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School of Nursing

STUDY PROTOCOL

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Comparing Virtual Reality CAVE and Simulated Home Experiences on Self-Perceived Clinical Competence, Self-Confidence, and Satisfaction in Community Health Nursing: A Crossover Randomized Controlled Trial

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Title

Comparing Virtual Reality CAVE and Simulated Home Experiences on Self-Perceived Clinical Competence, Self-Confidence, and Satisfaction in Community Health Nursing: A Crossover Randomized Controlled Trial

Investigators of the project

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VR Cave, cave automatic virtual environment, Simulation, Community Nursing, Simulation in Nursing, Nursing Education

Abstract

Community health nursing courses represent a crucial component in the baccalaureate preparation of nurses. Nonetheless, faculty often face challenges in delivering high-quality, effective training (Thompson et al., 2021; Zeydani et al., 2021). The shift from a hospital environment to community-based care is typically challenging for nursing students, particularly concerning skilled home visitation, leading to poor self-perceptions before field practice. Many students feel nervous, awkward, and anxious ahead of their first home visits (Dalton et al., 2009, Alıcı et al., 2020), affecting their motivation to learn and achieve desired learning outcomes. Thus, it is essential for academic staff to deliver effective community nursing training that promotes optimal learning and skills acquisition (Meeley et al., 2021).

Research on simulations for community nursing is somewhat sparse. Past studies have investigated the impact of home-visit simulation, high fidelity mannikin simulation, and standardized patients on improving the confidence, emotional intelligence, self-efficacy, empowerment, and stress management of nursing students (Hwang et al., 2020; Um, 2023; Ruiz-Fernández et al., 2022; Richards et al., 2010). However, these studies could not address the fundamental limitation of efficient teaching strategies for improved community nursing, primarily due to a lack of varied practice scenarios and overly hospital-centric circumstances, offering limited realism (Distelhorst & Wyss, 2013). A mixed-methods systematic review on the use of simulation practices in public or community health nursing revealed minimal simulation practices in public health nursing, suggesting a need for improvement (Aslan, 2021).

Technological advancements have led to the development of the Cave Automatic Virtual Environment (CAVE), a form of Virtual Reality (VR) that surpasses replicating real-world or

imagined environments and interactions with head-mounted VR displays. The emerging VR CAVE enhances environmental realism and immersion by projecting highly realistic environments onto surrounding walls (Abbas et al., 2024). The VR CAVE's strength lies in its ability to realistically emulate spacious environments, making it an ideal tool for practicing home assessments. This cost-effective and versatile training environment supports evidence-based and discovery-driven training, marking a significant advancement in community nursing education. A pilot study found that VR CAVE applications, which can recreate a broad range of household environments, are helpful and inspiring for the design of new technologies to support home care (Brennan et al., 2013). This could help overcome the limitations of the less versatile simulated home or VR simulation. However, no studies have used VR CAVE in community health nursing simulation for nursing student training. Further research is needed to confirm its efficacy and feasibility in enhancing their knowledge, self-confidence, satisfaction, and cultural competence.

Therefore, this study aims to evaluate the outcomes and feasibility of applying VR CAVE simulation compared to a simulated home in community health nursing simulation for nursing students, with the goal of enhancing their knowledge, self-confidence, satisfaction, and cultural competence.

Objectives

The specific objectives of this project are:

1. To evaluate the effectiveness and feasibility of using the VR CAVE simulation in enhancing nursing students' knowledge and self-confidence in community health nursing;
2. To assess the impact of VR CAVE simulation on nursing students' satisfaction with their learning experience and their ability to provide effective care in community health settings;

3. To explore the potential of VR CAVE simulation in boosting the cultural competence of nursing students in community health nursing;
4. To compare the outcomes of VR CAVE simulation with those of traditional simulated home in terms of enhancing knowledge, self-confidence, satisfaction, and cultural competence in community health nursing among nursing student

Expected outcomes/ benefits/ deliverables

Nursing students will enhance their knowledge, self-confidence, satisfaction, and cultural competence in community health settings.

Primary outcomes

1. Nursing students will demonstrate a significant increase in knowledge and self-confidence in community health nursing following the application of VR CAVE simulation as compared to a traditional simulated home;
2. The use of VR CAVE simulation will enhance nursing students' satisfaction and cultural competence, improving their ability to transition from hospital-based care to community-based care.

