DEVELOPMENT AND VALIDITY OF SERIOUS GAME FOR TEACHING-LEARNING IN SURGICAL SITE INFECTION PREVENTION

Kleiton Gonçalves do Nascimento[1]
Juliana da Silva Garcia Nascimento[2]
Maria Beatriz Guimarães Raponi[3]
Patrícia da Silva Pires[4]
Luciana Mara Monti Fonseca[5]
Maria Helena Barbosa[1]

[1]Universidade Federal do Triângulo Mineiro, Programa de Pós-Graduação em Atenção à Saúde. Uberaba, Minas Gerais, Brasil.
[2]Academia de Simulação em Saúde. Uberaba, Minas Gerais, Brasil.
[3]Universidade Federal de Uberlândia, Faculdade de Medicina. Uberlândia, Minas Gerais, Brasil.
[4]Universidade Federal da Bahia, Instituto Multidisciplinar em Saúde. Vitória da Conquista, Bahia, Brasil.
[5]Universidade de São Paulo, Escola de Enfermagem de Ribeirão Preto. Ribeirão Preto, São Paulo, Brasil.

ABSTRACT

Objective: To develop and validate serious game for teaching-learning regarding surgical site infection prevention.

Method: This is a methodological study conducted in stages: game content development and validity based on virtual simulation (preparation, participation and debriefing) and challenges; game development, following the concept, pre-production, prototype, production and post-production stages; and usability validity, using an instrument called Heuristic Evaluation for Digital Educational Games. To assess the game content and usability, 12 nurses and 08 experts in digital games were involved.

Results: The serious game script contained three sequential pre-, intra- and post-operative periods, focusing on nursing interventions aimed at preventing surgical site infections. A Content Validity Coefficient above 0.80 was obtained for game content. Regarding gameplay assessment using the assessed heuristics, all statements present in game script were considered adequate, and adjustments were implemented regarding feedback, access to the theoretical framework on preventing surgical site infections, the inclusion of images in the study material and directing players to the debriefing session.

Conclusion: The serious game developed was considered valid and a potential pedagogical tool in nursing for learning how to prevent surgical site infections.

DESCRIPTORS: Surgical wound infection. Video games. Validation study. Students, nursing. Simulation training.

DESENVOLVIMENTO E VALIDAÇÃO DE SERIOUS GAME PARA ENSINO-APRENDIZAGEM DE PREVENÇÃO DE INFECÇÃO DE SÍTIO CIRÚRGICO

RESUMO

Objetivo: desenvolver e validar *serious game* para o ensino-aprendizagem referente à prevenção de infecção de sítio cirúrgico.

Método: estudo metodológico conduzido por etapas: desenvolvimento e validação do conteúdo do jogo, baseados na simulação virtual (preparação, participação e *debriefing*) e desafios; desenvolvimento do jogo, seguindo as etapas de conceito, pré-produção, protótipo, produção e pós-produção; e, validação da usabilidade, por meio do instrumento Heuristic Evaluation for Digital Educational Games. Para avaliação do conteúdo e usabilidade do jogo, contou-se com 12 enfermeiros e 08 especialistas em jogos digitais.

Resultados: o *script* do *serious game* conteve três períodos sequenciais pré, intra e pós-operatório, com enfoque em intervenções de enfermagem voltadas para prevenção de infecção de sítio cirúrgico. Obteve-se um Coeficiente de Validade de Conteúdo acima de 0,80 para o conteúdo do jogo. Referente à avaliação da jogabilidade pelas heurísticas avaliadas, todas as afirmativas presentes no script do jogo foram consideradas adequadas e houve a implementação de ajustes no que se refere ao feedback, ao acesso ao referencial teórico sobre prevenção de infecção de sítio cirúrgico, à inclusão de imagens no material de estudo e ao direcionamento do jogador à sessão de *debriefing*.

Conclusão: o *serious game* desenvolvido foi considerado válido e potencial ferramenta pedagógica na área de enfermagem para aprendizagem da prevenção de infecção de sítio cirúrgico.

DESCRITORES: Infecção da ferida cirúrgica. Jogos de vídeo. Estudo de validação. Estudantes de enfermagem. Treinamento por simulação.

