

Characteristics of a Virtual Reality scenario for anatomy learning: A literature review

Características de un escenario de Realidad Virtual para el aprendizaje de anatomía: Una revisión bibliográfica

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Abstract: Virtual reality (VR) has received great attention due to its ability to envelop and involve the user sensorially . It is postulated that VR would be capable of transforming abstract and intangible learning to concrete and manipulable, through scaled and modifiable scenarios, especially involving anatomical structures that are difficult to learn and access in cadaveric material. The evidence shows that students have greater motivation and better perceptions when using it in an educational context. Thus, the implementation of these proposals could constitute an efficient method in teaching and learning. The objective of this review is to determine if VR is an effective tool to teach anatomy and to identify what a virtual setting should be like to positively impact anatomy learning. A search was performed in three databases (ERIC, ISI: Web of Science and SCOPUS) for articles or reviews published in English or Spanish in any year. The search terms were: “impact on learning”, “virtual reality” and “anatomy”. Qualitative or quantitative, and empirical or primary studies focused on learning and/or impact of the use of VR in anatomy in higher education were included. The findings were synthesized into two groups, the design and implementation of the virtual setting, identifying eight principles: having an anatomically correct setting, allowing differentiation of anatomical structures, freedom to manipulate the setting, adding theoretical support within the virtual setting, the justified choice of the virtual scenario, availability of technological resources, readiness to use VR and addition of theoretical study material.

Keywords: Virtual Reality, anatomy, education, learning strategies, health science education.

Resumen: La realidad virtual (RV) ha recibido gran atención debido a su capacidad de envolver e involucrar sensorialmente al usuario. Se postula que la RV sería capaz de transformar el aprendizaje abstracto e intangible a concreto y manipulable, mediante escenarios a escala y modificables, especialmente involucrando estructuras anatómicas de difícil aprendizaje y acceso en material cadavérico. La evidencia muestra que los estudiantes presentan mayor motivación y mejores percepciones al usarla en un contexto educativo. Así, la implementación de estas propuestas podría constituir un método eficiente en la enseñanza y aprendizaje. El objetivo de esta revisión es determinar si la RV constituye una herramienta efectiva para enseñar anatomía e identificar cómo debe ser un escenario virtual para impactar positivamente en el aprendizaje de anatomía. Se realizó una búsqueda en tres bases de datos (ERIC, ISI: Web of Science y SCOPUS) para artículos o revisiones publicadas en inglés o español en cualquier año. Los términos de búsqueda fueron: “impacto en el aprendizaje”, “realidad virtual” y “anatomía”. Se incluyeron estudios cualitativos o cuantitativos, y empíricos o primarios enfocados en el aprendizaje y/o impacto del uso de RV en anatomía en educación superior. Los hallazgos fueron sintetizados en dos grupos, el diseño y la implementación del escenario virtual, identificando ocho principios: tener un escenario anatómicamente correcto, permitir la diferenciación de estructuras anatómicas, libertad para manipular el escenario, adición de apoyo teórico dentro del escenario virtual, la elección justificada del escenario virtual, disponibilidad de recursos tecnológicos, un apresto para utilizar RV y adición de material estudio teórico.

Palabras clave: Realidad Virtual, anatomía, educación, estrategias de aprendizaje, educación en ciencias de la salud.

1. Introduction

In recent years, virtual reality (VR) technologies have received great attention due to their ability to envelop and engage their users sensorially (1). From the first approach to VR to the present, VR has been used in various fields as varied as audiovisual entertainment, professional training programs for air flight simulations, rehabilitation therapies for various diseases, even having an impact on education at different scales (2–4). Despite the diversity of uses of VR, there is currently no consensus or standardization on its definition, and there are various meanings. When performing a search for VR definitions to identify and establish common and key elements between the different authors, it is revealed that the use of computational technology and an interactive three-dimensional world (5) are mainly mentioned, which allows the creation of an artificial environment (6). Regarding the user experience, a large number of authors emphasize that VR provides sensory stimuli of different types (7), as well as a response to the movement of the individual (*feedback*) (8). Finally, another fundamental element corresponds to the immersion capacity that distinguishes this technology (9). Considering these elements, it was determined that the most complete definition of VR corresponds to that of M. Gigante: “ *The illusion of participating in a synthetic environment, rather than observing externally. VR is based on three-dimensional (3D), stereoscopic displays, with head tracking, hand/body tracking, and binaural sound. Virtual reality is an immersive, multi-sensory experience* ” (10).

