

Evaluation of a Gamified 3D Virtual Reality System to Enhance the Understanding of Movement in Physics

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Abstract: The creation of new technological tools in education provides different learning opportunities to students. The present research evaluates an application that we have developed for the use of virtual reality to enhance the understanding of movement in physics, using gamification techniques on the application allowed us to improve the motivation of the students to learn, the validation of this research was made using a methodology to evaluate the didactic value of educational software, and this evaluation was carried out on a group of teachers.

1 INTRODUCTION

Education is constantly improving in every country; however this improvement is affected by different factors like economic, political and social capacities, of which the economic aspect is the most critical in different countries, creating a tangible limitation.

The use of technology in education allows low-cost alternatives to improve education; one of these technologies is virtual reality.

For instance the term virtual reality has two virtually opposite concepts: real (which has real and effective existence) and virtual (which has not physically existing).

Consequently virtual reality is the name given to a set of computer-based techniques and technologies that approximate the visualization of concepts, objects and actions in three dimensions in an interactive way, that resembles or not reality (Gobbetti and Scateni, 1998).

In addition, virtual reality gives the possibility of rebuilding the real world, creating digital scenarios so realistic that create the sensation of being transported to fantastic worlds in seconds, this is a reason why virtual reality is a technology that can be used in various areas.

On the other hand, many of the principals developments in virtual reality are focused on entertainment, from video games to video consumption, there

are other less publicized but interesting application, such as in the area of medicine and art (Mazuryk and Gervautz, 1996).

The characteristics mentioned before turns virtual reality into a technological tool with potential for the creation of educational software, although this technology is not suitable for teaching directly, a set of processes and procedures are necessary to guarantee the correct use in the classroom.

In fact, educational software is a technological tool created to improve the learning process at different learning levels (Fredes et al., 2012) (Bustos Sánchez and Coll Salvador, 2010), this technology combined with Virtual Reality allows to place students in scenarios, that could not be accessed in reality.

In addition the use of gamification in education helps to improve the student motivation to learn, through the use of game elements in learning environments with the goal of maximizing entertaining and engaging the student, which helps them to continue learning. (Dicheva et al., 2015).

Summing up, the section 2 will show research related to virtual reality and the impact that generates in the educational field. The proposal of the immersive laboratory for enhance the understanding of movement in physics, that we develop will be discussed in section 3. Section 4 shows the system that we develop, exploring the configuration, scenarios and ac-

tivities that the virtual laboratory contain. The experiment and results are shown in section 5, where this educational software was validated against teachers, who have pedagogical experience. Finally, section 6 shows the conclusions.

2 RELATED RESEARCH

In recent years the investigations related to the use of virtual reality in the educational field has begun to increase.

In fact, education is currently one of the most promising areas for the design and development of virtual reality applications, mainly thanks to the ability to introduce the student to immersive and multi-sensory environments (sight, touch, ears). In which students can interact with an virtual environment that stimulates their learning process.

2.1 Educational Software

Educational software is the technological tool to the new learning society (Fredes et al., 2012) (Colegio and Minnaard, 2016), because of this, strategies have been adopted at different levels, from an institutional level to a classroom level, searching for the appropriate use of educational software. Simulation in virtual environments can be a powerful tool to place students in "practical" scenarios that could not be accessed in reality (Saxena et al., 2016).

For example virtual environments are autonomous, intercommunicated worlds that interact with an user that is also located inside the computer; there are two types of virtual environments applications that can be applied on education: simulators and video games.

At all the different levels of education, virtual reality has the potential to be involved on the learning process, to lead students to new discoveries, to motivate and stimulate the process of learning (Ott et al., 2015). In fact, students can participate in the learning environment with immersion, that is a sense of presence of being part of the environment.

2.2 Virtual Reality in the Education

In brief virtual reality is an alternative world filled with computer generated images that respond to human movements. These simulated environments are usually visited with the aid of head-mounted goggles and fiber-optic data gloves (Steuer, 1992).

For instance, some of the main characteristics of virtual reality are immersion and presence, whose are

focused on generating the sensation of being present in a simulated place, this allows to give a focused viewpoint in terms of human experience rather than technology to virtual reality. However, the concept of presence does not refer to what surrounds one, as in the physical world, but to the perception of the environment through an automatic and controlled mental process (Gibson, 2014), on the other hand Immersion can be defined as the feeling of being present in a certain environment.