DESARROLLO Y VALIDACIÓN DE UN JUEGO SERIO PARA LA ENSEÑANZA-APRENDIZAJE SOBRE LA PREVENCIÓN DE INFECCIONES DEL SITIO QUIRÚRGICO

RESUMEN

Objetivo: desarrollar y validar el serious game para la enseñanza-aprendizaje sobre la prevención de infecciones del sitio quirúrgico.

Método: estudio metodológico realizado por etapas: desarrollo y validación del contenido del juego, basado en simulación virtual (preparación, participación y debriefing) y desafíos; desarrollo de juegos, siguiendo las etapas de concepto, preproducción, prototipo, producción y postproducción; y validación de usabilidad mediante el instrumento Heuristic Evaluation for Digital Educational Games. Para evaluar el contenido y usabilidad del juego participaron 12 enfermeros y 08 expertos en juegos digitales.

Resultados: el guión del serious game contenía tres períodos pre, intra y postoperatorios secuenciales, centrándose en intervenciones de enfermería destinadas a prevenir infecciones del sitio quirúrgico. Se obtuvo un Coeficiente de Validez de Contenido superior a 0,80 para el contenido del juego. En cuanto a la evaluación de la jugabilidad mediante las heurísticas evaluadas, todas las afirmaciones presentes en el guión del juego fueron consideradas adecuadas y se implementaron ajustes en cuanto a retroalimentación, acceso al marco teórico sobre prevención de infecciones del sitio quirúrgico, inclusión de imágenes en el material de estudio y orientación del jugador en la sesión de debriefing.

Conclusión: el serious game desarrollado se consideró válido y potencial herramienta pedagógica en el área de enfermería para aprender a prevenir infecciones del sitio quirúrgico.

DESCRIPTORES: Infección de la herida Quirúrgica. Juegos de vídeo. Estudio de validación. Estudiantes de enfermería. Entrenamiento simulado.

INTRODUCTION

Surgical site infections (SSI) are one of the main complications related to the surgical procedure caused mainly by prolonged surgery time, surgical wound contamination, unfavorable clinical status of patients and use of immunosuppressants[1]. These conditions require the successful implementation of preventive measures to decrease SSI incidence[2].

In the nursing field, investment in innovative educational strategies during graduation, on SSI prevention, represents a challenge and a possibility for changing future professionals' behavior[3].

In this context, simulation stands out, defined as a teaching and learning strategy that replicates real situations in a safe and controlled environment, providing the development of clinical skills[4]. This perspective is strongly recommended by the World Health Organization (WHO) for teaching SSI prevention[5].

Among the types of simulation, virtual represents a technology offered through computers and/or mobile devices connected to the internet[6], generally made possible in the form of a serious game[7], a virtual educational game that necessarily has the purpose of teaching and the ability to simulate real situations, promoting the reuse of the game as many times as necessary to increase learners' perception of self-efficacy and satisfaction levels[7].

It is considered, however, that, even in the face of scientific evidence[8] capable of demonstrating the effectiveness and benefits of using serious games as a pedagogical strategy to support the teaching and learning process in various areas of health, studies that support its applicability in the prevention and control of infections are still incipient, especially in nursing education[9].

Added to this scientific gap is the impact of this complication on the global health system[5] and the advantages of using innovative, attractive and technological educational strategies in the teaching and learning process in nursing, capable of promoting knowledge about prevention measures inherent to SSI[10]. Therefore, this study aimed to develop and validate a serious game for teaching-learning regarding SSI prevention.

METHOD

This is a methodological study for the development and validity of a serious game for teaching and learning SSI prevention, carried out from November 2019 to June 2021 at a public university in Brazil, consisting of two stages: 1) serious game script elaboration and content validity, covering scripts based on virtual simulation (preparation, participation and debriefing)[4] stages and challenges; and 2) serious game development and usability validity.

To develop and validate the serious game script content, the methodological framework on psychometrics[11] was adopted, divided into: 1) theoretical procedures; 2) empirical procedures; and 3) analytical procedures.

