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ENHANCING THE TEACHING/LEARNING OF MATERIALS MECHANICAL CHARACTERIZATION BY USING VIRTUAL REALITY

D. Vergara[a], M.P. Rubio[b], F. Prieto[b] and M. Lorenzo[c]

[a] Technological Department, Catholic University of Avila, Spain; *diego.vergara@ucavila.es*

[b] EPS de Zamora, Campus Viriato, Universidad de Salamanca, Spain; *mprc@usal.es*

[c] ETSII de Béjar, University of Salamanca, Spain; *mlorenzo@usal.es*

ABSTRACT

The use of virtual laboratories (VLs) in teaching/learning is increasing in the last decade. As each virtual tool, these educational resources must be constantly updated in order not to become obsolete and, so, to keep student motivation. Thus, an up-to-date and sophisticated virtual 3D environment - fitted as a serious game - is presented in this paper, which shows the operation of a universal testing machine in an interactive way. This 3D-VL motivates students to study the mechanical characterization of materials. According to survey results, students demand not only the combined use of both real and virtual laboratories for their experimental classes, but also they request virtual environments designed in 3D. Thus, 3D interactive VLs become really attractive for teaching, since their use is highly encouraging.

Keywords: *virtual laboratory, 3D virtual worlds, virtual reality, mechanical characterization.*

INTRODUCTION

Since active class sessions can help to motivate students [1], Active Learning (AL) practices in university are currently increasing [2]. Besides, taking into account the well-known importance of the use of Information and Communication Technology (ICT) in the wider society, nowadays the combined use of AL and ICT is a relevant topic in education [3-5]. Concretely, with regard to the application of ICT in engineering education, there are many examples of virtual laboratories (VLs) based on AL[6-16]. Indeed, due to the common difficulties in spatial visualization that engineering subjects exhibit [17], there are evidences that interactive simulation in engineering curricula can enhance student learning and improve engineering education [18,19]. In addition, the effectiveness of using virtual environments in engineering education was proved in many research papers[20-23].

Taking into account the increasing usefulness of these types of environments, it seems to be convenient to summarize the most important benefits when *virtual laboratories* are used in engineering education:

- To palliate problems related to the overcrowding of practical classes, which imply that many students were not able to observe the performance of the corresponding machine [24].
- The time availability for handling the tool as much as one wishes [25].
- The chance of implementing, in the virtual environment, didactical applications for reinforcing the acquired knowledge [10].
- To motivate student body for the study of the matter by bringing them closer to a friendly and familiar environment [23,26].
- To economize costs of some practical classes [9,24,27].
- To avoid potential risk of dangerousness which can appear at some physical (real-life) laboratories when certain materials are used [25,28].

An interactive application can be considered as a VL when the following aspects are satisfied[23]:

- A VL must show the phenomena and allow controlling the variables, which affect it.
- A VL must have the ability to obtain the numerical data of the involved magnitudes.
- A VL must include the ability to obtain the value of the relevant variables by using of measurement devices such as rule, chronometer, thermometer, balance, sample, etc.
- A VL should allow the observation of the magnitudes.

Regarding virtual environments linked with tensile testing or mechanical characterization of materials, there are different examples of teaching/learning: (i) virtual tools [9,12,22,29]; (ii) web pages including not only a vision of tensile test but also interactive exercises in order to enhance the student learning (*SteelUniversity.org*); and (iii) video recording of real tensile tests really useful for teaching (different videos in YouTube Nevertheless, to date, no reference of a virtual tool linked with mechanical characterization of materials has been designed in a tridimensional (3D) interactive environment. A 3D virtual environment involves a higher realistic simulation than a 2D environment and, therefore, 3D virtual tools become more attractive and motivating to students [15,30].

3D virtual laboratory shows the information in a 3D environment and allows the interaction with it. In this way, an abstract experience (the information processing) is converted to an experience similar to that of the real world (*virtual reality*). The typology of virtual environments used in the teaching/learning process covers from relative simple tools to the very complex ones. However, in general terms, two categories can be cited [23]:

- *window in the world*, where the user's vision of the world is achieved by means of a computer screen that acts as a "window".
- *immersion*, which introduces the user into a virtual world trough haptic devices and helmet- mounted glasses.