In the past there have been certain difficulties in the use of technologies focused on the use of virtual reality, there were problems with the technological devices as they were expensive and not very widespread, and on the other hand, their characteristics were such that often cause a sense of aversion to their users due to the mismatch between head movements and the corresponding change in the scene (Ohta and Tamura, 2014).

Now with the creation of commercial products such as Google Cardboard which is a development platform created by Google to use mobile devices as virtual reality glasses. For example the glasses are used by placing a mobile device in the back and making the visualization through the lenses in the front (MacIsaac et al., 2015) (Laffont et al., 2016).

Evidently, due to the versatility of virtual reality technology, the uses of this technology is not limited in a specific area for such reason among the areas in which it can be used are: military training, education, health, entertainment, fashion, museums, business, engineering, sports, media, scientific visualization, telecommunications and construction (Cumings and Bailenson, 2016).

On the whole, education is an area in which virtual reality is used through the creation of teaching and learning situations, allowing large groups of students to interact with each other in three-dimensional environments (Helsel, 1992)

2.3 Gamification in the Education

The term gamification is the application of game elements and principles of game designs in other non-game contexts. In brief gamification uses game design elements to improve user motivation, participation, and productivity (Deterding et al., 2011).

A general definition of gamification is the use of game design elements in contexts other than games (Deterding et al., 2011).

In fact the use of gamification in education, helps to improve the motivation on students to learn through play elements in learning environments, with the goal of maximizing entertaining and engaging the stu-

dent and inspiring them to continue learning (Dicheva et al., 2015).

The main advantages of using gamification in education are:

- Freedom for trial and error without negative repercussions, increasing the fun in the classroom.
- Differentiated education according to the student's abilities.
- Visualization of the realized learning, providing a set of tasks and subtasks
- Motivate students to continue their learning and give the student the freedom to do their own learning.

2.4 Virtual Laboratories

Lessons made in classrooms are not always appreciated by the students, in a classroom; both the learning and the motivation of the student and the teacher can be affected by external stimulus or by a lack of attention and interest.

Nevertheless, to be able to do the correct laboratories practices of what is learned in a theoretical way, it is necessary to manipulate instruments and objects, the classes in these laboratories require a set time and a suitable room.

Evidently, the large number of students enrolled in the first years of higher education, material limitations (number of rooms, facilities) and lack of human resources make it difficult to learn only through practical exercises in the classroom.

Certainly taking into account the evolution of students' attention capacity, lack of time and resources for acquiring knowledge through practice, an alternative that has been used is the application of virtual labs in which classes can be held remotely; These laboratories seek to consolidate the learning in class and acquire additional knowledge (Ballu et al., 2016).

For example, the following are the main advantages of using virtual laboratories (Bonde et al., 2014):

- **Economic:** Virtual systems turn out to be a more profitable alternative in schools and universities, since it allows taking classes in a laboratory of high quality.
- **Flexibility:** You can easily create different virtual experiments and these can involve different components.
- **Multiple Accesses:** Multiple students can use the same virtual laboratory at the same time.

- **Configurable:** It is possible to modify the parameters, allowing the creation of more adaptable exercises.
- **Damage Resistance:** Allows interaction with the different components without running the risk of damaging the equipment if an incorrect interaction is made by the user.
- **Visibility of Components:** Because you work in a virtual environment it is possible to see the internal structure of the different components.

3 PROPOSAL

3.1 System Proposal

In this research, students of the National University of Saint Agustín of Arequipa (UNSA) are expected to use virtual reality to learn physics concepts through a virtual environment in which they interacted with a Google Cardboard.

This immersive laboratory of physics is oriented to university students who follow who follow the physics curriculum of the UNSA. About the laboratory, three types of users have been identified:

1. The user who makes normal use of the laboratory and learns.
2. The user who already knows the educational content, therefore will have little interest in learning.
3. The user who has problems using the laboratory.

In terms of the competencies and skills, students have to achieve according to the national standards of learning, progress maps are established where learning goals are defined, to identify what is expected to be achieved with each competency.

One of the main problems identified when conducting the different surveys and interviews with the students is the great dependence that exists to a physical place when performing the laboratory practices, due to this to realize the practices it is necessary to request the laboratory classroom; which has time limitations according to a pre-established schedule and does not allow the repetition of such practices.

