International Journal for Innovation Education and Research

ONLINE ISSN: 2411-2933 PRINT - ISSN: 2411-3123

A Serious Game for the Cardiovascular System Anatomy: A case study of the performance effects on health sciences students

Karolini R. da Conceição;Robson R. Lemos;Patricia J. Fiuza;Cristian Cechinel;Cristiane M. Rudolph

Abstract

The study aims to investigate the effects of a serious game on the performance of health science students in the education of the cardiovascular system anatomy. Experiments were performed using a serious game to teach the cardiovascular system anatomy to Physiotherapy undergraduate students. Data collection was performed through pre and post-tests with a study group using knowledge questionnaires of the cardiovascular system anatomy. In addition, a usability scale and open-ended questions were answered by students and human anatomy experts following experiments in the computer lab. From the data analysis, it has been observed an increase in the educational performance of the students with the use of the serious game to aid teaching of the cardiovascular system anatomy in a virtual 3D Web environment.

Keyword: Serious games; Virtual human anatomy; Educational Technology; Cardiovascular system anatomy

Published Date: 12/31/2019 **Page.115-128** **Vol 7 No 12 2019**

DOI: https://doi.org/10.31686/ijier.Vol7.Iss12.2018

A Serious Game for the Cardiovascular System Anatomy: A case study of the performance effects on health sciences students

Karolini R. da Conceição, MSc
Sciences, Technologies and Health Center, Federal University of Santa Catarina, Araranguá, Santa Catarina, Brazil.

Robson R. Lemos, PhD (Corresponding author)
Sciences, Technologies and Health Center, Federal University of Santa Catarina, Araranguá, Santa Catarina, Brazil.
Robson.lemos@ufsc.br

Patricia J. Fiuza, PhD
Sciences, Technologies and Health Center, Federal University of Santa Catarina, Araranguá, Santa Catarina, Brazil.

Cristian Cechinel, PhD
Sciences, Technologies and Health Center, Federal University of Santa Catarina, Araranguá, Santa Catarina, Brazil.

Cristiane M. Rudolph, PhD
Sciences, Technologies and Health Center, Federal University of Santa Catarina, Araranguá, Santa Catarina, Brazil.

Abstract

The study aims to investigate the effects of a serious game on the performance of health science students in the education of the cardiovascular system anatomy. Experiments were performed using a serious game to teach the cardiovascular system anatomy to Physiotherapy undergraduate students. Data collection was performed through pre and post-tests with a study group using knowledge questionnaires of the cardiovascular system anatomy. In addition, a usability scale and open-ended questions were answered by students and human anatomy experts following experiments in the computer lab. From the data analysis, it has been observed an increase in the educational performance of the students with the use of the serious game to aid teaching of the cardiovascular system anatomy in a virtual 3D Web environment.

Keywords: Serious games; Virtual human anatomy; Educational Technology; Cardiovascular system anatomy

1. Introduction

Human anatomy is an essential curricular component in health science courses, where its objective is to

learn the structural and functional organization of the human body [1][2]. In that broad concept, anatomy is the science that studies, macro and microscopically, the constitution and development of organized beings [3]. For many years anatomy teaching has focused on traditional methods and 2D drawings, which according to [4] lead to difficulties for students to mentally visualize the human body 3D architecture for a realistic representation of each anatomical structure.

Studying human anatomy is not a simple task. The huge nomenclature of anatomical structures, as well as the relationship between them and the understanding of the concepts associated with structure and function, characterize the teaching of human anatomy [2]. Such a reality can make learning complex for students [5]. Another difficulty regarding anatomy teaching is the high cost of maintaining anatomy laboratories. The conservation of structures considered small and fragile, such as the blood vessels of the cardiovascular system, which require perfect dissection and are difficult to preserve, make their study in laboratories a challenge [6].

Regarding the advances for a better understanding of human anatomy by students and health sciences professionals, new teaching methods based on computational tools have been implemented in conjunction with traditional approaches [7]. With the rapid evolution of technologies, there is a great opportunity for innovation in the design of digital game-based learning environments. Especially in health sciences, there is a need for technological application developments to assist teaching and learning process, since only the use of traditional resources (e.g., textbook, teacher or labs) cannot always provide students with real dimensions of anatomical structures [8].

The use of technologies for teaching anatomy plays an important role in learning, providing a new study environment beyond the anatomy laboratory [9]. Gradually the technological advances on computer graphics has allowed a growth in the development of digital games, emerging as a powerful educational tool [10], and that has been gaining ground in the academic field.

Recent technological advances and ease of access, particularly in games, have increased the use of technology in various areas, such as health sciences [11]. The use of games has gained space and relevance in the research field, and can be seen as a tool capable of combining learning and entertainment. In recent years, the term serious games have gained space and importance. Applied in various areas of knowledge, serious games are focused on learning. Those games, with specific purpose and content, focus on providing the user with a knowledge input (content) that will be further tested [12]. Currently, there are a variety of digital games and applications that are characterized as virtual environments for the Web. In that context, the generic term Web3D is used to refer to any type of three-dimensional (3D) graphic technology supported by the World Wide Web (WWW). Focusing on the field of human anatomy and presenting general information on human body systems, two virtual environments can be emphasized: Biodigital [13] and Complete Anatomy [14].

