

The Level of Interactivity in a Virtual Reality Learning Environment: A Design Key Factor

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Abstract

The increasing use of virtual laboratories (VL) based on virtual reality (VR) in the academic field is associated with the need to constantly evaluate and improve the educational effectiveness of these educational tools. Currently, there are different studies that clarify what factors must be considered when teachers design and implement this type of VLs in their classrooms. In this sense, equipping a VL with the appropriate level of interactivity has been revealed as a key factor to ensure that students learn better the concepts that they are studying and, in addition, they are able to retain them in their memory for longer. This article describes and compares two versions of the same non-immersive VR-based VL that simulates a Rockwell hardness test and that were programmed with different levels of interactivity. Although both VL versions guide the user through the virtual experiment, the first version offers few possibilities of interaction with the virtual environment, while the second VL requires a greater degree of interaction with the virtual elements to perform the experiment. The analysis carried out through the comparison between both VL versions can serve as a guide for teachers when deciding which level of interactivity is the most appropriate for the VL they are developing.

Keywords: Virtual reality learning environment, virtual laboratory, materials science and engineering, Rockwell hardness test, interactivity, education.

1. Introduction

Virtual reality (VR) has experienced a great expansion in the last decade [1], being nowadays a relatively cheap and easy to acquire technology. VR technology can be materialized in different ways, but the two most widespread are [1]:

- *Non immersive virtual reality (NIVR)*: displays the virtual environment on a screen (e.g. a computer or tablet screen). User interaction with the virtual environment usually relies on a keyboard and mouse, touch screen or control knobs. Most of the video games currently developed for game consoles and computers represent the best known application of the NIVR.
- *Immersive virtual reality (IVR)*: uses a head-mounted display (HMD), which is a device that places a screen in front of each eye, to visually immerse the user within the virtual environment. The user's interaction within the virtual environment is usually carried out by means of control commands. An example of the use of the IVR is HMD systems like Oculus[®] or Vive[®].

VR technology is already used in many areas such as architecture, industrial plant engineering or medicine, to mention just a few examples. Education is one of the areas where VR is increasingly used [1-3], being virtual laboratories (VLs) the most widely accepted teaching tools among teachers and students [4,5]. VLs based on VR simulate laboratories in which students can (i) conduct virtual experiments similar to those they would conduct in a real laboratory, and (ii) use some features of virtual environments to enhance the learning of certain concepts. Performing experiments in a VL instead of a real laboratory has advantages such as cost reduction or elimination of hazards associated with the use of machinery or toxic products, among others [4].

VLs using VR have proven to have great potential in supporting teaching. For this reason, in recent years research has been conducted into the methodology to be followed in all phases of the VL life cycle in order to achieve a high degree of training efficiency [2,6]: design, development, classroom use, evaluation, and improvement. Several studies [2-7] indicate that the level of interactivity with which a VL is programmed has a decisive influence on the difficulties that students encounter during learning and on the knowledge retention rates after instruction. Therefore, when designing a virtual

reality-based VL, the way in which users will interact with the virtual environment must be carefully analyzed to ensure that the educational objectives are achieved.

This paper compares two versions of the same VL using NIVR to simulate a Materials Science and Engineering (MSE) laboratory where a Rockwell hardness test is performed [7,8]. However, to carry out the virtual experiment in the first VL version [7] a control system with a very low level of interactivity is used, while in the second version a control system that requires a higher degree of interaction between the user and the virtual environment is used. The comparative analysis allows us to identify which educational objectives can be achieved with each VL version and, therefore, which situations would call for the use of one over the other. In this way, this study can serve as a reference for teachers who design similar tools to establish how they want their students to interact with the VL.

2. Description of the Virtual Laboratory

The VL recreates a MSE laboratory similar to that found in any engineering school (Figure 1). On a laboratory table there is a CENTAUR RB2 hardness tester, which is used in the VL to perform Rockwell hardness tests in two different scales (RH-B and RH-C) [7]. The application runs on a personal computer and the interaction between the user and the virtual environment is carried out using a keyboard and a mouse. The VL allows users to move freely around the virtual lab and explore the Rockwell hardness tester from different angles in order to become familiar with it, after which the virtual experiment starts. A final exercise puts an end to the experiment.

