Utilizing Virtual Reality to Assist Students in Learning Physics

Foteini Grivokostopoulou[1,3], Isidoros Perikos[1,2,3], Konstantinos Kovas[1], Michael Paraskevas[2,3] and Ioannis Hatzilygeroudis[1]

[1]Computer Engineering and Informatics Department, University of Patras, Greece
[2]Computer and Informatics Engineering Department, Technological Educational Institute of Western Greece, Greece
[3]Computer Technology Institute and Press "Diophantus", Patras, Greece

Abstract—**Physics constitute a fundamental course which poses particular challenges to students to deeply understand. In most cases, classroom lectures are not enough and students should also be involved in experimental procedures in the laboratory to examine procedures and how operations are conducted. In this paper we present the formulation of an innovative 3D virtual reality educational environment that aims to assist students in learning and teachers in explaining various processes of the physics course. In the 3D virtual reality environment laboratories facilitate students to carry virtual experiments, explore procedures and get a deeper cognition and understanding of how procedures are conducted and physics processes work. In addition, pedagogical virtual agents are designed to guide students in the virtual environment and assist them during the training activities. Preliminary studies indicate quite interesting results.**

Keywords—virtual reality; 3D virtual worlds; physics education; science;virtual agents

I. INTRODUCTION

School is the most important period for students. During the years of primary and secondary school education students learn basic aspects of fundamental courses and formulate background knowledge where higher education learning will later build on. It is important that students learn efficiently and deeply the topics of their various courses during their primary and secondary school education and also in entertaining ways with the use of the opportunities that current technological advances offer.

A fundamental course of all levels of primary and secondary school education is Physics. Physics is important to help students understand how the world works and is the main course that higher education on the field of science and technology builds on. In secondary education and in K-12 it is particularly important for students to learn the various topics of physics in depth and efficiently. However, it is commonly acknowledged that physics constitutes a challenging course for students to comprehend. Indeed, several studies point out that students have particularly difficulties in learning aspects of physics and also physics is the course that scares them the most [5]. What is more, for physics education, the classroom lectures are not enough and students should also be involved in experimental procedures in the school laboratories [20]. Indeed, experimentation is the best way to help learners to study physics and understand phenomena and various procedures. S,o it is important to offer to the school community innovative environments that will attract students' interest in physics course and also assist them in learning physics in an entertaining and efficient way. However, the teaching of physics in schools in most cases is restricted solely to traditional education approaches based on classroom lectures, which are passive and fail in efficiently teaching how to solve problems, and recite the solutions instead something that can lead to student frustration [16][11].

In this paper we present the formulation of an innovative 3D virtual reality educational environment that aims to assist students in learning and teachers in teaching a physics course. It is based on 3D virtual worlds technology and it is implemented in Opensimulator, an open source platform for formulating 3D virtual reality environments. Virtual worlds naturally allow more complex interactions, learning experiences as well as encourage learners' empowerment through increased interactivity and can drive in more constructive understandings of learning [1] [3] [4]. They have been used in various challenging domains [6][8] and are quite useful for offering participatory learning processes, and are reported to lead to a better cohesion and cooperation among students' [14] [17]. The educational environment could be utilized both in formal and informal learning approaches and become an assistive tool for school education. In the virtual environment, various educational infrastructures such as virtual classrooms, agents and laboratories aim to represent the real world.

The rest of the paper is structured as follows: Section II presents the 3D virtual reality environment developed to assist teachers in teaching and students in learning physics while Section III presents the evaluation study conducted and the results collected. Finally, Section IV concludes the paper, discusses the main findings of the work and presents key directions that future work will examine.

978-1-5386-0900-2/17/$31.00 ©2017 IEEE 12-14 December 2017, The Education University of Hong Kong
2017 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)

II. VIRTUAL REALITY ENVIRONMENT

A. Educatuinal Infrastructure and constructions

The 3D virtual reality educational environment possesses innovative educational infrastructure, and offers immersive and efficient learning opportunities. In the virtual environment, the students will have the ability to virtually visit virtual laboratories, perform experiments, explore procedures and phenomena, examine the ways that they are conducted and also be guided towards analyzing and explaining them through the scientific method.

The virtual educational environment and the laboratories will be designed in a way that supports students to form appropriate mental models of involved concepts, by visualizing them and allowing interactions with the virtual phenomena and processes. When students learn new abstract concepts it is quite hard without appropriate connection to concrete examples. The 3D virtual reality educational environment and the visualization of procedures aim to help students connect abstract concepts and procedures to concrete experiences and examples. Indeed, one of the most vital and promising affordances of the 3D virtual environment is to provide spatial instruction. Also, by teaching the students to study in 3D virtual reality and by using visualization techniques their spatial cognition can be enhanced [13]. In addition, simulations are used as a mean to help students confront their cognitive constraints and develop functional understanding of physics [12] [18]. Simulations can facilitate students' active engagement in the construction and reconstruction of conceptual knowledge in their learning of abstract concepts in the microscopic physical world [12].