Secondary outcomes

1. The VR CAVE simulation will serve as a model for the development of innovative, cost-effective, and versatile training environments that support evidence-based and discovery-driven training in community nursing education.
2. A comprehensive report detailing the effectiveness and feasibility of applying VR CAVE simulation in community health nursing education will be submitted for

presentation at a medical education/nursing conference and an international peer-reviewed publication.

3. The study will aid in the design protocol for a VR CAVE simulation model that can recreate a broad range of household environments, thus contributing to the advancement of teaching strategies in community health nursing education.

Statistical Analysis Plan

General Principles

All statistical analyses will be conducted using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). Statistical significance will be set at a two-sided $p<0.05$. Continuous variables will be presented as mean and standard deviation (SD) or median and interquartile range (IQR) where appropriate, while categorical variables will be summarized as frequencies and percentages.

Analyses will follow the intention-to-treat (ITT) principle, including all participants as randomized regardless of protocol adherence. A per-protocol analysis may also be conducted as a sensitivity analysis.

Study Design Considerations (Crossover Structure)

This study adopts a two-period, two-sequence crossover randomized controlled design:

Sequence A: VR CAVE → Simulated Home

Sequence B: Simulated Home → VR CAVE

Each participant serves as their own control, improving statistical efficiency and reducing between-subject variability.

Key effects to be evaluated include:

Intervention (VR CAVE vs simulated home)

Period effect (first vs second session)

Sequence effect (order of intervention)

Carryover effect (residual effect from first intervention)

Outcome Measures

Primary outcomes:

Clinical competence (CCQ total and subscale scores)

Self-confidence and satisfaction (SSS scores)

Cultural competence (CCA total and subscale scores)

All outcomes are treated as continuous variables.

Baseline Analysis

Baseline characteristics (e.g., gender, prior clinical experience) will be compared between the two randomized sequences:

Categorical variables: Chi-square test or Fisher's exact test

Continuous variables: Independent samples t-test or Mann–Whitney U test (if non-normal)

This step assesses the success of randomization.

Primary Analysis

A linear mixed-effects model (LMM) will be used to evaluate intervention effects while accounting for repeated measures and crossover design.

Model specification:

Random effect: Participant ID

Fixed effects:

Intervention (VR CAVE vs simulated home)

Period (1 vs 2)

Sequence (A vs B)

Time (pre vs post)

Interaction terms (e.g., intervention × time)

The primary parameter of interest is the intervention effect, estimated as the difference in outcome scores between VR CAVE and simulated home conditions.

Carryover Effect Assessment

To assess potential carryover effects:

A sequence effect will first be examined within the mixed model.

Additionally, an interaction term (intervention × period) may be explored.

If a statistically significant carryover effect is detected ($p<0.05$), analysis will be restricted to first-period data only, effectively treating the study as a parallel-group trial.

Within-Group and Between-Condition Comparisons

Pre–post changes within each condition will be analyzed using paired t-tests or equivalent model-based contrasts.

Between-condition differences (VR vs simulated home) will be derived from the mixed model estimates.

Handling Missing Data

Missing data will be assessed for patterns (missing completely at random, MCAR; missing at random, MAR).

Linear mixed models inherently accommodate missing data under MAR assumptions.

If necessary, multiple imputation will be performed as a sensitivity analysis.

Assumption Checking

Model assumptions will be evaluated:

Normality of residuals (Q-Q plots, Shapiro–Wilk test)

Homogeneity of variance

Linearity

If assumptions are violated, appropriate transformations or non-parametric alternatives will be considered.

Subgroup and Sensitivity Analyses

Where sample size permits, exploratory subgroup analyses may be conducted based on:

Prior clinical experience

Gender

Baseline competency levels

Sensitivity analyses:

Per-protocol analysis

First-period-only analysis (if carryover is present)

Effect Size Reporting

Effect sizes will be reported alongside p-values:

Mean differences with 95% confidence intervals (CI)

Standardized effect sizes (e.g., Cohen's d) where appropriate

Software and Reproducibility

All analyses will be conducted using SPSS v28. Syntax files and anonymized datasets will be retained to ensure reproducibility and auditability.

Project Plan

This project consists of the following four phases: 1) Preparatory phase -Developing two sets of VR CAVE community scenarios; 2) Briefing sessions; 3) Implementing the VR CAVE scenarios; and 4) Data analysis and generating design principles for VR CAVE model for community health nursing.