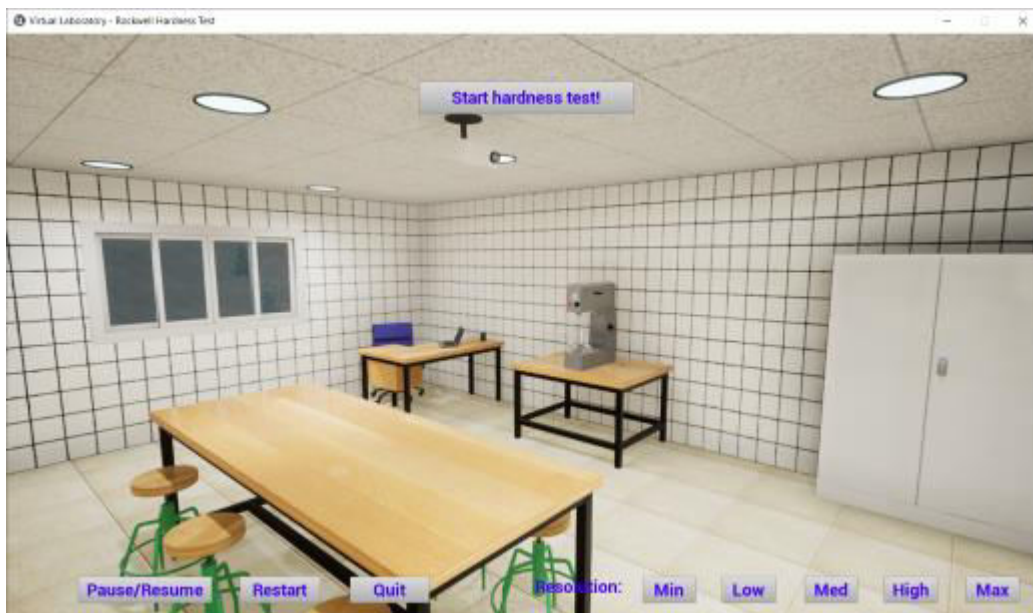


Fig.1. General view of the virtual laboratory where durometer is placed in a central position.

However, once the experiment has started, users' interaction with the VL is different in each of the versions:

- In the first version [7] the user is asked to press a certain key on the keyboard to perform the next step of the experiment (Figure 2). Once the requested key has been pressed, an (automatic) animation shows how that step is performed without the user intervening again. Then, when the animation is complete, the VL requires the user to press another key to activate the animation for the next step of the experiment. This mode of interaction is similar to showing an animation that teaches how to perform an experiment but is automatically paused before starting a new action that is important for the experiment.
- In the second version [8], when a new step of the experiment is to be started, the user is asked to click directly on certain virtual elements with the mouse (Figure 3) or, on other occasions, he/she is asked to click on on-screen buttons. When the user performs the action requested by the VL, animations are activated showing the result of such actions. As an example, the test tube is put on the holder when the user clicks on it. Then, the user is required to click repeatedly on certain handles until the test tube is situated near the indenter.



Fig.2. First version of the VL asking user to press “I” keyboard key to insert indenter.

