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Learning Approaches in a 3D Virtual Environment for Learning Energy Generation from Renewable Sources

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Abstract

Virtual worlds open up new horizons in education. Given the technological characteristics of virtual environments, a primary research area concerns the consideration of the pedagogical approaches that efficiently leverage their unique capabilities and enhance students learning. In this work, we examine the efficiency of learning approaches in a 3D virtual world environment developed to assist tutors in teaching and students in learning topics of the domain of renewable energy sources. In the 3D virtual environment, several types of power plants, factories and constructions have been designed to simulate their real world operations. The environment provides learners the possibility to interact with 3D machines and constructions and manipulate their parts, aiming at getting a deeper understanding of their functionality. Various learning activities based on the principles of constructivism have been designed, aiming to actively engage students and make learning more entertaining and efficient. The platform has been evaluated in real classroom conditions and the results indicate that the utilization of suitable learning activities in terms of students' active engagement and constructivism knowledge acquisition can motivate students and improve learning efficiency.

Introduction

Virtual environments are gradually becoming an important part of the educational technology landscape, mainly due to their intrinsic capability of involving 3D simulations to represent real world operations (Allison et al. 2012). They naturally allow more complex interactions and learning experiences as well as encourage the learners' empowerment through increased interactivity and drive in more constructive modes of learning (Chesney et al. 2009; De Freitas et al. 2010). Also, they are useful for offering participatory learning processes, can lead to a better cohesion and cooperation among students (Pellas 2014) and have been used with great success in challenging domains (Mikropoulos and Natsis 2011), to offer immersive learning processes to learners and give them the opportunity to explore how procedures are conducted and constructions operate via proper simulations and visualizations (Ku and Mahabaleshwarkar 2011).

The domain of energy generation from renewable energy sources (RES) is considered to be a difficult domain for tutors to teach and learners to deeply understand (Blockstein et al. 2010) and cannot be approached as a traditional engineering subject, since it consists of complex processes that traditional education fails to efficiently teach. To assist tutors in teaching and students in learning topics of energy generation from RES, we have developed a 3D virtual world environment. In the virtual environment, several types of factories and power plants have been designed to simulate their operation in the physical real world. Educational infrastructure, such as virtual libraries and classrooms, offer tutors the ability to conduct synchronous lectures, while virtual laboratories allow learners to experiment with specific processes and constructions.

In this work, we present the educational approaches adopted and the learning activities offered in the virtual world environment and examine their learning efficiency. Learning activities were designed in line with students' active learning and constructive knowledge acquisition principles, aiming to engage learners by offering entertaining ways of learning, while effectively leveraging the unique characteristics of virtual worlds for the best benefit of students.

Construction Principles of the Virtual World

The 3D virtual world simulates the real world environment so that the learners can study in an environment that is close to reality. In the virtual world, several power plants, like hydroelectric plants, and constructions like wind turbines, photovoltaic panels and hydropower turbines have been developed with the aim to represent and simulate their functionality in the real world. The students have the ability to virtually visit those plants and factories and explore their parts and how they operate. The virtual machines and constructions have been designed in a way that supports students forming appropriate mental models of involved concepts, by visualizing them and allowing interactions with the virtual phenomena and processes (Grivokostopoulou et al. 2015). It can be hard for students learn new abstract concepts, without appropriate connection to concrete examples (Ma et al. 2014). 3D constructions and visualization of operations 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 constructions is to provide spatial instruction. Also, by teaching the students to think in 3D, using visualization techniques, their spatial cognition can be enhanced (Merchant et al. 2012). In this spirit, students and tutors can interact with a construction inside the virtual world, can inspect and manipulate specific parts of it, aiming at getting a deeper understanding of their operational characteristics and the exact way that it functions and interacts with other parts of the construction. When manipulating a part of an object, proper explanations are presented to the student, indicating how it operates, how it is interconnected with other parts of the machine and explain its exact role in the process conducted by the machine. In Figure 1, a basic 3D construction that represents a simple type of wind turbine is illustrated.