Based on that, it is necessary to develop innovative tools that enable health science students to explore essential characteristics during the study of human anatomy. This study is part of an ongoing research project entitled EducaAnatomia3D which is a Web3D serious game for teaching Anatomy of Skeletal, Muscle, Cardiovascular and Nervous Systems. The design and development of the serious game is being carried out in partnership with human anatomy experts who assist in the identification and inclusion of important concepts associated with the structure and organization of the organs that make up the systems.

In that context, the aim of the current study was to investigate the effects of a serious game on the educational performance of health science students in the teaching of cardiovascular system anatomy. Thus, the content of the serious game corresponding to the cardiovascular system was developed in such a way that the following research question can be answered through group study evaluations with students and health sciences experts: which are the effects of the proposed serious game on the educational performance of health science students in teaching the anatomy of the cardiovascular system anatomy?

The remainder of the article is structured as follows: Section 2 provides a brief description of related work. The serious game for teaching human anatomy with an emphasis on the cardiovascular system is presented in Section 3. Section 4 describes the characteristics of the study group. Section 5 describes tools for data collection, such as the cardiovascular system knowledge questionnaire, usability scale, open questions about a game session, the experiment implementation process, and data analysis. Section 6 presents the results. And, Section 7 presents the conclusion of the study performed and future work.

2. Related Work

Studies related to virtual environments for human anatomy education can be classified into three main categories: serious games for health science education; virtual environments for education in human anatomy; and, augmented and virtual reality for human anatomy education.

In the context of serious games for health science education, [15] presented a systematic review of the literature on serious games for health sciences and proposed a classification of games based on the following topics: the main goal (entertainment, teaching or health), the stages of the disease being treated (monitoring, detection, treatment, rehabilitation or health education), and the type of end users (general population, patients, or health professionals). According to the authors, the development of a serious game involves different processes, technologies, and experts. The authors also mentioned that in the case of serious games, special attention should be given to the content provider. Meaning that the content providers need to supply game-related information as well as share their knowledge to define game parameters such as level of difficulty or appropriate rewards. [8] conducted a comprehensive review of serious games in health professions. The authors compared serious games with traditional simulators, taking into account four key factors: entertainment factor, development costs, development time, and deployment costs. According to the authors, in serious games users enjoy the need to improve their performance, which is usually measured by some kind of scoring mechanism and the challenge of achieving a particular goal.

In terms of virtual environments for human anatomy education, [16] presented a pioneering study in the description of a fully online undergraduate anatomy course. The course was designed to work in parallel with a traditional classroom course. The classroom lectures were delivered to students using a web collaboration software along with an interactive whiteboard. The same collaborative software was used to present laboratory demonstrations in which 3D virtual anatomical models were manipulated. In addition, online materials for the central nervous system were available on a website containing 360° images of prospective plasticized brain samples. In that way, different types of interaction were explored during the course, such as student-instructor and student-student interactions. [17] investigated the interaction between learning material presentation formats, spatial skills and anatomical tasks. The first study

conducted by the authors aimed to explore how presentation formats (dynamic vs. static visualizations) support the learning of functional anatomy. And, the second study was conducted to investigate the interaction between spatial skills (spatial visualization and spatial relationship) and presentation formats in relation to the functional anatomy of the human upper limb. It was observed that dynamic visualization models can help to solve spatial difficulties encountered when learning anatomy, but those models can be difficult for novices to process. [2] investigated studies that explore 3D anatomy models and their impact on health sciences students learning, as well as the current quality of research conducted in that area. A systematic literature review was performed and the main inclusion criteria were the studies that could evaluate the impact of using the 3D anatomy model on the student learning process. The authors concluded that students favored the use of 3D anatomical models and that, in general, the students found the 3D models more satisfactory when compared to traditional anatomy teaching. However, the authors found no solid evidence that the use of 3D anatomy models is superior to traditional teaching.

Regarding virtual and augmented reality for human anatomy education, [18] presented the use of web-based 3D technologies including virtual reality capabilities for applications of teaching anatomy. Two case studies were presented to investigate virtual reality for anatomy learning purposes. It was proposed four principles to be considered in the design of educational applications, such as: learning from interaction with an artificial real environment, learning from problem solving to promote creativity, motivating students to learn, and virtual reality as a learning tool. The authors mentioned that when educators apply virtual technology to educational design environments, they need to consider how a learning theory influences the learning process. Based on that, the authors concluded the study by presenting a guideline for the effective use of virtual reality for learning purposes. [19] has developed an app to study neuroanatomy topics using mobile augmented reality technology. The main objective of the study was to evaluate the effects of learning anatomy using mobile augmented reality application through academic performance and cognitive load. In the case study, two main groups of medical students participated in the study. An experimental group that used the mobile augmented reality app and a control group that used printed books to study neuroanatomy topics. According to the authors, the mobile learning app helped students learn better by exerting less cognitive effort. The authors also mentioned that the ability to have real-time interaction with the environment allows students to structure their knowledge and complete learning tasks.