The 3D virtual reality educational environment can support both formal and informal learning and also synchronous and asynchronous learning activities. The immersive capabilities that they can offer, constitute a great way to attract students' interest, stimulate and engage them in proper and effective learning approaches that promote active learning and cultivate the students' critical thinking. It will also offer innovative learning activities and the virtual educational platform that will be developed will support students' active learning, allowing learners to experiment and put theoretical knowledge into practice.

A special part of the virtual reality environment concerns the virtual laboratories that will be designed to facilitate students to carry experiments, explore procedures and get a deeper cognition and understanding of how procedures are conducted and physics processes operate. The virtual laboratories consist of various objects and constructions that enable students to interact with them and experiment in similar conditions to the real world environment. In Figure 1, example constructions and objects that visualize and simulate various procedures are illustrated.

An important functionality and an advantage of virtual laboratories lies in reducing the number of expensive physical laboratories that must be maintained by school and also in allowing students to remotely access virtual labs at any time [19]. Along with the visualizations of physics phenomena and the simulation of their actions and their behavior, the laboratories provide realistic mechanisms for the user to interact with the underlying physical and mathematical models involved. Laboratory experiments and virtual reality simulations can enable the students to compare theoretical with experimental results since they embody learning by doing [19][2]. Students can be engaged in various educational activities and learning scenarios that offer students an attractive, entertaining and efficient way to learn various procedures of the physics curriculum.

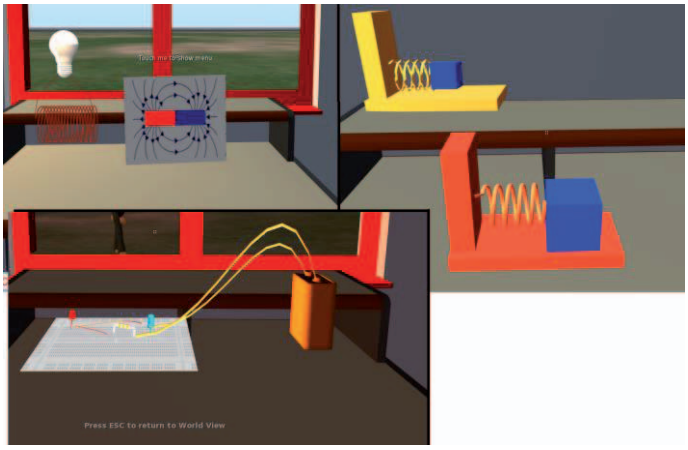

Fig. 1. 3D constructions visualizing procedures and operations in the virtual laboratory

B. Pedagogical Agents

In the virtual environment all users and the students are represented as avatars and can move within the world, visit laboratories and classrooms, examine 3D objects and interact with them and study educational materials. The use of avatars in the virtual world provides a sense of presence and awareness and enhances the ability to interact with the 3D constructions in the world and also communicate and collaborate with the other students and the teacher.

Fig. 2. Albert Einstein pedagogical agent as a teacher in a laboratory in the virtual world

The pedagogical virtual agents are designed to guide students in the virtual environment and assist them during the training activities. In Figure 2, a pedagogical agent that is designed after Albert Einstein is presented.

C. *Physics Topics Analysis*

The specification of the topics of the physics curriculum that are offered in the virtual world and the corresponding visualization and simulation of their procedures concern an important aspect to determine. So, to this regard, a two stage analysis was conducted. The first stage of the study aimed to specify the exact content of the physics topics and the second to analyze them and specify the difficulty that each topic poses to students to understand and deeply comprehend.

In the first stage, as mentioned above, a preliminary study was conducted in order to specify the topics of the physic curriculum that are part of the secondary educational system. The results concluded to three main topics that are the "Mechanics and forces" "Electricity and magnetism" and the "Structure of matter". Each one of the topics is further analyzed to a series of subtopics as illustrated in Table I.

