Does virtual reality help students learn to use optical measurement techniques?

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Does Virtual Reality help students learn to use optical measurement techniques?

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Virtual Reality has been used in the course 'Optical diagnostics: techniques and applications' at the Applied Physics department of the Eindhoven University of Technology, to allow students to perform experiments in a laboratory without being exposed to potential dangers of lasers. Students learn about the use of lasers in a laboratory and apply knowledge to do this safely in a virtual laboratory environment. Students' evaluation and interviews showed satisfaction with the use of Virtual Reality in this assignment. As the use of the equipment is very intuitive, all students could start experimenting with the equipment immediately, even those who had no experience with Virtual Reality.

Keywords: Virtual reality, experiential learning environments, active learning.

INTRODUCTION

Using virtual laboratories is an interesting approach to allow students to perform laser experiments without being exposed to potential dangers of lasers. In the course 'Optical diagnostics: techniques and applications' at the Applied Physics department of the Eindhoven University of Technology, students learn about the use of lasers in a virtual laboratory environment and apply knowledge to do this safely.

One way to learn how to use lasers is by experimenting with them [1]. For example, students can measure distances with a laser, build time delays or experience how the diameter of a laser beam can be changed. However, working safely with lasers requires expertise and training [2]. The motivation for this experiment was to know whether Virtual Reality (VR) is an appropriate method to understand measurement techniques.

The assignment consisted of making first a sketch of the setup with mirrors and prims that students build afterwards in the Virtual Laser Lab. In this virtual lab students perceive the laboratory environment through Virtual Reality glasses and make measurements on time delay by moving mirrors and prisms on the laser table with two handlebars [3].

Results of students' evaluation and interviews showed satisfaction with the use of VR in this assignment. As the use of the equipment is very intuitive, all students could start experimenting with the equipment immediately, even those who had no experience with VR.

THE CONTEXT FOR VIRTUAL REALITY

We live in an era of technological developments that offer and expand opportunities for students to learn regardless time and space. This opens up additional venues for students to navigate own interests and follow learning paths. The combination of multimedia with the use of computers and communication technology paves the way to provide different environments to learn and to teach [4]. In addition, the amount of knowledge is rapidly increasing and the advances in information and communication technology hugely increase the volume of easily accessible information in the so-called "knowledge age" of the 21st century society.

In this context, and in line with the Eindhoven University of Technology (TU/e) educational vision 2030, students are expected to have an increasingly broad background in different disciplines and develop professional skills relevant for the engineers of the future. In this regard, students learn to apply these skills in multidisciplinary teams to be able to operate in a system-thinking and strong high-tech industry. Today's students have been socialized differently than students in the past. Moreover, the new generation often called 'Generation Alpha' or 'Generation Z', is born in the digital era and is considered to have different learning preferences, navigates through self-designed paths and has individual interests. Students in this generation are more visually than verbally oriented and more hands-on focused ready to 'trial-and-error' to observe the outcome of the experiments in order to carry out interactions [5]. Students are therefore less 'sit and listen'. This type of students are also expected to demand personalized and customizable learning environments that meets own learning expectations and needs. Preparing this new generation of engineers for the future for the world of work demands an educational shift in Engineering Education, and more specifically for the purpose of this experience, a paradigm shift to educate the physicist for the future and prepare them for the age of technology.

THEORETICAL CONSIDERATIONS

Experimenting, inquiry and inductive teaching are fundamental didactical principles to teach physicists. The combination of these principles together with the use of technology in the form of computer animations, simulations of complex procedures, interactive e-environments to deepen knowledge or the integration of videos and multimedia to visualize physic concepts are a valuable mean to enrich experiments and induct students to think beyond facts [4].

Virtual Reality, as an evolution of computer-assisted instruction [6] facilitates efficient and safe environments that help diving into a three-dimensional world representing real life scenarios. This technique allows students to go through experiences, learn from applying deep knowledge in hands-on practical assignments and analyze data that otherwise could not have been possible due to risks for health, high costs in equipment and implantation, lack of time and alike.

In addition, advantages to include technology in education, and more specifically, virtual labs, is to provide authentic learning environments and prepare physicist to cope with situations that resemble problems of real live devices and systems [7]. In some cases, operating equipment in real settings may imply risks for health and can be dangerous. Simulations in this regard can turn to general while virtual reality environments can offer the real settings to demonstrate situations and problems to experiment with devices, measure errors and verify data without jeopardizing students' health.

