Virtual Reality to teach anatomy

M. Fairén[1] and M. Farrés[2] and J. Moyés[1] and E. Insa[2]

[1] ViRVIG Group, Universitat Politècnica de Catalunya, Barcelona, Spain
[2] GIEES Group, Campus Docent Sant Joan de Déu-Fundació privada, Barcelona, Spain

Abstract

Virtual Reality (VR) and Augmented Reality (AR) have been gradually introduced in the curriculum of schools given the benefits they bring to classical education. We present an experiment designed to expose students to a VR session where they can directly inspect 3D models of several human organs by using Virtual Reality systems. Our systems allow the students to see the models directly visualized in 3D and to interact with them as if they were real.
The experiment has involved 254 students of a Nursing Degree, enrolled in the Human anatomy and physiology course during 2 years (2 consecutive courses). It includes 10 3D models representing different anatomical structures which have been enhanced with meta-data to help the students understand the structure. In order to evaluate the students' satisfaction facing such a new teaching methodology, the students were asked to fill in a questionnaire with two categories. The first one measured whether or not, the teaching session using VR facilitates the understanding of the structures. The second one measured the student's satisfaction with this VR session.
From the results we can see that the items most valuated are the use of the activity as a learning tool, and the satisfaction of the students' expectations. We can therefore conclude that VR session for teaching is a powerful learning tool that helps to understand the anatomical structures.

Keywords: Virtual Reality, Health sciences, Nursing, Teaching.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual Reality

1. Introduction

Using 2D images to teach the structure of 3D objects is typically complicated. Especially in courses where those 3D shapes can be hardly complex, as is the case of organs inside the human body. This difficulty is even harder when dealing volumetric objects with internal information that also needs to be displayed.

This is exactly the problem that appears when anatomical structures are presented to nursing students. Often teachers need to explain textually what the students are unable to imagine by looking at the 2D images.

The human heart and its internal structures such as ventricles, atriums, valves, arteries, veins, etc, is a clear example of a complex anatomical organ which is difficult to understand. Other difficulties that appear during class are, the difficulty of understanding the exact position of some organs inside the human body, or the relative dimensions of those organs. These are just a handful of examples that professors find difficult to explain when teaching anatomy.

In this paper we present our experience on teaching an anatomy class to nursing students in their first course of the degree. In this class students may experiment with 3D models of several anatomical organs by using two different Virtual Reality systems, a powerwall and a CAVE. Each VR session is given to a small group of 15-20 students divided in two subgroups of 6-10, and it is directed by two assistant teachers (one per group) who explain the anatomical organs and their functions while the students are interacting with the models.

By using Virtual Reality the student is able to inspect and interact directly with the anatomical structure. This experience has been really appreciated by both teachers and students.

This paper is organized as follows; first we review previous work in using Virtual Reality applications to teach in other disciplines. Then we detail the difficulties that the students encounter when trying to understand the anatomical structures using only 2D pictures. In section 4 we explain in detail the models that the students inspect and the Virtual Reality systems used. Finally we provide an evaluation of the results, the opinions obtained and discuss our conclusions.

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2. Related work

Virtual Reality (VR) and Augmented Reality (AR) are technologies that have become popular in recent years and have been successfully used in applications for education. They are known as the Virtual Reality Learning Environments (VRLEs) (Chittaro et al, 2007 [CR07], Monahan et al, 2008 [MMB08], Azuma 1997 [Azu97]). Both technologies (VR and AR) are being introduced gradually in the curriculum of schools given the benefits they provide to classical education.

Although both technologies (VR and AR) have much in common, they have very different objectives. While Augmented Reality aims to improve or augment the reality (the real environment) by simply adding virtual objects or information to it, Virtual Reality wants to replace completely the real environment making the user feel that he/she is somewhere else.

