MERIT OF COMPUTER GAME IN TACIT KNOWLEDGE ACQUISITION AND RETENTION

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ABSTRACT: Although many efforts have been exerted to increase safety on construction sites, it has never been easy to run a construction project with zero accidents. Previous research indicated that lessons learned from previous projects could help construction professionals prevent repetitive mistakes, but those lessons are based on individual experience, and therefore it is difficult to document and reuse them. Various Web-based database systems were suggested to better manage this tacit knowledge in construction, but transforming someone's tacit knowledge into value for the next project using these systems is still challenging.

Well-designed computer games often offer a number of constructive instructional features especially for young generations who have grown up in an era of computer games. Research in education reports that visual presentation facilitates the human's cognitive process. Would visual representation of tacit knowledge in a computer game help construction professionals acquire tacit knowledge and use it to reduce repetitive accidents on construction sites? In order to figure out whether visual presentation of accident cases in a computer game could improve tacit knowledge acquisition and retention, a prototype Xbox 360 computer game presenting accident scenes using 3D computer models was developed and tested with college students working in the field of construction management.

The data collected from the experiment shows that visual representation in a computer game has potential to improve tacit knowledge acquisition and retention. This paper presents how tacit knowledge was represented in the computer game, how the test was implemented, and some findings.

***Keywords**: Visualization, Computer Game, Knowledge Management*

1. INTRODUCTION

Knowledge management in the project-based construction industry involves the process of collecting knowledge from the previous projects and utilizing it for future projects. Many construction professionals learn lessons from the previous projects and use them to prevent repetitive mistakes. The tacit knowledge of how to prevent repetitive mistakes also enables construction professionals to innovate the construction processes and increase productivity in future projects. Brockmann and Anthony [1] noted that the efficiency of making decisions, serving customers, or producing products, and the accuracy of task performance are improved by the use of tacit knowledge.

Managing tacit knowledge deals with the know how that individual construction professionals gain while the construction projects are executed. Unlike explicit knowledge such as cost data and document templates that can be easily collected in written format, tacit knowledge of know how is highly personal, and therefore is difficult to see, share, copy, and manage [2]. Most tacit knowledge gained during the project is lost if not recorded or shared properly [3]. According to Hickins [4], only 2% of personal experience gained during the construction project is properly recorded and transformed into knowledge that can be shared with others.

Previous research suggest using Information and Communication Technology (ICT) to improve tacit knowledge collection and sharing process [5, 6, 7]. The Internet and wireless telecommunication technology enable users to access Web-based systems to share and exchange information at any time regardless of their location. Therefore, Web-based systems are anticipated to encourage construction professionals to share their tacit knowledge with others.

Most Web-based tacit knowledge management systems, suggested by previous studies, use text or photos to manage tacit knowledge. According to Polanyi [8], who introduced the distinction of knowledge as explicit and tacit, tacit knowledge is not easy to formalize or communicate because it is highly personal and context specific. Converting tacit knowledge into explicit knowledge is therefore difficult and requires a significant amount of time. As Tan et al. [6] recognized, any Web-based tacit knowledge management systems may end up incurring additional workload. Considering that insufficient time is one of the major barriers in knowledge management [9], the merit of Web-based tacit knowledge system may not be fully utilized when tacit knowledge has to be recorded in text.