Currently there are various methodologies for teaching anatomy. Among them, the best known are, without a doubt, the atlases that illustrate the anatomy of the human body and the dissection of corpses or fixed human material. There is controversy among anatomists around the world about which corresponds to the best methodology and whether human material should continue to be preferred for this learning (11). However, the teaching of human anatomy has evolved and during the last decades these methodologies have had certain detractors, such as their cost, availability of quality anatomical pieces and the arrival of new technologies. Therefore, it is imperative to reflect on the implementation of the new proposals that have arisen, such as VR, since they can constitute efficient methods in the teaching and learning process (12). VR in the field of education is considered one of the Information and Communication Technologies (ICT), in which 3 main characteristics stand out: it facilitates constructivist learning, provides alternative ways of learning and enables collaboration between students beyond of the physical space. On the other hand, the use of this type of technology allows increasing the interest of students by “learning by doing”. (13). Thus, the incorporation of this type of technology in education would allow students to acquire the ability to “master, retain, and generalize” knowledge through experience-based learning (14). In addition, it allows the abstract and intangible to become concrete and manipulable based on scaled and modifiable scenarios. (15), which allow users to be transported to distant places or places that are impossible to physically visit. On the other hand, some limitations that occur in conventional educational environments are avoided, be they economic, physical, security, among others, allowing more than one student at a time to observe and interact with a virtual setting of their choice (14). Likewise, VR is presented as a lasting and modifiable tool over time.

Regarding its effectiveness in teaching anatomy, there is evidence of positive results in relation to the perception and motivation of the students, which can influence the correct fulfillment of the learning results (16, 17). However, the most obvious advantages occur in contexts where traditional tools do not fulfill their role or do so poorly and at very high costs. An example of this is a study of the middle ear, a cavity that has historically been difficult to approach with cadaveric material because it is scarce, difficult to obtain and maintain, which does not allow a correct understanding due to the large number of structures in a reduced space and difficult access (18) . So, after the aforementioned and considering the rise of virtual education, as well as the appearance of new tools such as VR applied in this area, the need arises to consider what a VR scenario should be like in this discipline with this objective. This considering as the main benefit, both for teachers and students, the facilitation of learning, obtaining optimal results in it and making efficient use of these new technologies.

Therefore, based on this systematic review, the aim is to: 1) Analyze based on the evidence whether VR constitutes an effective tool for teaching anatomy by itself, or as support for conventional methodologies. 2) Identify what a VR scenario requires to meet the learning objectives, what its characteristics should be and what it requires for its implementation.

2. Methods

2.1 Review methodology

This review was conducted in October 2020 according to the methodology described below. This review did not require ethical approval, as it corresponds to a bibliographic review of published literature. The quality of the included studies was guaranteed with the exclusive selection of articles published in journals reviewed by the authors.

2.2 Search strategy

The systematic search was performed in three databases (ERIC, ISI: Web of Science and SCOPUS) for articles or reviews published in English or Spanish, in any year. Search terms included 'impact on learning', 'virtual reality' and 'anatomy'. A keyword search strategy from the ERIC Thesaurus was used to determine the terms to search for in the respective data sources, which included the following combination: "Learning OR impact" AND "Virtual Reality" AND "Anatomy" (Table 1).

Table 1. Identification and expansion of the basic search concepts: algorithm applied in the databases

Search 1: expansion of the "Learning OR impact" concept
<i>Thesaurus:</i> Learning
<i>Free Quest:</i> impact
Quest 2: expansion of the "Virtual Reality" concept
<i>Thesaurus:</i> Virtual Reality
Quest 3: "Anatomy" concept expansion
<i>Thesaurus:</i> Anatomy
Search 4: 1, 2 and 3 combined with AND and with the delimiters of full text, articles or reviews published in English or Spanish, in any year.