In the theoretical procedures stage, the serious game script on SSI prevention was prepared based on guidelines from the Brazilian National Health Regulatory Agency[12] and the American Center for Disease Control and Prevention[13], which guided the narrative in seven concepts created by national literature[14]: 1) history: adoption of best practices for SSI prevention; 2) plot: logical organization of facts for players to make decisions; 3) scenes: based on perioperative periods; 4) characters: leading player – a nurse; a patient undergoing orthopedic surgery; two orthopedic physicians; an anesthesiologist; a circulator nurse and a surgical technologist; 5) dialogues; 6) emotional action: planning and overcoming challenges; 7) physical action: characters moving to overcome challenges.

In the empirical procedures stage, serious game script content validity was carried out by experts, identified by the *Curriculum Lattes* Platform, including professional nurses, physicians,

experienced on SSI prevention, who obtained at least five points in the classification determined by international theoretical references[15].

A total of 50 experts were selected, who received an invitation to participate in the study and an Informed Consent Form via email. Of these, 12 agreed to participate and responded to a Google Forms-type form, containing questions to characterize their profile as well as questions to validate serious game script content based on 12 pre-established criteria[11], assessed using a Likert scale (strongly disagree (value 1); disagree (value 2); do not know (value 3); agree (value 4); and strongly agree (value 5). The time available for judges to answer was 30 days.

In the analytical procedures stage, calculation was carried out to verify the item and total Content Validity Coefficient (CVC) of the serious game script, using a formula[11] that goes through five stages: (1) based on judges' scores, which ranged from 1 to 5 points, the average (X) of their scores for each item was calculated; (2) using the average (X) obtained, the CVC per item (CVCi) was calculated, dividing it by five - the maximum value that the question could receive; (3) the error (Pei) was calculated to discount possible biases of judges, in each question, by dividing the number 1 by the total number of judges, raised to the same number of judges $(1/J)^J$; (4) the CVC per item was calculated by subtracting the CVCi from the Pei; (5) the total CVC of the scripts (CVCt) was calculated by subtracting the average CVCi (XCVCi) from the average Pei (XPei). It was considered valid to obtain an agreement equal to or greater than 80% or CVC>0.8[11].

In the serious game development and usability validity stage, game, pedagogy professionals and researchers developed the proposed serious game entitled "Prevent game", completing five phases: (1) concept; (2) pre-production; (3) prototype; (4) production; and (5) post-production[16]. The development was based on the principles of Meaningful Learning Theory[17], elements of a game[18], spontaneous start, engagement, presence of objectives, use of rules and challenges, aesthetics, narrative, mechanics, and technology.

To assess the Prevent game usability, it was sought in the *Curriculum Lattes* Platform a group of experts, physicians in the field of digital games, who presented at least five points, according to pre-established criteria[15].

A total of 48 experts were identified and an invitation to participate in the study was sent by email, followed by an Informed Consent Form. Of these, eight agreed to participate and responded to a Google Forms-type form containing questions to characterize the profile and questions about validating usability heuristics, composed of statements capable of assessing the game's problems. The time available for experts to respond was 30 days.

To validate the game usability heuristics, an instrument called Heuristic Evaluation for Digital Educational Games (HEDEG) was adopted, translated, adapted and validated for Brazilian Portuguese, consisting of 36 items, distributed across five heuristics, such as interface, pedagogy/education, content, gameplay, and multimedia[19].

For each statement, it was possible to score from zero to four: zero (0), a problem that did not necessarily harm the game; one (1), a problem that did not necessarily require correction; two (2), a low priority problem; three (3), a high priority issue; four (4), an urgent priority issue[19].

For usability validity, the criteria of at least 75% absence of type 3 and 4 problems and less than 25% of type 3 and 4[19] problems were considered. Descriptive statistical analysis was performed with absolute and relative frequency using heuristics and type of problem.

The study was approved by the Research Ethics Committee of the *Universidade Federal do Triângulo Mineiro*. The serious game was produced through its own financing.

RESULTS

A priori, the proposed serious game script was prepared, which covered three scripts on the pre-, intra- and post-operative periods, based on virtual simulation stages, consisting of preparation (pre-simulation and pre-briefing), participation and debriefing[4,20] as well as 15 challenges aimed at teaching-learning to prevent SSI. The components of the three itineraries and their respective challenges were presented in Chart 1.

