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3D Simulation Game for Teaching Concrete Formwork

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Abstract
Engaging technology savvy students in the concrete formwork learning process with their preferred learning style is a challenging task. The differences in teaching and learning styles result in problems such as disengagement of students and loss of learning aptitude. This active student engagement challenge can be addressed through three dimensional (3D) concrete formwork simulation game learning environment. This learning environment engages students in active learning processes and helps them to focus on their learning. It also encourages students to take more responsibility for their own learning process. This ubiquitous learning environment provides anytime time access, facilitates the students to learn at their own pace and promotes learning beyond the regular classroom boundaries. This paper discusses about the 3D simulation game for teaching concrete slab formwork to enhance the learning ability of the students. This paper also discusses about a usability study results of this game.

Keywords
3D, Simulation Game, Concrete, Formwork, Visualization

1. Introduction

The ability to visualize the built environment and learn construction processes is critical for students in the architecture, engineering, and construction disciplines (Irizarry et al., 2012; Nikolic et al., 2011). Due to lack of experience, it will be challenging for students to visualize the design assumptions, different components and construction processes of the concrete formwork (Wasim et al., 2011). Incorporating site visits in the curriculum helps the students to corroborate the learning components to the real world. Due to current COVID situation inclusion of site visits in the course became challenging. This pandemic has forced to change the teaching modality from in person face to face to online mode. This online teaching modality has added one more dimension of difficulty to engage and involve the students in the active learning environment. Some of these challenges faced by construction programs across the nation and the world can be addressed by using three-dimensional (3D) simulation games in construction education. Studies have demonstrated that the game-based approach can enhance students' learning process through their active participation (De Gloria et al., 2014). Virtual Constructor Simulator (VCS) was developed and implemented to engage students in active learning environment about planning and management of a construction project (Castronovo et al., 2015). 3D game environment was used to impart trench safety education to the construction trade students (Dickinson et al., 2011). The success of these 3D game learning environment in construction education motivated the authors to use 3D simulation game for teaching material quantity take off and construction process of concrete formwork. This 3D simulation game will create visual and kinesthetic learning environments and will actively engage students in the learning process in both in person face to face and online mode. This visual rich learning environment will improve the student visualizations skills and enhances their performance. The 3D simulation game will promote ubiquitous learning environments. For example, anytime time access facilitates the students to learn at their own pace and promotes learning environment beyond the regular classroom boundaries. Thissimulation game focuses on the material quantity estimation and construction aspects of concrete slab formwork. Theauthors want the game to be deployed on various platforms such as Mac, Windows and mobile phones. This can be accomplished by developing a game on an engine which has capability of publishing on multiple platforms. Considering all these requirements, Unity software was chosen to develop the 3D simulation game. Unity has powerful game development engine which can work on Mac and Windows. It has capability of deploying games on desktop,

mobile, web and consoles. It can create standalone desktop game on PC, Mac and Linux operating system [Unity, 2021]. It can deploy games on major mobile ecosystems such as iOS, Android, Windows Phone 8 and BlackBerry 10 [Unity, 2021]. It can deploy on consoles such as Xbox one, Xbox 360, PlayStation, PlayStation Mobile and Wii-U [Unity, 2021]. It can provide stable and efficient web deployment on all major browsers such as Explorer, Chrome, Safari, and Firefox [Unity, 2021]. The following sections discusses about the 3D concrete slab formwork simulation game and it's usability study results.

2. 3D Concrete Slab Formwork Simulation Game

Formwork for concrete must be designed to support all applied vertical and lateral loads until these loads can be carried by the concrete structure itself. In general, formwork system consists of sheathing to retain concrete and supporting members necessary to hold the sheathing firmly in place. The typical components of slab formwork are shown in Figure 1. Members which provide support to the sheathing are referred as joists. The cross members which support joists are usually refereed as stringers. The vertical members which support stringers are referred as shores. Based on these concepts a 3D concrete slab formwork simulation game was developed. This game helps to understand design assumptions, to learn about the slab formwork components, to learn about the slab formwork construction steps, and to learn about the slab formwork material takeoff. In this project, plywood is used for sheathing and lumber is used for joists, stringer and shores. The 3D concrete slab formwork simulation game has five modules. These include (a) Main Menu, (b) Shop, (c) Cut, (d) Assembly and (e) Finish. The details of these modules are discussed below.