For this reason, experiments made on the laboratory are affected by a specific time interval and a location with difficult access.

4 SYSTEM

4.1 Configuration

The system is shown in Figure 1.

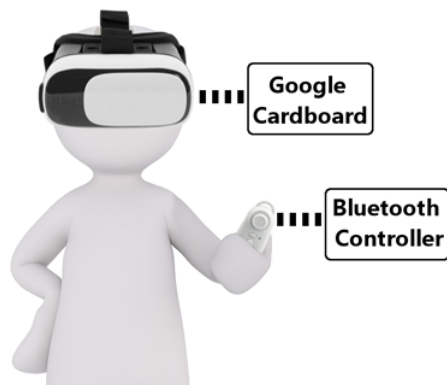


Figure 1: System Configuration.

The software used for the development of the system was the game engine Unity, the system was created in conjunction with teachers of the area of physics of the UNSA, the activities of the system were based on the first year courses in the area of physics, Which correspond to the displacement of objects, throwing of projectiles and the laws of newton, in any case students using the application must belong to the physics area.

The architecture of the system consists of a mobile device with a resolution of 2560 x 1440 pixels with a gyroscope sensor, an android version of 4.1 or higher; Which will be used with a Google Cardboard that will allow the virtual reality visualization and to achieve the interaction with the system, a Bluetooth controller will be connected to the mobile device.

We decided to use Google Cardboard to achieve a greater accessibility using the app, because it is not limited to a physical room. Before beginning to use the application the user must place the mobile device in his VR Box and start the application; when it starts, show a splash screen; after this, user must select the physics movement that they want to learn.

In order to make the selection, a hand-shaped icon will be displayed in the center of the screen. To perform the interaction with the application, the Bluetooth controller must be used;

As for the visualization with the helmet, the Google Cardboard gives the user freedom with respect to the physical space to be able to realize a turn of his head of 360 degrees and be able to observe the whole scene.

4.2 Use Scenario

The system flowchart is shown in Figure 2. Scene of using the system is in Figure 3.

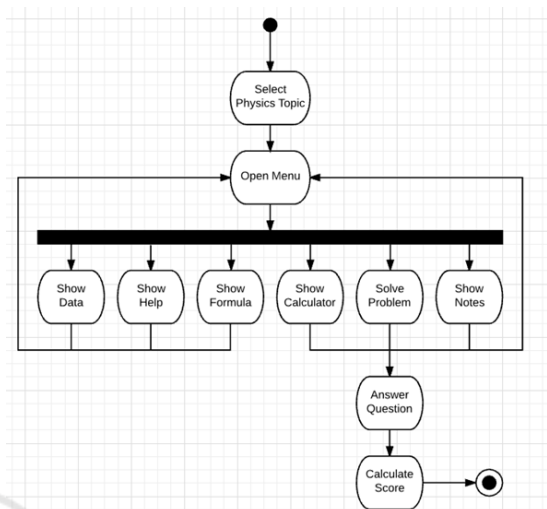


Figure 2: Flowchart of the virtual physics laboratory.



Figure 3: Using the system.

Before beginning to use the application the user must place the mobile device inside the VR Box and start the application; when the application starts is displayed a splash screen, in which the user must select the Movement in Physics that they want to study.

In order to make the selection, a hand-shaped icon will be displayed in the center of the screen. To perform the interaction with the application, the Bluetooth controller must be used;

As for the visualization with the Google Cardboard, the user has freedom with respect to the physi-

cal space to be able to realize a turn of his head of 360 degrees and be able to observe the whole scene.

Once selected the subject to study, a screen is presented in which a voice will guide the user with the actions to be performed to solve the activity in the virtual laboratory is shown in Figure 4.



Figure 4: System menu on the application.

At first the user must enter the data section to see the different variables and their values, the formula section must then be accessed in order to know the formula needed to solve the problem, then you enter the calculator section to make the corresponding calculations, the calculations are saved in the notes section, in the help section the user is allowed to use coins obtained in the application to solve the problem, where a step-by-step resolution of the problem is being carried out, and finally to write the correct answer the user must write the answer in the resolution section.

Once the correct answer is found the score is calculated based on the time used to solve the exercise and the numbers of attempts, to gain additional points the user is asked a question about the subject of movement in physics.