In the field of education, these technologies have been used in many areas, including the medical field. This field has taken advantage of its enormous potential especially in creating simulations for the training of professionals in surgical procedures (Larsen et al., 2009 [LSG*09]; Cabrilo et al., 2014 [CSB*14]; Okamoto et al. 2015 [OOY*15]; Soler et al., 2014 [SNP*14]; Nishimoto et al., 2016 [NTF*16]). It has also been used in recreating medical emergencies (Kilmon et al.2010 [KBGM10]) and, in a scope with real patients, with children with ASD to develop social and cognitive skills (Cunha et al., 2016 [CBV*16]).

These kind of simulations put students in situations that they may encounter in their real lives. The simulation allows, in many cases, to modify parameters, which gives rise to a new experience. They can experiment these situations without risk, in a controlled environment and with a view as realistic as you want (Jenson et al.2012 [CD12]). Such simulations improve the skills of students and their retention of knowledge (Smith et al. 2016 [SFU*16]).

Aside from simulations, Virtual Reality has also been used in the study of anatomy. The visualization of anatomical structures in 3D is a challenging aspect in the teaching-learning process. In this regard, plastic models of various organs and even complete bodies, help students to better understand the different parts of the body and their spatial interpretation. However this presents a limited access to specific details of the organ or structures studied. While body parts are used for some disciplines, this resource is not available in all schools due to the disadvantages in terms of cost, location, preservation and transfer of the pieces (Vernon et al. 2002 [VP02], Ferrer-Torregrosa et al. 2015 [FTTJ*15]). Moreover, one of the great challenges in education is how to motivate and engage students in learning.

Virtual Reality provides technological advances regarding image and degree of immersion, which allows us to deal with restrictions that plastic models present. VR also allows us to overcome the difficulty of having access to real cadavers. Therefore, VR may provide a solution to those problems, but their use for educational purposes must begin with a solid education. In this sense, in terms of education, before choosing the technological tool, one must design, create and implement strategies that engage students in the learning process. This starts by having solid targets for each discipline and academic level.

Research in the field of VR, has often focused on technical aspects (Burdea & Coiffet, 2003 [BC03], Sherman & Craig, 2003 [SC03]). These include studies on the use of various VR technologies, discussions of how VR can be integrated into the curriculum and how it relates to the commitment of the student in learning (Dickey, 2005 [Dic05]). Focusing on the learning process, an important aspect to take into account is the motivation. Motivation is defined as an internal state or condition that activates, guides and directs behavior (Kleinginna & Kleinginna, 1981 [KK81]).

Classical teaching makes the students be passively seated in a classroom, watching a teacher explaining a powerpoint presentation for one or two hours. Instead, by using Virtual Reality the students live an active experience, where immersion makes them fully engaged in the activity, without distractions. This allows them to focus all attention on what they are doing.

For Ferrer-Torregrosa et al. (2015) [FTTJ*15], the motivation includes reciprocal interactions between context, behavior and personal characteristics. They claim that the motivation is a self-regulated process that occurs when students take conscious control of their motivation and behavior that leads to a satisfactory learning outcomes.

Huang et al. (2010) [HRL10], focused their work on students' attitudes toward learning environments where you use VR. To them, student's learning motivation is focused on three critical factors of VR applications: the intuitive interaction, physical sense of imagination and sense of immersion. They also say, with respect to learning, that motivation is an important cognitive factor, so that motivated students can learn more effectively.

Training is easier if the experience is pleasant or enjoyable, which means higher level of engagement and understanding. The majority of nursing students prefer a hands-on, active approach to education (Boctor, 2013 [Boc13]). However, studying the attitude and motivation of students in VR environments do not compare the effectiveness of 3D versus 2D environments.

With respect to the effectiveness of learning through the use of VR in 3D, Nicholson et al. (2006) [NCFD06] support the hypothesis that students are more receptive to understand aspects of anatomy using 3D than using 2D. In comparing the teaching of musculoskeletal anatomy through VR traditional methods, Codd & Choudhury (2011) [CC11] indicate that VR can serve as a complement to traditional methods of teaching anatomy.