Phase 1: Preparatory phase

- Obtain HKU/HA HKW IRB.
- Inform and seek advice from Director of BN(FT) Program about the implementation of the project.
- Seek approval on using IAPCC-SV.
- Developing two sets of VR CAVE community scenarios
    - In this study, nursing students will use the VR CAVE to simulate home visits for two patients in a poverty home setting, Stone Wong and May Wong, each presenting unique health conditions and care needs. The VR CAVE will provide a realistic and immersive environment that replicates the patients' homes, complete with approximately twenty hidden cues in each case. These cues represent potential health hazards and cultural preferences related to health, challenging the students to observe, assess, and respond effectively.
    - Case 1 Summary: This case centers around Stone Wong, a 70-year-old man who was recently hospitalized due to difficulty in breathing. He was diagnosed with chronic obstructive pulmonary disease (COPD) with acute exacerbation. After

receiving various treatments, Stone showed clinical improvement and was discharged from the rehabilitation ward. As the assigned community nurse in this VR CAVE study, students are tasked with conducting an effective home visit to Stone. The objective is to identify potential health hazards in his home and understand his cultural preferences related to healthcare. Students are expected to demonstrate their knowledge and competency by conducting a respiratory assessment, providing education, and offering care tips for his Foley catheter. Approximately twenty hidden cues are present in the case to challenge the student's observational and assessment skills.

    - Case 2 Summary: The second case involves May Wong, a 65-year-old woman who was hospitalized due to a persistent cough with a low-grade fever. She was diagnosed with pulmonary tuberculosis after her chest X-ray revealed extensive bilateral cavitary disease with mild bronchiectasis, and her sputum smears were positive for acid-fast bacilli. As May's assigned community nurse in this VR CAVE study, students are expected to conduct a thorough home visit. The aim is to identify potential health risks in her environment and understand her cultural health preferences. The primary outcome is for students to help May identify side effects of TB drugs and provide appropriate education. This case also includes around twenty hidden cues to stimulate the student's ability to observe, assess and respond effectively.

- Measuring tools:

    - **Demographics**: includes items such as gender, years of work experience and specialty

- **Clinical Competence Questionnaire (CCQ):** the 47-item Clinical Competence Questionnaire (CCQ) was utilized to assess the nursing students' perceived clinical competency. The CCQ consists of four competency areas: nursing professional behaviors, general performance, core nursing skills, and advanced nursing skills. Items were scored on a 5-point Likert scale, with the total score ranging from 47 to 235 - the higher the score, the higher the perceived competence. The CCQ demonstrated high reliability, with a Cronbach's alpha of 0.98 (Gu et al., 2018). (Appendix1)

- **Student satisfaction and Self-confidence in Learning (SSS):** SSB was prepared by the National League of Nursing (NLN, 2005). The survey was administered online using online Qualtrics, and consisted of 13 items that evaluated the participants' satisfaction with the instruction and their self-confidence in learning through the simulation. (Appendix 2)

- **Cultural Competence Assessment Instrument (CCA)**: The CCA has 25 items in two subscales: cultural awareness and sensitivity and cultural competence behaviors. The instrument uses a 7-point response scale ranging from (1) strongly disagree to (7) strongly agree for the cultural awareness and sensitivity subscale and (1) never to (7) always for the cultural competence behaviors subscale. A higher score on the CCA indicates a higher level of cultural competence. The instrument's reliability and validity have been established (Doorenbos et al., 2003). For the study sample, Cronbach's alpha scores for the total CCA, cultural awareness and sensitivity subscale, and cultural competence behaviors subscale were 0.86, 0.70, and 0.90, respectively (Appendix3)

Phase 2: Briefing session

The project will be submitted to the Institutional Review Board of the University of Hong Kong for ethical approval.

All full-time Year 5 undergraduate nursing students (n=220) enrolled in the course Community & Global Health Nursing (NURS4604) will be invited to participate in this project. They are selected because Year 5 students must be equipped with fundamental knowledge about community health nursing, and must gain and expand clinical experiences and learn how to communicate and build relationships with the team, patients and their families.

The principal investigator will conduct a separate briefing session before the intervention at a mutually convenient time. This session will ensure that they understand all logistics and the knowledge required to guide the students through the cases in the study.

All participants will have a pre briefing time before the start of scenario. The principal investigator will explain the nature, purpose, procedures, risks and benefits of the proposed project to potential participants. Confidentiality and the voluntary nature of participation will be emphasized. Students who agree to participate will sign a consent form. The principal investigator will provide briefings on the project logistics and student expectations to ensure they are fully informed.

