MERIT OF COMPUTER GAME IN TACIT KNOWLEDGE ACQUISITION AND RETENTION FOR SAFETY TRAINING IN THE CONSTRUCTION INDUSTRY

A Thesis

by

NIDHI MAHAVIRPRASAD JAIN

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2010

Major Subject: Construction Management

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Approved by:

Chair of Committee,	Julian Kang
Committee Members,	Wei Yan
	Vinod Srinivasan
Head of Department,	Joe Horlen

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ABSTRACT

Merit of Computer Game in Tacit Knowledge Acquisition and Retention for Safety Training in the Construction Industry. (December 2010)

Nidhi Mahavirprasad Jain, B.En., Gujarat University

Chair of Advisory Committee: Dr. Julian Kang

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 game had 3D construction site accident scenes with treasure boxes hidden and the players had to find the treasure boxes and read the information obtained from it. The treasure boxes were placed relative to the information they carried. The text part had the same accident scenes explained in text with details of what should have been followed to avoid the accident. Students from the field of construction management and civil engineering were requested to participate in the test. Each participant went through two accidents in text and two accidents in the game environment and answered a set of 16 questions based on the knowledge they gained. There was no time limit for the test. They also had to answer an exit question as to which training method they preferred. The participants were asked to come again on the seventh day to answer a set of 16 questions without going through any training to check the retention of knowledge.

Statistically we can say that on an overall basis visual training had more correct answers than text for knowledge dissemination as well as retention. But there was no statistical difference seen in the number of correct answers obtained from dissemination and retention tests for text as well as visual training.

The data collected from the experiment shows that visual representation in a computer game has potential to improve tacit knowledge acquisition and retention.

DEDICATION

To my parents

ACKNOWLEDGEMENTS

First of all, I would like to thank my committee chair, Dr. Julian Kang for always motivating and guiding me during the entire period of my research work. I am also thankful to my committee members Dr. Wei Yan and Dr. Vinod Srinivasan for always being there to relieve my doubts and also for giving their precious time whenever I needed.

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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 (1998) 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 (Payne and Sheehan 2004). Most tacit knowledge gained during the project is lost if not recorded or shared properly (Fong and Wong, 2005). According to Hickins (2000), only 2% of personal experience gained during the construction project is properly recorded and transformed into knowledge that can be shared with others.

This thesis follows the style of the *Journal of Construction Engineering and Management*.

Previous research suggest using Information and Communication Technology (ICT) to improve tacit knowledge collection and sharing process (Lin et al., 2005; Tan et al., 2007; and Kivrak et al., 2008). 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 (1967), 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. (2007) 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 (Carrillo et al., 2004), 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 (1998) asserted that "sharing knowledge is power" as opposed to the common belief "knowledge is power." Tannenbaum and Alliger (2000) 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 (Tserng and Lin, 2005). However, knowledge retrieval and sharing has been a challenging task in the construction industry (Woo et al, 2004). 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. (2008), 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 (Fong and Chu, 2006; Kivrak et al., 2008). 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. MOTIVATION

Research shows that games can enhance knowledge training and retention (Randel et al., 1992; Ricci et al., 1996, Reese and Wells, 2007). After examining 67 studies on educational games in the area of social sciences, math, language arts, physics, biology, and logic, Randel et al. (1992) concluded that the use of games is superior to traditional classroom instruction for improving math achievement and knowledge retention. Ricci et al. (1996) provided empirical evidence that games can benefit knowledge acquisition and retention in military education. Reese and Wells (2007) 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 (1999) 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. Ricci et al. (1996) 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 (Murgio, 1969; Johnson-Laird et al., 1972; Nakano et al., 2000). 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. OBJECTIVES

The objectives for this research are as follows:

- To test the effectiveness of visual graphics/ game for dissemination and retention of tacit knowledge in the construction industry.
- To check the feasibility of the application of visual graphics/game for safety training personnel in the construction industry.

4. LITERATURE REVIEW

Knowledge is important and valuable to any company to a great extent(Stewart 1997). A company's level of quality gets better if their employees are trained with the latest technology.

Previous research suggested several methods for knowledge dissemination such as setting up list serves for individuals concerned about particular processes of construction (Shiltsone, 2005), live capture of facts obtained from meetings (i.e. minutes of meeting) or seminars or conferences (Tan,.et al. 2007).

4.1 Game for Interactive Learning

Games and simulations, as a medium for learning have long been established in the fields of language, medical training and communication. When asked to choose between classroom discussions and learning through games, students have preferred games as a better learning tool and expression of ideas. Also, students with English as a second language are assisted through games and encouraged to actively participate in experiments and learning the material. Learning through games and simulations are unbeaten and have proved to be successful tool beyond all hopes. (Garris, et. al (2002), Gaurdart(1999), Premkumar and Bonnycastle(2006))

Effectiveness of games as a tool for education as researched by experts concluded that learning through visual communication such as simulation or video games results into more retention of knowledge in the students. Randel et al(1992), examined 67 investigations to test the effectiveness of games for educational purposes covering a period of 28 years. Of these investigations, 38 found no difference between games and conventional classroom instruction, 22 favored the use of games, 5 favored games but used questionable control groups, and only 3 favored conventional instruction. Ten of the 14 efforts measuring retention reported significant effects favoring simulation and gaming for retention.

One of the reasons which explain effectiveness of computer-based games for learning is that the games act as a motivational factor in students. However, games may not result into a very effective training tool. Knowledge retention is greater in the students when a test is conducted after a presentation. Students then know what information they have acquired through the presentation and how much more do they need to concentrate and learn. Also, learning becomes an active interaction and competitive process when conducted using gaming approach.

4.2 Computer Game vs. Traditional Game

Training should be designed to optimize skill acquirement and retention. One of the primary reasons given as a justification for the effectiveness of computer-based gaming is that people get involved in gaming as compared with a conventional learning method. Studies have shown that knowledge training and retention can be improved by computer-based games (Ricci, et. al 1996). As far as training is concerned, computer-based games offers a number of constructive instructional features. Moreover, computer-based gaming might stimulate trainees to concentrate on matter to which they would not pay attention otherwise.