Recent studies has shown that virtual learning applications can provide the tools to learn in a quick and happy mode by playing in virtual environment (Pan et al. 2006 [PCY*06]).

Having collected the goals and advantages of using VR to teach anatomy in 3D environments as opposed to 2D, in this paper we present the activity carried out with nursing students in Campus Docent Sant Joan de Déu. We also show how VR has been introduced in the curriculum as an immersive tool for learning and facilitating the imagination of the anatomical structures, improving satisfaction and motivation of students during their learning process.

Figure 1: *Master class explaining the human heart structure.*

3. Problem statement

There are few empirical studies providing evidence that the use of 3D structures in the learning process facilitates the comprehension of the student when compared to traditional methodologies (such as, master class or 2D images). The spatial ability of students is vital in predicting the success when learning anatomical structures. The study of Garg et al., 2002 [GNE*02] argues (based on scientific evidences), that the ability to imagine is another critical point in learning anatomy.

Imagination is a basic human faculty (Gerber, 2015 [Ger15]) and it depends on the individual way of thought as well as on the context in which it takes place. In the field of nursing teaching is important to decide whether it grants a central position, or it is displaced and constrained.

In modern biomedicine, one can find traces of Renaissance with regard to the imagination (Kirmayer, 2014 [Kir14]) with a strong demand for rationality, reality and materiality. When we teach biomedical topics and more specifically anatomy, it is hard to predict the kind of mental representation that the students have, when they have never before seen a certain anatomical structure. Do they think in 2D or in 3D? The kind of thought, in the description of anatomical structures in the everyday teaching, depends on prior knowledge, the way of teaching-learning and the tools used. Therefore, it is very difficult to imagine an object in 3D when one has never seen it before in such way. In this sense the range of imagination and its mobility can be constrained by using conventional methods since it depends on:

a) The teacher ability to explain subjects in a descriptive way and to do it without stopping and contract conscience (see figure 1).
b) The quantity and quality of 2D images presented to the students.

Since it is not possible to know what the students imagine and how they form their thoughts, Virtual Reality could help them to understand the anatomical structures. This may confirm what they had imagined during the narrative of the teacher or may correct their wrong figures or elements. Therefore, the aim is that Virtual Reality, as a learning tool, can help students understand the structures, textures and different parts of the human anatomy.

4. Experiment design

The solution we propose aims at solving the problem described in the last section. For this purpose, we provide the students with a specific VR session where they can directly inspect 3D models of several human organs by using Virtual Reality systems. Virtual Reality allows the students to see the models directly visualized in 3D and interact with them as if they were real.

4.1. Preparing the experiment

Throughout the year of the activity preparation, before its final implementation, members of the group ViRVIG-UPC and members of the GIEES group of the Campus Docent were involved in the task. Among them there were anatomy teachers, engineers, members of the innovation team and student collaborators. It was needed to draw a questionnaire to gather information about the structures that were more difficult to understand by students. This questionnaire was answered by 10 students and by the coordinators and teachers of human anatomy and physiology. From the information gathered we chose the anatomy structures to work using VR and we adapted the 3D chosen models to the students needs. Before its implementation we did a pilot test with the same students and then we made an assessment of the activity.

In this assessment we decided the anatomy structures to be used and the VR interaction method for each structure. We also designed the experiment and prepared a support documentation for the activity with information about the anatomy structures that the students will work on. Then the teachers who would be the session guides were trained, agreeing with them on the learning targets and the dynamics of the activity.

4.2. Models and meta-data

We have chosen 10 different anatomical parts of the human body to be explored by the students using Virtual Reality. Each model has its own meta-data information and/or its own interaction method. Most of the models (8 from 10) are synthetic models that show in detail the structures to be explained to the students in the session (these models have been obtained from the web: www.turbosquid.com). But we have also decided to allow them to inspect other two models (*Chest* and *Aneurysm*) that have been reconstructed from CT (Computer Tomography) information of two real patients. These two models have been chosen in order to show the students real patients' data and how these data is visualized in 3D.

