup>. According to a previous study, virtual reality technology is a suitable learning medium for millennial students <sup>[14]</sup>. This is because virtual reality (VR) is a three-

dimensional computer platform simulation that provides an interactive and realistic experience<sup>[15]</sup>. Virtual reality head-mounted display (VR HMD) is a three-dimensional simulation technology that combines haptics, computer simulation, and audio with various information<sup>[16]</sup>. However, there is limited information on the use of virtual reality based on head-mounted displays to train technical expertise in infection prevention and control,

includes guidelines for using sterile and non-sterile equipment, as well as case simulation of infection problems<sup>[17]</sup>. Previous studies only focused on haptic and computer simulation technology to practice nontechnical skills such as interpersonal and social, procedural, and anatomy<sup>[18]</sup>. Although haptic and computer simulation technology offers several advantages, it is not suitable for teaching complex commands and handling complicated devices due to its high sensitivity and need for special care<sup>[19]</sup>.

Traditional learning methods for the prevention of CAUTIs for millennial nursing students have been unsuccessful in enhancing their learning potential. This makes it necessary to create a technology-based learning media that are cheap, realistic, user-friendly, and customizable to reduce safety, ethical and health concerns. Therefore, this study aimed to develop a virtual reality head-mounted display (VR HMD) for teaching millennial nursing students about infection prevention and control related to CAUTIs.

## **MATERIAL AND METHODS**

The effectiveness of the study, the evaluation was conducted using ADDIE (Analysis, Design, Development, Implementation, and Evaluation) development study model. The stages of the ADDIE study model were used as follows:

### ***1. Analysis***

The analysis phase included needs, teaching participants, technical, and content analysis<sup>[18]</sup>. Functional application needs and problems in the learning process were analyzed in May 2022 using literature review and interview methods. Subsequently, semi-structured interviews were conducted online using Zoom with five students, four lecturers, and nurses at the College of Health Sciences Karsa Husada Garut, West Java Province, Indonesia. The interviews showed that practicum learning media in the laboratory must be low-cost, realistic, easy-to-use, and easy-to-configure simulators to reduce safety, ethical and health concerns. Furthermore, the instructors were not bound by time and location using technology era 4.0.



The analysis of teaching participants showed that it was necessary to have innovative and attractive learning to clinical knowledge and skills, specifically in preventing CAUTIs. The formation of learning flows and compiling media content were also consistent with the Standard Principles of Nursing Operational Methods published by the Indonesian National Nurses Association (INNA) in 2021 [20].

The technical analysis proved that up-to-date learning methods are needed and suitable for the 4.0 era in form of computer software, the internet, and the character of millennial generation students.

## **2. Design**

Display design of the application was made by professional developers. The menu concept featured a white patterned box with green patterned writing. Infection treatment tools and materials consisted of 3-dimensional images of sterile and non-sterile tools with colors similar to their original shapes. A human-shaped three-dimensional animation was also included, which consisted of a male and female patient sleeping on a bed and wearing a green blanket and blue shirt. The patient also had a penis or vagina that can be used interactively to insert a urinary catheter. The practice and exam plans were presented in a white menu box display accompanied by instructions and a list of tools written in green. The design stage required some hardware and software to produce a virtual reality head-mounted display with realistic 3D depictions that respond to the user's perspective as well as recognize all actions and responses, such as the movement of head or eyeball [21]. Virtual reality head-mounted display hardware consisted of glasses using Oculus Quest 2, 128 GB, with operating systems Oculus Mobile and Android 10. Subsequently, software, including Visual Code Editor ver 1.54.3, was used to develop code for virtual reality head-mounted display application programs. Media 3D creation was made using Unity 2021.3.21 and a lightweight 3D engine.

## **3. Development**

The virtual reality head-mounted display that was developed included case simulations, practice, and practical exams. When the infection prevention and control application was turned on, it displayed several menus. The application was made with three-dimensional animation, making it immersive and almost lifelike, depicting the hospital environment, and using the Indonesian language. To access the menu, students are required to enter their identity, starting with their name, email, and student identification number. The

menu entry was separated into simulations of equipment and materials, catheter insertion, a theoretical module for urinary catheter placement, as well as directions for use and application.