The script containing the three scripts and 15 challenges related to SSI prevention were sent for content validity by 12 experts, all female, with an average age of 35 years and 17 years (average) of professional experience. The majority (09; 78.0%) had a doctoral degree in nursing as their highest degree and worked as professors in undergraduate nursing courses (10; 83.3%).

Regarding scientific production, 12 (100%) had articles on nursing care in the perioperative period and SSI prevention and 11 (92%) participated in scientific events on SSI prevention. Only one (8.3%) participated in a scientific event on digital educational games and two (16.7%) received training on the use of digital educational games.

Two assessments using the Delphi technique were necessary so that all criteria assessed in the three scripts and in the 15 challenges presented a Content Validity Coefficient per item (CVCi) and total Content Validity Coefficient (CVCt) greater than 0.80 and were considered valid.

After game script content validity, the development steps followed. In the concept phase, a serious game classified as an adventure genre was presented, in which a narrator guides the player through the perioperative phases of a virtual patient, undergoing orthopedic surgery, exposed to challenges regarding appropriate conduct to prevent SSI, based on following learning objectives: (1) Develop knowledge about preventing SSI in undergraduate nursing students; (2) Identify the period and suitable products for bathing, during the pre-operative period; antisepsis and hand preparation; appropriate time and equipment to perform trichotomy; adequate period for prophylactic antibiotic administration and adequate values for capillary blood glucose; (3) Identify the appropriate product and time for surgical hand antisepsis; (4) Indicate the appropriate oxygen concentration in the postoperative period; (5) Identify the appropriate period and products for cleaning the dressing in the postoperative period; (6) Develop decision-making in situations that may expose patients to SSI in the perioperative period.

A point and click system was adopted in which participants choose the location on the screen they want to reach (point function) and move the character (click function)[21]. This way, players win the serious game when they get all their challenges right, without a pre-determined number of attempts.

A graphics engine and game editor called Unreal Engine 4® developed by the company Epic Games was used to create games and applications, ranging from the console market to independent mobile devices[22].

In the pre-production phase, Game Design Document was prepared, considering the following criteria: (1) objective; (2) summary; (3) scenarios; (4) characters; (5) game mechanics; (6) user home screen interface; and (7) created scripts[17].

Chart 1 – Presentation of the components of the scripts relevant to the serious game on preventing surgical site infections. Uberaba, MG, Brazil, 2021

Virtual simulation stage	Guide 1: Guidelines and care in the pre-operative period	Guide 2: Guidelines and care during the intra-operative period	Guide 3: Guidelines and care in the post-operative period
Pre-simulation/and pre-briefing stage	Element 1: Tutorial about the game. Pre-simulation was made possible by the presence of theoretical frameworks on the topic of SSI prevention, exposed to learners in the game's materials tab. Pre-briefing took place through explanations about the game and the clinical case in question, during the tutorial narration.		
Participation stage	Element 2: Operative moment: pre-operative; Element 3: Environment: a ward room in the orthopedics sector of a general hospital; Element 4: Game characters: narrator, nurse and patient; Element 5: Game plot: interaction between a nurse and a 64-year-old patient who will undergo total hip arthroplasty surgery; Element 6: Game challenges: six problems relating to guidance and care in the preoperative period. Challenges 1 and 2: pre-operative bath; challenges 3 and 4: knitting; challenge 5: antimicrobial prophylaxis; challenge 6: glycemic control.	Element 1: Operative moment: intraoperative; Element 2: Environments: degermation room and operations room; Element 3: Characters: narrator, nurse, patient, two orthopedic surgeons, an anesthesiologist, a circulator nurse and a surgical technologist; Element 4: Plot: nurse's interaction with a 64-year-old patient and a multidisciplinary team, during total hip arthroplasty surgery. Element 5: Challenges: six problems regarding guidance and care during the intraoperative period. Challenges 7 and 8: surgical degerming of hands; challenge 9: skin antisepsis; challenge 10: prevention of hypothermia; challenge 11: operating fields; challenge 12: surgical dressing.	Element 1: Operative moment: post-operative; Element 2: Environment: post-anesthesia recovery room; Element 3: Characters: narrator, nurse and patient; Element 4: Plot: nurse's interaction with a 64-year-old patient after total hip arthroplasty surgery; Element 5: Challenges: three problems regarding guidance and care in the post-operative period. Challenge 13: adequate oxygen concentration; challenges 14 and 15: proper dressing.
Debriefing stage			Element 6: seven open-ended questions for reflection.