Heart: This 3D model (by *3dregenerator*) includes all the important parts involved in this vital organ. The students can observe ventricles, atriums, valves, arteries, veins and also papillary muscles and tendon strings.

In this model we have added, as a meta-data, a set of blue and red arrows that help on seeing the direction of the blood flow and the kind of blood (oxigenated or not). See figure 2-a).

Encephalon: This 3D model (by *leo3Dmodels*) includes the two hemispheres, the different lobules, the ventricular system, the basal ganglia, the cerebellum, the brain stem and the medulla bulb.

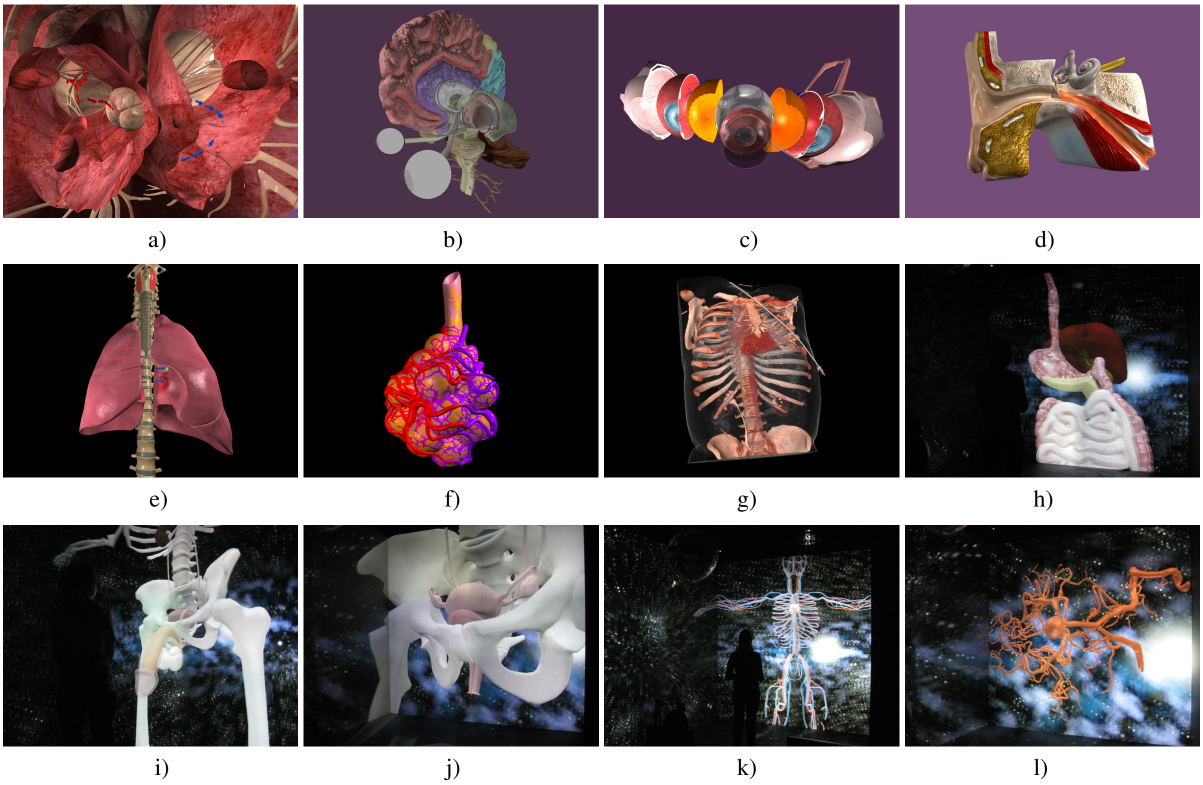

Figure 2: *Different models the student can interact with. a) Heart ventricles inside cut from bellow. b) Encephalon without an hemisphere. c) The eye separated in layers. d) Ear system. e) and f) Lung and zoomed alveol. g) Reconstruction of a real torax from a CT. h) Digestive system i) and j) Reproductive and urinary system for male and female. k) Circulatory system. l) Group of brain arteries with an aneurysm.*