Earlier studies on effectiveness of computer-based games for learning compared to learning through texts have concluded that the participants assigned to the game retained more knowledge and maintained it for a longer period of time when compared to participants assigned to text reading. It is important that the knowledge first acquired is retained through the period of use and also maintained over a period of disuse. Thus, the other attribute of learning through games and simulations over reading text is the knowledge retention even after a period of abandonment. Also, goal achievement and competition between students for points in the game results in to students making greater efforts at learning.

Benefits of computer-based gaming are (Ricci, et. al (1996)):

- Active participation: Students find themselves out of traditional classroom environment and therefore interact well, suggesting their ideas and understanding.
- Immediate feedback: After presentation test, resulting into immediate knowhow to the student about the part he/she learned and the portions of the presentation he/she still needs to concentrate on and remember.
- Dynamic interaction: After some experience with computer-based gaming approach, students get self-motivated and thus interact better in the learning process.
- Competition: Positive competition between students learning through computer-based games. Focus is on who achieves most points, therefore each student striving to get better and in the process learning more.
- Novelty: Entirely different and new approach compared to historical classroom learning and reading process. Game approach not only helps initial basic acceptance of knowledge but also aids retaining and maintaining the knowledge lifelong.
- Goal direction: Motivation to the students towards achieving a specific goal or a point balanced with other students achievements.

4.3 Visual Representation for Knowledge Dissemination

In a study done by George Ofori (1993), bad communication leading to loss in information from one person to another was one of the major problems in the industry. Berhane (1988) complained about the lack of importance given to new studies and practices which in turn de-motivates the people working towards advancement of the industry. According to United Nations Centre for Human Settlements (1988), many research works have been done and the next important step is to share it with the world. Thus, it is very important that all the corporations, big or small, to train their employees and also make sure that the work in offices as well as on site is well managed.

Visual images help organize, illustrate and understand the data. Students learn through visual communication faster when compared to reading text. As they can be easily comprehended, images still do not hold equal significance to that of reading for adolescent and adult learning. However, visual images aid students to describe, analyze, solve problems and notice important information. Students learn to think and analyze like experts in their fields. Visual images make it possible for students to pay attention, remember the numbers and build significance of the data represented to them. Any individual depicts an image based on his/her life and previous experience while students and experts need to organize the data in a way that they can look and pull out importance from the data they are observing. Thus, students start comprehending the complexity of the world and learn untangling the intricately woven human life.(Elizabeth, et. al., 2008)

Representation in the form of art or performance resulted into creating new worlds for the students. Students now are able to sense and grasp the thoughts that impact other persons' world. (Pineau (1998) and Fulton Suri(2003))

"The conventional vision divides rational thinking into distinct steps of 'sense-think-act'." (Colunga and Smith 2008) They also said that, if a person already has knowledge

about something he will think and act accordingly. That is why it is very important to train employees regarding all the aspects of the work they are expected to perform. So that their every action is based on some logic or knowledge they have gained earlier.
Previous experiments involving training of students through computer-based games have proven to be very successful in a way that trainees acquire and retain more information and knowledge. Through game based training students are able to grasp basic facts and concepts before they are able to compile and transform this knowledge into subsequent retention. (Ricci et al, 1996).

Moreover, if technologies are so selected which would improvise knowledge dissemination and retention then even personnel in the construction industry will agree to implement them.

Chou, et. al. (2007) designed the steps that would lead to better knowledge management in any organization. The steps were: ‘teachability, codificability, information acquisition, information dissemination, organizational memory, information integration and perceived usability’. They proved that the steps were inter-related. And hence knowledge attainment and dissemination are dependent on the way it was taught or transferred. And better knowledge dissemination will lead to smarter employees which will lead to improved organization and hence enhanced construction industry.

Shiltsone (2005) has also pointed out that even though American Concrete Institute has been working since several years in dispensing knowledge through periodicals still they hear criticisms such as people do not read their articles and they are not able to provide information in the proper way.

Information stored in the organization is very much dependent on how the information was achieved and for which operation it is to be used. Knowledge transfer becomes important once the information stored in any company becomes huge. Otherwise that stored information becomes useless. This is the reason why information management is so important. And as the knowledge dissemination increases the information stored in the company will also keep on increasing, and this is how the company will make a strong place in the market.

Tan et. al.(2004) suggested that, to improve knowledge dissemination in the industry there should be a method so as to record whatever happens at the site during the construction process. They recommended a web-based knowledge management system which would also help in revisiting and learning what happened on previous projects. A survey taken in UK concluded that half of the participants thought using this managing knowledge would help in inventing new technologies in the industry. Another survey showed that about $2/5^{th}$ organization were using storing and reusing the knowledge they had and other $2/5^{th}$ were planning to start on doing that. In spite of knowing the significance of organizing information, proper dissemination is not yet achieved to gain all the benefits.

Since many years, research is being done for advance technologies and practices in the construction industry but very little have been achieved. To improve this, Orfori (1993) suggested that an organization which would work worldwide for the betterment of the industry should be formed.

5. METHODOLOGY

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. This text message is retrieved directly from a table saved in SQL Server which is connected to the game. It is expected that the user can fully understand what happened and why it happened from reading these descriptions.

Some pictures showing the accident scenes, treasure boxes and pop-up messages are given below(Figs 5.1-5.8) for a better understanding of the game.