In the prototyping and production phases, the serious game was implemented, analyzing test adequacy and relevance through a prototype capable of identifying problems in the design and making refinements to the game before coding began. Finally, the post-production phase allowed the serious game to be played from beginning to end, obtaining a game version sent for usability assessment.

Of the total of eight experts who participated in the usability validity process, five (62.5%) were male, with an average age of 39 years and 12 years (average) of professional experience. They presented a doctoral degree as their highest degree and worked as professors in the area of digital games (06; 75%).

As for scientific production, eight (100%) had articles on serious game development and participated in scientific events in the last five years. Half of judges (04; 50%) reported having specific courses in the serious game area.

Table 1 presents the general percentage of problems identified by experts in each heuristic assessed in the proposed serious game.

Table 1 – Presentation of the general percentage of problems identified by experts in each heuristic assessed in the proposed serious game. Uberaba, MG, Brazil, 2021.

Heuristics	Total problems				
	Level 0(%)	Level 1(%)	Level 2(%)	Level 3(%)	Level 4(%)
Interface	41(51.3)	14(17.5)	21(26.2)	4 (5.0)	0
Pedagogy/education	19(39.6)	10(20.8)	14(29.2)	2 (4.2)	3(6.3)
Content	26(54.2)	12(25)	5(10.4)	4(8.3)	1(2.1)
Gameplay	33(41.3)	12(15)	16(20)	2(2.5)	3(3.7)
Multimedia	34(85)	5(12.5)	1(2.5)	0	0

In the heuristics assessed, all statements were considered adequate, since none reached more than 25% of type 3 and 4 problems. Given the findings, even considering the criteria of the validated heuristics, the suggestions made by experts to improve the serious game usability (Chart 2).

Chart 2 – Presentation of experts' suggestions regarding usability heuristics and adjustments made by the researcher. Uberaba, MG, Brazil, 2021.

Experts' suggestions	Adaptations
(A) Improve feedback.	(A) The incorrect answer was highlighted in red and the correct answer in green. The page referring to the question content was indicated to direct players.
(B) Provide content on preventing SSI during the game.	(B) The theoretical framework access tab was inserted in all game scenarios.
(C) Consider different levels of learning.	(C) Suggestion not suitable for the purpose of the game, as it is considered linear; all items are important, considering their respective difficulty levels.
(D) Include figures about the procedures mentioned in the study material.	(D) The figures were included in the material.
(E) Direct players to the debriefing session with a specific tab at the end of the game.	(E) The tab was inserted at the end of the game.
(F) Make the game available for mobile technologies.	(F) Suggestion planned for future adaptation.

Figures 1 and 2 illustrate the Prevent game, after usability validity and suggestions from judges. Figure 1 shows the image of the preoperative period scenario. The location of the challenge is indicated by the question mark in the scenario. Patients' medical record' can be accessed in the tab located in the lower left corner of the screen. The study material was located in the tab present in the lower right corner and players' score in the upper right corner.

Figure 1 – Presentation of the simulated virtual scenario of the preoperative period. Uberaba, MG, Brazil, 2021.