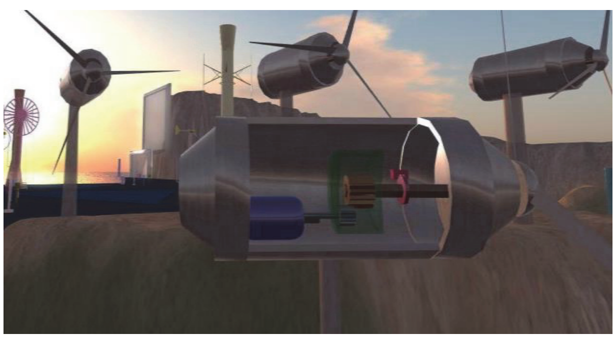

Fig 1. A simple wind turbine in the 3D virtual world

When students interact with the constructions and manipulate their parts, specific visualizations and dialog messages may appear describing the characteristics, functionality and animating the sub-processes of the main process. In this line, theoretical and abstract concepts can be associated via the object's animations with specific operations and practical functionalities

Learning Approaches in the Virtual World

A fundamental aspect of the students' training in 3D virtual environments concerns the learning approaches that are offered to them. In the virtual world, several learning activities and training scenarios have been designed and are offered to learners. The goal of the learning scenarios is twofold. First, to actively engage students to experiment with constructions, put theoretical knowledge into practice and get a deeper understanding of the constructions and their parts/operations. Second, to provide learning in an entertaining way. In general, in the virtual world, the training scenarios and the learning activities have been designed in line with students' active learning, rely on constructionism and aim to engage learners, by offering entertaining ways of learning. However, most of all, they effectively leverage unique characteristics of virtual worlds for the best benefit of students.

To support the first objective, constructionism learning approaches, requiring the formulization, building and rebuilding of explicit objects (Papert 1980), are adopted in the 3D virtual world environment, which demonstrates various capabilities and facilitates the manipulation of objects and constructions by learners (Girvan and Savage 2010). It can offer more effective learning activities and is interesting to be implemented in virtual worlds (Bessiere et al. 2009; Fominykh and Prasolava-Forland 2012). In this spirit, learning scenarios mainly rely on the principle to engage students in activities, where they should interact with constructions, manipulate parts of machines, and formulate complex constructions in a constructionism approach.

In addition, to achieve the second objective of learning in the virtual world, the scenarios were formulated in line with gamification principles that "gamify" various real world problem situations and learning occasions. Gamification can enhance learning activities with motivational affordances in order to invoke "gameful" experiences and further behavioral outcomes (Hamari et al. 2014). In this spirit, a student has to manipulate constructions in the context of gamification scenarios. For example, students can participate in training scenarios, where electrical failures have occurred and have blacked out the energy production in a factory. Then, students, working as individuals or in teams, are requested to trace the failure and make appropriate actions to fix it. To face the problem and complete the purpose of a training scenario (e.g. the blackout problem in this example), students have to examine the power plants and constructions, trace the origin of the malfunction and make suitable actions to fix it. The solution may require to identify the faulty part of a machine and to replace it by determining an item/part having the necessary specifications. After successful repair of the faulty object and resolution of the problematic situation, rewards can be given to students, who were able to accomplish the tasks.

Furthermore, in some training scenarios, students are given practice exercises consisting of sets of questions to answer that require them to visit factories and examine special processes or devices and interact with them. The aim is to examine those process and interact with the devices in order to understand the way they operate and after that specify the answers to the questions. In the learning scenarios, students can take part as individuals or as teams consisting of two or more students and the activities assigned to them can support and enhance their communication and collaboration.

Evaluation

An experimental study was designed to assess the learning capabilities of the virtual environment and the efficiency of learning approaches. The participants were 105 students enrolled in the renewable energy course of a vocational school. All students were in the 2nd or 3th year of study and their age ranged from 15 to 17 years. In order to evaluate the learning effectiveness of the virtual world environment, we followed a pre-test and post-test approach. The students were randomly divided into three groups, of 35 students each, namely groupA, groupB and groupC, and the numbers of girls and boys in each group were almost the same. Initially, all participants took a pre-test, aiming to assess students' domain prior knowledge on renewable energy concepts. The pre-test consisted of multiple choice exercises of various difficulty levels and the maximum pre-test score was 10 points. Its duration was 45 minutes and was conducted in the school's computer room.

A preliminary analysis of the pre-test scores was performed using a one-way Analysis of Variance (ANOVA), to determine whether there was any prior knowledge difference. The means of pre-test for groupA, groupB and groupC were 3.74, 3.625 and 3.57 respectively. The comprehension check scores indicated no significant differences among the students of the groups ($p=0.381 > 0.05$, $F=0.974$). The results of the students' data showed that the random division of students resulted in no statistically significant differences between the three groups.

After that, each group was selected to study for two weeks under different learning conditions and approaches in one session of 30 minutes per day. GroupA was selected to study the course topics by using the conventional education material (textual presentations) from the content repository of the course, groupB was selected to study freely in the 3D Virtual World without using any learning scenarios and the students of groupC to learn through the 3D Virtual World using the available learning scenarios and training activities. After the two weeks learning phase, all participants took a post test that consisted of multiple choice questions of the same difficulty levels with those in pre-test and the students were given 45 minutes to complete the test and submit their answers.