2.3 Selection process

First, the titles of the studies returned by the search were reviewed independently. These were distributed equally among the authors, and each one selected their relevance according to the inclusion and exclusion criteria established in Table 2. Then, the titles were redistributed among the authors, so that each reviewed the inclusion and exclusion criteria of different works, and without knowing the judgment of the author who reviewed in the first instance. This repetition was carried out to allow group discussion between the discrepancies generated, and thus reduce the differences in judgment between authors. In this way, the titles that presented approval by two authors in each review or that were accepted in the group discussion prior to a discrepancy between the first and second review were kept as selected. Subsequently, this same process was carried out with each abstract of the studies selected by title, redistributing the authors so that they reviewed different works. Qualitative or quantitative studies were included, whether empirical or primary, focused on learning and/or the impact of the use of VR in the study of anatomy in higher education. Non-

empirical or secondary studies, focused on a population other than higher education or that sought the validation and/or construction of instruments, were excluded.

Table 2. Inclusion and exclusion criteria applied in the bibliographic search

Inclusion criteria	Exclusion criteria
Empirical or primary studies focused on learning and/or impact of the use of virtual reality in anatomy.	Non-empirical or secondary studies, such as reviews, editorials, commentaries, and books.
Studies that report research in Higher Education.	Studies in populations other than students or professors in Higher Education.
Quantitative or qualitative studies with adequate definitions, reliable methods, operationalization of concepts and data analysis.	Studies focused on the validation and/or construction of instruments.
Studies available in Spanish or English.	Studies published in languages other than Spanish or English.

3. Results

3.1 Selection of studies

A total of 449 studies published up to October 2020 were identified (231 studies from SCOPUS, 204 from ISI: Web of Science, and 14 from ERIC). Of these, 426 studies were excluded due to duplication and title/abstract screening. One study was added by free search. Of the remaining articles, 24 were selected based on their title, abstract, and full-text post-review. Thus, 19 studies were excluded, resulting in 5 studies that met all the inclusion criteria and were part of this literature review. The process is explained in Figure 1. The main reasons why articles were excluded was the existence of studies that do not correspond to VR according to the definition agreed upon by the authors of this paper, studies not focused on learning anatomy and its impact in education, and literature reviews.

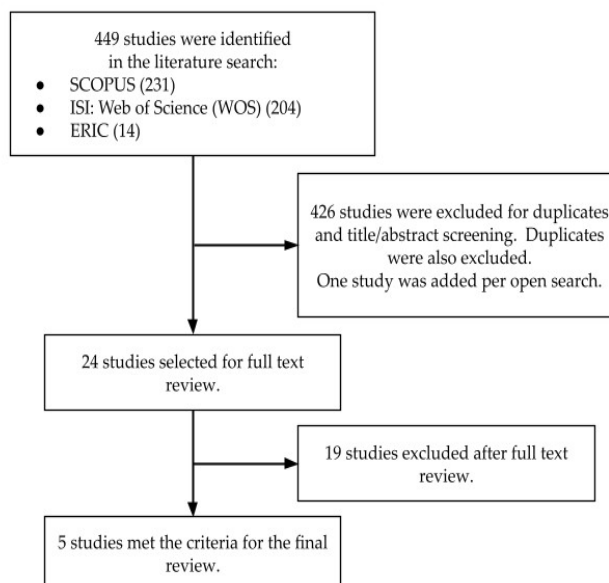


Figure 1. Flow diagram of the search and selection process of studies in a systematic review in the literature on the impact of VR on anatomy learning.

3.2 Characteristics of the studies

The selected studies were published between 2017 and 2020, which reflects that it is a contemporary and current topic of research. In addition, they were carried out in developed countries such as China, the United States, Australia and Canada. The methodology used was quantitative and the main way to collect information was through theoretical evaluations of anatomy before and after the intervention, together with questionnaires on the subjective experience of the participants in terms of VR. The summary of the characteristics of each study is presented in Table 3.

3.3 Common themes found in the studies

Of the 5 selected studies, different characteristics were found in common, which were classified into 2 large categories: design of the VR scenario (relative weight 62.5%) and implementation of the VR scenario (relative weight 37.5%). These findings are mentioned in Table 4 according to the corresponding category. A more detailed description follows.

