3D virtual classroom environment for teaching renewable energy production and substation equipment

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Abstract In this investigation, a virtual classroom for Uşak University’s Electricity Program is designed, implemented and then tested by using the 3D virtual environment Second Life. When online, learners and instructors are able to correspond with each other by using their own avatars, chat vocally, make presentations and watch videos, as well as utilise all opportunities of a 3D virtual environment. Furthermore, learners can access the educational materials of the Electricity Program and interact with each other even when the educator is not available, giving opportunities for both synchronous and asynchronous distance education. The 3D virtual environment is analysed and evaluated here in terms of education costs, and advantages or disadvantages for both learner and educator.

Keywords distance education; Second Life; teaching renewables; virtual classroom

Along with developing technology, distance education gains more and more ground. With cheap access and widespread use, the Internet now presents a frequently used environment for distance education. Thanks to powerful graphic cards, it is possible to offer more realistic distance education opportunities through internet-based three-dimensional (3D) virtual worlds than just web sites.

Modelling and simulation represent important aspects of educational processes where practice is not feasible in the real world.1 Through a simulator, students can be educated synchronously or asynchronously in 3D virtual learning environments which are conducted to manage presentation, administration and assessment of coursework.2 In these worlds educators can implement student-centered teaching pedagogies utilising immersive, deep, authentic, active and constructivist learning over a range of subject disciplines.3 For example, Aydin and Yuzer reported a virtual classroom project prepared for a Distance English Language Teacher Training Program;4 Li et al. proposed to build an immersed virtual e-learning environment;5 Kara et al. designed and developed a remote and virtual environment for experimental training in Electrical and Electronics Engineering.6 A virtual chemistry laboratory and English language education system have been demonstrated in a virtual reality environment.7 Wei described an online virtual experiment on an integrated circuits laboratory.8 Lucia et al. presented a large body of literature on virtual classroom and 3D virtual learning environments.9
Virtual environments in education
There exist many virtual environments for educational purposes, such as Second Life (SL), Active Worlds, There, Croquet, Worlds, Tixeo, I-maginer and Moove. In a comparative study by Reis et al., which takes into account six criteria: ‘realisation of world’, ‘user interface’, ‘communication’, ‘avatar’, ‘scalability’ and ‘security’, SL scored more total percentages than either Active Worlds or There environments. Among SL, Active Worlds, There, Croquet, Worlds, Tixeo, I-maginer and Moove, the most promising environment, according to the results of a review by Tsiatsos et al., is SL.

Second Life has already been tested in a variety of educational contexts. In a study by Hansen et al., undergraduate students experienced developing in-world collaborative projects in SL; McKinney et al. used SL with learning-disabled students in higher education; and Chen et al. constructed a 3D virtual university using SL. In a previous power engineering application, Aydogan et al. designed and implemented a 3D hydroelectric power plant to teach undergraduate students in SL. For readers requiring more details of the approach, a large literature review of education in SL was investigated in Refs 16 and 17.

Renewable energy systems
Due to the combination of decreasing and already limited fossil energy sources and increasing rate of energy consumption globally, facilities based on renewable energy systems, especially those of wind power, have been enlarged. These facilities are built and operated by electrical engineers and technicians and theoretical courses about such facilities should be supported through practical experience in order to teach and train qualified individuals in faculties or colleges. However, for valid safety reasons, entering an electrical substation area is not allowed when it is operating; likewise, the interior of a wind turbine cannot be viewed. In cases of these or other obstacles to achieving practical experience, 3D virtual environments can be used as an interactive learning area. We chose Second Life as a 3D world because of its useful tools and advantages as mentioned above.

In this study, through building and scripting abilities, electrical energy produced by a wind farm will be distributed by using the substation in an SL virtual environment. Here, the relevant students can understand the entire process by interacting with objects and talking to the educator. Following an overview of SL, the creation and use of a 3D energy simulation field will be described. In the conclusion part, the pros and cons of SL in terms of education costs, and potential benefits or disadvantages for learners and educators will be reported.

An overview of Second Life
Second Life is a multi-user 3D virtual environment, in which avatars controlled by users can interact with each other, and with objects and scripts. The avatars can buy land or a region in this virtual world and use it for their own purposes, such as to construct a library, museum, university or classroom, as well as for fun. Many educators and teaching institutes, particularly in the USA and UK, already investigate and use SL as a teaching platform.
Exploring, communicating and connecting in SL are needed to create a SL personality for free as well as to download free 3D browsing software from the SL official website (http://secondlife.com). Users can also choose premium membership payment to own a virtual private home or some benefits listed in Ref. 18. For the 3D browsing software, the user’s computer must meet some system requirements as listed in Ref. 18.