TABLE I. TOPICS AND SUBTOPICS OF PHYSICS CURRICULUM

MECHANICS AND FORCES	
	Linear motion (velocity, acceleration, vectors and scalars)
	Newton's laws of motion (force, momentum)
	Gravity
	Conservation of momentum
	Moment – conditions for equilibrium
	Work
	Energy (conversion, principle of conservation, power)
	Oscillations and waves
	Gases (density and pressure)
ELECTRICITY AND MAGNETISM	
	Electrification by contact
	Electrification by induction
	Distribution of charge on conductors
	Force between charges
	Electric fields
	Electric energy
	Potential difference
	Capacitors and capacitance
	Electric sources
	Electric current
	Resistance
	Effects of electric current
	Magnetic fields
	Current in a magnetic field
STRUCTURE OF MATTER	
	The electron
	Thermionic emission
	Photoelectric emission
	X-rays
	Structure of the atom
	Structure of the nucleus
	Radioactivity
	Nuclear energy
	Ionizing radiation and health hazards
	Quarks and the Standard Model

A total number of 33 subtopics where specified. More specifically, the physics teachers specified 9 subtopics for the topic of Mechanics and Forces, 14 subtopics for the Electricity and magnetism and 10 subtopics for the Structure of matter. After the specification of the topics and the subtopics of the physics course, a second study was conducted. The aim of the study was once again twofold. First, a main aim was to assess the challenges and the difficulties that each topic of the physic domain poses to students. The second aim was to assess the difficulties that physics teachers faces while explaining procedures of physics topics. The participants in the study were three physics teachers having many years of experience in secondary education. In the context of the study, the teachers were given the main topics of physics curriculum of secondary education level that are presented in Table I among with the main subtopics of them and specified for each one, i) the challenges that it poses to students to deeply understand ii) the challenges that it poses to teachers to properly explain. The teachers were asked to assess the topics and specify their challenges on a five-level evaluation scale. The results of the study are illustrated in Figure 3.

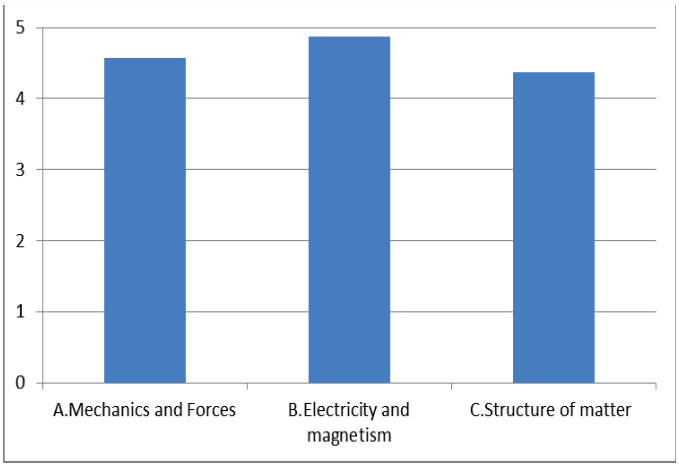

Fig. 3. Teachersagent as a teacher in a lab in the virtual world

The results indicate that among the topics the most challenging for students to understand is the Electricity and magnetism for with a difficulty level of 4.87 and after that the Mechanics and forces for which the teachers specified to have an average difficulty of 4.56. Finally, the difficulty of the topic of Structure of matter was specified to be 4.37. The analysis conducted reveals quite interesting findings regarding the aspects and the topics that pose quite great challenges for students to deal with. Given the analysis from the teachers, the subtopics of Electricity and magnetism consist of the most complex concepts that pose quite great challenges to students to comprehend and deeply understand.

III. Concusions and Future Work

Physics constitute a fundamental course of school education which contains aspects that pose particular challenges to students to deeply understand. In this work we present an innovative educational environment that is based on virtual reality which aims to assist students in learning efficiently several topics of physics course. In the 3D virtual reality environment laboratories facilitate students to carry virtual experiments, explore procedures and get a deeper cognition and understanding of how procedures are conducted and physics processes work. In addition, pedagogical virtual agents are designed to guide students in the virtual environment and assist them during the training activities. Preliminary studies indicate quite interesting results.

There are various directions that future work will focus on. Initially, a main direction will focus on the integration of gamification learning scenarios that will enhance the learning procedures and the training activities with entertaining and fun factors. Another direction concerns the formulation of a feedback sequencing framework like the one presented in [15] that will provide students with assistance while working on experiments and also properly and in detail explain possible errors that they may make. What is more, we plan to conduct a large scale evaluation study that will assess students' opinions and experiences while learning with the virtual reality educational environment and also assess the efficiency of the various learning scenarios and training activities designed in the 3D environment. Finally, future work will also focus on the integration of learning analytics mechanisms in the virtual reality environment that will record students' actions and analyze their behavior during the learning activities and also utilize educational data mining techniques to analyze and extract knowledge regarding students' learning construction.