The effects of the use of virtual reality in education have been recently researched. There are studies investigating for instance how virtual environments can stimulate learning and comprehension while processing symbolic and experiential information [8]. Research indicates students' improvement performance in engineering education with the use of virtual reality environments [9]. Recent studies have looked at the interaction and conceptual learning showing how virtual learning can support learning [10]. In the field of physics, virtual reality has been abundantly used to help students understand the qualitative dimensions of the phenomena they are studying showing benefits on conceptual understanding and higher-order learning [11-12]. Webster [13] indicates that gaining declarative knowledge can also be gained through VR environments. Research in this regard shows that VR produce higher scores and statistically significant interaction. Bossard et al. (2008) [14] investigated how virtual reality can be applied in educational contexts to learn skills.

A reason to use virtual reality in education is that VR allows for experimentation by the use of forms and methods of visualization and representations [6]. This supports a close up investigation of objects and their features, measurements and devices used for experimentation. In addition, VR can motivate students as they are deeply and actively involved in the implementation of the assignments in which they have to apply knowledge and theories. Furthermore, the possibility to use VR infers that learning takes place with no barriers as students can make use of this technique regardless time and space.

For the purpose of this study, Virtual Reality has been integrated in the master elective course ‘Optical diagnostics’ with the purpose of using a VR-lab as a means to allow students to experiment with lasers with no risks for health. In addition, we also wanted to investigate whether Virtual Reality is a suitable mean for instruction.

INSTRUCTIONAL DESIGN OF THE COURSE

Preliminary considerations for the development of optical measurement techniques in a virtual environment

In order to learn how to deal with lasers and how to use them is by experimenting with them. For example, students can measure distances, create time delays between two laser beams, create a telescope to increase or decrease the size of a laser beam. However, working safely with lasers requires expertise and training. Creating a safe environment in which experiments with lasers can be carried out was our motivation for designing a virtual environment, the Virtual Laser Lab (https://dev.vr-lab.nl/portfolio/virtual-laser-lab/). In addition, we also wanted to know whether Virtual Reality is an appropriate method to better understand how students use measurement techniques.

For the development of the VR-lab of the ‘Optical diagnostics’ course we took into consideration educational theories constructivism and situated learning, so that the creation of the virtual reality environment can represent activities in which students are actively engaged in order to develop motivation and interest. In these authentic scenarios from real life students are responsible for own learning as they first sketch and plan own method to implement in the VR-lab. Moreover, students are to integrate existing knowledge gained in lectures regarding measurements in the hands-on practical assignments in the VR-lab.

The course 'Optical diagnostics' and the assignment in the VR Lab

The master's course module 'Optical diagnostics: techniques and applications' is about the basic principles on which optical measurement techniques such as emission spectroscopy, absorption spectroscopy, laser-induced fluorescence and Thomson scattering are based. Experts in the field of these techniques show on the basis of applications which system parameters, such as temperature, density and speed, information can be obtained, and the advantages and disadvantages of the different techniques. One of the components of the course is the execution of an assignment in the Virtual Laser Lab.

For the assignment students had to build a set-up by using mirrors and / or prisms to enable a laser pulse with adjustable time delay to arrive at a detector. Measured from the laser, the time delay had to be adjustable between 5 and 15 ns. Beforehand they made a sketch of the setup. Then they built the setup in the Virtual Laser Lab (see figure 1) and showed how the time delay could be adjusted. Figure 1 shows how the student perceives the laboratory environment via VR glasses (the screen at the bottom right shows what the student sees at that moment). With two handlebars he can move mirrors and prisms on the laser table and switch the laser on and off. The time delay can also be read from the screen of the box on the laser.