In this paper, a novel 3D virtual laboratory is presented for enhancing the teaching/ learning of mechanical characterization of materials. Taking into account that the tensile test is the most common method for obtaining the material's mechanical properties [31], a 3D interactive VL including a universal testing machine is exposed in this paper. However, it is advisable to emphasize that the use of 3D interactive virtual tools –similar to video-games– in teaching/learning activities is not a guarantee of success and, in this way, the effectiveness of using ICT in education is a current topic of research [32].

To make sure that this 3D-VL is really useful in teaching/learning process, an educational support with practical exercises linked with the mechanical characterization of materials was included in the virtual tool. To design this educational support, the opinion of both students and teachers were considered. Thus, this educational tool has suffered continuous improvements up to reach the final version shown in this paper, which is expected to have a high didactic effectiveness. Besides, an educational experience of using this 3D-VL in an AL environment is exposed in the paper.

3D VIRTUAL TOOL

Two commercial software were used to design the 3D virtual laboratory: 3D Studio Max® and Quest 3D®. The most important features of this 3D-VL are: (i) 3D environment, (ii) interactivity, (iii) high realism, (iv) easiness of use, (v) motivation (awaked in the students), (vi) movement in real time and, finally, (vii) it allows one to implement a didactic accessory for helping students to enhance the knowledge of mechanical characterization of materials.

3DStudioMax© is a software for creating graphics and 3D animations. This general-purpose software allows the export/import of different models and animations to other applications, e.g., AutoCAD© or Quest3D©. This software was used for (i) 3D modelling of the laboratory environment, the furniture and the own universal testing machine; (ii) to assign the material type to each component;
to create the more adequate lighting in the virtual laboratory, thereby looking as real as possible. Later on, the models obtained with 3DStudio Max© were exported to the software Quest3D©, which is a tool that comprises graphical engine in real time of execution (movements in real time) and an object oriented programming system. The Quest3D© environment is used for including the interactivity of the movement within the scenario and the interaction with other objects placed within. In this sense, Quest3D© has some advantages with regard to other software which allow implementing visual interactive components [33]:

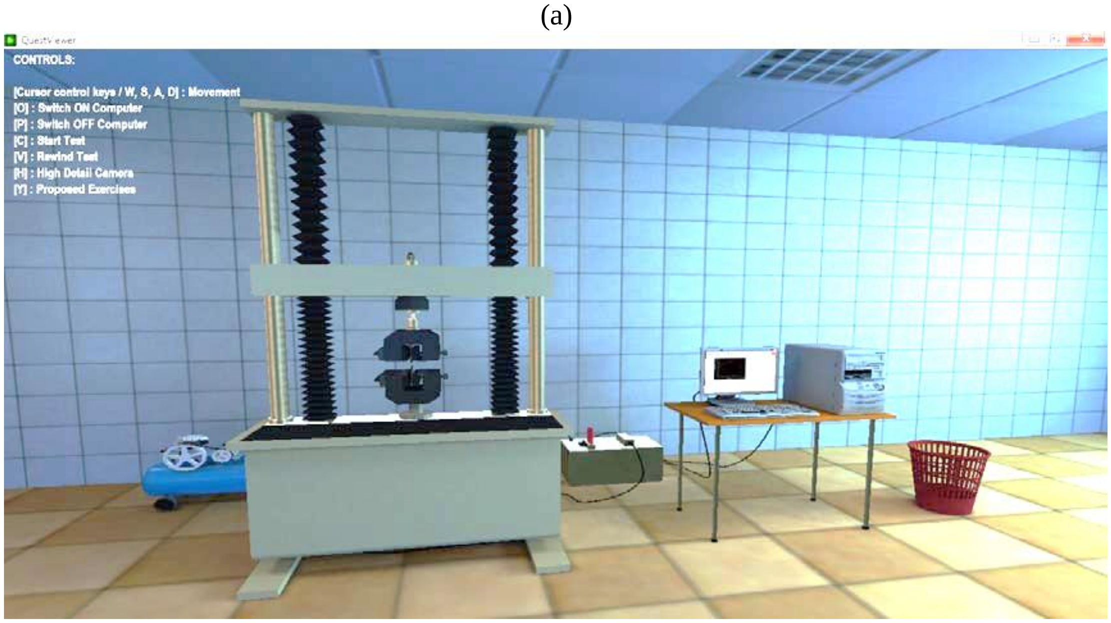
(i) quick integration/delete of components in the model;
(ii) easiness in the work flow definition;
(iii) flexibility for changing the geometry and characteristics of objects in the model;
(iv) 3D visual integration with capability for importing/exporting entities from/to other sources;
(v) accessibility for each educative institution through academic licenses;
(vi) the programming is based on the philosophy "WYSIWYG" (What You See Is What You Get), that is to say, results are directly seen in the program, so that one does not need to render or to export the application in order to verify the programming.