Knowledge adds value only when it is shared. Liebowitz and Beckman [10] asserted that "sharing knowledge is power" as opposed to the common belief "knowledge is power." Tannenbaum and Alliger [11] also noted that knowledge sharing is the heart of knowledge management. If people do not share what they know, then there is generally little knowledge to be managed. Sharing knowledge is the ultimate goal of knowledge management [12]. However, knowledge retrieval and sharing has been a challenging task in the construction industry [13]. It is observed, especially when insufficient time is available, that knowledge management systems have not been fully utilized by project team members to retrieve knowledge acquired from previous projects. According to Kivrak et al. [7], many knowledge management systems do not provide systemic ways to capture, store, share, and reuse knowledge. For some construction professionals, it is therefore still difficult and time-consuming to retrieve the relevant knowledge using the existing systems. Construction professionals, instead, have a tendency to rely on meetings and phone calls with experienced individuals for problem solving in emergency conditions [7, 14]. Challenges in retrieving necessary knowledge in the knowledge management systems affect the new employee training as well. It would not be an exciting way of learning new knowledge when one has to keep reading many text-based documents without getting a proper guidance based on a training curriculum. The ability to learn across projects is still difficult to achieve.

2. MOTIVATIONS

Research shows that games can enhance knowledge training and retention [15, 16, 17]. After examining 68 studies on educational games in the area of social sciences, math, language arts, physics, biology, and logic, Randel et al. [15] concluded that the use of games is superior to traditional classroom instruction for improving math achievement and knowledge retention. Ricci et al. [16] provided empirical evidence that games can benefit knowledge acquisition and retention in military education. Reese and Wells [17] also reported that the conversation game, where participants use introduction cards to exchange their opinion on a subject, could help English as a Second Language (ESL) students learn discussion skills. Gaudart [18] suggested that games promote an experimental learning environment that keeps learners engaged with the subject matter dynamically.

Well-made games are anticipated to provide an interactive learning-by-doing environment, where the knowledge acquisition and retention process can be improved. Many computer games indeed offer a number of constructive instructional features. Ricci et al. [16] stated that "traditional classroom approaches for teaching knowledge are not always enthusiastically received by young service members who have grown up in an era of computers and computer gaming, and gaming could be considered a potentially powerful instrument for training". Research in educational psychology reports that visual presentation facilitates human's cognitive process [19, 20, 21]. One may be wondering then, whether visual

representation of tacit knowledge in a computer gaming environment would facilitate construction professionals to acquire and retain tacit knowledge.

3. COMPUTER GAMES AND EXPERIMENT PREPARATION

In order to figure out whether a visual presentation of accident cases in a computer game would improve tacit knowledge training in the construction industry, a prototype Xbox 360 computer game presenting accident scenes was developed. Effectiveness of teaching construction professionals safety-related tacit knowledge through the use of the computer game was also evaluated. The computer game was developed to show accident scenes in a virtual space and provide the users with additional information of the accident. The accident scenes were reproduced using 3D computer models of destroyed buildings and injured personnel in a virtual site. The users can fly around the virtual space using a controller and browse these 3D computer models showing the accident scenes. Treasure boxes placed near the accident scene are used to explain what happened. When the user approaches a treasure box, it pops up a window presenting additional information about the accident in text. It is expected that the user can fully understand what happened and why it happened from reading these descriptions. Figure 1 shows the screen of the computer game developed for our investigation.

Fig. 1 A screen of the computer game showing an accident case.

The experiment was designed to seek if visual representation of accident scenes in a computer game would result in better knowledge acquisition and retention than the normal text-based description of accidents on construction sites. More specifically, the experiment was designed to show accident scenes visually in a computer game and see how it helped people acquire knowledge and retain it. Experiment participants were exposed to both the visual gaming environment and traditional text-based training environment to acquire tacit knowledge relative to a certain accident that took place on a given job site. In the gaming environment, the accident scene is described using 3D computer models. A treasure box is used to provide additional information about the accident. In the text-based training environment, the experiment participants are provided a paper-based document describing the same accident thoroughly. The length of this document is generally longer compared to the text-based descriptions provided in the gaming environment for additional information.

After reviewing various accidents reported in ENR magazine, four common accidents were chosen for the test. These four accident cases were then described either in the game using 3D computer graphics or in a paper-based document. In all, we produced four computer game series and four paper-based documents describing these four accident cases. Experiment participants were exposed to these accident cases either by browsing the accident scenes in the computer game or by reading paper-based documents. In order to minimize any bias that could be caused by the learning effect, experiment participants were randomly divided into four groups and they acquired information about 4 accident cases using different representation means.