The model has been adapted to be shown either as a full model or divided in parts. We can remove half brain to be able to see all the internal parts together, and we can also show separately the ventricular system and the basal ganglia. The different lobules can also be colored in order to be able to differentiate them. See figure 2-b).

Eye: This 3D model (by *Alef itd*) has the different layers and parts of the human eye. The students can differentiate the sclerotic, choroid and retina layers and also the cornea, iris, pupil and chrystalline. At the rear part of the eye there are also the fovea and taint where the image is perceived by the special cells of the eye.

The original model has been modified to include an animation that separates the layers and shows clearly all the different parts. It also includs the vascularization in the choroid layer. The model can be also cut in half in order to show more clearly the back part where the fovea and taint are. See figure 2-c).

Ear: This 3D model (by *Imagework*) is the simplest one. It shows directly all parts involved in the sense of hearing. The students can see the auricle, the auditory canal, the eardrum, the Eustachian tube, the ossicles (malleus, incus, stapes), the cochlea and the semicircular ducts. See figure 2-d).

Lung: This 3D model (by *scyrus*) consists of two parts: the lungs as a complete organ, and an alveol. In the lungs the students can distinguish between the right lung (having 3 lobules) and the left lung (having only 2 lobules). They can also see the trachea, bronchi and bronchioles and the mediastinum. In the alveol they can observe how the blood is being oxigenated.

In this model we have included some blue and red arrows to simulate the blood flow through the arteries and veins and also an animation that goes from the complete lungs vision to a zoomed vision of the alveol. See figure 2-e) and 2-f).

Circulatory system: This 3d model (by *dugongmodels*) includes all the main arteries and veins of the human body. The student can distinguish in it the systemic circuit from the pulmonary circuit, the differences between arteries and veins, which is not related to the color that represent them. They can also see the renal circulatory system and its real position in the body. See figure 2-k).

Digestive system: The 3D model representing the *Digestive system* has been created by joining different models (by *3d moliere and Activepoly*) in order to display together the esophagus, stomach and intestine, and also the liver, pancreas and gallbladder. By observing this model the students are able to situate correctly all these organs in the body.

Students are able to travel through the digestive system by following the way from the esophagus until the anus. See figure 2-h).

Reproductive and urinary system: This system is composed by two different models (by *MotionCow*), the one for female and the

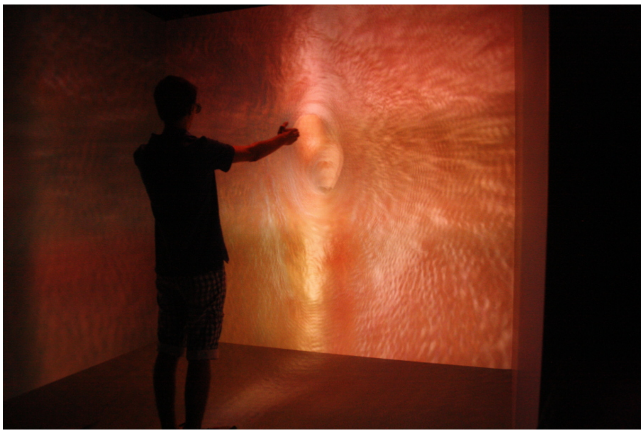

Figure 3: *User in the CAVE system. He is traveling through the interior of the brain arteries of the aneurysm model.*

one for male. In both cases there is a skeleton model added in order to see how the organs are located with respect to the skeleton.