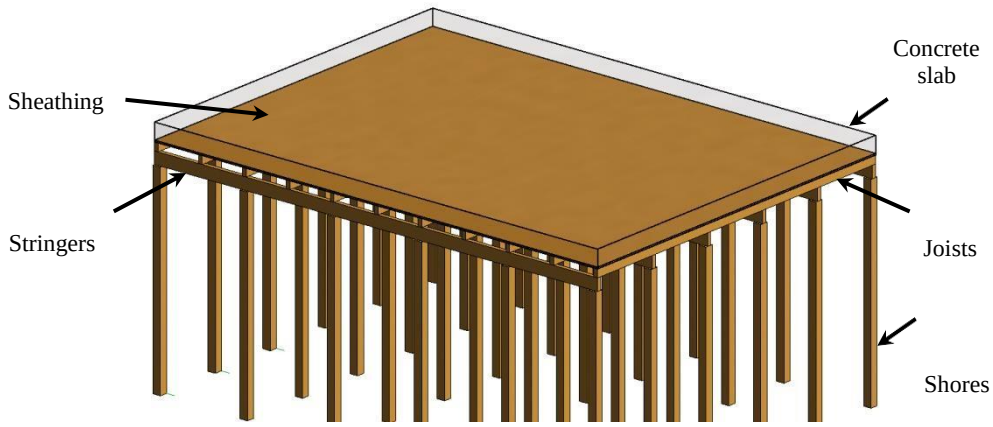

Fig. 6. Typical components of slab formwork

2.1 Main Menu

This component provides the details of the slab to be formed. These include design assumptions, cross section dimensions of members, plan and elevation views. Using this information, the player will estimate the required quantities of materials. A sample screen shot of the main menu interface is shown in Figure 2.

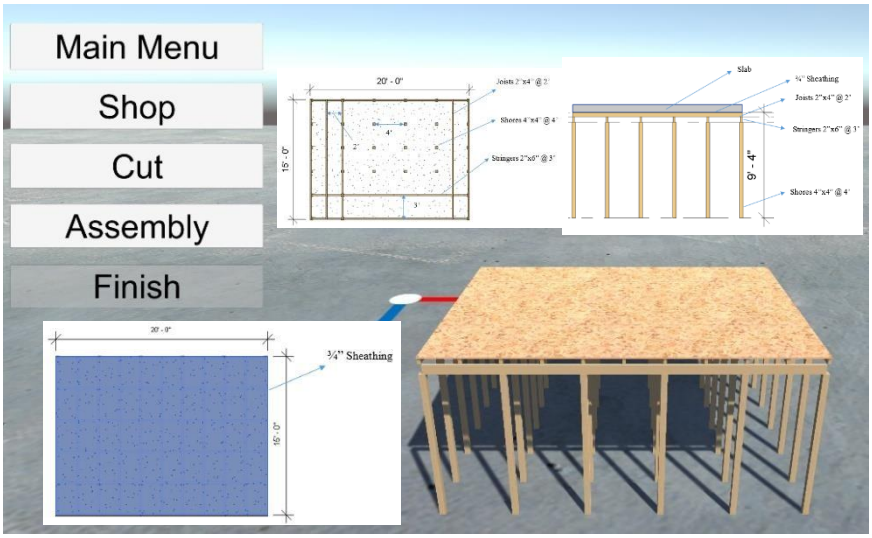

Fig. 2. A sample screenshot for Main Menu window of slab formwork

2.2 Shop Module

This portion of the game will test the players' understanding of the concept of material loss due to resizing and cutting, and the necessary additions to material dimensions for proper construction of the formwork, such as overlapped edges and how to maximize component pieces usage to reduce wastage. For example: The player will be asked to input the amount for each type of material which the player believes to be necessary for completing the formwork with as little waste as possible and without having to return to purchase additional materials. A sample screen shot of the shop interface is shown in Figure 3. Penalty will be imposed once the player buys the material and returns to the shop module to purchase more materials.