Then, students will be asked to take a pre-test and post-test on knowledge, self-confidence, satisfaction, and cultural competence in community health nursing.

Phase 3: Implementing the VR CAVE model

In the second semester, the VR CAVE model will be applied with Year 5 nursing students in the Community & Global Health Nursing (NURS4604) course. Students will form groups and actively participate in conducting home assessments and identifying health hazards for the patient with a play time of 20 minutes In the proposed study, fifth-year nursing students will interact with a VR CAVE, a virtual reality environment designed to simulate home visits for two unique patients, Stone Wong and May Wong, both situated in a poverty-stricken home setting (Figure 1). With around twenty hidden cues in each case, the VR CAVE provides a realistic and immersive environment that mirrors the patients' homes. These cues symbolize potential health risks and cultural preferences related to health, thus challenging the students to observe, assess, and respond effectively.

Prior to the intervention, an online Qualtrics e-consent will be obtained from the participants. Furthermore, a pre-test will be conducted using the Clinical Competence Questionnaire (CCQ), Student Satisfaction and Self-confidence in Learning (SSS), and Cultural Competence Assessment Instrument (CCA). This will allow us to measure the baseline competencies of the students before the intervention.

The intervention group will then undergo the VR CAVE experience in Lab 1, while the control group will conduct a simulated home visit in the same lab. After completing the simulated home visit, the students will take an online Qualtrics post-test on the CCQ, CCA, and SSS. This will provide us with data to compare the competencies of the students post-intervention, and to assess the effectiveness of the VR CAVE as a training tool for nursing students.

Following the initial lab session, the two groups will switch settings for the second lab, thus ensuring a comprehensive and balanced assessment of the effects of the VR CAVE intervention. The intervention group that initially experienced the VR CAVE will now shift to the

conventional simulated home, while the control group will have the opportunity to experience the VR CAVE intervention. This crossover design will provide a holistic view of the students' learning experience in both simulated environments.

Before the second lab session, participants will once again provide e-consent using Qualtrics. This reaffirms the ongoing voluntary nature of their participation. As in the first lab session, students will complete pre-tests using the Clinical Competence Questionnaire (CCQ), Student Satisfaction and Self-confidence in Learning (SSS), and Cultural Competence Assessment Instrument (CCA). This will allow us to monitor any changes in competencies as a result of the initial lab session.

After completing the second lab session, students will perform the same set of post-tests online via Qualtrics based on the CCQ, CCA, and SSS. This will enable us to evaluate any shifts in clinical, cultural, and satisfaction competencies following exposure to both the VR CAVE and the conventional simulated home. This comprehensive testing strategy will ensure that we capture a wide range of data to assess the overall effectiveness and impact of the VR CAVE technology in nursing education. The flow chart is shown in Figure 2.