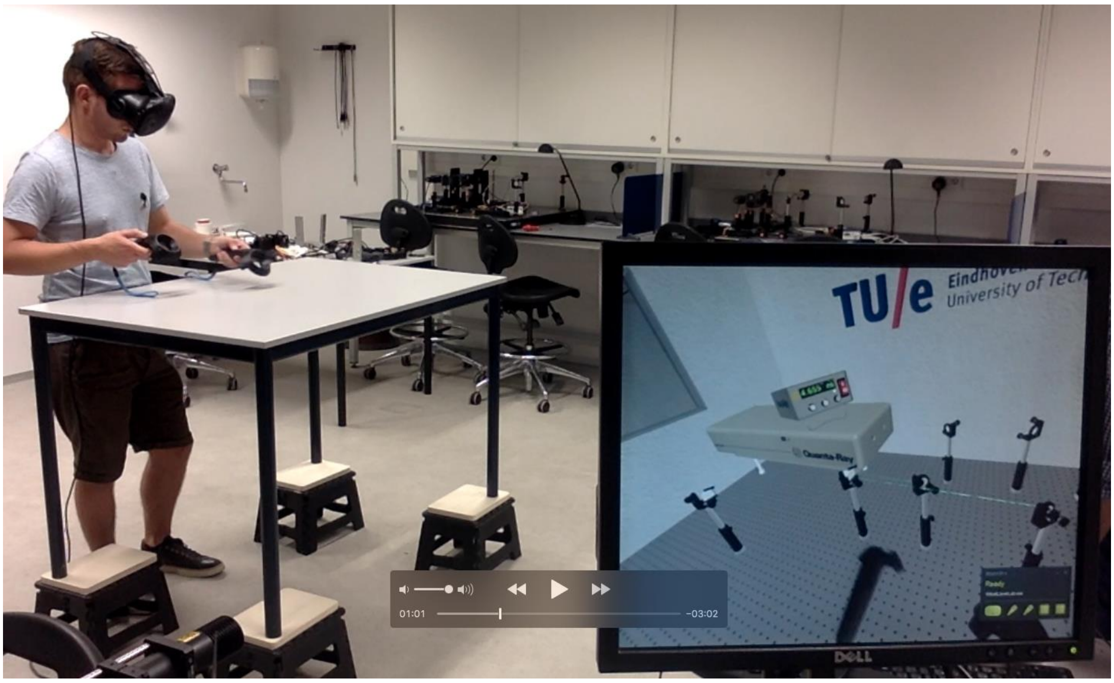

Figure 1. Student experiences the Virtual Laser Lab application and shows how he builds an arrangement to apply a variable time delay in an experiment with a pulsed laser. The computer screen shows what the student sees.

WORK IN PROGRESS: FIRST RESULTS

Although a lot of research has been done into the effectiveness of learning with Virtual Reality, in this first experience we especially wanted to test whether Virtual Reality is an appropriate method to learn to use optical measurement techniques. We also wanted to know if Master students are enthusiastic about the use of VR for carrying out this type of assignment. To find this out, we interviewed a small group of students (N = 4) and set out a short questionnaire. From the 26 students that completed the VR assignment in the lab, only seven filled out the questionnaire (see Table 1). The results of the survey and evaluation interviews with the students showed that they are above average satisfied with the use of VR in this assignment.

Table 1. Students' survey regarding the VR assignment (scores on a scale 1 to 5)

Questions	Average	Standard Deviation
The VR assignment was instructive	4.3	1.1
The experience of the VR-lab was very authentic as the experience in a real lab	3.7	1.0
There is an added value of the implementation of the experiment with the VR-lab.	3.7	1.0
I have enjoyed the experience with the VR-lab	4.9	0.4

During the interviews the students mentioned that the environment is very close to reality, and the handling of the laser and the opto-mechanics in the application was very 'intuitive'. All students could use the equipment immediately, even those who had no experience with VR. This indicates that the use of the VR devices does not detract from the virtual experiment. With more challenging experiments, students will be able to acquire knowledge and develop skills in the use of lasers at the Virtual Laser Lab.

In addition, besides considering the VR assignment intuitive they also found it easy to conduct. Students suggested to integrate more challenging assessments in the VR assignments, which could then count up as interim tests for final grades.

CONCLUSIONS

There are positive lessons learned from this first experience with Virtual Reality to develop new applications and assignments. First of all, VR as embedded in this course offers the possibility to apply optical techniques such as emission and absorption spectroscopy, or laser induced fluorescence and Thomson scattering to gain experience in practice, which would otherwise be difficult (financially) and dangerous to apply in a real lab. Secondly, this experience has been instructive for the students who also see other possibilities for an optimal embedding of VR in the content of the course.

Future plans include the development of other applications on topics such as beam shaping, light polarization, or the use of dispersive optical elements. These topics are very suited to be linked with assignments that can be more problem-solving oriented. These new applications would be an extension of the current diagnostic methods that offer more functionalities regarding optical measurement techniques. The assignments would therefore be more complex in execution and could be used to assess students. In addition, we will include the feedback function within the VR system. In this regard, students will get more interaction with and immediate feedback from the teacher so that iterations and improvements can be conducted in the assignments.

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