References

[1] Christopoulos A., Conrad M. and Shukla M. (2016). How Do Students 'Really' Interact with Virtual Worlds? - The Influence of Proper Induction for Virtual Interactions.In Proceedings of the 8th International Conference on Computer Supported Education, ISBN 978-989-758-179-3, pages 43-54. DOI: 10.5220/0005755700430054

[2] Dalgarno, B. (2002). The potential of 3D virtual learning environments: A constructivist analysis. Electronic Journal of Instructional Science and Technology, 5(2), 3-6.

[3] De Freitas, S., Rebolledo-Mendez, G., Liarokapis, F., Magoulas, G., & Poulovassilis, A. (2010). Learning as immersive experiences: Using the four-dimensional framework for designing and evaluating immersive learning experiences in a virtual world. *British Journal of Educational Technology*, *41*(1), 69-85.

[4] Duncan, I., Miller, A., & Jiang, S. (2012). A taxonomy of virtual worlds usage in education. *British Journal of Educational Technology*, *43*(6), 949-964.

[5] Freedman, R. A. (1996). Challenges in teaching and learning introductory physics. *From High Temperature Superconductivity to Microminiature Refrigeration*, *313*.

[6] Grivokostopoulou, F., Perikos, I., & Hatzilygeroudis, I. (2016, December). An innovative educational environment based on virtual reality and gamification for learning search algorithms. In Technology for Education (T4E), 2016 IEEE Eighth International Conference on (pp. 110-115). IEEE.

[7] Grivokostopoulou, F., Perikos, I., & Hatzilygeroudis, I. (2017, September). Examining the Efficiency of Feedback Types in a Virtual Reality Educational Environment for Learning Search Algorithms. In International Conference on Brain Function Assessment in Learning (pp. 169-175). Springer.

[8] Grivokostopoulou, F., Perikos, I., Konstantinos, K., & Hatzilygeroudis, I. (2015, July). Teaching Renewable Energy Sources Using 3D Virtual World Technology. In Advanced Learning Technologies (ICALT), 2015 IEEE 15th International Conference on (pp. 472-474). IEEE.

[9] Grivokostopoulou, F., Perikos, I., Kovas, K., & Hatzilygeroudis, I. (2016, March). Learning Approaches in a 3D Virtual Environment for Learning Energy Generation from Renewable Sources. In FLAIRS Conference (pp. 497-500).

[10] Hashemipour, M., Manesh, H. F., & Bal, M. (2011). A modular virtual reality system for engineering laboratory education. *Computer Applications in Engineering Education*, *19*(2), 305-314.

[11] Iskander, M. F. (2014, July). Multimedia and technology based electromagnetic education. In *Antennas and Propagation Society International Symposium (APSURSI), 2014 IEEE* (pp. 531-532). IEEE.

[12] Jimoyiannis, A., & Komis, V. (2001). Computer simulations in physics teaching and learning: a case study on students' understanding of trajectory motion. *Computers & education*, *36*(2), 183-204.

[13] Ma, T., Xiao, X., Wee, W., Han, C. Y., & Zhou, X. (2014).A 3D Virtual Learning System for STEM Education.In Virtual, Augmented and Mixed Reality. Applications of Virtual and Augmented Reality (pp. 63-72). Springer International Publishing.

[14] Pellas, N., (2014). A theoretical cybernetic macro–script to articulate collaborative interactions of cyber entities in virtual worlds. International Journal of Learning and Change,7 (3),156-180.

[15] Perikos, I., Grivokostopoulou, F., & Hatzilygeroudis, I. (2017). Assistance and feedback mechanism in an intelligent tutoring system for teaching conversion of natural language into logic. International Journal of Artificial Intelligence in Education, 1-40.

[16] Pirker, J., Riffnaller-Schiefer, M., & Gütl, C. (2014, June). Motivational active learning: engaging university students in computer science education. In *Proceedings of the 2014 conference on Innovation & technology in computer science education* (pp. 297-302). ACM.

[17] Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrović, V. M., & Jovanović, K. (2016). Virtual laboratories for education in science, technology, and engineering: A review. *Computers & Education*, *95*, 309-327.

[18] Rutten, N., Van Joolingen, W. R., & Van der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers & Education*, *58*(1), 136-153.

[19] Scheucher, B., Bayley, P., Gütl, C., & Harward, J. (2009). Collaborative virtual 3d environment for internet-accessible physics experiments. *International Journal of Online Engineering*, *5*(REV 2009), 65-71.

[20] Wu, Y., Chan, T., Jong, B., & Lin, T. (2003, July). A web-based virtual reality physics laboratory. In *Advanced Learning Technologies, 2003. Proceedings. The 3rd IEEE International Conference on* (p. 455). IEEE.