

Construction Safety Education Model Based On Second Life

Quang-Tuan Le and Chan-Sik Park
 Department of Architectural Engineering
 Chung-Ang University
 Seoul, South Korea
 lequangtuan2009@gmail.com, cpark@cau.ac.kr

Abstract—Construction industry is a very complicated and complex environment that causes high accident rate. The development of advanced virtual world has become an important issue for safety education in order to reduce dangerous occurrence in the construction site. However, most researchers on virtual world still have limitations such as the offline virtual world simulation, the low level of interaction between users in virtual world, and so on. With the regard to this issue, this paper proposes the adoption online 3D world Second Life (SL) platform which allows students to perform role-playing, dialogic learning, and social interaction for efficient and effective construction safety and health education. In this approach, construction safety education model based on Second Life (CSESL) is developed, which consists of the following three modules: 1) Safety information and knowledge preparation to understand the critical causes of accident in construction site; 2) Collaborative simulation for safety case study to transfer unsafe case or dangerous occurrence information to 3D modeling; 3) Reflection on safety lesson for education and training to enhance practical safety knowledge by participating in 3D inspection game. The CSESL advantages and disadvantages are identified by testing the model using a real case scenario. This study presents the potentials and benefits of SL which could enhance construction safety and health education.

Index Terms—construction safety and health; virtual environment; Second Life; education

I. INTRODUCTION

Due to the complicated working environment, construction site presents high accident rate [1]. In spite of the attention given in the construction site injuries, the incidence rate of accident in construction industry is reported to be twice comparing with the industrial average [2]. Safety improvement is therefore a major problem in the construction industry. The advancements of digital media and virtual environment have started to play greater roles on the construction safety and health education process. Abundant researchers on this study have been performed such as the game technology based visualizing safety assessment for safety and health training [3], safety education through virtual mine teaching platform [4], and so on. However, current studies taken advantage of virtual environment simulation and internet technologies still have following limitations: 1) the virtual reality simulations are offline without the cooperation of educators; 2) traditional construction education approaches of lectures, seminars, and

team work have not really taken advantages of the virtual simulation; 3) the interaction level between users in virtual safety game is still low; 4) the limitation of spaces and students in some virtual room education.

These limitations have required a high demand for online interactive multi-user in virtual reality environment to achieve the education and training purposes. The integrated social networking and virtual reality in Second Life (SL) would help to successfully obtain the safety education and training purpose. SL is an online virtual world developed by Linden lab that enables SL users to interact with each other through avatar [5]. SL supports a rich communication, virtual collaboration, and 3D content that allow practitioners to interact with each other and with virtual environment through avatars [6]. Learners and educators can explore virtual spaces, share experiences with the others, meet people and make friend, work in team, and engage in commercial activities [7]. By providing immersive environment, data visualization, simple simulation, collaborative spaces, and social interactions, 3D world SL therefore has great potentials for construction safety teaching and learning.

This paper proposes a construction safety education model based on Second Life (CSESL) that takes advantage of multi-user aspects and virtual reality technology for better construction safety and health teaching and learning processes. Three main objects would be suggested in CSESL included Safety information and knowledge preparation module (SIKP), Collaborative simulation for safety case study module (CSSC), and Reflection on safety lesson learned for education module (RSLE). The SIKP allows professors and student groups to plan and discuss about accident situations and its causes through their avatars in SL. In the SIKP module, accident data provided by professors will be converted to safety information through student analysis. Each student group will transfer safety information to virtual 3D modeling as team test about the understanding of the safety information in CSSC module. It is noted that students in each group will online collaborate to simulate 3D modeling for achieving best description. The 3D modeling of each group will be confirmed by professor who will use that modeling for cross teaching to another group in RSLE module. After professor's lectures are provided, students will join in an individual test by inspecting the error of 3D modeling situations that causes accidents. The CSESL is tested

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by real scenarios in order to address the model's potentials and limitations. The study emphasizes the advantages and benefits of SL that could provide students with the real construction safety experiences through learning by doing.