Figure 1 VR CAVE model for poverty home

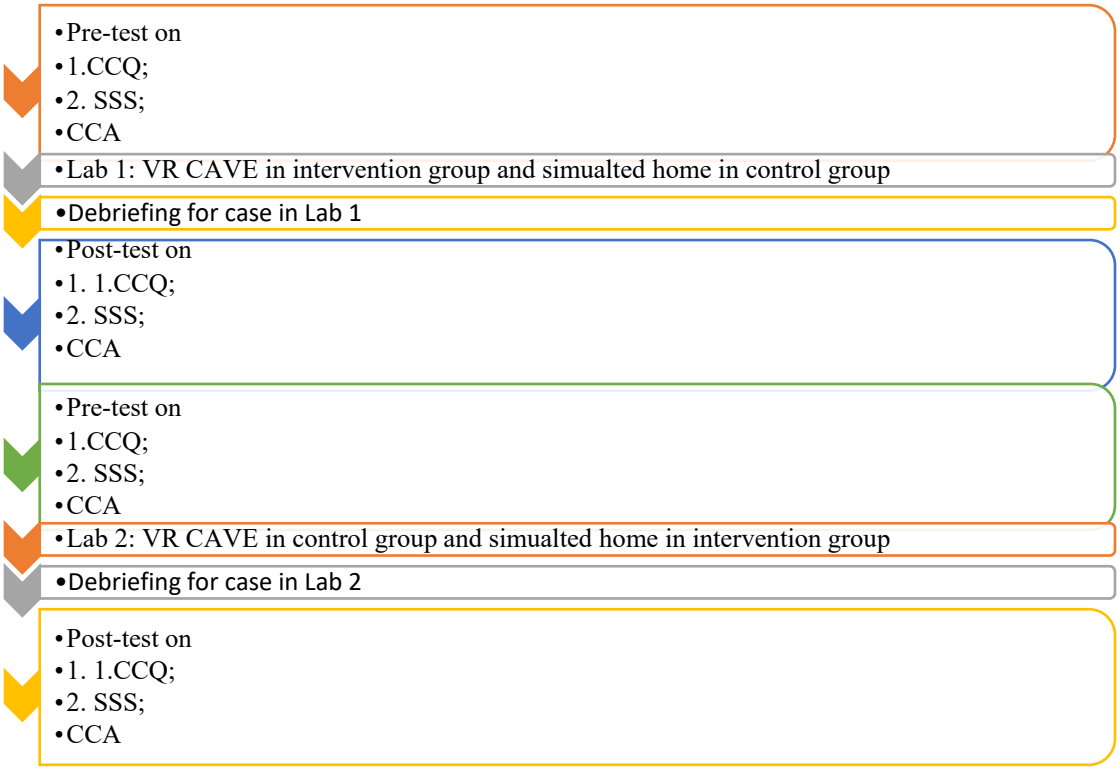

Figure 2 Flowchart of the study

Phase 4: Data analysis and generating design principles for a VR CAVE model

The primary and secondary analyses will involve descriptive statistics, including mean and standard deviation, to summarize participants' demographics and scores from the Clinical Competence Questionnaire (CCQ), Cultural Competence Health Practitioner Assessment (CCHPA-129), and Student Satisfaction and Self-Confidence in Learning (SSS). Baseline characteristics of the intervention and control groups will be compared using the $\chi 2$ test or Fisher's exact test for categorical data and the independent t-test for continuous data.The CCQ, CCHPA-129, and SSS scores will be evaluated using a linear mixed-model analysis. Participants will be included as the random effect with time, group, randomization sequence order, and group x time interaction as fixed effects. The analysis will adhere to the intention-to-treat principle,

conducted on subjects as randomized. All statistical analyses will be performed using IBM SPSS version 28.0. All statistical tests will be two-sided with the level of significance set at 0.05.

Design principles specific to the context of the VR CAVE will be generated based on the findings of this project. These design principles will guide and be applied in further designing and developing VR CAVE for community health nursing.

Project schedule

Phase	Estimated Completion Time
1: Preparatory phase	January 2025
2: Briefing session	February 2025
3: Implementing the VR CAVE model	April-August2025
4: Data analysis and generating design principles for a VR CAVE model phase	January 2026

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Appendix 1 Clinical Competence Questionnaire

Nursing professional behaviors:

1. Following health and safety precautions
2. Taking appropriate measures to prevent or minimize risk of injury to self
3. Taking appropriate measures to prevent or minimize risk of injury to patients
4. Preventing patients from problem occurrence
5. Adhering to the regulation of patients' and families' confidentiality
6. Demonstrating cultural competence
7. Adhering to ethical and legal standards of practice
8. Maintaining appropriate appearance, attire, and conduct
9. Understanding patient rights
10. Recognizing and maximizing opportunity for learning
11. Applying appropriate measures and resources to solve problems
12. Applying or accepting constructive criticism
13. Applying critical thinking to patient cares
14. Communicating verbally with precise and appropriate terminology in a timely manner with patients and families
15. Communicating verbally with precise and appropriate terminology in a timely manner with healthcare professionals
16. Understanding and supporting group goals

Skill competencies:

17. Taking a history for new admissions
18. Performing and documenting patient health assessment
19. Answering questions for patients or families
20. Educating patients or families with disease-related care knowledge
21. Charting and documentation
22. Developing care plan for patients
23. Performing shift report
24. Performing hygiene and daily care routines
25. Providing rest and comfort measures
26. Assessing nutrition and fluid balance
27. Assessing elimination
28. Assisting activities and mobility, and changing position
29. Providing emotional and psychosocial support
30. Performing venipuncture
31. Starting intravenous injections
32. Changing intravenous fluid bottle or bag
33. Administering intravenous medications (or into intravenous bags)
34. Administering intramuscular medications
35. Performing subcutaneous (or intracutaneous) injection
36. Administering oral medications
37. Administering blood transfusion
38. Performing urinary catheter insertion and care
39. Performing sterile techniques
40. Performing postural drainage and percussion, and oxygen therapy
41. Performing preoperation/postoperation care
42. Performing enema
43. Performing upper airway suction
44. Performing tracheotomy care
45. Performing nasogastric tube feeding and care
46. Performing chest tube care with underwater seal management
47. Performing wound dressing care