Taking into account the aforesaid features, authors of the present work chose this environment for designing the 3D-VL of tensile testing.

The main idea of this tool is framed within the so-called *serious games*, which can be aimed to a wide variety of users, from students to professionals [34,35]. Thus, this type of virtual games can be used for each gender, can use any game technology and can be developed in any platform. In the 3D-VL shown in this paper there are mainly two phases. The first one is based on this type of serious games, in this case of didactic character (Figures 1 and 2), and the second one consisting in a collection of virtual exercises designed from the most purely educative point of view (Figure 3).

In the first phase (serious game), *realism* is one of the key issues. Thus, students have a sensation of being in a real testing laboratory (virtual reality). To achieve that goal, the designed 3D-VL includes not only a realistic model of the testing machine but also a realistic simulation of the whole laboratory (Figure 1). In addition, the use of Quest 3D© environments

(a)



(b)

Figure 1. Realism of the 3D-VL: (a) virtual environment; (b) detailed view of the universal testing machine used for tensile testing.

allows student to freely move. within the virtual laboratory, placing himself/herself anywhere and, even, students can rotate on themselves for visualizing the laboratory from any point of view. Thus, this 3D-VL is able to capture a higher degree of realism than other VL used previously in teaching tensile tests, since all of them are simulated in 2D environments [9,12,22,29].

On the other hand, the interactivity of this 3D-VL helps student to self-understand the testing machine performance (*self-learning*) and, furthermore, it helps to promote an active learning activity. Thus, students decide the right time (i) for placing the specimen in the machine jaws, and (ii) for activating the loading and, after that, they can visualize the specimen elongation during testing whilst the

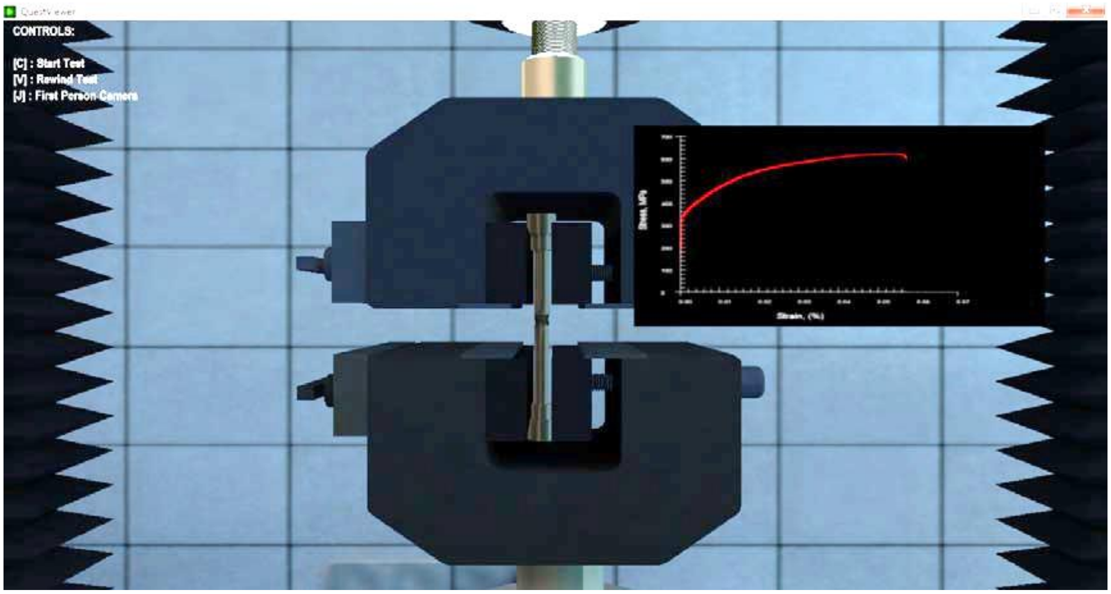


Figure 2. View of the high resolution camera during a virtual tensile test.