II. VIRTUAL WORLDS AND EDUCATION

From the perspectives of technology, virtual environment has much greater potentials both in terms of teaching and learning of constructing safety knowledge [8]. Virtual world supports online communication and user interaction to exploit computer based simulated environment. According to Messinger et al, virtual worlds are emerging as a novel form of social computing where thousands of people can interact in 3D space to represent critical implications for business, education, social sciences, technology, as well as society [7]. Messinger et al, also emphasized that virtual worlds offer a window into the future of the internet and provide rich real-time form of social and economic interactions with abundant applications and subsequent implications [7]. Furthermore, virtual worlds and social networking influenced on the way people do their work and communicate as well as brought about new opportunities on learning and teaching processes [9].

There are several accessible virtual worlds to available for the public included There [10], Worlds [11], Second Life (SL) [5], and so on. The most prominent application of 3D virtual worlds is SL, which provides a place to connect many people, to explore knowledge, and to practice education as well. Hobbs et al, noted that SL is an interactive and immersive environment that facilitates the information flow, supports communication, commits to group discussion, and collaboration among members [12]. Additionally, Jarmon et al, emphasized that SL has significant impact in absorbing practical experience through learning by doing [13]. Members of SL through motional avatars can communicate, socialize, and participate with others via avatar-to-avatar activity as real as face-to-face to create and trade virtual properties and services for knowledge acquisition [8]. In addition, SL adopted the emergence of social network innovations included: easy created profile; a trusted circle of friends and capabilities for public and private message dissemination; new media elements; and a structure of various classes of social networks, to provide better environments for collaborative and experiential educative manipulation [7].

With the reality in mind, it is worthwhile to mention how the safety education issues would benefit from advanced of SL. It can be summarized as followed: 1) Active role-playing learning: students and teachers take part in contributing as well as solving safety problems through active roles to acquire construction safety knowledge; 2) Collaborative and dialogic learning: learners interact with each other and with the virtual environment to exchange safety experience and cooperatively solve safety problems; 3) Real-case learning: the real accidents would be simulated to 3D virtual modeling in the immersive environment for education and training.

III. CONSTRUCTION SAFETY EDUCATION MODEL BASED ON SECOND LIFE (CSESL)

The main purpose of developing a construction safety education model based on Second Life (CSESL) is to focus on

improving construction safety education process by taking advantage of active role-playing learner, collaborative and dialogic learning, and real-case learning in virtual environment of SL. This can be achieved via three modules – Safety Information and Knowledge Preparation (SIKP), Collaborative Simulation for Safety Case Study (CSSC), and Reflection Safety on Lesson for Education and Training (RSLE) – which is illustrated in Fig. 1.

Model Process	Safety Information and Knowledge Preparation (SIKP)	Collaborative Simulation for Safety Case Study (CSSC)	Reflect on Safety Lesson for Education and Training (RSLE)
Location in SL	•Exhibition Room	•Operation Area	•Reflection Area
Main Tool	•Safety Semantic Wiki Template (SSWT)	•Prim Creation of SL •Sketch Up Tool	•Safety Lecture •Safety Game
Main Activities	•Safety Information Contribution •Safety Knowledge Analysis	•Safety 3D simulation from safety case of previous phase by students	•Safety learning •Safety Inspection

Figure 1. Construction safety education model based on Second Life.

Unlike some virtual education systems, CSESL is purposely designed to help learners understand the insight causes of accident and dangerous occurrence prevention methods in construction industry based on visualization data and simple simulations, easy communication and flexible interactions, collaborative spaces and immersive environment of SL. Owing to the integration among three modules under engaging SL environment, CSESL would provides better opportunities for developing effective and efficient collaboration education on construction safety and health knowledge.

A. Safety Information and Knowledge Preparation

In this section, teachers and students would use motional avatars to perform all activities at exhibition room in SL with the supporting of Safety Semantic Wiki Template (SSWT) [14] as illustrated at Fig. 2.

The screenshot shows the SSWT interface for a construction accident case. The title is "Fall off a topping scaffold". The description states: "A worker was assigned to service some roof painting work at a building. He was erecting a mobile scaffold along a corridor at the fourth stores of the building when the scaffold toppled. As a result, the worker fell off from the scaffold and out of the building onto the ground 1.2m below." The result section states: "The mobile scaffold (with a cantilevered structure) was not in a stable position and as not secured to the building structure or metal railing along the building corridor at the time of accident. When the worker climbed onto the mobile scaffold to tie the deck to the cantilevered structure, the mobile scaffold toppled and the worker fell off from the scaffold and building. One Worker Death". The cause analysis section lists immediate causes: "Improper position for task", "Inadequate or improper protective equipment", and "Failure to secure scaffold". Basic causes listed are: "Lack of experience" and "Inadequate work standards". Recommendations include: "Use an alternative method of work, or institute safe work procedures for such work", "Conduct risk assessment prior to job commencement", and "Ensure proper safety measures are in place such as securing of mobile scaffold to the building structure and provision of lifelines for the workers".