No-payment users can build and script in places where permissions are not needed. The avatars can create buildings for entertainment, shopping, educational purposes etc. Thus, the SL world grows along with its users. The users can communicate with each other through using the typing-enabled or the voice-enabled chat system, walk or fly to reach desirable places, and change their avatar’s skin, clothes or accessories in SL.

In this study, SL is used to build a 3D classroom, a wind turbine system and the substation equipment. The aim is to teach how electricity is produced and transmitted in a renewable energy system, for undergraduate students in the Electricity Program at Uşak University in Turkey. For this, four students were chosen to be trained and experiment with SL's features such as walking, flying, controlling a camera and basic skills. Afterwards, they attended a 3D classroom and the building parts to learn about the power system.

Creation of a 3D classroom and power system in SL
A 3D virtual classroom was designed to give basic information about wind turbine energy systems to relevant students (Fig. 1). In SL, the students can watch the presentation and listen by using voice-enabled chat and ask the educator questions.

Fig. 1  The virtual classroom in SL.
After the introduction phase, a wind farm system with a substation was demonstrated and interacted with by the students. The students have the opportunity to study how a wind turbine producing electrical energy works, while looking at the inner parts of the turbine. This is represented in Fig. 2.

Figure 3(a) shows the voltage produced by the wind farm. This voltage is influenced by variation’s in wind speed, so the form of the voltage is not pure 50 or 60 Hz sinusoidal and it is not suitable for transmission, distribution and consumption. The producing voltage has first to be converted to a controlled d.c. level by using a converter. Then a d.c.-a.c. inverter is used to obtain useable 50–60 Hz a.c. voltage. The educator explains the conversion system utilizing 3D parts in Fig. 3.

After the conversion, a.c. voltage should be increased by using a power transformer, as shown in Fig. 4(a). The students can investigate it from any side and figure out how it works. In Fig. 4(b) the educator explains how a circuit breaker works.

After the circuit breaker, energy reaches the switches which can operate under no-load conditions. The educator can change the position of the switches to separate the power lines so that the students can understand how the switches work and see the benefits (Fig. 5(a)). In order to control the electrical energy, both currents and voltages should be measured by using the transformers in the substation field. Figure 5(b) and Fig. 6(a) show current and voltage transformers, respectively.

At the far end of the substation, the high voltage energy lines are connected to the transmission line (Fig. 6(b)).

Note that this wind farm, the conversion system, the substation equipment and the high voltage pole are not true-scaled or may not be true-placed. This work was intended as a teaching aid to help students understand the basic workings of the entire system.

Analysis and evaluation

This study was conducted in the autumn term of the 2010–2011 academic year at Uşak University in the Department of Electricity and Energy, for the ‘Production, Transmission and Distribution of Electrical Energy’ course. The success of the students was evaluated through written exams by comparing the mid-term, final and end of semester general grades of 4 students educated in SL with those of other students in the class who were educated in a conventional classroom setting.

In Table 1 the measurement values of the other students’ exam grades are shown. There were 30 other students. As seen in the table, the mid-term exam mean value of the other students’ is 61.17647 and final exam mean value of the other students’ is 81.20588. In addition, the end of semester general success grade mean value was found to be 73.20588. Also, the standard deviation means were found to be 13.98369, 10.69063 and 10.05373, respectively.

In Table 2 the mean of 4 students educated in SL are shown. The mean value of the mid-term exam is 75 and the final exam mean value is 85. Also, the end of semester general success grade mean value was found to be 81.

Comparing the mid-term, final and end of semester general grades of 4 students educated in SL with those of other students in the class who were not educated in
Fig. 2  *Creation and simulation of the wind farm in SL.*
Fig. 3  *The conversion system.*
Fig. 4  (a) The transformer; (b) the circuit breaker.
Fig. 5  (a) The switch; (b) the current transformers.
Fig. 6  (a) The voltage transformers; (b) the high voltage pole.
SL, it can be clearly seen that students educated in SL far outperformed the other students who were educated in a conventional classroom setting. Although the sample of 4 students is small, the trends are clear. While the mid-term exam mean of 4 students educated in SL is 75, the mid-term exam mean of other students in the class is 61.17647. Moreover, the final exam mean of 4 students educated in SL is 85 whereas the final exam mean of other students who were not educated in SL is 81.20588. This finding also shows that SL had a positive impact on students’ learning. Lastly, when the end of semester general success grades is compared, it is seen that 4 students’ general success grade who were educated in SL is 81 but other students’ end of semester general success grade was found to be 73.20588. This finding also shows that SL has the potential to make a major contribution to students’ learning. Students who were educated in SL got higher grades in written exams than those of other students who were educated in a conventional classroom setting.