FIG. 5.1. Accident scene1

FIG. 5.2. Accident scene2

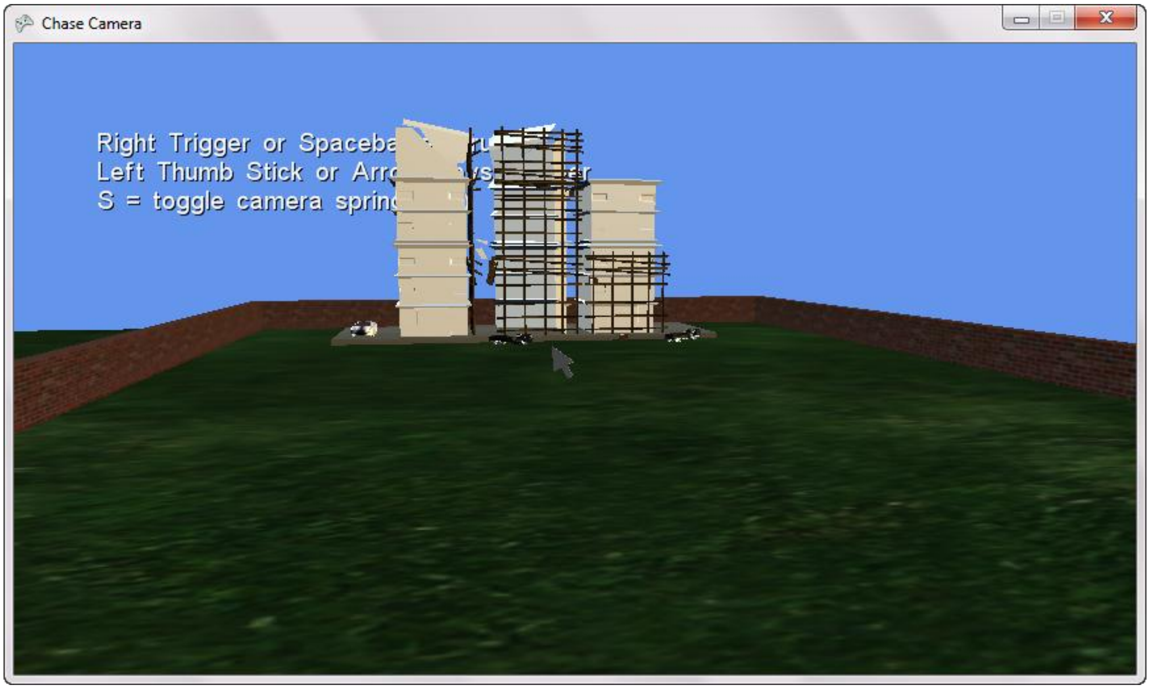


FIG. 5.3. Accident scene3

FIG. 5.4. Accident scene4

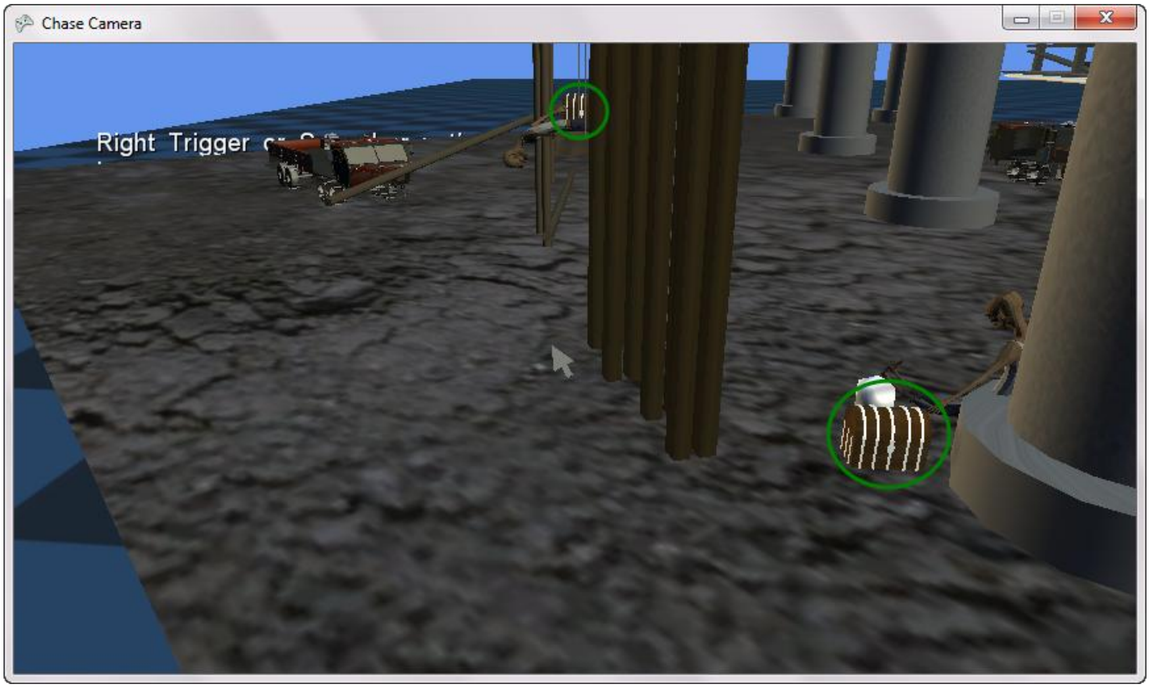


FIG. 5.5. Scene showing treasure boxes

FIG. 5.6. Another scene showing treasure box

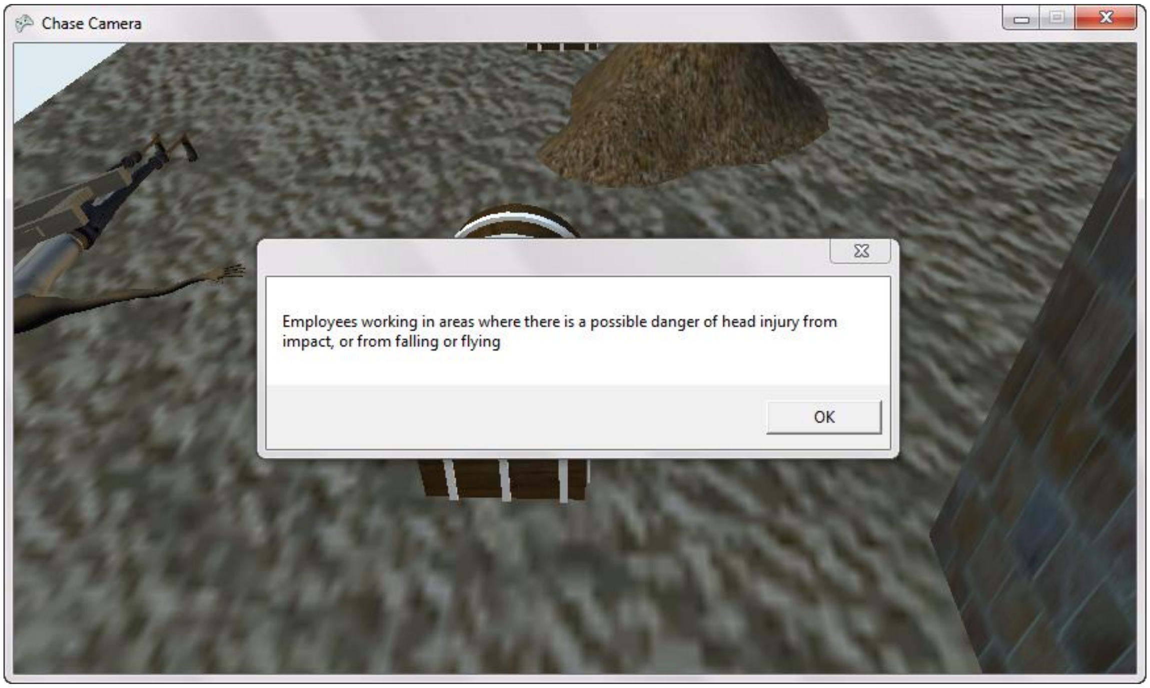


FIG. 5.7. Scene showing a pop-up message

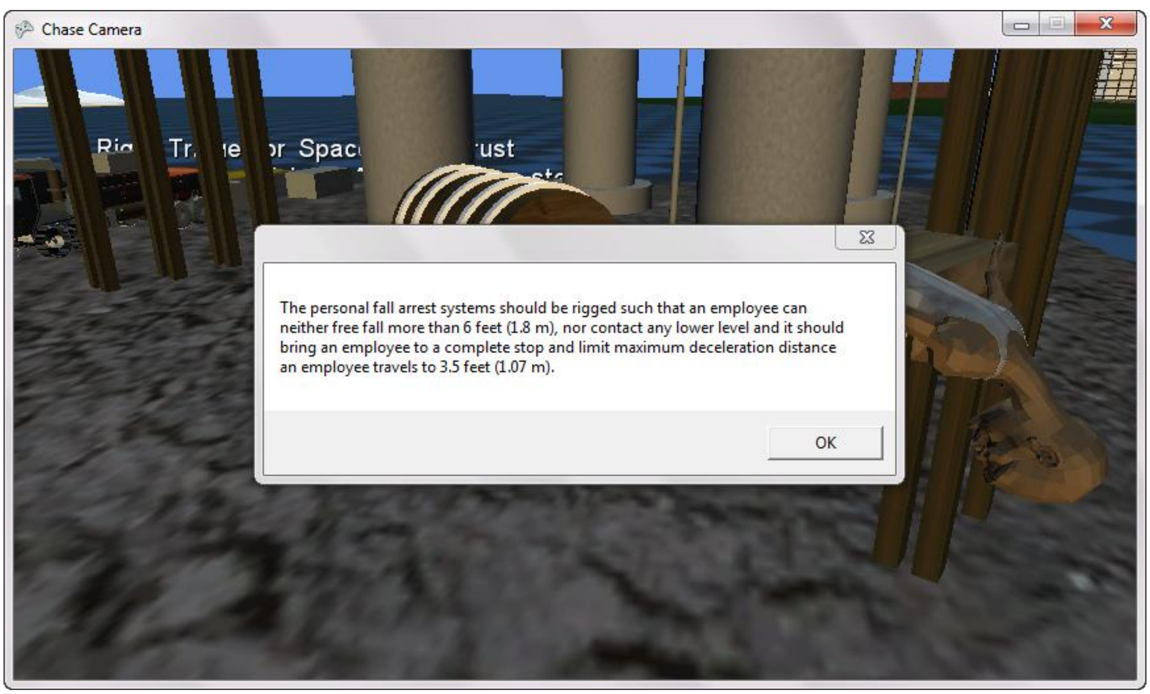


FIG. 5.8. Another scene showing a pop-up message

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 (Appendix A.1). 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, there were 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 Table 5-1 below.

TABLE 5-1. 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

6. EXPERIMENT

For the experiment, first of all we had to get the approval from the Institutional Review Board (IRB) for the protection of humans participating in the research as participants. After going through the various application types, it was concluded that this research would come under the exempt application.

Prospective participants were students of department who have knowledge and/or experience in the area/field related to construction namely, Department of Construction Science and Department of Civil Engineering at Texas A&M University. They were invited using letters of invitation and sending emails for invitation. The research involved minimal risk. Those who agreed to participate in the research were given time-slots. The participants were emailed again for confirmation. This email also had the information regarding the place where the experiment would be conducted.

The experiment was conducted in the J.K. Williams Administration Building, Room 010 on Texas A&M University. The participants had to come there for 30 minutes for the first day and for 15 minutes after a week. The research was anonymous and no monetary compensation was given to the participants.

A total of 32 college students working on construction management from the college of architecture or students from the civil engineering department were recruited for the test. Based on the group they were assigned to, each participant was requested to acquire information about the accident cases from browsing two accident scenes in the computer game and by reading two accident scenes from 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. And an exit question was asked to know the method they preferred.

After a week the participants were asked to come again at the same place. And this time they had to answer only a questionnaire which had 16 questions. This time did not have to go through any training. The questions in this questionnaire were the same as the questions in the questionnaire on the first day but in a different order. The options to the questions were also in different order. The number of corrected answers was collected to measure how accurately the participants retained knowledge about the accident cases.

