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Abstract:
This paper briefly illustrates the design procedure, implementation and findings of a three year research project. Virtual Interactive Construction Education (VICE) is a project-based pedagogical model that uses a simulated environment to alter traditional subject-based lectures into virtual project-based interactive learning methods in construction education. For this purpose, the context of construction engineering and management curricula were aggregated into six construction project prototypes. VICE-Bridge is the first of these six prototypes that exposes players to experiential problem solving activities toward achieving a goal situation (construct the bridge) from an initial situation (start of construction). It was designed for students with little or no knowledge in construction. The optimal solution to the goal situation is a pre-determined sequence of construction activities. Resource decisions for each construction activity are compiled into actionable solution sets within a range of reasonable options. Each actionable solution set is developed as an animated sequence. Achievement of objectives was measured by increase in construction knowledge gain, level of engagement, and perceived construction knowledge gained as a result of the VICE intervention. The results support development of more construction management education and indicate that this particular simulation is an effective tool for construction education.

Literature Review

Improvements in construction education lead to better trained and more knowledgeable professionals in the construction industry which directly relates to industry (Goedert, Rokooei & Pawloski, 2012). The annual gross output of the construction industry is over a trillion dollars, which consists of roughly 5% of the Gross Domestic Product (GDP) (National Association of Home Builders, 2013). There are currently hundreds of construction programs in the US and in each of them hundreds of students pursuing their chosen profession. Construction education content has not been unanimously agreed upon by all instructors of this field. AbouRizk and Sawhney (1994) believed of traditional construction curricula are not efficient and urge alternative methods for construction education. McCabe, Ching and Savio (2000) addressed some deficiencies of traditional curricula and stated that most of coursework only present some theoretical notions and therefore, are not successfully able to enhance the capabilities of students in solving real world problems. Rojas and Mukherjee (2005) believe that traditional construction curricula do not completely perform their mission and, therefore, has led practitioners in construction education to investigate new learning method and tools like simulation. Simulations and serious games for education have been increasing in the last decade (Goedert, Rokooeisadabad & Pawloski, 2013). Providing project-based learning method and simulation in construction results in more capable graduates that impact economics and technology. In addition, using simulation in construction education provides a new way for female students to participate and learn construction materials (Rokooei, Goedert, Weerakoon, 2014).

Methodology

VICE Bridge is a game-based simulation platform to facilitate collaborative and competitive project-based student learning of construction scenarios. The platform provides a rich learning experience by enabling students to interactively find solutions to construction problems posed by domain experts. These problems support several construction specific parameters like governing resources, personnel and time with multiple solutions. Students learn by engaging in problem solving sessions leading to optimal, sub-optimal, and infeasible solutions. The whole project consists of three sections. Pre-game quiz, VICE Bridge, and Post-VICE survey. Participants sign in with an ID and password that are linked to demographic information. Participants are then directed to the pre-game quiz where they respond to various construction content questions to provide a baseline understanding. Users are allowed three attempts for computational questions after which the next question is shown without revealing the correct answer. Game play begins with the player to correctly sequencing the work breakdown structure (WBS). An avatar directs the users throughout the stages of the game while another avatar acts as a consultant provided information at a

charge of $250 per request. An animation shows the consequences of each selection. Once players successfully complete the WBS, they are sequentially directed to decisions and education modules within each activity of a single span bridge. Players are required to determine the appropriate quantity and make-up of personnel, materials and equipment. An animation responds to the player selection to simulate the construction space and attributes of specific activity selections. Cost and schedule variances are a performance measure built into the game. These accumulate in response to selection of resource. The accumulated cost and time are displayed during game play on the main screen. Education modules introduce new concepts and test students' construction understanding as appropriate during game play. In this way it is possible to assess the player's ability to transfer knowledge as opposed to rote memorization (Goedert et. al., 2013). Once the game is finished, players are automatically directed to where they self-report their perceived learning gains of a construction project with the retrospective pre and post survey questions. The survey asks the players to assess, on a five point Likert-scale, their own perception of construction knowledge gained.

Results

Forty high school students and twenty students from an undergraduate construction program successfully completed the test during spring and summer 2013. Seventy eight percent of all participants had no previous work experience and 80% of them reported no previous experience with virtual learning. Actual performance data were categorized into five areas and then, a paired sample t test was used for comparing each of these areas. As shown in Table 1, the paired sample t-test indicates that there was a significant difference between the mean scores of the pre and post-test construction content knowledge questions at a .05 significance level for all areas. Thus, VICE was shown to be an effective educational tool for construction education using the comparison of the pre- and post-evaluation of practical construction knowledge.

Questions	Excavation		Productivity		Pipepile		Formwork		Beam	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Not Solved (%)	100	20	54	14	90	57	99	89	85	44
Solved - Third Attempt (%)	0	3	6	5	3	3	1	0	5	34
Solved - Second Attempt (%)	0	28	19	19	3	12	0	3	4	6
Solved - First Attempt (%)	0	48	21	62	3	28	0	7	6	16
Mean	1	3.05	2.07	3.29	1.2	2.12	1.01	1.28	1.31	1.94
Std. Dev.	0	1.15	1.25	1.08	0.65	1.34	0.07	0.84	0.81	1.07
t-Test Result	Different		Different		Different		Different		Different	

Table1: Actual Performance Comparison For Pre and Post Simulation

Discussion

This test confirms previous findings, regarding that the capabilities of simulation in construction education. Positive results of VICE supports the existing findings that educational simulation can provide students with a learning platform to relate subject matter in a way that leads them to a better understanding of their disciplines. While more testing is necessary for conclusive results, the findings in this study suggest that continued efforts in this area are warranted.

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