In the male system the students can clearly see the urinary track and the seminal duct, the position of the prostate and how both circuits are combined. They can also see how the penis is used for both systems (urinary and seminal). See figure 2-i).

In the female system the students can inspect how the uterus and the urinary bladder are located with respect to the skeleton. They can also see the pubic symphysis, and also the vagina and urinary tracks. See figure 2-j).

Chest: This 3D model has been reconstructed from the CT information of a real patient. In this model the visible structures are bones, blood flow and structures which are in contact with the air.

The students can see how a real chest is and they can inspect bones like breastbone, ribs, spine and clavicle. They can observe the blood flow distinguishing a very big amount of blood in the heart, aorta artery, kidneys blood flow, etc. They can also see clearly, since these structures are in contact with the air, lungs (very well defined), skin, stomach and intestinal gas. See figure 2-g).

The interaction with this model allows also the user to change the transference function in order to decide whether to hide or show any of the anatomical structures represented in the model.

Aneurysm: The *Aneurysm* model has been also reconstructed from the CT information. It represents the arteries of the brain where the patient has an aneurysm. See figure 2-l).

This model has been augmented by adding a trajectory that the student can follow so he/she sees what the doctor would see in a catetherism. The model also let the students see that the aneurysm has been produced in those areas where there are more artery branches so where the walls are ligther. See figure 3.

4.3. Virtual Reality systems

The Virtual Reality systems chosen for the experiment are a Powerwall (see Figure 4) and a 4-wall CAVE (see Figure 5). We decided to use projecion-based VR systems because they are better than other VR systems (such as HMDs) when it comes to sharing the experience with a small group of students. In both systems we used a tracking device to track the user position and orientation and detect his/her natural movements. This tracking allows an implicit interaction with the 3D model which gives more realism to the model inspection.

Figure 4: *The grup working with the Powerwall.*

During the session there is only one student who is guiding the inspection (the one wearing the tracking for implicit interaction) but this inspection can be easily followed by the rest of the group (5-9 students) and the teacher. Therefore, all the students can follow at once the explanations of the teacher which are directly related to the inspection that is being done in that moment.

Besides the implicit interaction, there are also some activities or functionalities of the models that are implemented by using explicit interaction, such as changing the part of the model to show, or turning on/off some added meta-data. In these cases, we are using devices like keyboard, wanda or wii-mote.

In order to decide which models to see in each VR system, we took into account the real dimension of the model and the characteristics of the system. The final decision was that the models the students can inspect in the Powerwall are:

- *Heart, Encephalon, Eye* and *Ear* which are visualized using a commercial software.
- *Chest* which is visualized using our VRMed software [MDNV09].

And the models shown in the 4-wall CAVE, all of them visualized using our CAVE visualization software, VisViRVIG [ABV*16], are:

- *Lung, Circulatory system, Digestive system, Reproductive and urinary system* and *Aneurysm*.

Figure 5: *The group looking at the CAVE while one student is inspecting the model.*

4.4. Session development

The activity with the nursing students consists in a 2 hours and a half session in the ViRVIG VR center. Each session involves 15 to 20 students who are briefly introduced to VR when the session starts. After the introduction, the students are divided into 2 groups of 7-10 each, and the first hour one group is using the Powerwall system and the other the CAVE. At the end of the first hour, the groups interchange the VR system to use and the second hour of the session they experiment the other VR system (CAVE or Powerwall). Therefore all students can inspect all models and both VR systems involved in the activity.

The activity is guided by two teachers and two technicians, one for each VR system. The teacher is in charge of explaining the anatomical models and asking questions to students, while interacting with them to guide them through the session. The technician helps with the VR technical questions and follows the teacher explanation by doing the explicit interaction with the models. This makes the session more fluid since the students do not have to be trained in using VR devices for explicit interaction. Therefore, students can focus their attention in the implicit interaction and in following the teacher's explanation. However, at the end of the session they are allowed to try the explicit interaction if they wish.