3.4 Design of the virtual reality scenario

The findings associated with the design of the VR scenario correspond to 5 characteristics that were found in each study, but not necessarily carried out in the same way, developing different alternatives to meet them.

- Anatomically correct scenario (via imaging and/or expert verification): This finding in the study by Maresky et al. (19) was achieved by transforming CT and MR images into computer models, arranging the details of the technique, and reviewing the model output with anatomical experts. Most of the studies (20–22) followed the same pattern, varying the program used for image conversion and subsequent editing.
- Allow differentiation of anatomical structures (through colors, named labels): This finding encompasses the methods used to identify the different anatomical structures within the scenario, which facilitates the understanding by the user. This was through specific colors for each element in the case of the study by Chen et al. (20) or through labels in the study by Ellington et al. (twenty-one). This, taking into account that an overload of information that can generate confusion and hinder the learning process must be avoided.
- Freedom of manipulation of the scenario: The third finding refers to the different tools and options provided by the scenario that allow the movement of the user and of the objects within it for a more suitable visualization of the structures. These include total freedom of movement within the scenario (21), the possibility of moving, rotating, zooming in and out of objects (19), the option of grouping the structures by systems to be analyzed independently from the rest and dissecting by layers emulating the experience of a real dissection (21). This has the advantage of being able to constantly repeat the experience without the need to acquire new material each time, as is the case of resecting cadaveric material.
- Add theoretical support within the virtual scenario: Here reference is made to the theoretical support related to the topic to be treated within the scenario, either through expandable text in each structure, an audio similar to a class to guide the use of the scenario (23), and including the integration of schemes within the scenario to explain concepts in a more didactic way (20).
- Justified virtual scenario: The fifth finding gives validity to the construction and implementation of the scenario, determining that the virtual scenario must be justified. That is, it must have a valid reason to prefer a VR model over the use of conventional material, either for a physical reason, such as the loss of structural integrity and anatomical relationships in the case of cadaveric heart material. (19) or in the case of structures that are difficult to access such as the middle ear and larynx (23).

3.5 Implementation of the virtual reality scenario

They correspond to the set of characteristics that allow the VR scenario to be correctly implemented once it has been designed and acquired, allowing to get the most out of the resource.

- Availability of the necessary resources to use VR technology: This finding refers to having high-end equipment that allows the use of the necessary software at a correct resolution and refresh rate (20, 23), in addition to having the economic resources suitable for the acquisition of such technologies and implements due to their current high cost (20, 22).
- Readiness to learn how to use VR technology: The second finding of this group refers to making a sufficient readiness to learn how to use VR technology. This point was mentioned in all the studies reviewed, either in their design (19, 21, 22) or in their discussion (23), with even the short time available to learn how to use VR technology being a limitation to have achieved better results (20).
- Additional theoretical study: Finally, this point corresponds to the addition of prior theoretical study, either in the form of introductory lectures on the topic prior to immersion in VR (20, 22) or encouraging autonomous study (21).

3.6 Limitations of the study

Within the limitations of this work, associated with the inclusion and exclusion criteria, the language must be considered, since studies that have not been translated into English or Spanish may have been left out of the review. On the other hand, the decision not to include works on the construction of the scenario could have set aside research on more technical areas; however, these were considered insufficient since they do not contribute to answer the work question as they do not have an empirical basis or results in learning impact. A similar situation occurred with bibliographic reviews on the subject, since although they could provide data in the field of learning, which was included as an introduction, there were no reviews that focused on the area of medicine, specifically anatomy. Finally, it should be noted that the database search date was carried out prior to the SARS-CoV-2 pandemic, at which time the authors of the study had to pause the review of the bibliography. The search for evidence of VR and its impact on learning could be expanded with evidence created during and after the impacts of SARS-CoV-2 in the educational setting, as well as creating larger experimental studies that use VR as a tool and create evidence. higher level empirical.