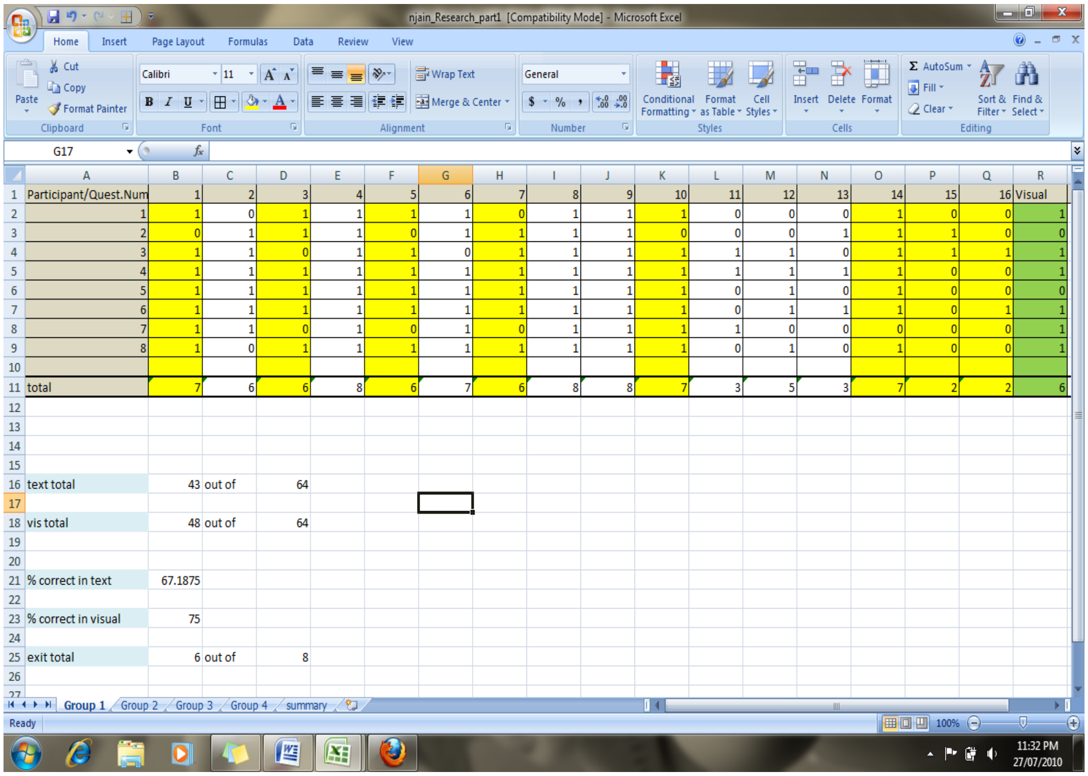
7. DATA COLLECTED

7.1 Knowledge Dissemination

As mentioned in the methodology section (Section 5) the participants were divided into four groups randomly, to remove bias. The groups were different with respect to the order of the textual and visual representation of the accident scene and the order of the accident scenes. Each participant was given a questionnaire which had 16 questions – 8 based on knowledge gained from text and 8 based on knowledge gained from game. Basically there were 4 questions based on every accident scene. These questions were also randomly arranged to remove bias.

After the first part of the testing, the answers were checked for each questions and the data was arranged in an excel sheet group-wise. (Figures 7.1, 7.2, 7.3,7.4)

The excel sheet had the number of participants on one side and the question number on the other. The questions that were answered correctly were given 1 point and the questions that were not answered correctly were given 0 point. The total of all the points for each questions were calculated. The questions that were from the text-based training for each group were marked in yellow. And then the total of all points achieved for text-based questions and visual based-questions were calculated. And the percentage of correct answers for text and visual were calculated.
As mentioned earlier, an exit question was asked on the first day of testing, to know whether the students preferred training via visual method or textual method. The exit question answer was marked in green. If the students marked visual method then 1 point was given otherwise 0 point was given. The total of the points for that question was calculated.