The simulation menu provided tools and materials for students to learn about sterile and non-sterile materials used in exams and exercises. In the exercise simulation, there was a variety of sterile equipment such as gloves, commas, cotton or gauze for perineal hygiene, tweezers, syringe, and clamps. Meanwhile, the non-sterile equipment included catheter in pure plastic according to dimensions, urine bags, antiseptic, aqua bidest, jelly, plaster, scissors, and garbage bags. These materials should be selected based on the on-screen text instructions and the use of tools must be in line with the name, type, and sequence marked with a bright yellow circle.

The simulation menu also included the installation of urinary catheter for women and men. In this simulation, students can take, store, smear, install, and wash their hands. The process began with the case simulation and patient conversations, followed by the insertion of tools, and washing hands in running water with soap.

Students also performed genital hygiene steps and inserted a urinary catheter. Furthermore, when students was not in order, the sign continued to glow, and the instructions will not change. In the exam session, there were time limits, scores, and the bright yellow circles indicating the order of tools usage were removed during the testing phase, and instructions for tools selection were not display.

#### ***4. Implementation***

This study was carried out at College of Health Sciences Karsa Husada Garut, West Java Province, Indonesia. The data were collected in September 2022 to March 2023 and the application was tested on 115 nursing students who were selected by purposive sampling. The inclusion criteria were students who were actively studying, attending laboratory practicums, studying conventionally and did not have myopia and diplopia eye disorders. Meanwhile, the exclusion criteria were students with leave status and those who left as respondents before the study was completed. Students were given a virtual reality head-mounted display of infection prevention and control for CAUTIs and the simulation of tools as well as materials for the activity lasted for 20 minutes.

#### ***5. Evaluation***

The evaluation in this study used a User Experience Questionnaire (UEQ) and the signing

of a consent form. The UEQ had six measurement scales divided into 26 question items and the availability of tools to perform data analysis in excel format made it easier for users to measure attractiveness, clarity, efficiency, accuracy, stimulation, and novelty [22]. Respondents can select a circle closer to their thoughts about a product with a value range of 1-7. The data were analyzed with UEQ Data Analysis Tool version 10 [23] and categorized as excellent ( $>1.60$ ), good (1.00-1.60), and average ( $<1$ ) [22]. Furthermore, mean values ranging from -3 to +3 results were all positive, and other scores were negative. The confidence interval values  $>1$  showed a good confidence level for the results, while values  $<1$  indicated a bad confidence level. Moreover, Cronbach's alpha value  $>0.7$  indicated sufficiently consistent and values  $<0.7$  showed consistent results [24]. The validity of infection prevention and control application was assessed by a media and a medical-surgical nursing expert with a twelve-item and a ten-item questionnaire, respectively.

## RESULTS

Infection prevention and control application was evaluated by a medical-surgical nursing expert, a media expert, and students who used the UEQ. A total of 65 UEQs were received and the application was considered very valid and suitable for use. Based on the characteristic of the participants in Table 1, 70% of them were 20-24 years, 60% were female, and 80% had a Bachelor's degree.

**Table 1** Characteristics of the participants

Characteristic	Category	n	%
Age	1. 15-19 years	35	30
	2. 20-24 years	80	70
Gender	1. Male	46	40
	2. Female	69	60
Degree	1. Bachelor	92	80
	2. Associate	23	20

Table 2 showed that all the mean values were positive and  $> 1$ , indicating an excellent result for the application. Furthermore, the confidence interval was good as all mean values had a confidence level greater than 1.

**Table 2** Mean and confidence interval per scale for Infection prevention and control application

Scale	Mean	Std. Dev	Confidence	Confidence Interval
Attractiveness	2.26	0.411	0.100	2.162- 2.362
Perspiciuity	2.30	0.530	0.129	2.167- 2.425
Efficiency	1.89	1.014	0.246	1.646- 2.139
Dependability	1.88	1.416	0.344	1.536- 2.225
Stimulation	1.72	1.692	0.411	1.304- 2.127
Novelty	1.61	1.574	0.383	1.225- 1.990

The results of the six assessment components of the UEQ Data Analysis Tool in Table 3 revealed that all scales were consistent, as Cronbach's alpha was  $>0.7$ .