Appendix 2 **Student satisfaction and Self-confidence in Learning (SSS)**

Student Satisfaction and Self-Confidence in Learning

Instructions: This questionnaire is a series of statements about your personal attitudes about the instruction you receive during your simulation activity. Each item represents a statement about your attitude toward your satisfaction with learning and self-confidence in obtaining the instruction you need. There are no right or wrong answers. You will probably agree with some of the statements and disagree with others. Please indicate your own personal feelings about each statement below by marking the numbers that best describe your attitude or beliefs. Please be truthful and describe your attitude as it really is, not what you would like for it to be. This is anonymous with the results being compiled as a group, not individually.

Mark:
1 = STRONGLY DISAGREE with the statement
2 = DISAGREE with the statement
3 = UNDECIDED - you neither agree or disagree with the statement
4 = AGREE with the statement
5 = STRONGLY AGREE with the statement

Satisfaction with Current Learning	**SD**	**D**	**UN**	**A**	**SA**
1. The teaching methods used in this simulation were helpful and effective.	O 1	O 2	O 3	O 4	O 5
2. The simulation provided me with a variety of learning materials and activities to promote my learning the medical surgical curriculum.	O 1	O 2	O 3	O 4	O 5
3. I enjoyed how my instructor taught the simulation.	O 1	O 2	O 3	O 4	O 5
4. The teaching materials used in this simulation were motivating and helped me to learn.	O 1	O 2	O 3	O 4	O 5
5. The way my instructor(s) taught the simulation was suitable to the way I learn.	O 1	O 2	O 3	O 4	O 5
Self-confidence in Learning	**SD**	**D**	**UN**	**A**	**SA**
6. I am confident that I am mastering the content of the simulation activity that my instructors presented to me.	O 1	O 2	O 3	O 4	O 5
7. I am confident that this simulation covered critical content necessary for the mastery of medical surgical curriculum.	O 1	O 2	O 3	O 4	O 5
8. I am confident that I am developing the skills and obtaining the required knowledge from this simulation to perform necessary tasks in a clinical setting	O 1	O 2	O 3	O 4	O 5
9. My instructors used helpful resources to teach the simulation.	O 1	O 2	O 3	O 4	O 5
10. It is my responsibility as the student to learn what I need to know from this simulation activity.	O 1	O 2	O 3	O 4	O 5
11. I know how to get help when I do not understand the concepts covered in the simulation.	O 1	O 2	O 3	O 4	O 5
12. I know how to use simulation activities to learn critical aspects of these skills.	O 1	O 2	O 3	O 4	O 5
13. It is the instructor's responsibility to tell me what I need to learn of the simulation activity content during class time..	O 1	O 2	O 3	O 4	O 5

Revised December 22, 2004

Appendix 3 Cultural Competence Assessment Instrument

Scale 2: Behavior[a]

12. I include cultural assessment when I do client or family evaluations
13. I seek information on cultural needs when I identify new clients and families in my practice
14. I have resource books and other materials available to help me learn about clients and families from different cultures
15. I use a variety of sources to learn about the cultural heritage of other people
16. I ask clients and families to tell me about their own explanations of health and illness
17. I ask clients and families to tell me about their expectations for health services (Original item—I ask clients and families to tell me about their expectations for care)
18. I avoid using generalizations to stereotype groups of people
19. I recognize potential barriers to service that might be encountered by different people
20. I act to remove obstacles for people of different cultures when I identify such obstacles
21. I remove obstacles for people of different cultures when clients and families identify such obstacles to me (Original item—I act to remove obstacles for people of different cultures when clients and families identify such obstacles to me)
22. I welcome feedback from clients and their families about how I relate to others with different cultures (Original item—I welcome feedback from clients about how I relate to others with different cultures)
23. I welcome feedback from coworkers about how I relate to others with different cultures
24. I find ways to adapt my services to my clients and their families' preferences (Original item—I find ways to adapt my services to client and family cultural preferences)
25. I document cultural assessments
26. I document the adaptations I make with clients and their families (Original item—I document the adaptations I make with clients and families)
27. I learn from my coworkers about people with different cultural heritages