3. EducaAnatomia3D: A Serious Game for the Cardiovascular System Anatomy

EducaAnatomia3D is a serious game for teaching human anatomy which allows the study of skeletal, cardiovascular, muscular and nervous systems. The serious game is available for free, requiring only that students and health sciences professionals to have access a web browser [20][21]. The development team for the serious game is comprised of information and communication technology researchers, health science students, and human anatomy specialists. Human anatomy specialists play an important role in game design and are responsible for: defining the content to be used in the game, defining the hierarchical or sequential order of how content should be presented in the virtual environment, and developing the questions for knowledge questionnaires based on a desired level of difficulty. The serious game is currently available in Portuguese (official language in Brazilian universities) following the universal anatomical

terminology, which was last updated in 1999 and is still used to teach human anatomy for health science courses.

In the context of digital games, EducaAnatomia3D qualifies as simulation-based games as it simulates the visualization of anatomical systems of the human body in a 3D virtual environment, allowing the use of spatial features that are often not possible to be realized in real life [22]. In the design of the serious game, open source technologies have been adopted for web application development, such as HTML©, CSS©, and Javascript© for interface development. And, to allow interaction with 3D objects, Web3D technology was used through the BabylonJS© framework (WebGL framework for building 3D games). The 3D objects responsible for the representation of anatomical structures were obtained from the BodyParts3D© database [23] (with permission "BodyParts3D©, The Database Center for Life Science licensed under CC Attribution-Share Alike 2.1 Japan"). Regarding the database for the web application, MySQL© was chosen and so that the application could query the database, the PHP© language was adopted.

The digital game-based learning (DBGL) model [24] was adopted for the design and development of the serious game. The serious game has functionalities to manage each user's registration information, creation and deletion of virtual rooms, and user ranking. In general, the serious game is subdivided into two main phases: the first phase corresponds to content presentation, and the second phase corresponds to the content fixation. From the specific point of view of the cardiovascular system, it is possible to study the structure and organization of the main arteries and veins of the human body (Figure 1).

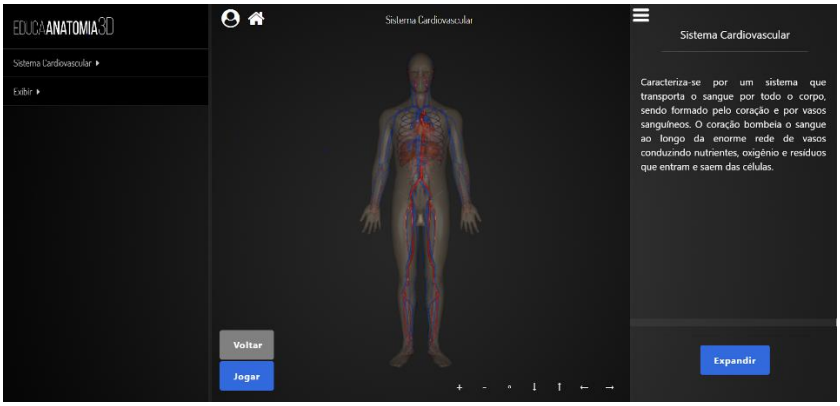

Figure 1: Content presentation phase for the cardiovascular system [20].

The cardiovascular system is responsible for transporting blood throughout the body, and is formed by the heart and blood vessels (arteries, veins, and capillaries). In the cardiovascular system, the heart is the starting point. Important organ that acts as a contractile-propellant pump, from where it departs from the aorta, giving rise to all other arteries, being responsible for propelling the blood throughout the body [25]. In the context of the cardiovascular system, the main objective is to present the anatomical content in such a way that enables students and health sciences professionals to know the anatomical structures and the spatial relationship between them. Such functionality is presented in the first phase of the game, which corresponds to the content presentation phase. At that stage, the game allows 3D visualization, selection and access to information associated with the anatomical structures of the cardiovascular system.

The selection of each 3D object can be done through the hierarchical menu which contains the object names

for each anatomical structure (interface left panel) or by the pointing device itself (i.e., mouse) through a selection of the object in the 3D virtual environment (interface central panel). Selecting a 3D object provides detailed information about the anatomical object in text and image formats (interface right panel) (Figures 2 and 3).

Initially, the cardiovascular system presents the complete human body, containing organs and bones, along with blood vessels (arteries and veins). Blood vessels are subdivided into arteries and veins, small and fragile anatomical structures, which in a traditional anatomy laboratory require perfect dissection for satisfactory visualization. The arteries and veins are subdivided into five regions (head and neck, thorax, abdomen, upper limb and lower limb), thus grouped according to their place of origin and irrigation.

When selecting an artery or vein in the human body, the visualization of the selected 3D object will be highlighted and the other 3D objects will be displayed with a transparency color. From the object selection, the interface (right panel) shows the anatomical course content related to the selected artery or vein (Figures 2 and 3). Thus, during the content presentation phase, the student or health science professional studies has the ability to manipulate and visualize the human body in 3D space with the respective anatomical objects.