**Table 3** Scale consistency of the UEQ from Infection prevention and control application

Scale	Cronbach's Alpha
Attractiveness	0.83
Perspiciuity	0.80
Efficiency	0.80
Dependability	0.86
Stimulation	0.82
Novelty	0.82

The media expert also assessed infection prevention and control application and described it as an interactive, innovative, as well as immersive hospital environment that allows students to learn with remote access. The expert suggested that the color of the image was more pleasing to the eye.

According to the assessment of the medical-surgical nursing expert, the application consisted of a simulation menu, exams, and quizzes. The patient case simulations in the application only focused on CAUTIs and did not include other disease complications. Meanwhile, the expert recommended the use of personal protective equipment such as

masks, gowns, and face shields for nurses in the simulation of tools and materials, although gloves were already included.

## DISCUSSION

The results showed that VR HMD application possessed excellent attractiveness and stimulation, which was also supported by Bayram & Caliskan, (2020) This application provided interactive and realistic experiences in three-dimensional form that allow users to move, feel the clinic environment, touch, and act on simulated objects, thereby providing real perception (immersive) and engaging experience [25]. Traditional learning methods in nursing education usually involve lectures, textbooks, as well as hands-on clinical and laboratory experiences, which often resulted in students boredom and saturation [26]. However, virtual reality enhanced knowledge by providing students with enjoyable experiences in clinical decision-making, collaboration, communication, and problem-solving, including confidence and readiness for practice in hospitals or clinics [27].

The use of VR HMD for infection prevention and control devices, specifically for CAUTIs showed excellent Novelty and Perspicuity. The results of this study are in line with the research of [12] showing that VR HMD can stimulate visual, auditory, and emotional experiences to prepare a real environment for students who learn through the use of computers with easy to use and configure [12]. Meanwhile, traditional learning methods in nursing education had been limited by physical constraints, such as the availability of simulation rooms, real-life clinical experiences, expensive resources, and materials, as well as supervising, time- and location-bound instructors. To overcome these problems, immersive learning with VR HMD offers a unique experience for students who can learn anywhere, any time, with unlimited time to practice [28]. However, the use of virtual reality for more than 120 minutes can cause dizziness, headaches, and eye strain [29].

The results showed that VR HMD application has excellent efficiency and dependability. Similarly, a previous study used virtual reality head-mounted display in high-risk settings in medical education to help trainees acquire skills in a safe environment [21]. The use of virtual reality for simulated patient assessment is more effective and interactive compared to lecture and presentation methods [30]. Traditional clinical teaching approach still plays

an important role in nursing education, as it allows direct interaction with instructors and peers, real-world clinical experience, and hands-on practice <sup>[31]</sup>. However, VR HMD has various simulation procedures that enable students to gain experience without compromising patient safety and students' competence <sup>[5]</sup>.

## **CONCLUSION**

This study was validated by medical-surgical nursing and media expert. Virtual reality head-mounted display Infection prevention and control application was found to be excellent in terms of attractiveness, clarity, efficiency, accuracy, stimulation, and novelty, as confirmed by nursing students. Therefore, this application is suitable for millennial nursing students who become more skilled when practicing in a hospital.

Nursing students and instructors can also use the application for innovative and attractive learning, to improve clinical knowledge and skills. Furthermore, it can be used by nursing students as an alternative to laboratory learning.

## **LIMITATIONS OF THE STUDY**

The sample selection did not consider the class level and achievement. Furthermore, virtual reality head-mounted display was based on the Android operating system and should be developed on the IOS application. This study only assessed the user experience and needs by assessing the effectiveness of learning with infection prevention and control applications compared to conventional methods for further study.

## **ACKNOWLEDGMENT**

The authors are grateful to Bakti Tunas Husada University for testing study ethics, Telkom University, STIKes Karsa Husada Garut for collecting data, and to all participants.

## **ETHICAL PERMISSION**

This study was approved by Bakti Tunas Husada University, Indonesia (No. 218/ec.01/kepk-bth/IX/2022).

## **DECLARATION OF INTEREST**

The authors declare no conflict of interest.

## **AUTHORS' CONTRIBUTIONS**

All authors contributed to the study's conception and design. AN conceptualized the study. IP, AN, and EK collected data. PS and WF performed data management and analyses.

All authors have approved the final manuscript

## **FUNDING**

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