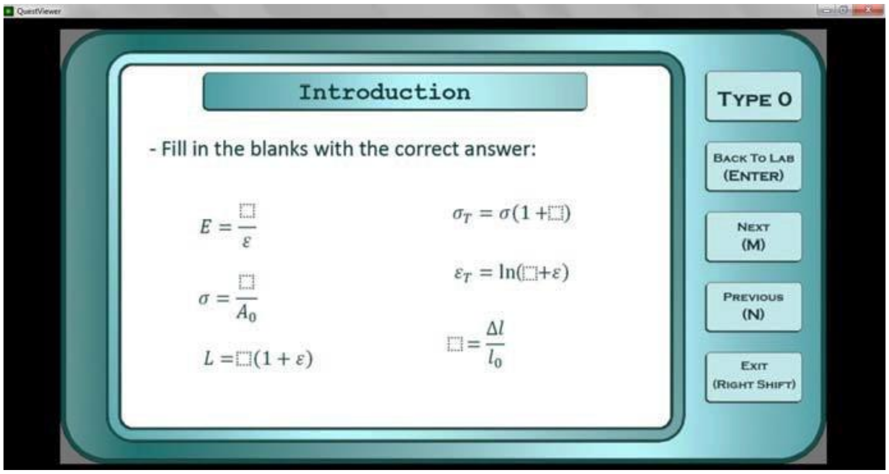
stress-strain curve is plotted on the screen of the virtual computer (Figures 1b and 2). Besides, they can check that the maximum load instant occurs simultaneously with the beginning of necking phenomena (Figure 2). This way, student has the feeling to be running a real test (with an added advantage of being able of repeat any action if something is not well understood). Furthermore, optionally students can activate the detailed visualization in real time of the stress-strain curve plotted during testing (Figure 2). To increase the realism of the 3D-VL, the most common sounds appearing during a real tensile test, were incorporated: the sound of loading application, sound of specimen catastrophic fracture and, even, the sound of the Windows© switch on of the virtual computer.

Finally, to make the tool easy to handle, a simple and clear legend was included on the left upper corner of the computer screen (Figures 1 and 2). Since this legend is always visible on the screen, students can easily find such key information in the case of any doubt.

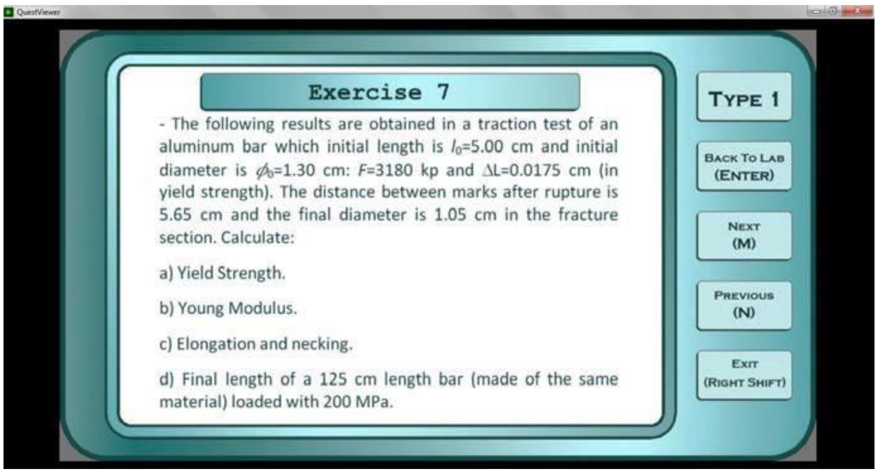
METHODOLOGY

The methodology used in the classroom consisted in applying the virtual tool after previous theoretical explanation in a master class. The total duration of the class based on handling the 3D virtual tool was about 2 hours, divided in two stages:

