Hi kids: that's funny!

Mechanics 3D Virtual lab

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***Abstract*—The Universidade Júnior, Junior University, is a pioneering initiative of University of Porto taking place during July, since 2005. At the Faculty of Engineering of University of Porto different activities are regularly offered in many of its nine departments and oriented for STEM areas also concerned with trying to contribute to foster young students into these areas.**

The use of emerging technologies is highly accepted by youngsters. So, some of the activities proposed in the context of the Junior University rely on them. Given the great attractiveness created by the use of remote experimentation, virtual reality and augmented reality with haptics interaction, a new application was developed. It is based on the integration of the Oculus Rift Development Kit 2 with a developed set of virtual reality applications. The present work reports results of the use of the Oculus Rift to create the user emersion in a virtual room where different experiments are available and can be "touched" by using 1 DOF haptic. The authors are concerned in evaluating aspects as motivation, adequateness and its immersive capabilities. This work presents a preliminary evaluation study.

Keywords—Virtual reality; HMD; haptic device; Next-Generation VR technology

I. INTRODUCTION

The seed of Junior University (U.Jr.) had been, in 2004, an internal reflection of the University of Porto (U.Porto) prepared by one of the authors and based on the analysis of the lack of vocations for the STEM areas. As the answer from U.Porto, U.Jr., was launched in 2005 by Jose Ferreira Gomes, one of its Vice-Rectors at that time, involving all its schools together. U.Jr. was born with innovative programs specially shaped for different students' maturity grades and extended to different knowledge areas of Porto University, among them areas related with STEM.

Since then, every July, more than 5000 secondary school students from all regions of the country come to U.Porto and are engaged in different activities spread across its 14 Faculties. Every year in July, since 2005, the University of Porto organizes a variety of actions to receive students between 11 and 17 years old from secondary schools in Portugal. Different programs are offered by its 14 faculties:

- Try It in the Summer, 11-12 years old;
- Summer Workshops, 13 to 14 years old;
- Thematic Workshops, 13 to 14 years old;
- Summer Projects, 15 to 17 years old;
- Language Schools, 11 to 17 years old.

The activities have one week duration, since Monday to Friday, 9:00 to 18:00. Language schools usually take 2 weeks [1]. Students are totally integrated in each Faculty where the activity runs, conducted by tutors (usually undergraduate students in the activity's knowledge area), using all Faculty facilities, such as labs, gardens and canteens. In specific moments they also contact with teachers and researchers. In some activities students also do short visits to research labs where some activities take place, trying to demystify the idea of being a researcher and doing research. Each students group is no bigger than 14 elements.

Different programs have distinct structures and objectives. Some include short contacts with different realities along the week. Others are focused on a specific activity like a small project, mainly depending on the maturity of the students. A more detailed description can be found in different references [1-3]. The last reference also presents a brief analysis concerning the period of seven editions, 2005-2011.

The U.Porto Faculties of Engineering and Sciences are aware of the universal problem of attracting and stimulating young people to STEM. So, these actions have also been used to create a deeper dissemination of "Science and Technology with Fun".

The attractiveness of youngsters to the STEM area and the investment on it have been the focus of governments' attention and oriented actions in many places around the world.

In the United States, the Committee on STEM Education (CoSTEM) of the National Science and Technology Council prepared an intermediate report in February 2012 entitled "Coordinating Federal STEM-Education Investments: Progress Report". In this document it is stated that "The health and longevity of our Nation's, citizenry, economy and environmental resources depend in large part on the acceleration of scientific and technological innovations, such as those that improve health care, inspire new industries, protect the environment, and safeguard us from harm. "Maintaining America's historical preeminence in the STEM fields will require a concerted and inclusive effort to ensure that the STEM work force is equipped with the skills and training needed to excel in these fields" [4].

The United States believes that STEM education is of great relevance for "scientific discovery and innovation" needing great investment and so the document analyses and defines different directions for reaching this objective in the coming years.

Similarly, the Committee on Employment and Social Affairs of the European Parliament requested a study focused in providing an "up-to-date overview of the labor market situation in STEM occupations and to analyze European and national approaches to encourage STEM uptake in relation to these labor market needs.", with the objective of identifying practices to increase the quality of STEM skills and qualifications for the future labor market [5]. Even within the present economic crisis the STEM skilled labor in the European Community is increasing up to 2025. The retirement of people from the STEM sector is also important during this period. So, the perspective is that around 7 million of new jobs will be available up to 2025. The document also supports "Initiatives to Encourage STEM Studies and Careers" [5].This document is a measure of the EC perspectives and worries concerning the future market and industries and it is of great relevance mainly when employment is a problem near everywhere in Europe.

Emerging technologies like remote, virtual and augmented reality experimentation and the users interaction with them by increasing the degree of immersion with the virtual replicas of the reality, will be familiar in the future STEM labor environments.

Those IT tools are usually received by STEM students with great enthusiasm and a common feeling of "That's funny".

However, it is crucial to evaluate the real value and the efficiency of the tools and of the effort involved in their development.

This work is focused in the preliminary evaluation of the application named "A Next Generation Lab", whose development was briefly described in [6]. The idea was to offer an experimental room with different experiments inside which where the user can move, choose the experiment, "feel" it and then, just do it!

In the next section a very short description of the lab will be made. Then, the evaluation method will be described, the sample is characterized, and finally, the results will be discussed offering, at the end, a set of conclusions.