At any given time, one student is wearing the tracking device, which drives the first person implicit interaction. The rest of the students follow his/her inspection. This is done by having the students taking turns in wearing the tracking device, so that all the students get to experience inspecting at least one model in first person. For the rest of the models, they will observe the inspection of another student in the group.

Once the two hours class is finished, the students are required to fill in an exercise answering questions about the session and the anatomical structures studied. This exercise counts a 10% of the grade of the anatomy course. They are also asked to complete a questionnaire (described in detail in next section) about their opinion of the experience.

5. Evaluation and results

The experiment described in last section has involved a total number of 254 students of the Nursing Degree of the Campus Docent Sant Joan de Déu. The students were taking the *Human anatomy and physiology* subject, 123 students from the 2014-15 course and 131 students from the 2015-16 course. Both courses had a group of students in morning schedule and another in afternoon schedule. All the students were taking the course Human anatomy and physiology for the first time.

The questionnaire the students answered about their opinion of the experience had 8 items organized in two blocs or categories (see Table 1). Each item was assessed on an ordinal scale from 1 to 10. The first bloc assessed whether the VR tool facilitates learning (see Category 1 in Table 1 to see the questions). The second bloc assessed the student satisfaction (see Category 2 in Table 1 to see the questions).

Category 1. Virtual Reality facilitates learning?	
1.	Do you think the Powerwall tool facilitates the theoretical understanding of human anatomy?
2.	Do you think the CAVE tool facilitates the theoretical understanding of human anatomy?
3.	Do you think the activity is helpful to learn?
4.	Respect your level of knowledge, do you think you have improved?
Category 2. Student satisfaction	
1.	Do you think in the Powerwall/CAVE you develop the contents of most interest in anatomy?
2.	Do you think the coordination of the session, logistics and dynamics have been appropriate?
3.	Do you think the session length has been adequate to achieve the objectives set?
4.	Has the activity met your expectations?

Table 1: *Questionnaire for assessing the activity.*

The results of the first bloc or category are shown in Table 2. They show that all students (from both courses 2014-15 and 2015-16) assessed that the Powerwall tool facilitates the understanding of the theoretical contents more than the CAVE tool. This is caused by the fact that the models shown in the Powerwall (heart, brain, eye, ear and thorax) are more attractive than those shown in the CAVE (digestive system, circulatory system, urinary system, lungs and aneurysm). In both courses the best valuated item is the use of the activity to learn and all other items have values above 7.4 (average) out of 10.

In Table 3, showing the results about satisfaction, you can see the students valuated as the best item the satisfaction of their expectations, and the second is the one talking about the interest of the contents shown in the experience. The worst valuated item in this category, for all students, is the session length, and this is because the students only have 2 hours and a half for the whole session. We believe that this is a short amount of time to see all the structures in both VR systems (Powerwall and CAVE) and to follow the explanations of the teacher.

We can also see in both tables that the students enrolled in the

VR facilitates learning	2014-15		2015-16	
	Morning	Afternoon	Morning	Afternoon
1. Powerwall facilitates learning	8,12 (1,31)	7,92 (1,47)	8,66 (1,24)	8,25 (1,38)
2. CAVE facilitates learning	7,92 (1,33)	8,18 (1,51)	8,57 (1,29)	8,31 (1,23)
3. Activity helpful to learn	8,12 (1,39)	8,33 (1,50)	8,78 (1,21)	8,46 (1,17)
4. Improved knowledge	7,48 (1,62)	7,44 (1,64)	8 (1,66)	7,76 (1,34)

Table 2: *Results of questions in Category 1. Average (standard deviation).*

Student satisfaction	2014-15		2015-16	
	Morning	Afternoon	Morning	Afternoon
1. Maximum interest contents	7,76 (1,33)	7,76 (1,29)	8,25 (0,97)	7,86 (1,40)
2. Activity coordination	7,83 (1,32)	7,75 (1,37)	8,30 (1,14)	7,49 (1,51)
3. Adequate session length	7,73 (1,53)	7,80 (1,51)	7,97 (1,56)	7,31 (1,82)
4. Expectations satisfaction	7,83 (1,74)	7,73 (1,57)	8,07 (1,66)	7,95 (1,60)