Figure 2. Safety Semantic Wiki Template (SSWT).

SSWT provides platform with existing items related with construction accident and hazard case information. With the availability of SSWT in exhibition room of SL, professors can easily transfer safety exercises to student while students can conveniently answer as well as present the results without any complicated computer science background.

Safety Information and Knowledge Preparation (SIKP) module basically includes four main steps as shown in Fig. 3.

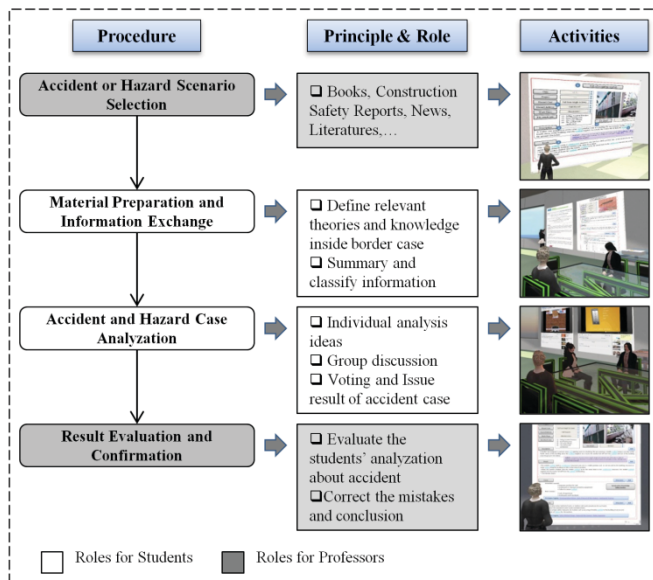


Figure 3. Safety Information and Knowledge Preparation (SIKP).

- Accident and hazard scenario selection:* Professors who are experts in construction safety and health will upload accident and dangerous occurrence information as exercises for students to find the causes and solutions through SSWT boards at exhibition room;
- Material preparation and information communication:* Online class students will be split into groups. Each group would solve one problem following the professor assignment. In this step, every member of each group would cooperate to find out the relevant theories and information of group's exercise then summarize them. Tasks of each member will be classified through social interactive discussion and audio communication between whole group's members in the virtual environment of SL;
- Accident and hazard case analysis:* Based on data collection, every student of each group proposes the accident causes as well as the dangerous occurrence prevention methods. All ideas will be written in the SSWT boards that is available in exhibition room. After all ideas issue, all students of group through their avatars will discuss and vote to choose the best answer by utilizing voice chatting and virtual reality techniques of SL. The ideas which have highest voting score, would be retained in SSWT board after a pre-defined time;

- Result evaluation and confirmation:* The accident analytic result from each group will be evaluated and confirmed by their professor to achieve the valuable knowledge, which is used in two subsequent sections.

B. Collaborative Simulation for Safety Case Study

With the construction safety information and knowledge about accident and hazard cases from previous section, each group takes part in simulating to create 3D model for better understanding about accident cases as well as for mid-term examination in Collaborative Simulation for Safety Case Study module (CSSC). The CSSC consists of three steps: Assign Tasks, Collaborative Simulation, and 3D Model Checking (refer to Fig. 4).