In addition, after the teaching in SL was over, semi-structured interviews were conducted with the 4 participants educated in SL to learn students’ reactions to SL. Answers to questions on motivation and willingness to cooperate in SL were sought. Each interview lasted about 5–10 minutes. The interviews were written down and analysed. During the interviews a participant said that he enjoyed learning through this medium and was much more motivated compared to a conventional classroom environment. When the students’ responses were analysed in more detail, words like curiosity, interest and motivation were seen to be repeated most. Therefore, SL may be described as a place where motivation is internal. What is more, another participant said he could interact, collaborate and make connections with his peers and the educator easily in SL, which he felt comfortable with. As in face-to-face classrooms, it is seen that interaction and collaboration are important for the students in SL and they can be achieved by SL. The motivational factors seen in SL might have engaged students more in the learning process, which resulted in higher grades in the exams mentioned above.

| TABLE 1 | The measurement values of the other students’ exam grades |
|-------------------|-------------------|-------------------|
|                   | Mid-term exam     | Final exams       | End of semester general grades |
| Mean               | 61.17647          | 81.20588          | 73.20588                       |
| Standard Deviation | 13.98369          | 10.69063          | 10.05373                       |
| Minimum            | 30                | 55                | 60                             |
| Maximum            | 100               | 100               | 94                             |

| TABLE 2 | The mean values of exam grades for students educated in SL |
|-------------------|-------------------|-------------------|
|                   | Mid-term exam     | Final exams       | End of semester general grades |
| Mean               | 75                | 85                | 81                             |
Conclusions

A renewable energy system based on wind power was introduced within the SL 3D virtual environment and taught to relevant students in power systems studies. Many more learning activities were possible in the SL virtual classroom, compared to real-world classroom learning activities. It was observed that the motivational level of the students at the beginning of the course in the 3D virtual environment was higher than in a conventional classroom environment. After the presentation in SL, the students could interact with the wind turbines and the substation equipment as if they were in a non-hazardous real world.

Videos of this study can currently be reached on the link http://www.umhhms.com/?Lang=TR&Syf=24&vid_id=8108.

The authors considered the use of this approach from the point of view of educators and learners. The following advantages of teaching within SL were determined for the educators:

- Tutors could contact any students privately by voice-enabled chat and/or the instant messages;
- Many more experiments were possible using the 3D simulator;
- The approach lends itself easily to the current trend towards student-centred education;
- Less staff effort was required for higher-level teaching activities.

The following disadvantages of teaching within SL were determined for educators:

- SL needs a permanent Internet connection and good performance from PCs. This implies a good level of institutional support;
- The educators may not be sure of the identities of students;
- Emotional responses of students cannot be perceived by educators, unlike in a classroom setting. For example, in a real classroom the educator can change the subject or make a break if the students are getting bored.

The following advantages of working within SL were determined for the students:

- Opportunity for many more learning student-centred learning activities;
- Fun and learning can be combined, so that students are engaged with the topic;
- Students can interact with places or operating equipment which, due to extreme hazard, cannot be seen by them in the real world, such as the inner workings of a substation;
- Physically disabled students can benefit from SL controlling their avatar;
- Synchronous and asynchronous learning is possible.

The following disadvantages were determined for the students:

- SL needs a permanent Internet connection and a good performance of PCs which may result in extra financial costs;
- If students over-use SL outside learning hours, they may risk becoming socially isolated in real life.
In addition to the above, educational and experimental materials are created virtually which are free of cost to both educators and students as opposed to real-life learning environments. However, a fee needs to be paid to SL to own a region or land in SL.

The authors make the following suggestions and comments for educators who are interested in setting up a similar system:

- Initially, educators should learn how to build and write scripts in SL. Use of SL Help is a reasonable place to start.
- You are not allowed to build without permission. You should either have your own parcel or be on a time-limited permissible parcel named sandbox.
- You should take the number of active objects and active scripts into account in your land. Increasing them and the number of avatars will reduce the frame per second rate. Estate owners can set a maximum number of avatars.
- SL has a physical engine. If you set the feature of objects as physical, they will react as physical objects and interact with other physical objects and avatars.
- Textures of your creation can be found either free or paid in SL. Otherwise, you have to upload your textures as images into SL. This process is paid; however, you should use a photo-editor to merge multiple textures and upload it in a process. It is a cheaper way although it will reduce the resolution of textures.
- Vocal chat is an easy and effective way to contact students rather than typing chat. This feature should be enabled. If you are not an estate owner and this feature is disabled, there is no way of enabling it except by contacting the estate owner.

The findings obtained from this study may be shared with the managers of the Distance Education Vocational College at Uşak University so that they can also make use of SL in their practices/programmes in order to maximise the power of distance education.

In future work, other experimental places can be considered which may be investigated and evaluated for students of electronics and electrical engineering, in topics such as power distributions, energy line properties and consumption. Furthermore, it should be possible to design and implement a tool for students in SL to let them create their own layouts for equipment to be used in power systems.

References

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