4. Discussion

After the analysis carried out in this bibliographical review, it is possible to conclude that all the studies analyzed propose that VR is at least as effective for teaching anatomy as conventional cadaveric material (19–23). However, the cost of implementation can be considered high for universities with fewer resources devoted to learning anatomy (24). Despite this, the initial investment involved in the implementation of this model can become a long-term investment that reduces the manufacturing and maintenance costs of the cadaveric material that is being replaced, as well as providing an additional, versatile and effective alternative for teach (24). It is important to consider that the cost of this technology will probably decrease gradually over time as its use becomes more widespread (25), reducing the impact generated by the initial investment and generating a positive balance in terms of resources in shorter terms. The initial cost will largely depend on the platform on which the scenario is used. High-end hardware is especially preferred for greater fluidity when using a VR scenario (24), better user performance, a higher quality overall teaching experience, and fewer adverse effects associated with using VR (such as headache, dizziness, nausea, etc.). Additionally, the software that is used must be carefully selected, given the cost that it can mean not only in economic terms, but also in terms of learning and training in its correct use and maintenance (24, 26).

It should be taken into consideration that since it is a technology with which many students will not be familiar, the first minutes that the VR tool is used will be mainly focused on adapting to the controls and the operation of the platform, especially those students who do not have previous

experience. This is why a good readiness, or previous training in the use of technology, would allow spending most of the time learning the anatomy that the scenario intends to teach, this with less difficulty and distraction in between (20-22, 25). The total time dedicated to learning can also be optimized through guidelines or guides that guide the student during the activity, reducing the instances in which they are disoriented or unclear as to where to continue (25). This should not be detrimental to the time dedicated to self-learning, but rather, both spaces should be considered when planning the use of the VR scenario. It should be noted that in the studies analyzed in this review, students were exposed to VR scenarios in just one session, along with a proportion of the time spent getting used to the system and learning how to use it. Therefore, we consider it necessary to carry out VR studies that evaluate the impact of learning in anatomy that are carried out in the long term, with the use of scenarios during more than one session so that students can take full advantage of this tool and it can be evidenced if VR scenarios are the same, more effective or complementary to conventional anatomy teaching in higher education.

On the other hand, all the surveys carried out in the studies show a positive reception of the VR experience, with an increase in enjoyment and attention devoted to learning compared to traditional methods (20-25). The foregoing must be considered when evaluating the effectiveness of the VR scenario, because as has been shown on several occasions, motivation plays an important role in the learning process (27). The only study where learning through VR obtained better results than the control group was in the case of Maresky et al. (19), where the complexity of relationships between anatomical structures is not possible to easily visualize and understand in cadaveric material, since it loses its original shape during dissection. This problem does not occur with the VR scenario evaluated, in which the original position of the anatomical structures is maintained, allowing a more realistic view of the object of study.

An important point that should be considered in subsequent studies to be investigated in greater depth is the effectiveness of the use of VR as a complementary tool within a learning context, where there are different teaching methodologies that are capable of complementing each other in a multidirectional way. each other (25). In most of the studies, VR was evaluated in isolation (in the absence of other learning instruments) and without a significant or standardized contribution of introductory activities to the topic to be dealt with in the session, or preparation for the correct use of VR. technology used. Bearing this in mind, future studies could find significant improvements, or at least differences, in terms of the usefulness of these activities. This by coordinating the use of VR scenarios with cadaveric material and/or previous study programs designed with a specific approach for their use in a teaching scheme that incorporates VR, audio and interactive questions within the VR software used, among others. In the event that VR proves to contribute significantly to the teaching and learning process, either by itself or in a mixed model, it would be interesting to propose its long-term use over time, raising the need to create new VR scenarios, which present the aforementioned characteristics and to provide access to them continuously over time for free consultation and review.

Finally, based on the studies analyzed, it can be concluded that a VR scenario must have a series of characteristics to generate an impact on anatomy learning, such as being anatomically correct, having freedom to manipulate structures, containing theoretical support that guides the student within the immersion, among others. Thus, VR is presented as a pleasant, interesting, authentic, efficient and lasting tool over time (25, 26), which would allow, among other things, a better memorization and understanding of space and important structures in human anatomy, with consequent better student learning, but still corresponds to a new field of research in medical education that requires further study and improvement.