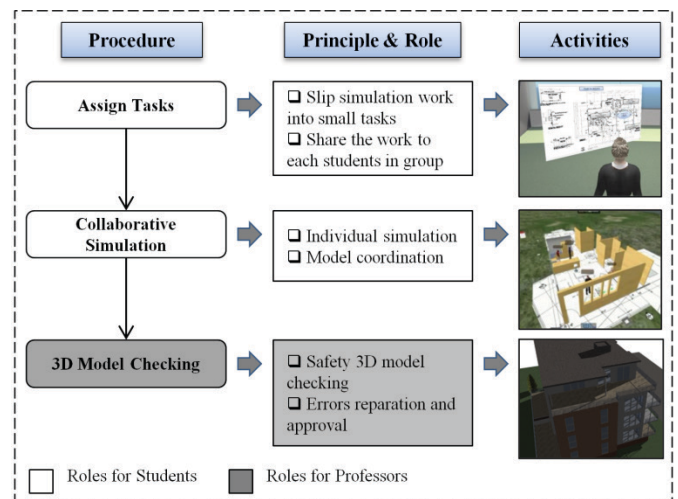


Figure 4. Collaborative Simulation for Safety Case Study (CSSC).

Firstly, group leader will classify and assign the simulation task for each student in the group. Secondly, each student will create individual 3D part of the whole model and connect with the others through prim simulation or sketch-up software (refer to Fig. 5). It noted that SL provides collaborative and interactive virtual spaces to make the cooperative simulation process faster than ever. Finally, professors would check and correct errors of 3D model.



Figure 5. Collaborative simulation.

In the CSSC, learners can play active role in establishing safety information and knowledge in form of 3D simulation procedure. Moreover, this feature will help students not only comprehensively understand the accident scenario but also improve their safety analyzing skills.

C. Reflection on Safety Lesson for Education and Training

After simulation tasks, all students would take part in construction safety courses and safety inspection game in Reflection on Safety Lesson for Education and Training section (RSLE). The RSLE fundamentally included three steps as illustrates in Fig. 6.

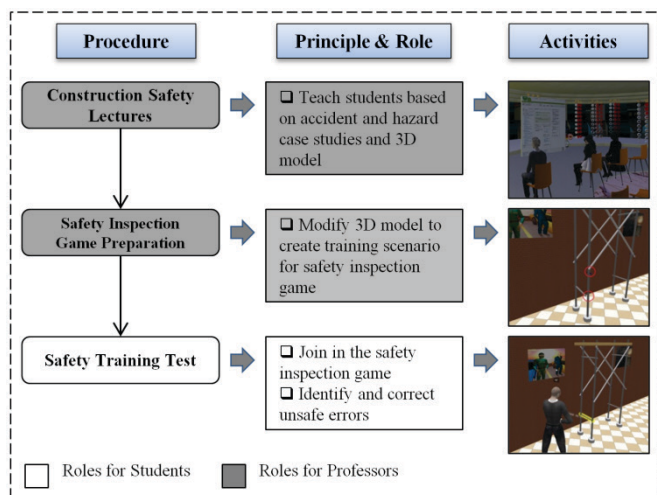


Figure 6. Reflection on Safety Lesson for Education and Training (RSLE).

The first step is construction safety lectures that are provided by the professor. Professors through audio communication and virtual environment of SL explain to the students about construction safety knowledge based on previous accident or dangerous occurrence cases. It is interesting to note that digital media and 3D model support would help to convey safety concepts to learner more effectively and efficiently. After safety lectures finished, the professor will modify 3D models to create safety training scenarios for student test. 3D safety training scenarios assembled unsafe site conditions, unsafe worker behavior, and unsafe working method sequences [3]. They would reply on the causes and solutions of accident and dangerous occurrence cases developed at previous sections (refer to Fig. 7). Finally, students through their motional avatars join in safety inspection game to identify and correct the hazard or dangerous situations that can cause accidents in 3D training scenarios as final exam (refer to Fig. 8). To obtain the training result, professor would use e-checklist that is scripted in monitoring screen (refer to upper left corner Fig. 8). After training, the e-checklist result and video recording would be sent to student for reviewing.

IV. MODEL EVALUATION

The model with real scenarios has been surveyed in order to determine the potentials and limitations of CSESL. The survey questions illustrated in Fig. 9 were issued to professors and students after online class. Results were summarized using student and teacher feedback:

- 1) *Student feedback:* Almost students strongly agreed that they satisfied with CSESL class. The most interesting of using CSESL was inspection game in SL, which was similar with real life, therefore would be useful for achieving real experience. However, learners also mentioned some difficulties in collaborative simulations due to the complex elements connection and complicated scripting in SL to meet scenario requirements;