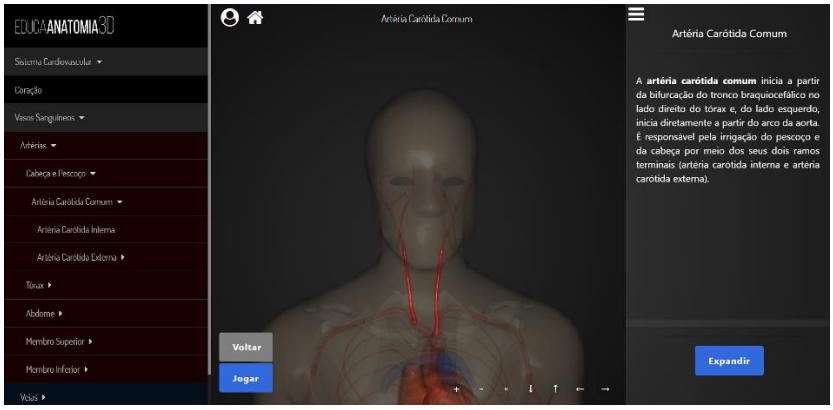

Figure 2: Content presentation phase for the study of arteries [20].

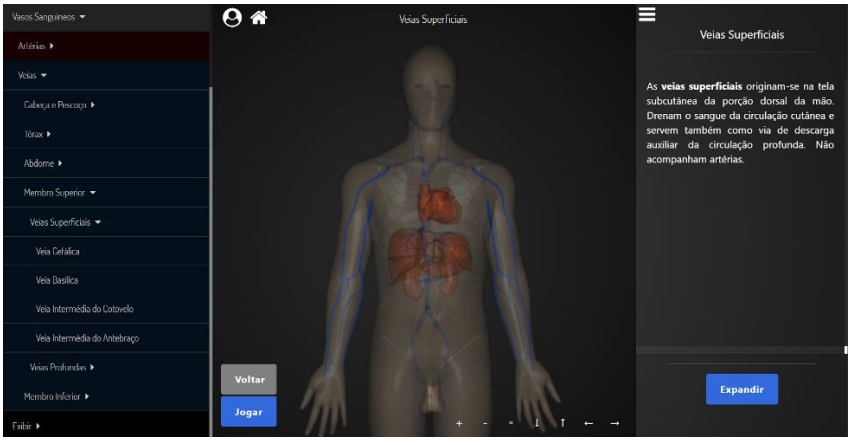

Figure 3: Content presentation phase for the study of veins [20].

In the content fixation phase, the second phase of the serious game, users have the opportunity to test their knowledge and skills through a knowledge questionnaire related to the subjects available (Figure 4).

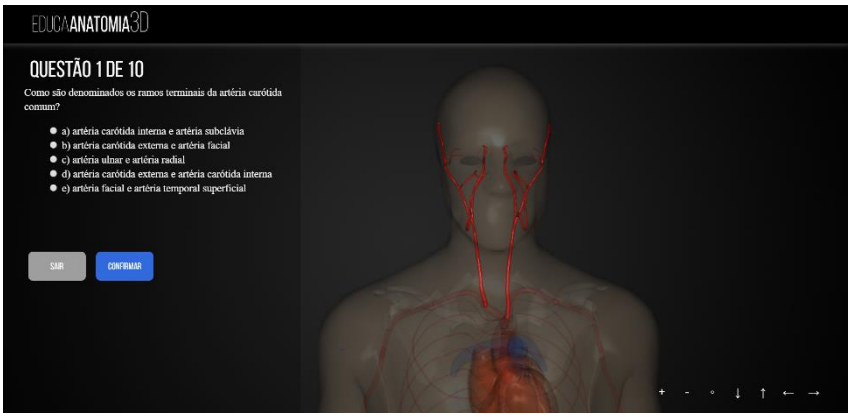

Figure 4: Content fixation phase for the cardiovascular system [20].

4. Study Group

Physiotherapy students of the Anatomy II course at Federal University of Santa Catarina (UFSC, Brazil) participated in the case study corresponding to the use of the serious game to teach the anatomy of the cardiovascular system. The teacher, who has extensive experience in teaching anatomy, also participated in the case study from an expert user point of view. For the case study, the students and the teacher were asked to sign the Informed Consent Form (ICF). Table 1 shows the demographic information of the case study participants.

Table 1: Demographic information of the participants

	Gender		Age	Level of Experience		
	Male	Female	Age Group	Beginner	Intermediate	Advanced
Study Group	7	22	18-42	17	12	0

5. Data Collection Tools

For the data collection, tools are used such as questionnaires of knowledge of the anatomy of the cardiovascular system, usability scale to investigate characteristics in the interaction interface, and open questions about the usefulness of serious game. And for data analysis, descriptive analysis and statistical methods are used to assess students' educational performance in teaching the anatomy of the cardiovascular system.

5.1 Cardiovascular System Knowledge Questionnaire

Data collection related to the cardiovascular system knowledge questionnaire is performed in the content fixation phase, the second phase of the serious game. Currently, there are a total of 194 questions related to the cardiovascular system, 80 questions about arteries and 114 about veins. The questions are presented basically in two formats: multiple choice questions (where the user must choose one of five options) and discursive questions (where the user must provide the name of a particular anatomical structure). On top of that, a panel, containing the anatomical structure including interaction and 3D visualization capabilities, is available for each question.