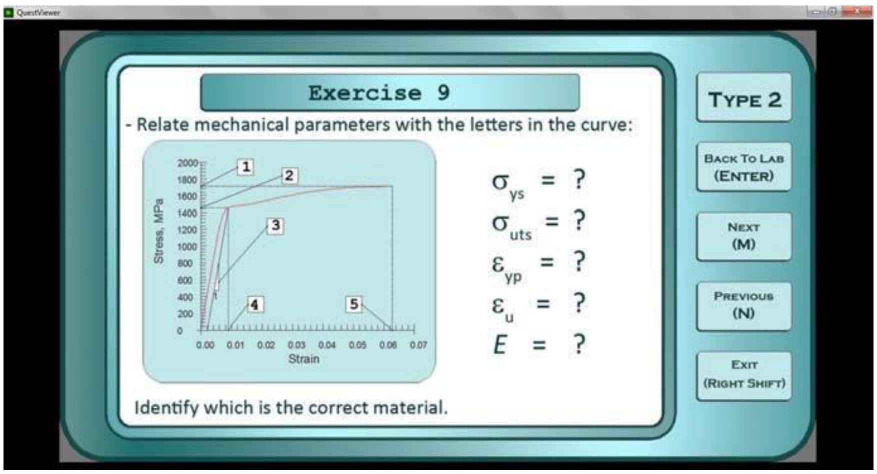
- *3D-VL*: 15 minutes for performing the virtual test in an interactive way and acquiring a perfect understanding of the stress-strain curve evolution (Figures 1 and 2). It is convenient that each student carries out this phase individually, thereby realizing of all details of the performance of the tensile test.
- *Educational Accessory*: 1 hour and 45 minutes for solving the practical exercises implemented in the virtual platform and checking the problems´ solutions (Figure 3). Exercises were designed in three different ways: (i) theoretical formulae (Figure 3a), (ii) problems with the mechanical properties of materials (Figure 3b) and (iii) examination of different



(a)



(b)



(c)

Figure 3. Virtual interactive exercises in the virtual tool: (a) Theoretical formulae; (b) problems; (c) mechanical parameters for different type of materials.