5. Conclusions

- There is no standardization on the definition of VR, and there are various meanings that make consensus difficult.

- There are considerations to take into account about the use of VR in higher education in the discipline of anatomy regarding the design of the scenario and its implementation.
- Eight principles that a VR scenario should have were identified: be anatomically correct, allow explicit differentiation of anatomical structures, provide freedom to manipulate the scenario, addition of theoretical support within the virtual scenario, the justified choice of the virtual scenario, availability of resources technological, make a preparation to use VR and seek an additional theoretical study.
- In the reviewed studies, it can be concluded that VR is just as effective as the use of conventional methodologies to teach anatomy, however, it presents a positive reception with greater enjoyment and attention devoted to learning compared to traditional methods. This can affect motivation and learning in the long term.
- Studies are needed to evaluate the use of VR in the long-term learning of anatomy, and its impact on its use as a complementary tool to conventional teaching methods.

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Table 3. Summary of the characteristics of the studies analyzed.

Item name	Author, year, country	The purpose of the study	Type of study	Sample	data collection	Analysis of data	Summary of Results
Can virtual reality improve traditional anatomy education programmes? A mixed-methods study on the use of a 3D skull model	Chen et al. (China, 2020)	To compare the results of teaching with VR versus traditional methods in skull anatomy.	experimental quantitative	74 undergraduate medical students with 2.5 years of study.	Theoretical evaluation and personal questionnaire	Statistical analysis and data distribution	Both groups improved but there was no significant difference. The experimental group positively values the way of learning implemented
Female Pelvic Floor Immersive Simulation: A Randomized Trial to Test the Effectiveness of a Virtual Reality Anatomical Model on Resident Knowledge of Female Pelvic Anatomy	Ellington et al. (United States, 2019)	To compare results of teaching with VR versus traditional methods in pelvic floor anatomy.	experimental quantitative	31 obstetrics and gynecology interns between the second and fourth year	Theoretical evaluation and personal questionnaire	Statistical analysis and data distribution	There was no significant difference in the improvement of both groups. The experimental group values positively the form of learning implemented
Immersive virtual reality as a teaching tool for neuroanatomy	Stepan et al. (United States, 2017)	Evaluate effectiveness, satisfaction and motivation associated with the use of VR in the study of neuroanatomy in medical students.	experimental quantitative	66 first and second year medical students.	Theoretical evaluation and personal questionnaire	Statistical analysis and data distribution	There was no difference between the results of both groups but the experimental group found the experience more satisfactory, useful and motivating.
The Effectiveness of Virtual and Augmented Reality in Health Sciences and Medical Anatomy	Moro et al. (Australia, 2017)	To compare if VR and/or AR are as effective as tablet applications in the study of structural anatomy.	experimental quantitative	59 students from biomedical and health faculties, medicine and others.	Theoretical evaluation and personal questionnaire	Statistical analysis and data distribution	There was no difference between the results of the 3 groups, but the VR group had more adverse effects.
Virtual reality and cardiac	Maresky et	Validate the use of VR	experimental	42 first-year	Theoretical	Statistical analysis	The experimental group obtained a

anatomy: Exploring immersive three-dimensional cardiac imaging, a pilot study in undergraduate medical anatomy education	(Canada, 2019).	by studying its effect to enhance traditional cardiac dissection	quantitative	medical students.	evaluation and personal questionnaire	and distribution	data	better post-intervention result than the control group on conventional, visuospatial and general content.
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VR: Virtual Reality, AR: Augmented Reality

Table 4. Main common findings

VR stage design	Implementation of the VR scenario
Anatomically correct scenario (via imaging and/or expert verification)	Availability of necessary resources to use VR technology
Allow differentiation of anatomical structures (by colors, named labels)	Ready to learn to handle VR technology
Freedom to manipulate the scenery (rotation of structures, modification of scale, dissection of individual structures or by anatomical systems and/or first-person focus)	Additional theoretical study (introductory classes and/or prior autonomous study)
Add theoretical support within the virtual scenario (audio and/or theoretical information)	
Justified virtual scenario (complex learning anatomical structure, structures difficult to access and/or dissection)	