In the content fixation phase, a panel is presented where the user must choose which blood vessels (arteries and veins) will be addressed in the knowledge questionnaire. After choosing the blood vessel type, the user needs to choose one of the five arteries or veins regions of the human body (i.e., head and neck, chest, abdomen, upper limb, and lower limb). When choosing a region of study, a digital roulette is presented for the draw the number of questions to be answered (Figure 5). Digital roulette has the following number of questions: 3, 5, 8, and 10. The results of the questions answered in the knowledge questionnaire are stored in the database for the respective user.

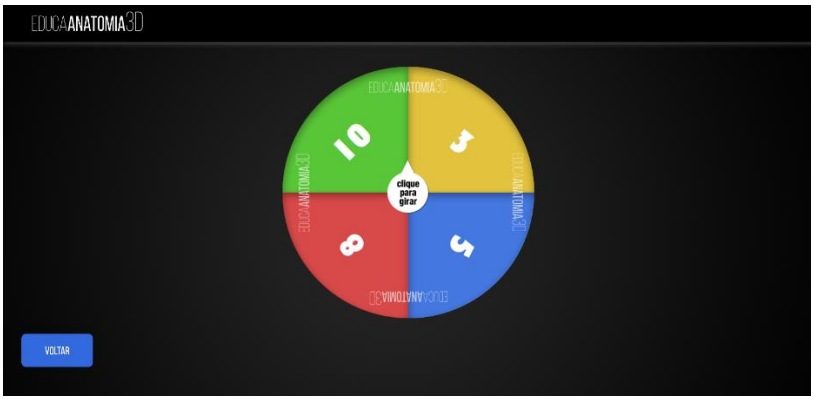

Figure 5: Digital roulette for the draw of questions [20].

5.2 Usability Scale

For the evaluation a usability scale was elaborated and adapted based on the five factors adopted by the Software Usability Measurement Inventory - SUMI [26] questionnaire, as follows: affect, control, learnability, efficiency, and helpfulness. Consisting of 12 affirmative questions in which the users should choose one of the five alternatives, according to the Likert scale of 5 points, such as: 1 - Strongly Disagree, 2 - Disagree, 3 - No Opinion / Not Sure, 4 - Agree and 5 - Strongly Agree.

The usability factors corresponding to the usability scale questions presented in Table 2 are as follows: (i) affect: questions 1, 6, and 7; (ii) control: questions 2 and 10; (iii) learnability: questions 3 and 9; (iv) efficiency: questions 4, 5, and 8; and, (v) helpfulness: questions 11 and 12.

Table 2: Usability scale

Usability Scale
1. The use of the serious game in general was a satisfactory experience.
2. During the use of the serious game it was possible to access the concepts associated with the cardiovascular system and the questionnaires for the content fixation through a minimum set of operations.
3. The serious game was important for performing activities related to the content fixation in the Anatomy course.
4. The interaction interface for the serious game was easily understood.
5. There was no need to stop the proposed activity in the face of obstacles in the interaction with the interface.
6. I have not encountered errors related to the serious game from the start to the end of the activities.
7. As a user of the serious game it was possible to visualize and interact with the cardiovascular system elements in an intuitive way.
8. The serious game presented the teaching terminology for Human Anatomy in a consistent manner.

9. The information provided by serious game was satisfactory for understanding the structure and function of the main elements of the cardiovascular system.
10. Regardless of the regularity of use of the serious game the functionalities of the interface were easy to memorize.
11. The information presented in the interface of the serious game was sufficient for its use.
12. During the use of the serious game the messages and warnings were sufficient for the study understanding during the content presentation and fixation phases.

5.3 Open Questions

Open questions for a game session correspond to three questions where users have the opportunity to provide feedback and suggestions for the game. The questions are: i) What are the benefits or advantages while using the serious game? ii) What are the difficulties or disadvantages while using the serious game? iii) What are your suggestions for improving the serious game?

5.4 Implementation Process

In the case study, the following steps were taken with the health science students to teach the cardiovascular system arteries (see Figure 6): step 1) A 15-minute pre-test was performed with the students without previous knowledge of the cardiovascular system. For the pre-test the students used the knowledge questionnaire available in the content fixation phase, the second phase of the serious game; step 2) The students studied the arteries of the cardiovascular system through the content available in the content presentation phase lasting 50 minutes, the first phase of the serious game; step 3) A 30-minute post-test was conducted with the students through the knowledge questionnaire available in the content fixation phase, the second phase of the serious game; step 4) Students answered the usability scale lasting 10 minutes; and, step 5) The students and teacher answered the open-ended questions for a game study session lasting 10 minutes.

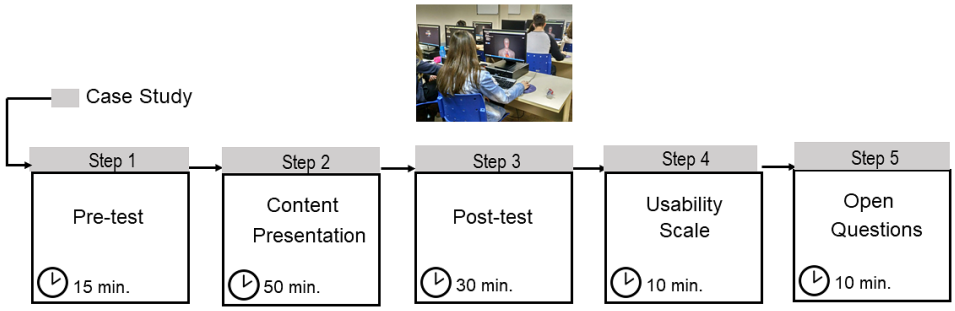

Figure 6: Planning of the case study.