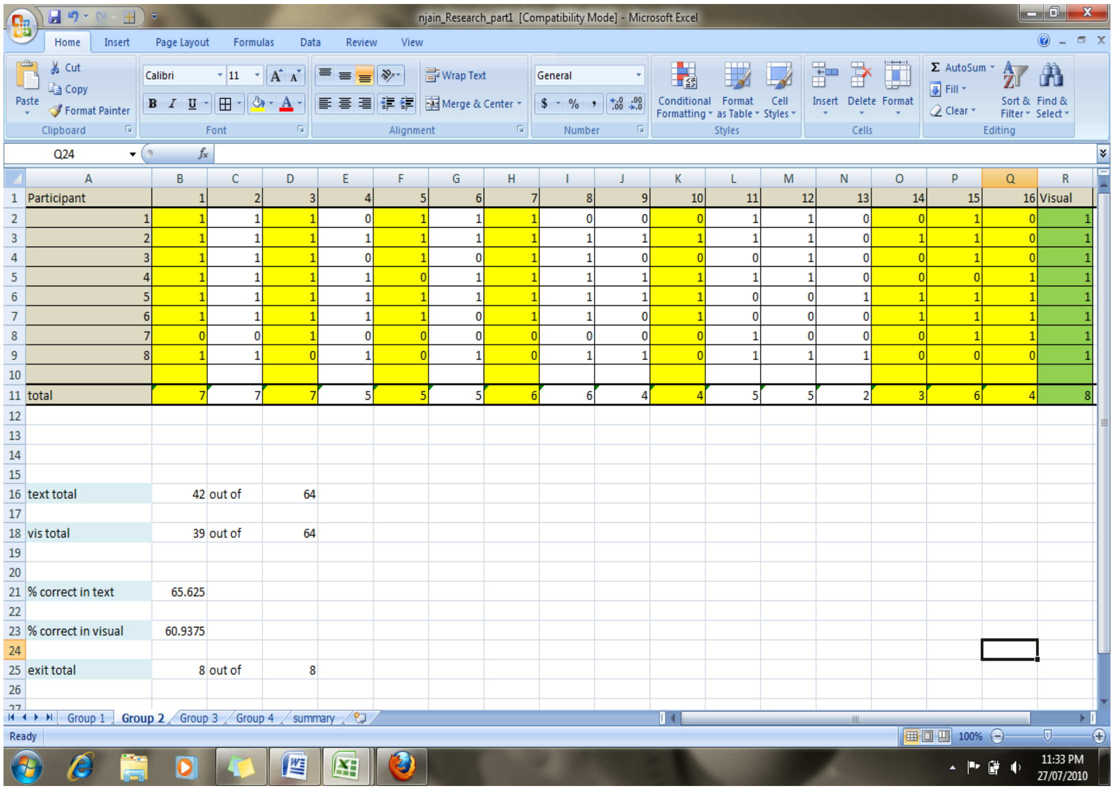


Participant/Quest.Num	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Visual
1	1	0	1	1	1	1	0	1	1	1	0	0	0	1	0	0	1
2	0	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0	0
3	1	1	0	1	1	0	1	1	1	1	1	1	0	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1
5	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	0	0
6	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1
7	1	1	0	1	0	1	0	1	1	1	1	0	0	0	0	0	1
8	1	0	1	1	1	1	1	1	1	1	0	1	0	1	0	0	1
total	7	6	6	8	6	7	6	8	8	7	3	5	3	7	2	2	6

text total	43	out of	64
vis total	48	out of	64
% correct in text	67.1875		
% correct in visual	75		
exit total	6	out of	8

FIG. 7.1. Screenshot of excel sheet showing data collected from group1 for knowledge dissemination

From Fig. 7.1, for group 1 (Table 5-1), the total correct answers for questions based on text-based training were 43 out of 64 (67.19%) and that for visual-based training were 48 out of 64 (75%). The total of the exit question was 6 out of 8.

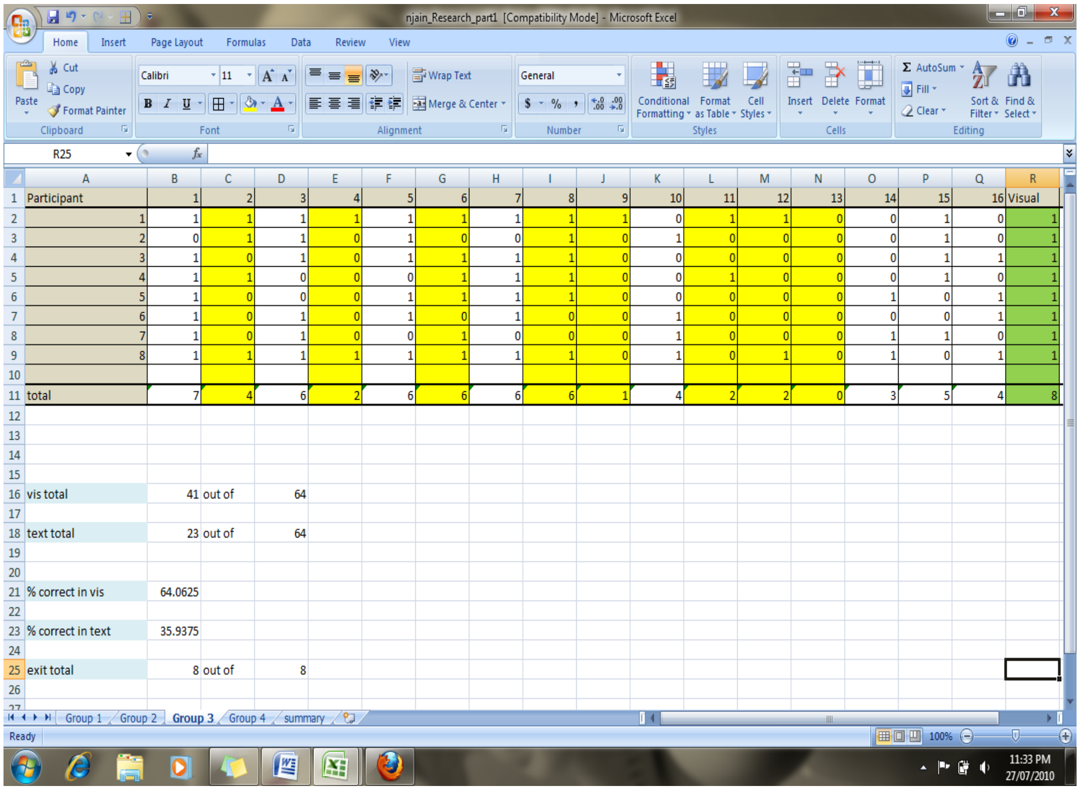


Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Visual
1	1	1	1	0	1	1	1	0	0	0	1	1	0	0	1	0	1
2	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1
3	1	1	1	0	1	0	1	1	0	0	0	1	0	0	1	0	1
4	1	1	1	1	0	1	1	1	1	1	1	1	0	0	0	1	1
5	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1
6	1	1	1	1	1	0	1	1	0	1	0	0	0	1	1	1	1
7	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	1	1
8	1	1	0	1	0	1	0	1	1	0	1	1	1	0	0	0	1
total	7	7	7	5	5	5	6	6	4	4	5	5	2	3	6	4	8

text total	42	out of	64
vis total	39	out of	64
% correct in text	65.625		
% correct in visual	60.9375		
exit total	8	out of	8

FIG. 7.2. Screenshot of excel sheet showing data collected from group2 for knowledge dissemination

From Fig. 7.2, for group 2 (Table 5-1), the total correct answers for questions based on text-based training were 42 out of 64 (65.63%) and that for visual-based training were 39 out of 64 (60.94%). The total of the exit question was 8 out of 8.