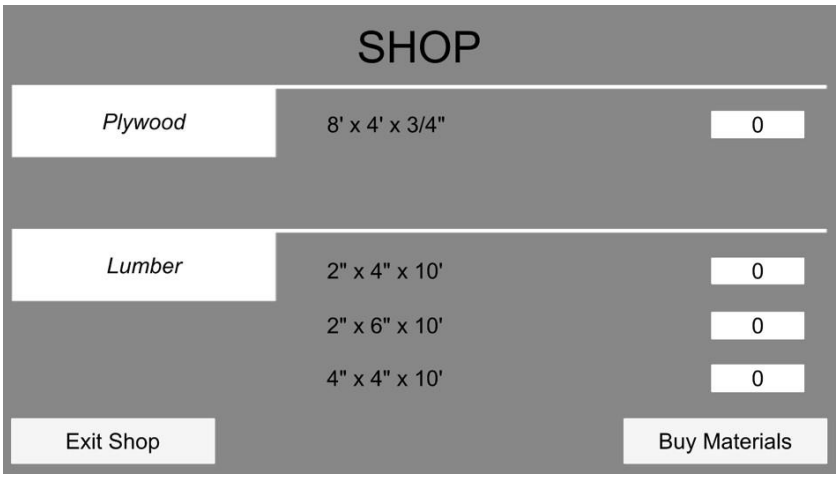

Fig. 3. A sample screenshot for shop window

2.3 Cutting Module

This component of the game deals with the cutting of the materials. Based on the size calculations, the player will be given option to cut the materials to the required dimensions size as necessary to built the formwork. Player must account for excess material needed for proper construction. A sample screen shot of the cutting interface is shown in Figure 4. Based on the purchased materials from shop module, the player is presented with the amount of available materials on left side. On right side, player will have drop down boxes to enter the required cut dimensions and quantity.

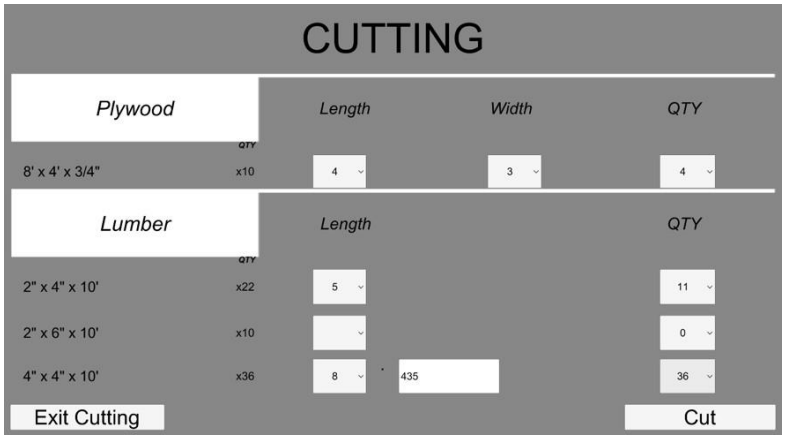

Fig. 4. A sample screenshot for Cut interface window

2.4 Assembly Module

In this module, using the stockpiles of cut formwork component pieces, the player will construct the formwork needed for the concrete slab. A sample screen shot of the assembly interface is shown in Figure 5. Based on the shop and cut module inputs, available materials inventory will be presented at bottom. In this view, a ghost image of the components to be placed is displayed. This will guide the player to snap the formwork components. The stock pile of the materials get dynamically updated as the player utilizes the material. Once the player snaps the component color changes to assigned material color. The player will have option to go to shop or cut module for making additional purchase or cut. However, these additional visits will come with penalty.

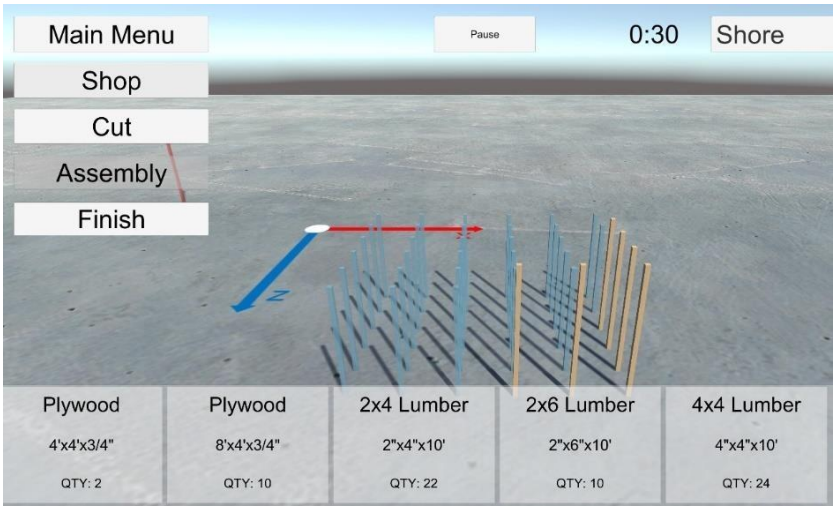

Fig. 5. A sample screenshot for Assembly of Slab formwork

2.5 Results Module

This module focuses on the assessment of the player's ability to learn concepts of concrete formwork. This is accomplished by grading shop, cut and assembly modules. In shop module, players are graded on how efficiently they select the quantities. Once the player purchases estimated quantities, then these quantities are compared with actual quantities for scoring. A penalty will be imposed for inaccurate quantity estimation and purchase. Inaccurate estimate includes a positive error (when the player estimates more than the actual) or negative error (when the player estimates less than the actual). In cut module, players are graded on how efficiently they choose what dimensions to cut. This is done by calculating how much waste material remains when cutting is completed and comparing it to a known lowest waste amount. In assembly module, players are graded based on the construction sequence of the formwork. The player construction sequence is compared with correct sequence and appropriate score will be awarded. A sample

screen shot of the results interface is shown in Figure 6. In this screen, points gained in each step and overall points are displayed.