5.5 Data Analysis

The data obtained with the knowledge questionnaire, usability scale and open questions of the game session were analyzed using a descriptive analysis. In addition, for the data obtained with the knowledge questionnaire in the case study, a paired-samples t-test was performed to determine whether differences in the percentages of correct pre and post-test responses reached a considerable level of significance.

6. Results

6.1 Case Study

In the case study, students' performance was investigated before and after the content presentation for the cardiovascular system arteries with the serious game through a knowledge questionnaire. To that end, the case study was conducted with Physiotherapy students enrolled in the Anatomy II course using the serious game to study the cardiovascular system arteries. Initially, a pre-test was performed with the students through a knowledge questionnaire, available in the content fixation phase, without any previous knowledge of cardiovascular system arteries. After a study session about the cardiovascular system arteries in the content presentation phase, a post-test was conducted with the same group of students through a knowledge questionnaire available at the content fixation phase (Figure 6).

6.1.1 Learning efficiency of the tool

As the difference of both samples of the percentages of scores followed a normal distribution (see Figure 7), it was performed a paired-samples t-test to evaluate whether the mean difference between the percentages of scores of pre and post-tests can be considered statistically significant. Table 3 shows the analysis results.

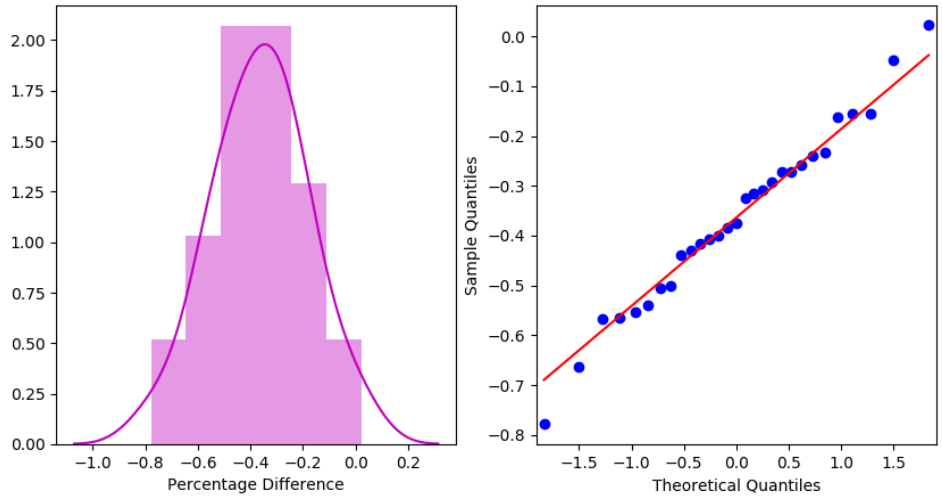

Figure 7: Distribution of the difference of the percentages of scores between pre and post-tests - and theoretical quantiles.

Table 3: Results of the paired-samples t-test

	N	Mean	S.D.	*Min*	*Max*	*t**
Pre-test	29	0.280024	0.158297	0.000000	0.733333	10.83
Post-test	29	0.643601	0.162434	0.222222	0.929412	

* p< .001

As it can be seen in Table 3, the mean percentage score of post-test (M = 0.643601, SD = 0.162434) is higher than the mean percentage score of pre-test (M = 0.280024, SD = 0.158297). The test was statistically significant at the 0.01 level thus meaning that students performed significantly better on the tests after using the tool.

For the pre-test performed with the students, the average percentage of correct answers was 28.0%. And, in the post-test, the average percentage of correct answers was 64.36%. Figure 8 shows the percentage of students' correct answers in the pre and post-test in the knowledge questionnaire regarding the cardiovascular system arteries. In addition, Figure 8 shows the difference between the percentage of correct pre and post-test answers for each student, representing an increase in the average percent of correct pre-test responses compared to the post-test of 36.36%.