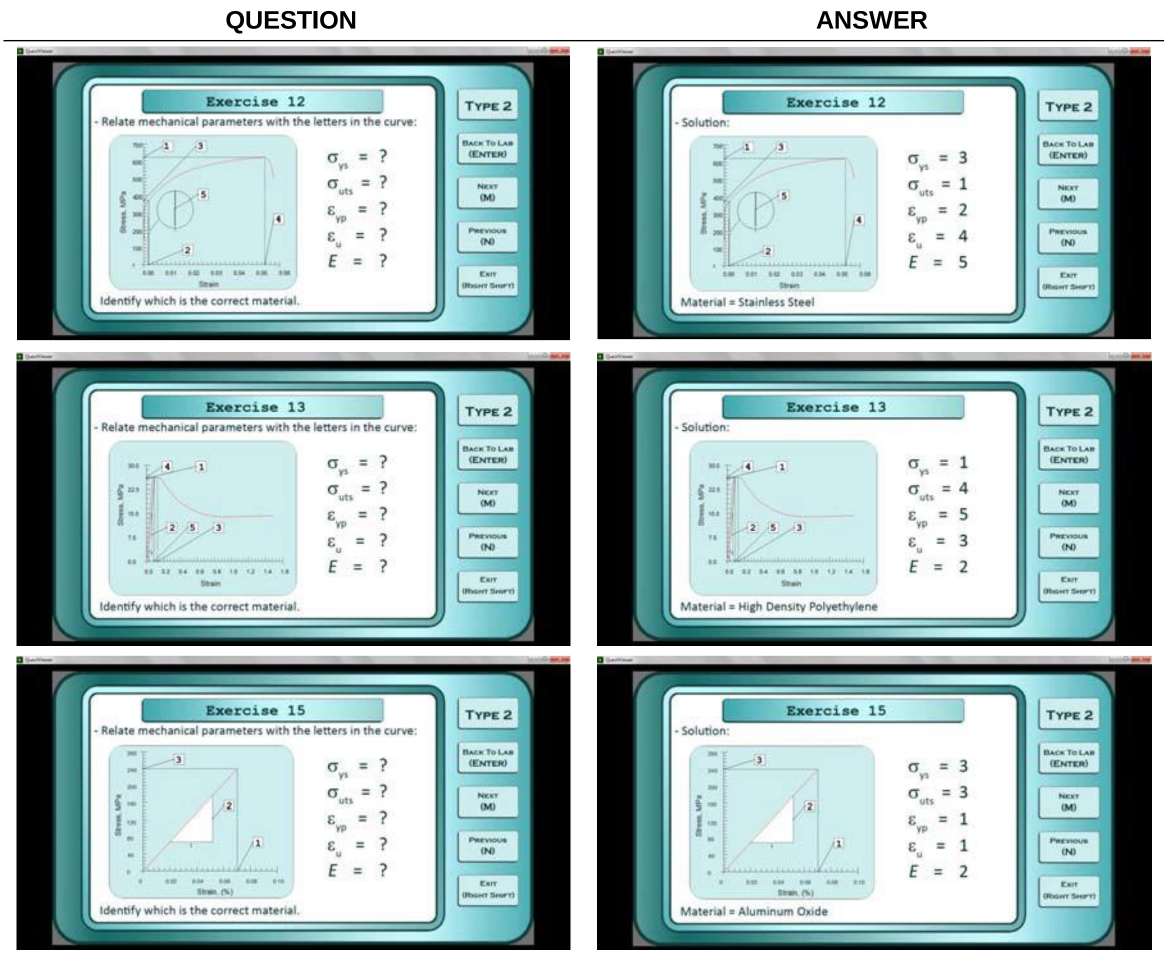


Figure 4. Exercises for different materials families.

- stress-strain curves to obtain the mechanical parameters for different type of materials (Figures 3c and 4), which, according to a previous paper [36], is an effective and clarifying method of teaching mechanical properties of materials. This last phase of solving problems is convenient to be trained by cooperative learning based on small groups of 2-3 students [37], since such groups can enhance by themselves a more effective cooperative learning.

Apart from that, students are really motivated to collaborate between themselves since these active classes with the serious game are evaluated. Thus, each student obtains his/her corresponding mark. A scheme of the methodological proposal is shown in Figure 5.

What is more important is to learn all the concepts related to materials mechanical characterization. Thus, to this end, the teacher must control cooperative learning in order to make sure that students are trying to solve the exercises in a correct way. Furthermore, it would be advisable that this educational activity is evaluated, so that students consider it in a serious way. In this way, authors linked this activity with the qualification of the whole practical classes of the subject. Students must write down a report about the experience, expounding both the results of the exercises and their own conclusions.

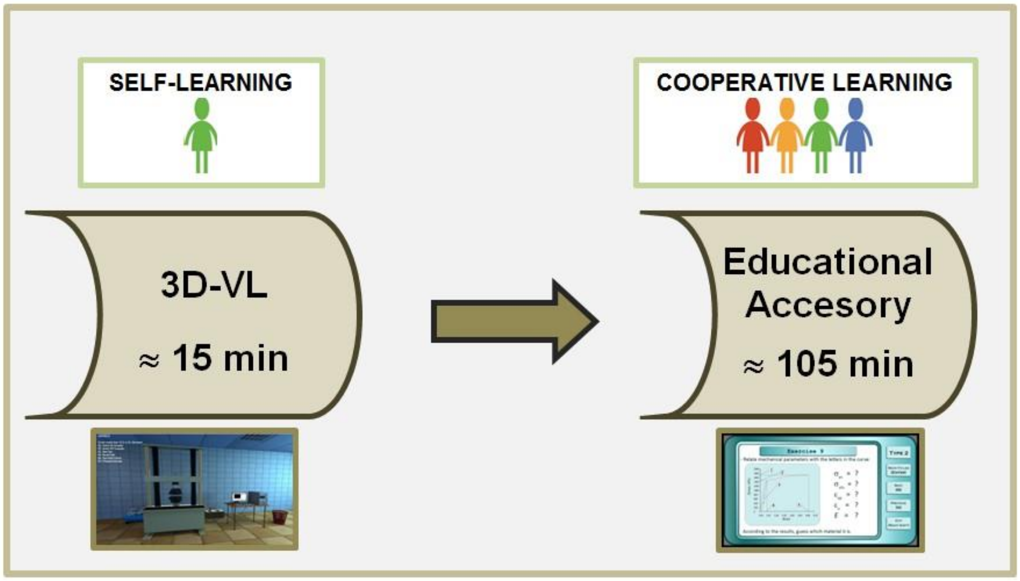


Figure 5. Scheme of the active learning methodology with the 3D virtual tool.