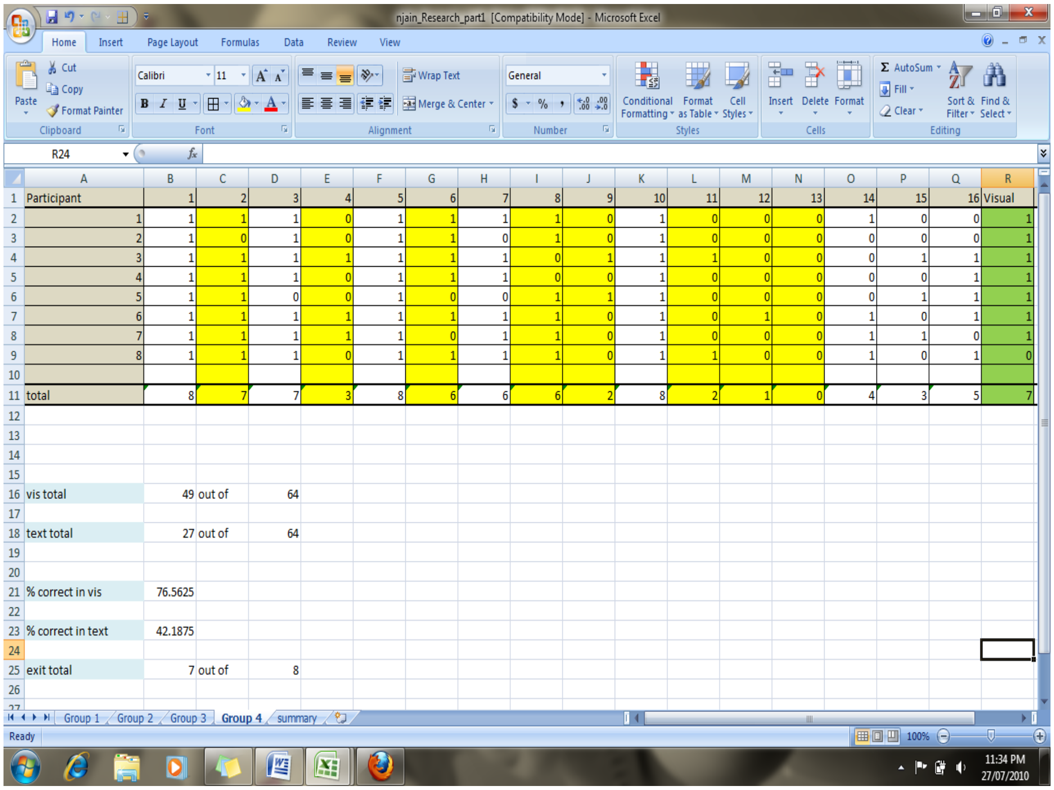


Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Visual
1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	1	0	1
2	0	1	1	0	1	0	0	1	0	1	0	0	0	0	1	0	1
3	1	0	1	0	1	1	1	1	0	0	0	0	0	0	1	1	1
4	1	1	0	0	0	1	1	1	0	0	1	0	0	0	1	0	1
5	1	0	0	0	1	1	1	1	0	0	0	0	0	1	0	1	1
6	1	0	1	0	1	0	1	0	0	1	0	0	0	0	0	1	1
7	1	0	1	0	0	1	0	0	0	1	0	0	0	1	1	0	1
8	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	1
total	7	4	6	2	6	6	6	6	1	4	2	2	0	3	5	4	8

vis total	41	out of	64
text total	23	out of	64
% correct in vis	64.0625		
% correct in text	35.9375		
exit total	8	out of	8

FIG. 7.3. Screenshot of excel sheet showing data collected from group3 for knowledge dissemination

From Fig. 7.3, for group 3 (Table 5-1), the total correct answers for questions based on text-based training were 23 out of 64 (35.94%) and that for visual-based training were 41 out of 64 (64.06%). The total of the exit question was 8 out of 8.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Visual
2	1	1	1	1	0	1	1	1	1	0	1	0	0	0	1	0	0	1
3	2	1	0	1	0	1	1	0	1	0	1	0	0	0	0	0	0	1
4	3	1	1	1	1	1	1	1	0	1	1	1	0	0	0	1	1	1
5	4	1	1	1	0	1	1	1	0	0	1	0	0	0	0	0	1	1
6	5	1	1	0	0	1	0	0	1	1	1	0	0	0	0	1	1	1
7	6	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	1
8	7	1	1	1	1	1	0	1	1	0	1	0	0	0	1	1	0	1
9	8	1	1	1	0	1	1	1	1	0	1	1	0	0	1	0	1	0
10																		
11	total	8	7	7	3	8	6	6	6	2	8	2	1	0	4	3	5	7
16	vis total	49	out of	64														
18	text total	27	out of	64														
21	% correct in vis	76.5625																
23	% correct in text	42.1875																
25	exit total	7	out of	8														

FIG. 7.4. Screenshot of excel sheet showing data collected from group4 for knowledge dissemination

From Fig. 7.4, for group 4 (Table 5-1), the total correct answers for questions based on text-based training were 27 out of 64 (42.19%) and that for visual-based training were 49 out of 64 (76.56%). The total of the exit question was 7 out of 8.