Table 3: *Results of questions in Category 2. Average (standard deviation).*

human anatomy and physiology subject in course 2015-16 valued more positively the activity (total average 8,12) than those enrolled in course 2014-15 (total average 7,86). This is because after the first year, which served as a pilot test, both teams, ViRVIG-UPC and Campus Docent Sant Joan de Déu met several times to review and improve the different structures. As examples we added liver and pancreas to the digestive system, and we incorporated some new structures like eye or lungs.

6. Discussion and conclusions

Before discussing the results we would like to emphasize that the conducted activity described in this paper, led to a multidisciplinary teaching design. An alternative way to teaching concepts of human anatomy and phisiology has been imagined. We want also to mention that, although we have not collected any questionnaire filled by teachers, they value very positively the experiment.

However, there are some limitations of the project that should be considered:

- *The number of sessions:* In order to make the activity feasible, the number of students for each session has to be limited to 20. This means that the session has to be repeated several times for covering all students enrolled in the course. This requires more time and higher economic cost. However it favors a learning centered in the student where there is more personal participation.
- *Location:* Although the Powerwall VR system could be installed in a normal medium size room, the CAVE system requires a specific space in order to be able to project models immersively in a 3mx3mx3m room. In this case, the students from the Campus Docent Sant Joan de Déu have moved to the facilities of the UPC VR center, however, the sessions have been scheduled either before or after their scheduled classes at university, in order to save time in traveling for the students.
- *Cost:* Creating 3D anatomical structures represents a cost that makes these applications unaccessible to students of all disciplines and universities (see [HRL10]). However, for Campus Docent Sant Joan de Déu, it has been an investment in the future in order to adapt to the demands of the European High Education Space and to train more competent professionals with the use of new technologies.

To conclude, according to other studies regarding whether the inclusion of a Virtual Reality environment in teaching anatomy improves learning, students appreciate that VR facilitates studying the different anatomical structures presented. Therefore, it has been proven to be a useful tool to learn. Different processes may contribute to the perception of the effectiveness, which include changes in the interpretation of the experience, expectations and given personal interaction.

- *Interpretation of the experience:* Although students move between different levels of commitment (varying degrees of intensity and conviction, different needs and/or demands of knowledge by the university), overall they were satisfied with the experience. Most students indicated that it had fulfilled their expectations.
- *Expectations:* In the same way that as demonstrated by scientific evidence, expectations about the therapeutic effects lead to physiological and cognitive changes (see [Kir99]). One should think that expectations in learning also lead to cognitive changes and could provoke a response in learning. We would need to run more specific studies and a detailed assessment tool to verify if this is the case or not. However, the documentation provided to students is a resource that helps to generate positive expectations even before the activity takes place. The results infer that the activity in the virtual environment is motivating for learning anatomical structures.
- *Interaction:* For students taking their first year in nursing, this activity is one of the first contact they have with the framework of the biomedical system. Teaching anatomy in a virtual environment entails assumptions that it will be used to structure the whole experience because they exert influence on its construction. In this regard, firstly, the VR anatomy reinforces a style of reasoning focused on objectivity, reality and materiality, and secondly, participation in activity plays a role in the identity formation and the generation of the feeling of belonging to a potential community, the biomedical.

In a context where various technologies and teaching tools coexist, and where traditional teaching methods coexist with other methods coming from new technologies, Virtual Reality tends a bridge between what can be imagined in 2D and the 3D reality.

Although more formal studies would be necessary in this regard, the experiment has been positive enough to consider exploring alternatives to the classical master class. The evocative power of images and immersive environment, as specific stimuli, participate in creating links between students' individual previous knowledge and responses to new learning.

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