A Low-Cost VR Imersive Learning Tool for MicroBiology

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Abstract— **Educators often struggle to teach cellular and molecular processes in microbiology because they usually only have tools based on only two dimensions and are not as attractive as multimedia tools. Learning research has demonstrated that visualizing processes in three dimensions aids learning, and animations are effective visualization tools for novice learners and aid with long-term memory retention. Thus, with increasing adoption of immersive virtual reality as an enabling strategy for teaching has challenged researchers, educators, and enthusiasts to produce both tools and content for these tools. High-fidelity graphics and immersive content using projection on increasingly inexpensive glasses have allowed students to explore complex subjects in a way that traditional teaching methods cannot. In this way, this work presents a prototype of a tool to facilitate the teaching of microbiology, contemplating both the pedagogical requirements of educational software and the technological ones necessary in the construction of an immersive virtual reality environment. Added to this proposal is the requirement to present a low-cost tool for both editing and visualization.**

Keywords—Virtual Reality, Learning Environment, Low-Cost, Microbiology

I. Introduction

We are amid ever-increasing technological advances, where every decade is moving further into the digital age. Technological impulses have transformed in all fields and go beyond the imagination of previous generations.

So have innovative educational applications, going beyond the scope of learning expectations and hovering over the objectivity of student authorship and knowledge representation. Technology in the field of biology has changed traditional teaching and learning, increasing the awareness of teachers at all educational levels [1].

In this case, a variety of possibilities of studies on the properties of Virtual Reality (VR) glasses, mainly concerning immersion and interaction, can be explored in the development of new educational applications [2].

Hence, Immersive Virtual Reality (IVR) applications and environments use Virtual Reality (VR) digital technology and empower the user to "be" anywhere without the need to leave their current location [3].

Thus, this emerges as an alternative tool to traditional learning, providing a social and experiential way of acquiring knowledge [4], and it promotes a high level of realism in simulations and dramatizations that were not present in a teaching environment before [5].

Another advantage of these tools is that they provide students with the ability to develop some special skills: exploration, simulation, and combining concepts. These concepts are significant as they develop learning autonomy [6]. The possibilities of interaction with virtual objects in VR promote the resignification of abstract concepts. Maybe because the conversion of subjective concepts into concrete ones occurs through more engage, active, and interactive learning [7].

II. Immersive Teaching with Virtual Reality

VR in immersive teaching is a technological tool that can modify traditional pedagogical approaches to students' knowledge. Its use is a new and easily accessible resource, providing information and developing skills.

VR immersive learning is based on four fundamental components: i) Virtual universe: the environment shown by a computer simulation program, programmed to imitate a real place; ii) Immersion: the physical and mental sensation of being in the virtual space. It is achieved by using head-mounted displays or room-like environments surrounded by computer-produced images; iii) Sensory feedback: Immersive VR element that provides direct sensory feedback to the participant through his physical positioning, known as tracking; and iv) Interactivity: where the whole responds and reacts to personal behaviour [8].

Furthermore, this technology can be used by promoting social interaction, encouraging behaviour, or even just improving the perception of the place where learning takes [9]. It is also that studies show that immersion has a positive effect on the knowledge acquired and the student's contentment when facing new knowledge because it explores the visual and sensorial information of the environment that corroborates the interpretation of the concepts shown [10].

III. Microbiology Learning

The content and concepts taught in microbiology are focused on the characteristics and behaviours of microscopic organisms[11]. It is noticeable that some students have difficulties regarding abstract concepts, which are often presented descriptively and statically. Indeed, there is a lack

of teaching strategies to facilitate the understanding of these concepts[12].

Traditional teaching contemplates the transmission-reception of concepts with emphasis on their memorization. It is a significant problem in teaching, and it deals with the study of organisms' invisible to the naked eye, increasing the challenge for students' understanding[13].

Finally, some methodologies approaches are currently being used in the teaching of microbiology, such as experimental classes [14], serious games [15] , development of models [16], and the use of audio-visual resources [17]. 3D visualization applications enable students to develop unique visual skills in microbiology, targeting abstract concepts, decreasing students' abstraction from microscopic events, and promoting a better interpretation of concepts [18].

IV. RELATED STUDIES AND TOOLS

The VR laboratory is considered a teaching strategy that is increasingly being used in several areas of health care for professional skills training and assessment as well as chemistry courses, biotech education, genetics, and a wide variety of other fields [19]. These virtual environments provide an extensive learning platform that not only adds to student learning but can also increase their motivation to learn and improve their self-efficacy in final exams when compared with a traditional lecture [12].

Fig. 1a shows the VRLab simulator [19] which proposes a pedagogical strategy for learners to develop some skills in dealing with items in the physical laboratory.

a) VRLab Simulation [19]　　　　b) LabSter Simulation [20]

Fig. 1. Laboratory Simulations

The Labster website (See Fig. 1a) presents various simulations in a virtual environment that emulates a biochemical laboratory [20] . Tus, these simulations have been shown to improve the achievement of learning outcomes among students, by making the learning experience more immersive and engaging.