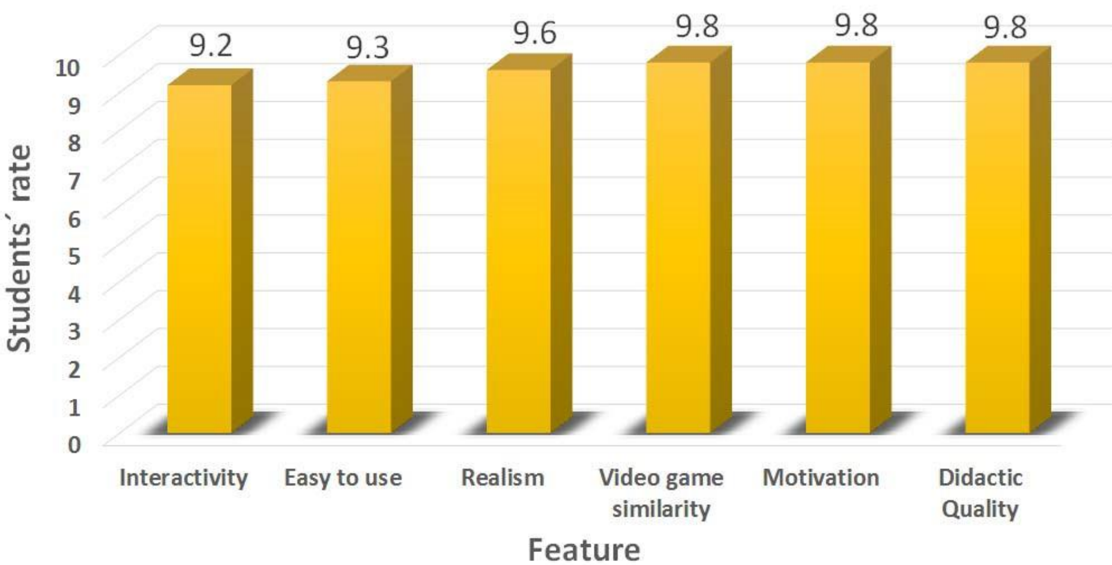


Figure 6. Students' valuation of the 3D Virtual Tool.

STUDENTS' OPINION

The 3D-VL has been evaluated by applying surveys to engineering students at diverse universities (University of Salamanca and Catholic University of Avila) and, furthermore, the surveys were also completed by a great variety of students of several European countries during a course organized by AEEPO (Autonomous European Educational Programs Organization). Thus, a total number of 110 students were surveyed to achieve the following results shown in this paper. Students were enrolled in five different degree programs: Mechanical Engineering, Geological Engineering, Civil Engineering, Architecture and Geology. Surveys rated the following features: interactivity, ease of use, realism, similitude with a videogame environment, motivation (for being an intuitive and easy-understanding tool), didactic quality, educational application, etc. Figure 6 was obtained from the arithmetic average of the student rating. Such results serve to verify the good assessment of this serious game by the student body, since all the VL features were given high ratings (over 9 out of 10). The features subjected to evaluation are placed in Figure 6 in an increasing order of students´ valuation. In addition, students were asked if they considered that a previous explanation is needed for understanding the 3D virtual tool or, otherwise, they consider that it is not necessary because of this tools is self-explaining. Survey answers indicate both options, on the one hand they think that the stage similar to a videogame is self-explaining but, on the other hand, a previous class with a teacher is needed for the complementary exercises.

In addition, it is worth to highlight the clear students´ demand of 3D virtual labs, due to the high importance that they give to realism and similitude with videogames. This idea is reflected on the results shown in Figure 7, when students were asked to choose between (i) "I prefer 3D-VL" or (ii) "I have no preference, 2D VL or 3D VL, the key point is just how didactic the tool is". Most of the students (61.7%) choose the 3D tool. This plot shows the today's importance of serious games in university teaching.

On the other hand, students were asked in the survey about which is the best methodology for the practical credits (of experimental subjects): (i) VL; (ii) Real Laboratory (RL); or (iii) Mixture of VL and RL. Results indicate that 78.3% of the student body chose the combined option VL+RL (Figure 8), i.e. students *do* demand the use of VL in the classroom, but as a reinforcement of testing in RL. The most logical order for applying such activities is, firstly the use of VL and later the RL, since the VL is in fact, a next step of the master class and enhances that student's wish for even more experimenting in the real world. On the other hand, the next question was included in the survey: "Would you like to have more classes with virtual tools in other subjects?" If the answer is yes, please list which subjects". Among the students´ answers, almost all the subjects including an experimental character of engineering degrees were listed.

Besides, many engineering students declared that, after seeing the tensile test in the RL, they did not learn more than after using the VL. This is mainly due to practical classes of a tensile test in a RL are conducted by a teacher, and the students act as a simple onlookers. Even so, the engineering student body demands the use of RL in their training, just as an essential way to verify the acquired knowledge during their classes with VLs.