Figure 2 shows the screen image of one of the challenges, referring to the moment in which the player selects the wrong answer. The correct answer is displayed in green. To access feedback, it is necessary to click on the tab in the bottom left corner of the screen and, to access the study material, it is recommended to click on the tab in the top right corner.
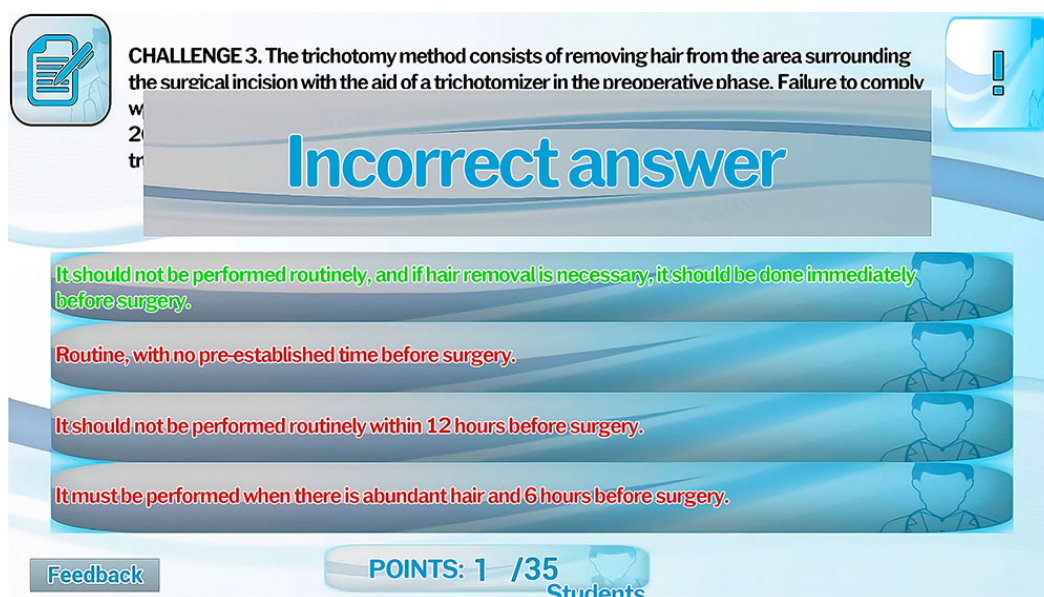

Figure 2 – Presentation of the screen for challenge number three, with visualization of the feedback offered by the game when faced with an incorrect answer from an undergraduate nursing student. Uberaba, MG, Brazil, 2021

DISCUSSION

The adoption of measures to prevent infections has proven to be a challenging practice for global health systems, characterizing itself as a problem that instigates reflection on contemporary educational strategies and their effectiveness in promoting knowledge and adherence to institutional protocols for infection prevention[9].

Although the serious game is already used in the teaching-learning process of infection prevention, it has not yet been developed, specifically, on SSI prevention[23], a condition that makes this study unique in nursing science, as it presents the Prevent game, a virtual learning object, based on simulation, that is attractive, easy to use, capable of promoting learners' autonomy and flexibility in the search for information on this topic.

The components covered for preparing the Prevent game scripts and challenges were arranged according to pre-briefing/briefing stages, virtual simulation participation and debriefing[4,24]. It is believed that combining virtual simulation with the serious game allows students to be involved in the decision-making process dynamically and immersively in clinical environments that resemble the real thing, guaranteeing moments of reflection on practice[24].

To achieve reliability of the proposed construct, we opted for the content validity process, including assessment by nurses experienced on the subject, a crucial factor for the reliability of this process[25]. A Dutch study, whose purpose was to develop a serious game, ReValidate!, aimed at the rehabilitation of patients with wrist and hand injuries[26], also adopted the content validity method, obtaining acceptable inter-rater agreement and considered the game produced to be a useful, fun, easy to use and ideal educational tool to complement the health pedagogical process.

Regarding usability validity, despite being incipient in scientific literature, adopting the HEDEG is encouraged due to its ease of understanding and handling, and generation of objective outcomes capable of being interpreted even by non-expert judges[27].

When assessing a game's usability, six main heuristics (criteria) are valued, and the identification of more acute problems valued four of them. When assessing the interface heuristics, the problem identified was feedback to student players, characterized by the process of conveying the game on learners' performance, directing them to best practices and self-assessment of their progress[28].

In this case, the feedback was deficient, and this context was resolved by adapting the response, which was immediately provided to players, along with an explanatory message. To help them find the correct answers, the topic page number was provided along with the justification for the incorrect answer in the feedback tab.