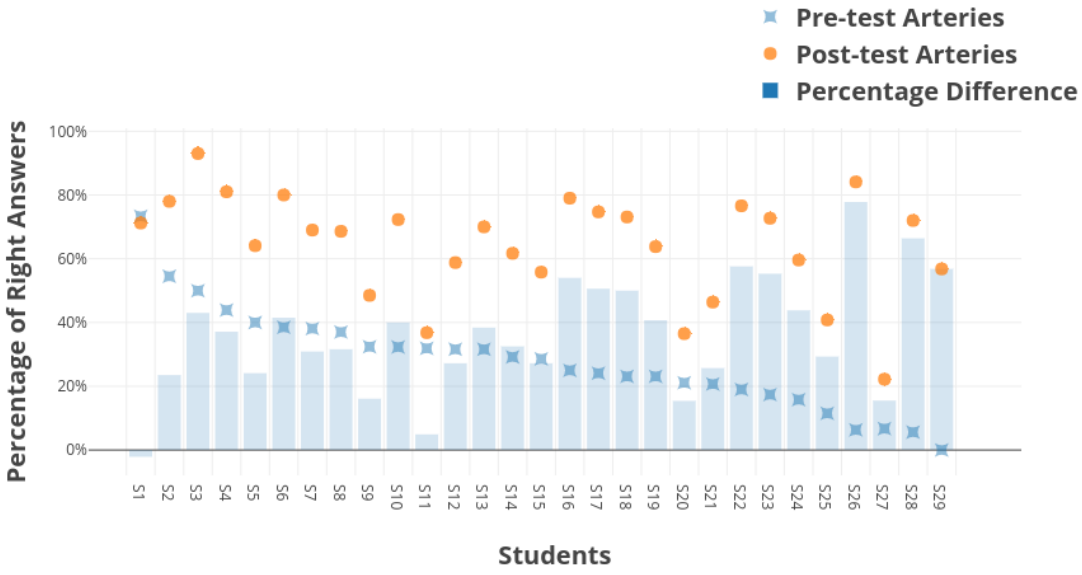

Figure 8: Case study for the cardiovascular system arteries. Percentage of correct answers in the pre and post-test knowledge questionnaire.

6.1.2 Usability evaluation

After applying the usability scale with the study group, the average of the usability factors was calculated. The highlight with the highest average results was for the Affect category with an average of 4.81. Then the Control category with an average of 4.70, Learnability category with 4.39, Efficiency category with an average of 4.14 and finally the Helpfulness category with 3.96.

Regarding the open questions for a serious game session, the main observations pointed out by the students and teacher are as follows:

i. **What are the benefits or advantages while using the serious game?** Students: "The game is easy to understand and memorize, and it allows interactive representations of the cardiovascular system in 3D." Teacher: "Students have the possibility to study through web browsers, not necessarily having to be in the university environment".

ii. **What are the difficulties or disadvantages while using the serious game?** Students: "During the content fixation phase there were some difficulties encountered in answering the questions within

60 seconds". Teacher: "Students need a better familiarity with the interaction of objects in 3D space."

iii. **What are your suggestions for improving the serious game?** Students: "Students mentioned that it would be interesting to add more questions in the content fixation phase". Teacher: "Teacher suggested adding in the game the content and the remaining structures of the heart."

7. Conclusion

Studies in educational technologies for teaching health sciences play an important role in driving innovation in the teaching and learning process for the digital and information age. The serious game EducaAnatomia3D aims to facilitate the teaching of human anatomy by providing a form of aid for studies and fixation of knowledge of the cardiovascular system. The study, developed in partnership with human anatomy specialists, enabled the identification and presentation of a set of digital resources that are fundamental to the teaching of the cardiovascular system in a virtual 3D environment.

In particular, the teaching of the cardiovascular system involves the study of anatomical structures (arteries and veins) that are mostly fragile and difficult to expose by dissection, which require, for a good understanding, a satisfactory visualization by the students. From that scenario, it is important to provide tools that enable students to explore virtual anatomical structures in three-dimensional space which provide adequate visualization, as well as the identification and display of organs, bones and ligaments to contextualize the system's anatomical cardiovascular structures in the three-dimensional space. There are serious games and virtual environments available in the literature for teaching and learning Anatomy [13][14]. However, the approach for the designing of serious games and virtual environments for teaching Human Anatomy found in the literature often presents several systems of the human body from the point of view of a 3D atlas.

Based on the digital resources available in the game, students are able to explore anatomical structures in an environment that provides three-dimensional anatomical objects (e.g., visualization, selection and manipulation of information for the spatial hierarchical representation of the cardiovascular system) and perform tests of knowledge (knowledge questionnaires). Also, in the context of serious game, teachers and students are able to create virtual rooms for the purpose of playing with a particular group of users. Thus, based on Web3D-based models and interaction and visualization techniques in a virtual environment, the cardiovascular system game allows researchers to explore innovative features in the pursuit of increased quality in teaching human anatomy.

Derived from the results of the case study, we have observed a satisfactory acceptance by the game users as an additional tool for the study of human anatomy. Thus, EducaAnatomia3D represents a step towards serious games, in which students in the health sciences can make use of a resource capable of presenting essential concepts for the understanding of human anatomy and its relations in three-dimensional space.

Pertaining to the analysis of the case study results, there was an increase in the average percentage of correct responses in the pre-test for the cardiovascular system arteries compared to the post-test by 36.36%. From that, with the paired-samples test (t-test) it was found that the differences observed are statistically significant. Thus, there was an increase in educational performance by students through the serious game

as a support for teaching the anatomy of the cardiovascular system in a 3D virtual environment.

Future work to assist in the assessment of performance and monitoring the evolution of health science students can be developed in the context of learning analytics techniques. For that, the modeling and data collection for the game is being adapted to take into account the data obtained during a game session by users. When EducaAnatomia3D is able to collect data for that purpose during a game session, data mining algorithms in education will be implemented and visualization techniques such as dashboards will be added to the game functionality. In that way, the EducaAnatomia3D team will be able to identify, for example, in which areas the users need to improve their performance or which parts of the serious game need to be redesigned to encourage users in their studies.