4.3 Educational Activities

In order to improve the user's interest in carrying out the educational activities, we chose to use gamification techniques in conjunction with educational activities.

A score system is created to evaluate the performance of each activity in which the user is rewarded according to his performance, this rewards can be used to purchase virtual objects within the application or as an aid resolving the activities

5 PEDAGOGICAL EVALUATION

The next step after the development of the educational software would be to do the pedagogical evaluation with the help of teachers, who have pedagogical experience, following this sequence, it is necessary to use a methodology for pedagogical validation of the educational software mentioned above, the methodology chosen will be the one developed by Abreu (Abreu, 2010), which was applied in other work, where they wanted to evaluate the didactic point of view of an educational material (Aceituno and Bruschi,).

This methodology consists of three groups of criteria to be evaluated, which are: general usability, didactic usability and usability of distance learning websites (Abreu, 2010)

For purposes of this work we used only the group of didactic usability. This group is composed of 10 criteria. The criteria to be evaluated in the didactic usability are the following:

- Control of the student.
- Student activity.
- Collaborative / cooperative learning.
- Orientation to Objectives.
- Applicability.
- Value Added.
- Motivation.
- Evaluation of previous knowledge.
- Flexibility.
- Feedback.

5.1 Objective

The main objective is to recognize the pedagogical value of the educational software developed, using a methodology oriented to measure the didactic usability.

5.2 Procedure

Once the methodology is chosen, it is necessary to make a survey to apply this methodology. This survey is based on the methodology criteria for didactic usability, which has 18 questions. The questions have the alternatives of "Agree", "Partially agree", "Undecided", "Partially disagree" and "Disagree". Questions are scored from 1 to 5 and mean the following (5) Agree, (4) Partially agree, (3) Undecided, (2) Partially disagree and (1) Disagree.

5.3 Result

The survey was applied to several teachers. The result of the survey is shown in Table 1, Where the criteria column represents the criteria evaluated, where some criteria are represented with two questions in the survey, the second column represents the average score obtained with each question.

Table 1: Results Obtained, Questions: 1. When I use the application I felt that I had control over the tool and not the other way around, 2. When I use the application, I have different ways to get to the same action, 3. When I work with the application, I can abstract myself so much that I lose track of time, 4. The application allows me to interact with other teachers, 5. You can define group jobs with the application, 6. The application shows me through the practice how much progress I had in its use, 7. The application itself shows why it is important to learn how to use it, 8. The application is based on the idea "someone learns better by practice", 9. The application fits into the student abilities, 10. The images in the application help to learn, 11. It is easier to learn topics with the application, than to learn using conventional methods, 12. I want to learn as much as I can from the application, 13. I would like to receive a high rating on future evaluations of the application, 14. I can use my previous knowledge when I use the application, 15. The application helps by displaying previous information before performing a complex task, 16. The application allows the development of consecutive tasks, 17. When I make a mistake the application sends me a friendly warning, 18. The application sends me a motivational feedback.

	Criterion	Average
1	Control of the student	4.714285714
2	Control of the student	4.857142857
3	Student activity	4.142857143
4	Cooperative learning	4.285714286
5	Cooperative learning	4.571428571
6	Orientation to Objectives	4.714285714
7	Orientation to Objectives	4.285714286
8	Applicability	4.142857143
9	Applicability	3.714285714
10	Value Added	5
11	Value Added	4.285714286
12	Motivation	4.857142857
13	Motivation	4.714285714
14	Evaluation knowledge	4.714285714
15	Evaluation knowledge	4.714285714
16	Flexibility	4.142857143
17	Feedback	4.285714286
18	Feedback	4.571428571

The results show a high value in score, all close to 5 or 4, meaning a general acceptance to the criteria of didactic usability.

The didactic value of this software is validated according to this methodology.

According to this methodology.

6 CONCLUSIONS

Through the tests carried out in the previous section and according to the objectives we can conclude the following:

- The results obtained from the point of view of the teachers demonstrate that the educational software developed has a high didactic utility.
- It is verified that when using virtual reality combined with gamification the didactic value of the educational software increases.
- It is shown that students of the UNSA can use virtual reality to enhance the understanding of movement in physics using Google Cardboard
- The educational software needs a feedback from teachers with pedagogical experience.

The evaluation with more teachers and students to measure the performance of the educational software will be carried out as future work.

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