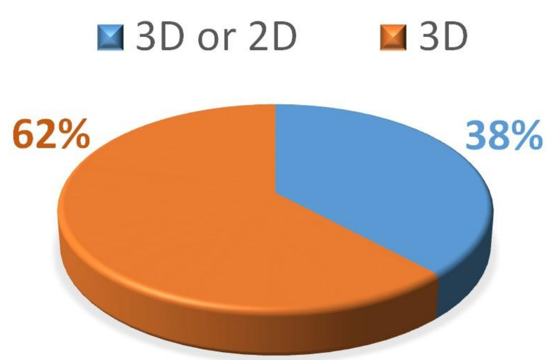


Figure 7. Students' opinion of the VL scene.

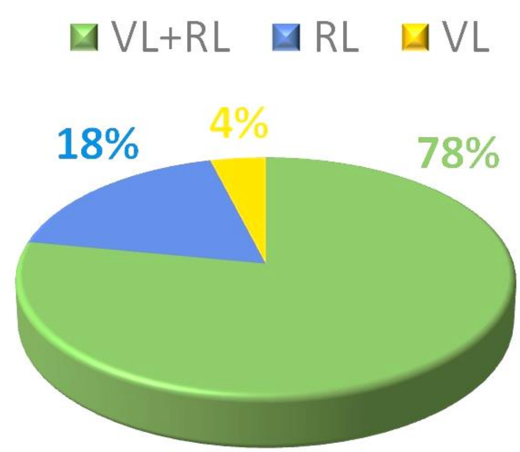


Figure 8. Students' selection of the best methodology for the experimental classes.

DISCUSSION AND CONCLUSIONS

The technological advance of any tool or machine, which uses electronic devices, supposes that the market permanency of any product would be short, since in a brief timeline a new commercial model appears, making the old one obsolescent. The same happens with the educative technologies and, therefore, teachers involved must constantly update their knowledge about ICT. In this sense, each day it is harder to motivate student body and to catch their attention by using "old" virtual environments, which from the aesthetic point of view seem to be obsolete. Taking this into account, authors of this paper think that it is really convenient to take advantage of the newest and most sophisticated resources to build up a didactic virtual environment. This idea is strengthen with the results obtained in the students' answers of the surveys included in this paper.

Therefore, VL used in the classroom must have, in addition of a high didactic quality, an appearance as realistic as possible for motivating student body to use them and, furthermore, to involve students in the teaching/learning process, thereby enhancing the Active Learning. These aims are clearly enhanced by using 3D environments. In fact, according the scarce motivation awaked in the engineering students when using 2D virtual tools and the students' opinion reflected in the surveys (Figure 7), it can be elucidate that 2D VL are becoming obsolescent. This fact supposes that teachers must periodically update the VL (with the most modern technologies), so that their didactic resources do not become old-fashioned. According to survey results (Figure 7), to be really effective, a virtual tool not only must be didactic but also it must get the students' attention. On the contrary, student body do not feel really motivated by using virtual resources.

Up to date, the 3D-VL presented in this paper exhibits an aesthetic appearance and design, which clearly attract students (even also some teachers who have handled it). This is supported by the survey results that show high ratings for all 3D-VL features (Figure 6). Even so, knowing the so exigent students demand with regard to keep virtual tools attractive, authors are currently expanding the educative complement including more stress-strain curves of diverse materials families: metallic, ceramics and polymers. Some examples are shown in the Figure 4. Thus, the traditional approach to the subjects linked with Materials Engineering analyzing almost exclusively metals for tensile tests is avoided. With this extension in the 3D-VL, engineering students can interactively learn the difference between a fragile and ductile behaviour, and they can compare, in a reasoning way, the mechanical behaviour of different materials (in the same way of the apps included in the web page *SteelUnivertity.org*).

Authors wanted to highlight with this paper an advance in designing educative technologies used for simulating virtual laboratories of Materials Science and Engineering, by using 3D environments based on serious games. Even so, authors are conscious that, as in the case of any virtual tool, which tries to keep catching the user attention, they will have to perform periodical improvements in the virtual platform with the aim of keeping its modern aspect in the future. To achieve that goal, it is convenient to carry out annual surveys with the aim of detecting when the tool is beginning, (from the didactic point of view), not to be motivating and effective. Besides, another aspect influencing the students' opinion is the methodology implemented in the virtual tool, which must be continuously updated as well.

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