The same situation was detected in another study, which also developed and validated the serious game e-Baby, focused on skin integrity, which highlighted the importance of player errors in maintaining realism in teaching and obtaining feedback on gaps existing performance levels for learning, plus the possibility of playing again[29].

Regarding the heuristic called educational elements, the present study pointed out the impossibility of learners selecting, during the game, different levels of learning. It is important to highlight that the absence of a difficulty level option in Prevent game is due to the linear characteristic of the chosen topic, in which no phase is superior to another.

This aspect was also similar to e-Baby, which did not include the selection of the level of difficulty, and the target audience consisted of beginners[30].

Students submitted to e-Baby felt satisfied with the gameplay and dynamics of this serious game, even in the absence of complexity and levels of difficulty[30], which corroborates and possibly makes the Prevent game experience also attractive and motivating.

In the content heuristic, the implementation of access to supporting educational material was requested by judges. Research that described a serious game aimed at developing communication skills for nurses also valued the need to make study material available to learners, especially in the face of inadequate responses, as reading allows the mediation of students' learning in accordance with training and interaction interests and encourages their leading role in learning construction[27].

The provision of excellent student support content is related to adequate flow of educational information that students will practice during the game and the integration of help elements for using the game, allowing the mediation of students' learning in accordance with training and interaction interests, which can be valuable in digital environments[27].

In the multimedia heuristics, it was suggested to make the game available for mobile technologies, an important aspect for learning as it provides ease of access to the desired information, when considering the scope of use of smartphones and other mobile computing devices.

Using mobile devices as learning resources anywhere, anytime makes access to information a growing and important trend for learning[30].

Access to the desired information formalizes a feeling of security in users, as it makes content easy to obtain and makes it possible to share the material with others[30], an aspect that still requires greater planning in Prevent game.

The main limitations identified in this study were the scarce production on serious games for healthcare-associated infection prevention, the incipient exploration of the field of usability heuristics for educational games, the lack of inclusion of the target audience (undergraduate nursing students) in the validity process and the challenge of reducing serious game production costs, making it available even for mobile devices.

CONCLUSION

Prevent game was configured as an educational technology valid in content and usability based on virtual simulation. Its application in the experience of the three operative moments presents four major benefits, highlighting knowledge development about preventing SSI through the feedback received, access to care guidelines and completion of proposed challenges as well as development of attitudinal skills, due to the need for decision-making, in search of improving care as the game's final objective.

Furthermore, the permission of errors in a safe and controlled virtual environment is seen as an important benefit that reduces adverse events for students and patients and support for pre-briefing, participation and debriefing, simulation stages that gave Prevent game the character of a potential pedagogical tool for learning how to prevent SSI in an innovative and fun way.

In the continuation of this scientific process, Prevent game, already validated, will be used to assess its effectiveness in learning how to prevent SSI in undergraduate nursing students to advance knowledge in the areas of learning through serious games.

It is hoped that Prevent game will be integrated as a didactic option in nursing curricula and health training programs, as it represents a technology possibly capable of promoting patient safety in the perioperative context and advancing contemporary education.

It is also important to highlight that future studies are necessary to analyze the Prevent game validity among the target audience and to compare the effectiveness of this technology with other pedagogical strategies to strengthen the teaching-learning process for SSI prevention.

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NOTES

CONTRIBUTION OF AUTHORITY
Study design: Nascimento KG, Nascimento JSG, Barbosa MH.
Data collection: Nascimento KG, Nascimento JSG.
Data analysis and interpretation: Nascimento KG, Nascimento JSG, Raponi MBG, Pires PS, Fonseca LMM, Barbosa MH.
Discussion of results: Nascimento KG, Barbosa MH.
Writing and/or critical review of content: Nascimento KG, Nascimento JSG, Raponi MBG, Pires PS, Fonseca LMM, Barbosa MH.
Review and final approval of the final version: Nascimento KG, Nascimento JSG, Raponi MBG, Pires PS, Fonseca LMM, Barbosa MH.

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CONFLICT OF INTEREST
There is no conflict of interest.

CORRESPONDING AUTHOR
Maria Helena Barbosa
mhelena331@hotmail.com