8. Acknowledgement

The research was financed by CAPES – Brazil and Federal University of Santa Catarina (UFSC).

9. References

[1] H. Brenton, J. Hernandez, F. Bello, P. Strutton, S. Purkayastha, T. Firth, and A. Darzi. “Using multimedia and Web3D to enhance anatomy teaching,” Computers & Education, 2007, pp. 32-53.

[2] S. A. Azer, and S. Azer. “3D anatomy models and impact on learning: a review of the quality of the literature,” Health professions education, 2016, pp. 80-98.

[3] J. G. Dângelo, and C. A. Fattini. Anatomia humana sistêmica e segmentar: para o estudante de medicina. Atheneu. Rio de Janeiro, 2000.

[4] F. Venail, A. Deveze, B. Lallemant, N. Guevara, and M. Mondain. “Enhancement of temporal bone anatomy learning with computer 3D rendered imaging softwares,” Medical teacher, 2010, pp. 282-288.

[5] C. F. Smith, G. M. Finn, J. Stewart, S. McHanwell. “Anatomical Society core regional anatomy syllabus for undergraduate medicine: the Delphi process,” Journal of anatomy, 2016, pp. 2-14.

[6] A. Gauthier, M. Corrin, and J. Jenkinson. “Exploring the influence of game design on learning and voluntary use in an online vascular anatomy study aid,” Computers & Education, 2015, pp. 24-34.

[7] M. Seitel, L. Maier-Hein, A. Seitel, A. M. Franz, H. Kenngott, R. De Simone, and H. P. Meinzer. “RepliExplore: coupling physical and virtual anatomy models,” International journal of computer assisted radiology and surgery, 2009, pp. 417-424.

[8] F. Ricciardi, and L. T. D. Paolis. “A comprehensive review of serious games in health professions,” International Journal of Computer Games Technology, 2014, pp. 1-12.

[9] A. Richardson, M. Hazzard, S. D. Challman, A. M. Morgenstein, and J. K. Brueckner. “A “Second Life” for gross anatomy: Applications for multiuser virtual environments in teaching the anatomical sciences,” Anatomical sciences education, 2011, pp. 39-43.

[10] A. Alamri, M. M. Hassan, M. A. Hossain, M. Al-Qurishi, Y. Aldukhayyil, and M. S. Hossain. “Evaluating the impact of a cloud-based serious game on obese people,” Computers in Human Behavior, 2014, pp. 468-475.

[11] R. B. Schroeder, and M. D. S. Hounsell. “SEU-Q-Um Instrumento de Avaliação de Utilidade de Jogos Sérios Ativos,” I Simpósio Latino-Americano de Jogos, 2015, pp. 136-145.

[12] F. Laamarti, M. Eid, and A. E. Saddik. "An overview of serious games," International Journal of Computer Games Technology, 2014, pp. 1-16.
[13] Biodigital, 2019. http://www.biodigital.com/
[14] Complete Anatomy, 2019. http://3d4medical.com/
[15] V. Wattanasoontorn, I. Boada, R. García, and M. Sbert. "Serious games for health," Entertainment Computing, 2013, pp. 231-247.
[16] S. M. Attardi, and K. A. Rogers. "Design and implementation of an online systemic human anatomy course with laboratory," Anatomical sciences education, 2015, pp. 53-62.
[17] S. Berney, M. Bétrancourt, G. Molinari, and N. Hoyek. "How spatial abilities and dynamic visualizations interplay when learning functional anatomy with 3D anatomical models," Anatomical sciences education, 2015, pp. 452-462.
[18] H. M. Huang, U. Rauch, and S. S. Liaw. "Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach," Computers & Education, 2010, pp. 1171-1182.
[19] S. Küçük, S. Kapakin, and Y. Göktaş. "Learning anatomy via mobile augmented reality: effects on achievement and cognitive load," Anatomical sciences education, 2016, pp. 411-421.
[20] EducaAnatomia3D, 2019. http://www.labanatomiainterativa.ufsc.br/ea3d
[21] R. R. Lemos, C. M. Rudolph, A. V. Batista, K. R. Conceição, P. F. Pereira, B. S. Bueno, P. J. Fiuza, and S. S. Mansur. "Design of a Web3D Serious Game for Human Anatomy Education," Advances in Educational Technologies and Instructional Design, 1ed.: IGI Global, 2019, pp. 586-611.
[22] M. A. Khenissi, F. Essalmi, M. Jemni, S. Graf, and N. S. Chen. "Relationship between learning styles and genres of games," Computers & Education, 2016, pp. 1-14.
[23] N. Mitsuhashi, K. Fujieda, T. Tamura, S. Kawamoto, T. Takagi, and K. Okubo. "BodyParts3D: 3D structure database for anatomical concepts," Nucleic acids research, 37(suppl_1), 2008, pp. D782-D785.
[24] N. A. M. Zin, A. Jaafar, and W. S. Yue. "Digital game-based learning (DGBL) model and development methodology for teaching history," WSEAS transactions on computers, 2009, pp. 322-333
[25] K. L. Moore, A. F. Dalley, and A. M. Agur. Anatomia orientada para a clínica. Koogan, Rio de Janeiro, 2006, pp. 944-947
[26] Sumi, 2019. http://sumi.uxp.ie/