II. The 3D Virtual Lab

With a pair of virtual reality glasses and a computer application, one is immersed in a lab with four different mechanical experiments that are explored with the help of a joystick and a 1 DOF Haptic device [7]. The joystick is used to get close to the set-up of one particular experiment. The Haptic device allows feeling the force involved when interacting with each of the experiments. The mechanical experiments can be briefly described as follows:

(i) *Ideal lever*: a movable inflexible beam or bar pivots on a fulcrum without friction. The fulcrum is not positioned in the middle of the beam. At one end of the beam there is a load. The beam can be kept in the horizontal position, by applying a force at the other end. The haptic device allows feeling the force necessary to keep the beam in the horizontal position. The concepts involved in this experiment are force, torque, lever arm and mechanical advantage.

(ii) *Double-acting pneumatic cylinder*: compressed air in a pneumatic cylinder produces a force, in a linear direction, that can be used to move some item. In the case of a double acting cylinder the air produces a force both in extend and retract strokes. Since the contact areas of the compressed air with the piston rod are different in extend and retract stroke, for the same pressure, the force is different. In this virtual experiment, this difference of the force involved when pushing or pulling can be felt with the haptic device.

(iii) *The elastic constant of a spring*: in this experiment one can feel the elastic force by compressing two virtual springs, made of different materials. It is possible to compare the force needed to produce the same displacement in a spring made of steel and another made of brass. The concepts involved are elastic force and elastic constant.

(iv) *Systems of pulleys*: there are three different systems with 1, 2 and 3 pulleys. One can compare the force necessary to raise a given weight, for each system. The concepts involved are force and mechanical advantage.

III. Breif Description of the Activity

In the context of the U.Jr. program, nineteen K12 students visited the virtual lab. Among them 10 students had finished the 9th grade, 6 the 10th grade and 3 the 11th grade.

Each of them used the glasses to enter the virtual room and they walked around it by moving their head and using a joystick to approach any particular experiment. The apparatus were then handled with the haptic device, and they felt the forces in each case.

The students answered a questionnaire about the 3D virtual lab and about the experiments therein, in the end. The questionnaire assesses the motivation to use such emerging technologies, and evaluates the usability of the applications and the adequacy of the experiments.

IV. Student's Opinion About The Virtual Lab

Table I presents the radar graphs obtained for the questions concerning the opinion of the students about the 3D virtual lab in general and Table II similar graphs about the experiments, themselves.

Each of the axis of the graph represents a level of a Likert scale from 1-totally disagree (TD) to 5-totally agree (TA). The level 3 indicates no opinion (NO). The average of the responses to the first question is 4.74 ± 0.45, indicating a high level of motivation to visit the virtual lab. It is also clear that the haptic device was considered very effective to feel the force (4.11 ± 0.66). However, moving around the laboratory was not considered to be very easy, with 26% of the students indicating that it was not easy.

TABLE I. STUDENTS' OPINION ABOUT THE 3D VIRTUAL LAB

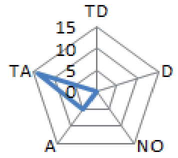
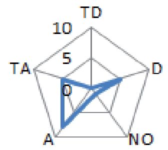
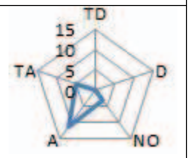
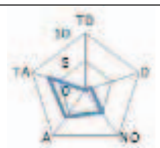
Question	Results
Entering this 3D virtual lab is motivating to learn mechanics.	
By using the joystick it is easy to move around the virtual lab.	
The haptic device allows feeling the force needed to handle the experiments in a very effective way.	

TABLE II. STUDENTS' OPINION ABOUT THE EXPERIMENTS

Question	Results
The pulleys experiment allows "to feel" the *mechanical advantage*	
The spring experiment allows "to feel" *the spring elastic force*	
The pneumatic cylinder experiment allows "to feel" the *available force*	
The lever arm experiment allows "to feel" the *mechanical advantage*	

As to the haptic device, students were able to effectively feel the force involved in the different experienced systems, with an average of around 4 (in 5), in each item of the questionnaire as depicted in Table II. About 22% of the students had no opinion concerning feeling the force with the haptic.

V. CONCLUSIONS

The goal of this work is to show results concerning K12 students' reaction to the "A Next Generation Lab" application. For that purpose, students answered a set of questions that assesses the usability of the virtual lab and indicates if it is viewed as a motivation factor to study engineering related subjects. The responses to those questions show that the virtual lab is able to motivate students and that it has overall good usability. It is also clear that there are some important changes to be made in the application in order to improve user's comfort when moving around the virtual room. These are preliminary results since only a small amount of students experienced with the application. However, they encourage us to continue this task of getting K12 students in contact with engineering related topics.

As mentioned before, universities around the globe are engaged in attracting youngsters to STEM. This is also one of the main goals of the activities proposed in the context of the U.Jr. program. In the case of this particular activity was also intended to show K12 students some emerging technologies in the context of engineering learning. When developing these learning tools, it is important to assess them as a motivating factor to learn and to establish if they can contribute for knowledge gain.

This experience also gives us guidance on how to improve the application so that quantitative studies can be performed, as in a real lab, increasing its' potential as a learning tool. This is just one of the first steps of a more broad and ambitious program of using emerging technologies in the classrooms not only to increase motivation to study sciences and engineering but also to improve knowledge gain.

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