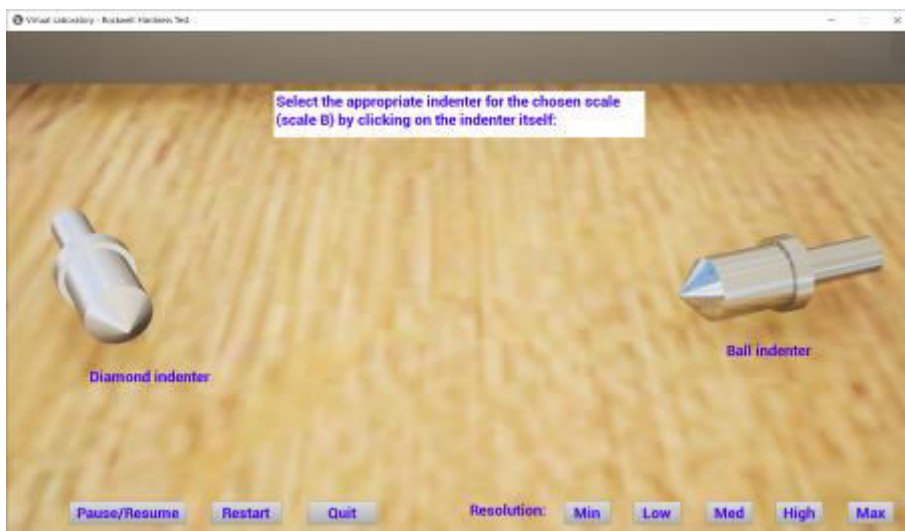


Fig.3. Second version of the VL asking user to click on the appropriate indenter to insert it.

3. Comparative Analysis

The VL described above aims to teach students how to conduct an experiment. For this reason, in both versions a step-by-step system is used to guide users in the performance of the virtual experiment [2], thereby improving the level of meaningful learning. However, as seen above, the way in which users interact with the VL throughout the experiment differs substantially from one version to the other, a fact that determines the pedagogical objectives that each VL version aims to achieve. It should be noted that the second version was designed with the purpose of improving some shortcomings that were detected when using the first version in the classroom, and which are detailed below.

3.1 First Version of the Virtual Laboratory: Lower Interactivity

As noted above, the first VL version (Figure 2) is strongly related to the display of three-dimensional animations. However, when using the VL students do not play a totally passive role as is the case when they just visualize animations. This is because before visualizing a new animation (which corresponds to a new step in the experiment), students must read the information on the screen and press the specific key required. By doing so, students stay focused during the experiment, which facilitates understanding. This lower level of interactivity allows students to focus exclusively on understanding those concepts intended to be taught through the VL, without having to divert their attention to think about how they should correctly interact with the application (they do not need to identify elements of the virtual environment, just find the key to be pressed on the keyboard at each moment). Conversely, the fact that

it is not necessary to identify elements involved in the experiment before moving on to the next step makes it difficult for the student to become familiar with precisely those elements and their manipulation. Thus, this VL version is suitable to be used for the purpose of teaching students about Rockwell hardness testing at a theoretical level, without pursuing the development of the skills required to conduct authentic experimental tasks in a real laboratory. The use of this VL version fits, for example, into MSE lessons where the fundamentals of the different types of existing hardness tests are taught.

3.2 Second Version of the Virtual Laboratory: Higher Interactivity

The second VL version (Figure 3) requires students to identify certain elements involved in the experiment and click on them to continue with the virtual experiment. Students' role is more active here than the role they play using the first version, which helps increase their motivation and the ease in understanding how the experiment is performed. This higher level of interactivity requires higher levels of attention to identify the elements to be clicked on to continue with the experiment. This process helps students have a clear idea of which elements are involved in the completion of the experiment and how such elements should be manipulated at each moment. Conversely, this mode of interaction requires more time and attention from the student to notice how he or she should interact with the application, removing the focus away from the development of the experiment as a whole. The use of this version of the VL is therefore suitable for preparing students - who have already assimilated the theoretical contents - to carry out a Rockwell hardness test in a real laboratory.

4. Conclusions

In this article, two versions of the same virtual laboratory (VL) based on virtual reality (VR) have been described, presenting similarities in design (step-by-step protocol that guides users throughout the performance of a virtual experiment) but having different levels of interactivity. The first version of the VL was programmed with a very low level of interactivity, while the second version was equipped with a higher level of interactivity than the first one. The comparative analysis between the two VL versions, based on the authors' in-class experience, allows us to conclude that the level of interactivity of a VL is a design key factor. Thus, several considerations regarding the interactivity level of a VL should be considered: (i) minimum interactivity when aiming to teach general theory about conducting an experiment; or (ii) higher level of interactivity when aiming to enable students to perform a given experiment in a real laboratory.

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