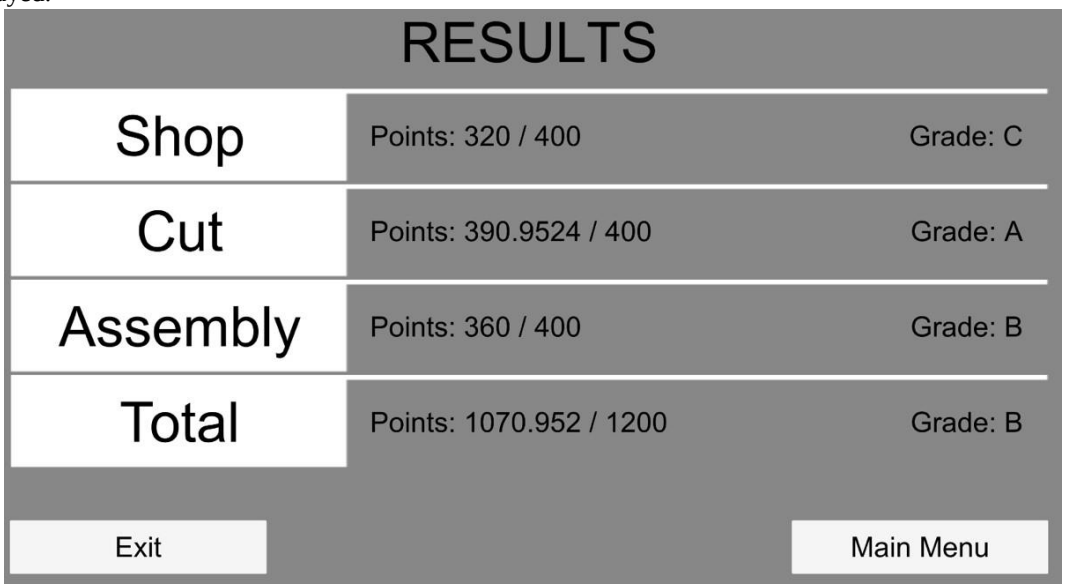

Fig. 6. A sample screenshot for Results of Slab formwork

3. Usability study

The game was developed by using Unity software. The game was evaluated by conducting twelve play test sessions by twelve different students. Four steps were included in each play test. They include i) instructions were provided to play the game; ii) students were given some time to practice and familiarize the navigation commands; iii) students were let to play the game and necessary help was provided when needed; iv) after finishing the game the students were asked to provide feedback about the usefulness of the game through a survey. The survey was designed to assess the usefulness of simulation game to help the students to understand design assumptions, to learn about the slab formwork components, to learn about the reducing the material wastage, to learn about the slab form construction steps, and to learn about the slab form material takeoff. Students were asked to express their satisfaction on these with 5-point Likert-type scale (1= Strongly Agree, 2 = Agree, 3=neutral, 4= Disagree, and 5=Strongly Disagree). The analyses of the results are shown in Figure 7. Most of the students were satisfied with the usefulness of simulation game.