Table 1. Post test results

	N	Mean	Std.Deviation	Std.Error
GroupA	35	4.987	0.781	0.110
GroupB	35	6.971	1.097	0.186
GroupC	35	8.514	1.025	0.173

A one-way ANOVA was conducted to determine whether there are any significant differences between the means of three independent groups for the post-test. The results of the ANOVA analysis showed that there is a statistically significant difference between our groups on learning the topics of the renewable energy course ($F(2,102) = 114.62$, $p = 0.00 < 0.05$). In addition, multiple comparisons show which groups differ from others. The Tukey post-hoc test is generally the preferred test for conducting post-hoc tests on a one-way ANOVA. The results show that there is a significant difference in the post-test between the groups ($p<0.05$) and indicate that students of groupC performed much better than those of the two other.

Table 2. Questionnaire Results

		GroupB			GroupC		
	Questions	Agree/ strongly agree	Neutral	Disagree/ strongly disagree	Agree/ strongly agree	Neutral	Disagree/ strongly disagree
1	It is easy to learn how to use the interface of VW.	82.86	12.86	4.29	85.71	11.43	2.86
2	I enjoy learning in the virtual world.	85.71	10.00	4.29	94.29	5.71	0.00
3	The VW increased the attractiveness of the RES course.	85.71	10.00	4.29	90.00	8.57	1.43
4	The VW can enhance my engagement in the RES course.	82.86	14.29	2.86	91.43	8.57	0.00
5	The VW can enhance my learning interest and motivation.	81.43	18.57	0.00	87.14	12.86	0.00
6	The VW helped me learn more effectively.	88.57	11.43	0.00	97.14	2.86	0.00
7	The 3D objects enriched my knowledge.	87.14	12.86	0.00	91.43	8.57	0.00
8	The interactions with the 3D objects helped me better understand by the representation of their operation.	84.29	15.71	0.00	92.86	7.14	0.00
9	I will suggest the VW to be integrated into the corresponding course and be used by the next year's students.	92.86	7.14	0.00	94.29	5.71	0.00
10	The scenarios in VW are clear and easy to understand.				91.43	8.57	0.00
11	The scenarios in VW constitute a contributing factor in collaborating with my peers.				88.57	11.43	0.00
12	The scenarios are entertaining and can improve my performance				92.86	7.14	0.00

After that, the students of groupB and groupC answered a questionnaire in order to explore their feelings and opinions (Table 2). The questionnaire of groupB consisted of 9 questions based on a Likert-scale (strongly agree, neutral, disagree) and that of groupC had three additional questions regarding the learning scenarios of the virtual world. The results showed that approximately 85% of students of groupB indicated that they enjoyed learning, while the majority of groupC students 94% indicated that they enjoyed learning, something that results from the training scenarios that were available to them. Students of groupC stated that the virtual world enhanced their engagement (91% in contrast to 83% of groupB) and also their interest and motivation (87% in contrast to 81% of groupB). An interesting factor concerns the students' impressions on the assistance of the virtual world to help them learn more effectively. In this case, the majority of students of groupC (97%) find learning to be effective, in contrast to 89% of groupB. Regarding the 3D objects in the virtual world, both teams found that they helped them enrich their knowledge (87% of groupB and 91% of groupC), while students of groupC state that the 3D objects helped them better understand operations and how constructions operate. This is an interesting factor since the training scenarios greatly scaffold students' practice with objects and also interactions and various objects manipulations. In addition, most students of both groups agreed that the virtual world is easy to use (83% for groupB and 86% for groupC). Also, the outcomes of the training scenarios are quite satisfactory in terms of increased motivation, engagement and collaboration in the learning tasks as well as enjoyment over them.

Conclusions and Future Work

In this work, we examine the efficiency of learning approaches in a 3D virtual world environment that assists students in learning topics of the domain of renewable energy sources. The evaluation study indicates that the virtual environment attracted student's interest and that the 3D constructions and visualizations can provide a great way to explain how constructions operate and processes are conducted and making students learning more efficient. In addition, findings indicate the training scenarios to be entertaining, improving students' performance and facilitating their collaboration with their peers. The overall conclusions we derive from this study are that the gamification training scenario in virtual environments in line with students' active learning and constructivism knowledge acquisition lead to the expected indications of student engagement and their deeper comprehension and understanding of the topics. As a future work a bigger scale evaluation will be conducted to provide a deeper insight of the platform's capabilities and the learning approaches efficiency. Furthermore, another direction concerns the formulation of collaboration learning activities, role playing situations and approaches to make students study, practice and cooperate in teams of professionals.

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