CellVerse is a VR [11] environment (Fig. 2a) designed for the classroom to give the student an intense and evocative experience of the biological environment as seen from the inside. Designed to give the student the feature of selecting and manipulating the biological images and objects displayed on a screen, it motivates the student to discover more about the element being touched.

The 360 RV tour is very useful to familiarise the student and immerse them in the context. This proposal proved to be attractive and motivating because it abuses colorful objects and demonstration of microbiological life through predefined animations. Fig. 2b shows the InCell Game [21], another VR Game to teach microbiology structures.

We observed the key to a successful VR experience is developing an intuitive environment that allows the user to explore the environment (data) at their own pace, while also

guiding them so they do not get lost or overwhelmed by the experience.
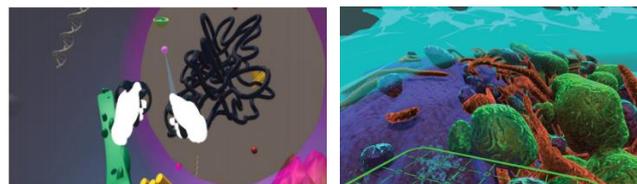
a) CellVerse Simulation [11]　　　　b) InCell Game [21]

Fig. 2. Inner Cell Simulations

In addition, most of the work reports the need for the guide, both for the 360° tour and for the spontaneous navigation and exploration, with the goal of the student not getting lost from the class in an area of the 3D environment without attention to the content presented.

Other papers present a more instrument-based approach to microbiology. These use the microscope to present cells, bacteria, and microorganisms simulated in computer graphics. Thus, Onlabs (see Fig. 3a) is a VR biology lab designed to offer a high level of realism regarding microscopy [22].
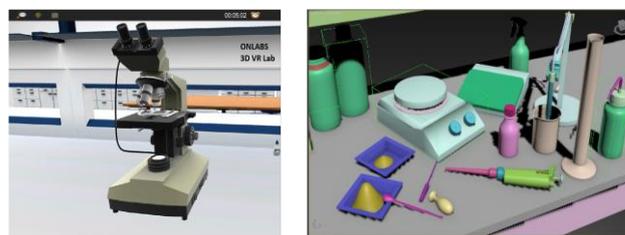
a) OnLabs VR Laboratory [22].　　　b) Essential Laboratory Techniques Lab [23].

Fig. 3. Virtual Instrumentations Laboratory

An interesting feature of On Labs is the possibility that the user can work in 3 different modes: The Instruction Mode, the Evaluation Mode, and the Experimentation Mode. When choosing the Instruction Mode, the user performs the microscopy experiment step by step by following instructions. When using the Evaluation Mode, the user conducts the microscopy experiment and at the same time, she/he is evaluated for his/her performance. Finally, when using the Experimental Mode, the user practices on the experiment without evaluations or instructions.

And finally, we present the Essential Laboratory Techniques Lab - a visual resource for basic lab tools and solution preparation [23]. This virtual lab (Fig. 3b) is designed to help students understand the flow of the experiment while learning the details of each step at the same time. In each laboratory experiment, the student learns about each instrument and how to apply it in biochemical study.

Interestingly, as the complexity of the experience increases, it is necessary to use a different virtual instrument. Interactions are done with the mouse and keyboard, yet the perception of the application's features is very similar to using real objects. Having presented these works we have listed some indispensable characteristics for our proposal, see in Table I.

TABLE I. APPLICATIONS FEATURES

Application	Requirement			
	Immersive	Interaction Mode	Experiment Mode	Add Resources
VRLab Simulation [19]	No	Mouse + Keyboard	Instruction Experimentation	3D Objects

Application	Requirement			
	Immersive	Interaction Mode	Experiment Mode	Add Resources
LabSter Simulation [20]	No	Mouse + Keyboard	Instruction Experimentation	3D Objects
CellVerse Simulation [11]	Yes	Joystick	Instruction	3D Objects
InCell Game [21]	No	Mouse + Keyboard	Instruction	YouTube Video
OnLabs VR Laboratory [22]	Yes	Mouse + Keyboard + Joystick	Instruction Evaluation Experimentation	Quiz
Essential Laboratory Techniques Lab [23].	No	Mouse + Keyboard	Instruction Experimentation	Tutorial

V. THE VRBIO APPLICATION

The Application was developed at UTFPR's Visual Computing Laboratory was designed to work on two different platforms: One of them on Windows desktop and another on Android Mobile. The desktop version was designed to meet the teacher's needs to guide the class during an exhibition. The mobile version was developed so that students can immerse themselves in the simulated universe created.