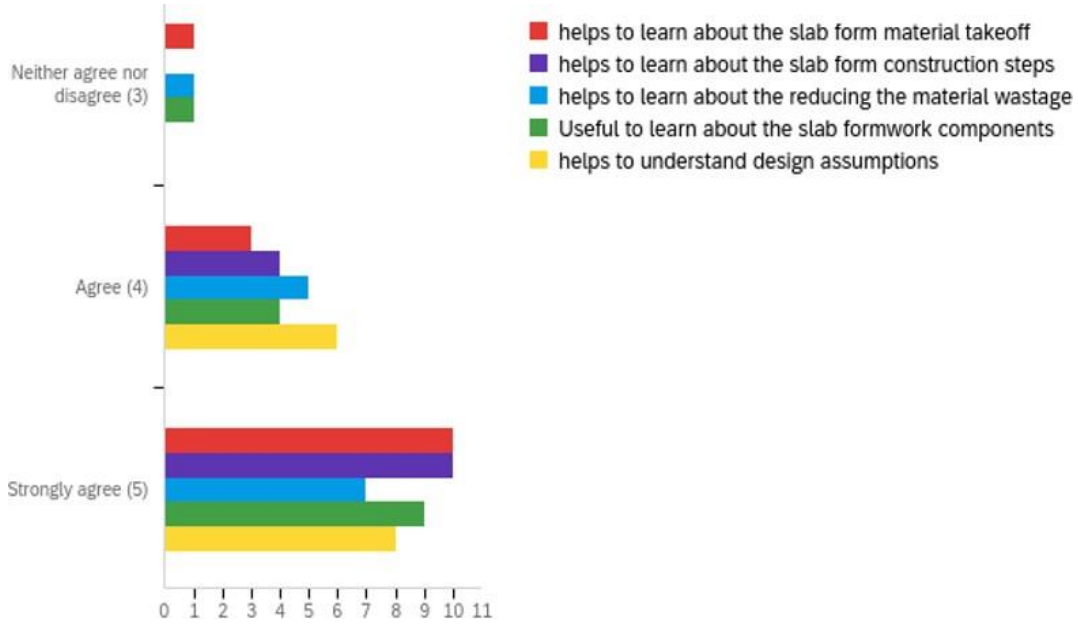

Fig. 7. Usefulness of simulation game survey results

The students were asked to express their satisfaction on ease of learning to play the simulation game with 5-point Likert-type scale (1= Strongly Agree, 2 = Agree, 3=neutral, 4= Disagree, and 5=Strongly Disagree). The analyses of the results are shown in Figure 8. Most of the students expressed their agreement with the statement "Overall, I am satisfied with ease of learning" (65% strongly agreed and 22% agreed).

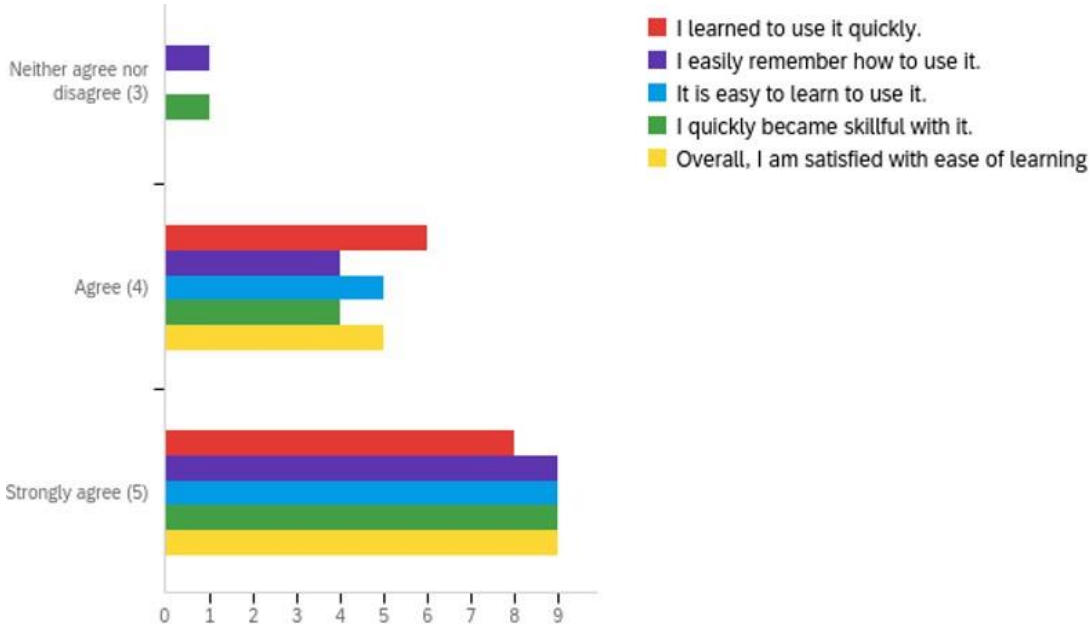

Fig. 8. Ease of learning to play the simulation game survey results

Conclusion

Concrete slab formwork 3D simulation game serves as a new teaching tool and helps to be more effective in communicating the information to the students. This learning environment provide 3D visualization and helps students to be actively engaged in the learning process. The 3D simulation game environment has the potential to make a paradigm shift in teaching and learning process. Although the game is proven to be effective for learning concrete slab formwork, there are some limitations to this study. They include 1) the number of paly test sessions were limited. The large number of play tests may reveal bugs which are not found at this stage; 2) the game simulates only slab formwork project further research may modify the game to make it capable of simulating different projects such as column and wall formwork projects. The framework of the slab formwork discussed in this paper serves as an initial step to further develop column and wall formwork 3D simulation games.

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