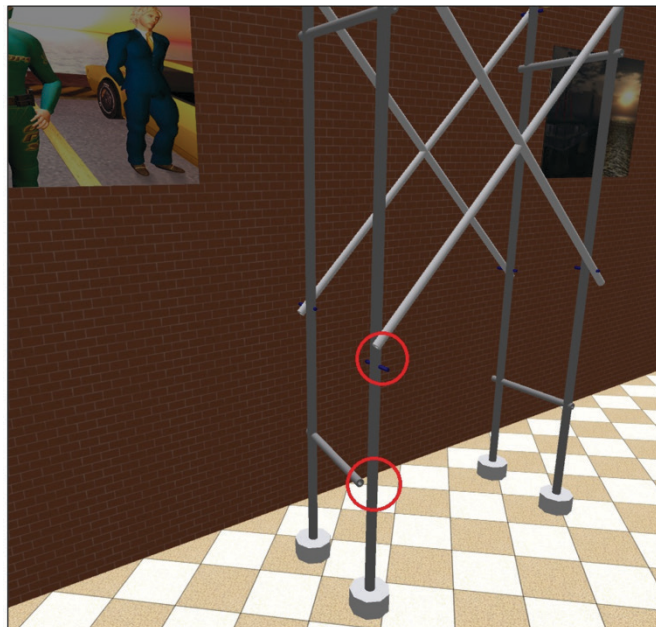


Figure 7. Safety training scenarios.



Figure 8. Corrective action by student.

- 2) *Teacher feedback:* Teachers basically pleased with the CSESL teaching method. They emphasized that role-playing and social interaction of SL would help to improve the effective and efficient of construction

safety education. Nevertheless, most of teachers said that gaming scenario preparation took much time because of complex scripting for real attributive of elements (at least two days for one scenario).

Name : _____	Occupation: Professor/ Student	
Date : _____		
Questionnaire Survey on Using Construction Safety Education Model Based On Second Life (CSESL)		
1. Do you satisfy with CSESL class?		
a) Very satisfactory	b) Satisfactory	c) Normal
d) Unsatisfactory	e) Very unsatisfactory	
2. What are your difficulties of using CSESL?		
3. Among your difficulties, which is the most difficult for you to use CSESL?		
4. What are the advantages of using CSESL?		
5. Among all the advantages of using CSESL, which is the best benefit for you?		
6. What are your proposal for improving CSESL?		
7. Do you think CSESL would replace traditional class in the future?		
a) Yes	b) No	

Figure 9. Questionnaire survey on using CSESL.

Finally, it can be concluded that CSESL creates potentially powerful and engaging environment for collaborative and experiential construction safety education by taking advantage of virtual reality and social networking of SL. Through CSESL, students will better understand about construction safety and health while professor can conveniently link theories with practical experiences and easily transfer these knowledge to student. In spite of many advantages in safety and health education process, it is important to mention some limitations of CSESL: 1) Collaborative simulation still meet some difficulties due to the complex of prim connection in SL; 2) The use of realistic construction activities such as duration, interaction, etc. are still limited and require careful collaborative construction procedure simulation; 3) The time-consuming in scenario creation process.

V. CONCLUSION AND DISCUSSION

This paper presents CSESL that utilizes state-of-the-art of SL for effective and efficient construction safety and health education. The cores of the proposed CSESL include three modules – SIKP, CSSC, and RSLE – that allow students perform active role-playing, collaborative and dialogic learning, and social interaction in 3D virtual world. A prototype model was developed and tested with a real case scenario. Through the recommendation via interviewing with students and teachers, the main potentials and limitations of the study are summarized as follows:

- 1) From the perspective of visualization technology, virtual world has many advantages to improve safety education on construction. However, critical factors such as the level of interaction between users, the

offline virtual simulation, and so on, remain unsolved. It is found that the CSESL has many potential for online interactive multi-user and 3D world simulation at real-time base;

- 2) In developing the model prototype, it is confirmed that the CSESL could greatly improve the current construction safety education process. However, there are still some limitations such as the complex collaborative simulation and the time consuming in scenario creation process that will be further examined.

In addition, even though the potentials of the proposed CSESL have been ascertained with the evaluation of a simple prototype, as future work, the model applicability should be validated more technically in terms of the performance of teaching and learning processes. And some research efforts would be directed toward the extensibility of the CSESL model to virtual game for safety worker training in construction site.

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