All participants were exposed to two games and two paper-based representations to acquire information about the accidents, but each group had a different order of going through the accident cases. For example, one group went through the paper-based documents first to acquire information about the accident cases 1 and 2, and then they were exposed to the computer games to gain information about the accident cases 3 and 4. In order to reduce the chance of biased result, from the test, the order of accident cases got mixed with the types of graphical representation.

The order of accident cases presented to the experiment participants is listed in the following table.

Table 1 Order of accident cases used for the test

Group	Accident cases and representation means			
1	Accident case 1 described in a paper-based document	Accident case 2 described in a paper-based document	Accident case 3 presented in a game	Accident case 4 presented in a game
2	Accident case 3 presented in a game	Accident case 4 presented in a game	Accident case 1 described in a paper-based document	Accident case 2 described in a paper-based document
3	Accident case 3 described in a paper-based document	Accident case 4 described in a paper-based document	Accident case 1 presented in a game	Accident case 2 presented in a game
4	Accident case 1 presented in a game	Accident case 2 presented in a game	Accident case 3 described in a paper-based document	Accident case 4 described in a paper-based document

4. EXPERIMENT AND DATA COLLECTED

A total of 32 college students working on construction management were recruited for the test. Based on the group they were assigned to, each participant was requested to acquire information about the accident cases either from browsing the accident scenes in the computer game or by reading the paper-based documents. The experiment participants were then requested to answer 16 questions about the accident cases they learned. Experiment participants were given an unlimited amount of time to finish the experiment. The number of corrected answers was collected to measure how accurately the participants gained knowledge about the accident cases.

Table 2 Knowledge Acquisition Test

Group	Correct Answers with the Paper Option	Correct Answers with the Game Option
1	67%	75%
2	66%	61%
3	36%	64%
4	42%	77%
Average	53%	69%

After a week, another questionnaire, but for the same accident cases, was given to the participants. This time they had to just answer the questions without going through any training. The following table shows the difference between paper-based option and game-based option.

Table 3 Knowledge Retention Test

Group	Correct Answers with the Paper Option	Correct Answers with the Game Option
1	73%	67%
2	53%	67%
3	42%	63%
4	45%	72%
Average	54%	67%

An exit question was also asked at the end of the questionnaire. 91% of participants preferred the computer game for knowledge acquisition.

5. DISCUSSIONS AND CONCLUSIONS

The data collected from the knowledge acquisition test shows that those who were exposed to the game environment achieved a higher score on the test. In average, 69% of answers provided by those who acquired knowledge in the gaming environment were correct. On the other hand, only 53% of answers provided by those who acquired information of the accident cases from reading paper documents were correct. The data collected from the knowledge retention test shows that the visual representation in the gaming environment might have something to do with knowledge retention. In average, 67% of answers provided by those who gained knowledge in the gaming environment were correct, while 54% of answers provided by those who gained knowledge from reading paper documents were correct.

The computer game developed for our investigation promoted an interactive learning-by-doing environment, which helped experiment participants get more engaged in the knowledge seeking process. Visual representation of accident cases helped them better understand the spatial condition in a hazard area. Experiment participants exposed to the visual presentation

of accident cases in the computer game appeared to gain more knowledge and retain it longer than those who were given paper-based documents. The experiment outcome gave us some idea as to how visual representation in a computer gaming environment would affect our tacit knowledge acquisition and retention. The exit survey clearly shows that participants liked to use the computer game than paper document for knowledge acquisition.

The experiment presented in the paper, however, does not suggest any solutions as to how we want to collect tacit knowledge and how we want to present it in the computer games. More research is needed to figure out how to collect tacit knowledge, and how to transform tacit knowledge into explicit knowledge that can be used for the educational game development.

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