Development in Multiple Layers was used, containing in the data layer the resources for accessing and managing the MariaDB database. As middleware it was developed in OGRE, adding the physics layers of the Newton Dynamics library. The sound resources were incorporated using the OpenAL library, and the data switching was performed by WinSoc Lib.
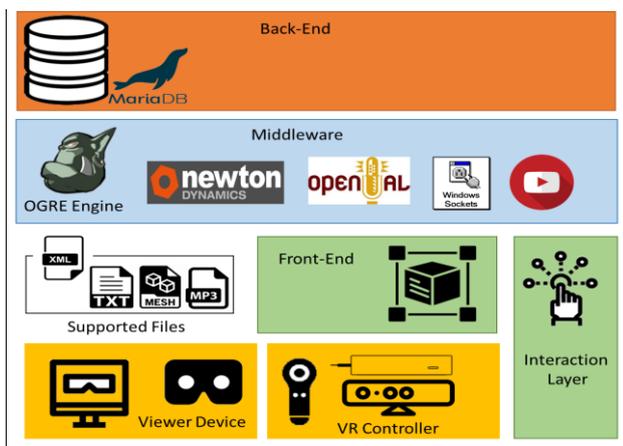

Fig. 4.   VRBio Archtecture

In Fig. 4 we show in the orange area the data layer, in the light blue area the middleware, in the yellow the control devices, and in the green the developed code areas. The tool used for integrating all these libs was OpenSpace3D. This tool is developed by I-maginer Group to provides different options like 3D meshes, 3D audio, 3D camera, VR Cardboard viewer, interaction's device (VR Controller, Kinect, Myo, LeapMotion, etc). This open-source software supports scene editing, feature structuring, connection to command interaction devices, and rendering process.
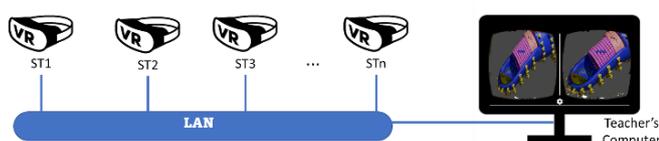

Fig. 5.   VRBio Comunication Layer

In Fig. 5 we see the illustration of VRBio in a LAN network, in which the points identified with ST (from 1 to n) are the visualization devices model CardBorad, synchronized accessing the same environment but generating different visualizations about the same object of study, controlled by the Teacher's Computer. The interactions with the objects: touch, movement, rotation, and translation, are recorded and stored in the database, and the visualization is updated synchronously for all ST points. It is considered a low update delay. The teacher organizes the visualization and leads the formulation of the tour and exploration of the environment.
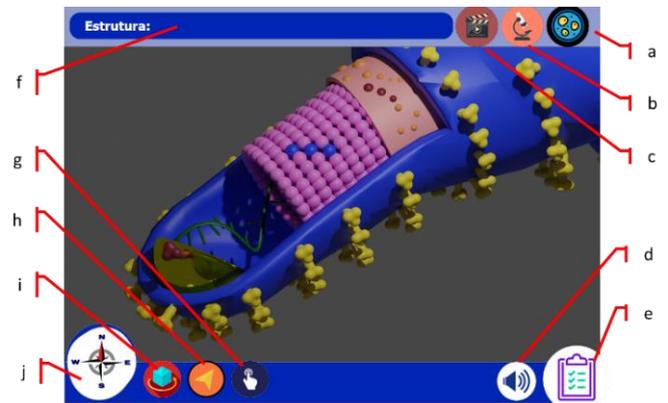

Fig. 6.   VRBio Desktop Interface

In the end, he/she triggers the quiz tool for the students to evaluate the content. So, Fig. 6 shows the structure of the application's interface on the desktop platform. It contains the areas identified by the letters a to j. These are explained below:

a) In Vivo viewer: Displays the natural environment scene from which the microorganism being study;

b) In Vitro viewer: Displays the petri dish laboratory environment in which the microorganism can also be studied;

c) Video player*:* Shows an instructional video;

d) Sound: Enable ambient sound, when in vitro viewer is checked it displays a refrigerator motor noise, and when in vivo viewer is checked it displays a liquid flow noise;

e) Quiz: Shows a quiz with multiple alternatives to check student achievement;

f) Struture Name: Shows the name of displayed microorganism;

g) Interaction Button: Provides the user to freely manipulate the displayed object, by touching some region of it and triggering an event, such as an animation;

h) Navigation Button: Allows the user to navigate in the environment, but keeping the presented object as the focal point of observation;

i) Rotate Button: Enables the user to rotate the viewed object;

j) Navigational Control: This allows the user to know which place to go to focus on the object of interest.

Fig. 7.   VRBio Desktop Interface

The mobile version is shown in Fig. 10. This has fewer interaction objects since that is used by linking via the ray tracing algorithm. Thus, the user interacts with the 3D objects with joystick control. In the upper right region are the icons identifying the type of view (In Vivo, In Vitro, and Video-player). And at the bottom of the same side is the icon that initializes the Quiz. Likewise, in the lower-left corner, there is an icon that displays a compass so that the user does not lose the orientation of the object in the virtual environment.

VI. FINAL CONSIDERATIONS

In this paper, we show some educational tools that are often incorporated in the learning process as self-paced learning tools that help students acquire confident knowledge of science and laboratory skills. We proposed a tool that could combine the best features of these works to be applied in the future in a real field study. We know the limitations of the teaching field, and for this reason, in addition to the release of the tool, a tutorial course on how to use it in the classroom will be considered, presenting practical cases of use in a didactic sequence.

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