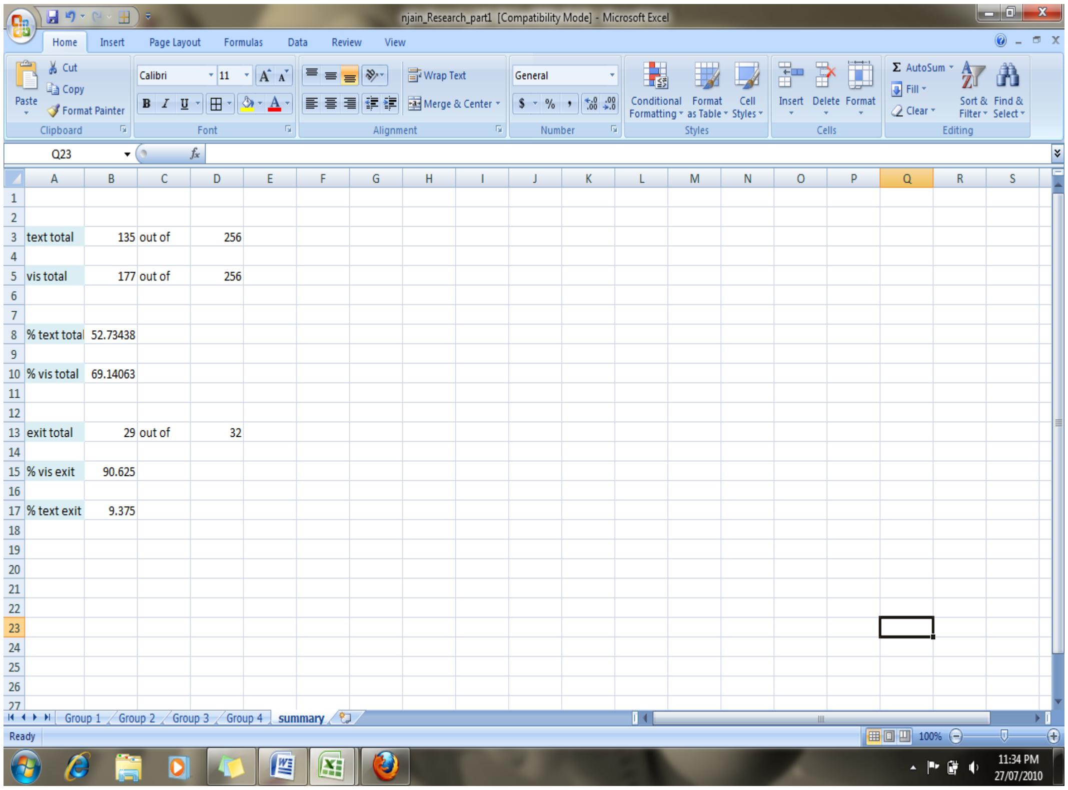


FIG. 7.5. Screenshot of excel sheet showing summary of data collected for knowledge dissemination

From Fig. 7.5, for the entire knowledge dissemination test, the total correct answers for questions based on text-based training were 135 out of 256 (52.74%) and that for visual-based training were 177 out of 256 (69.14%).

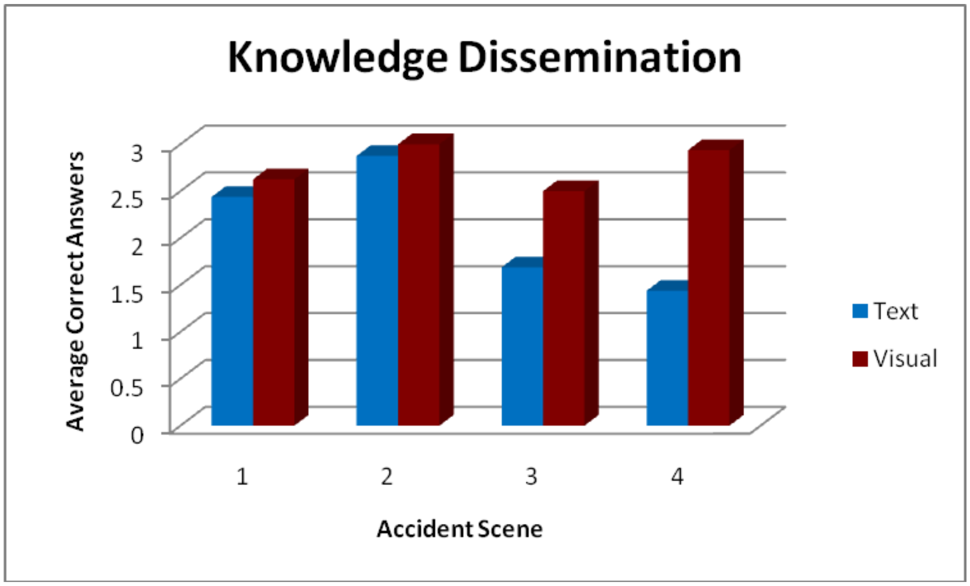


FIG. 7.6. Graph of knowledge dissemination data based on accident scenes

Fig 7.6 shows the comparison between the average correct answer per student for every accident scene for text-based training and visual training.

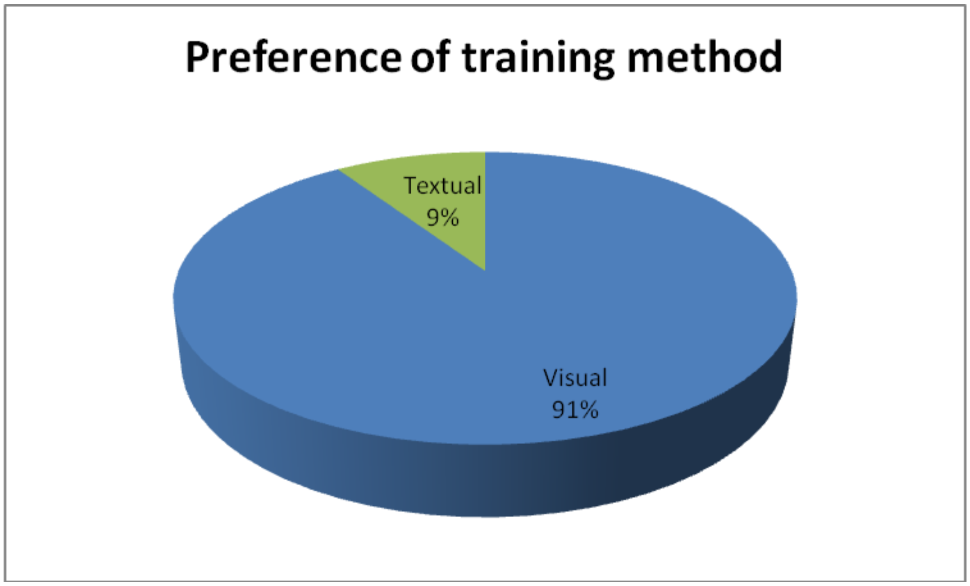
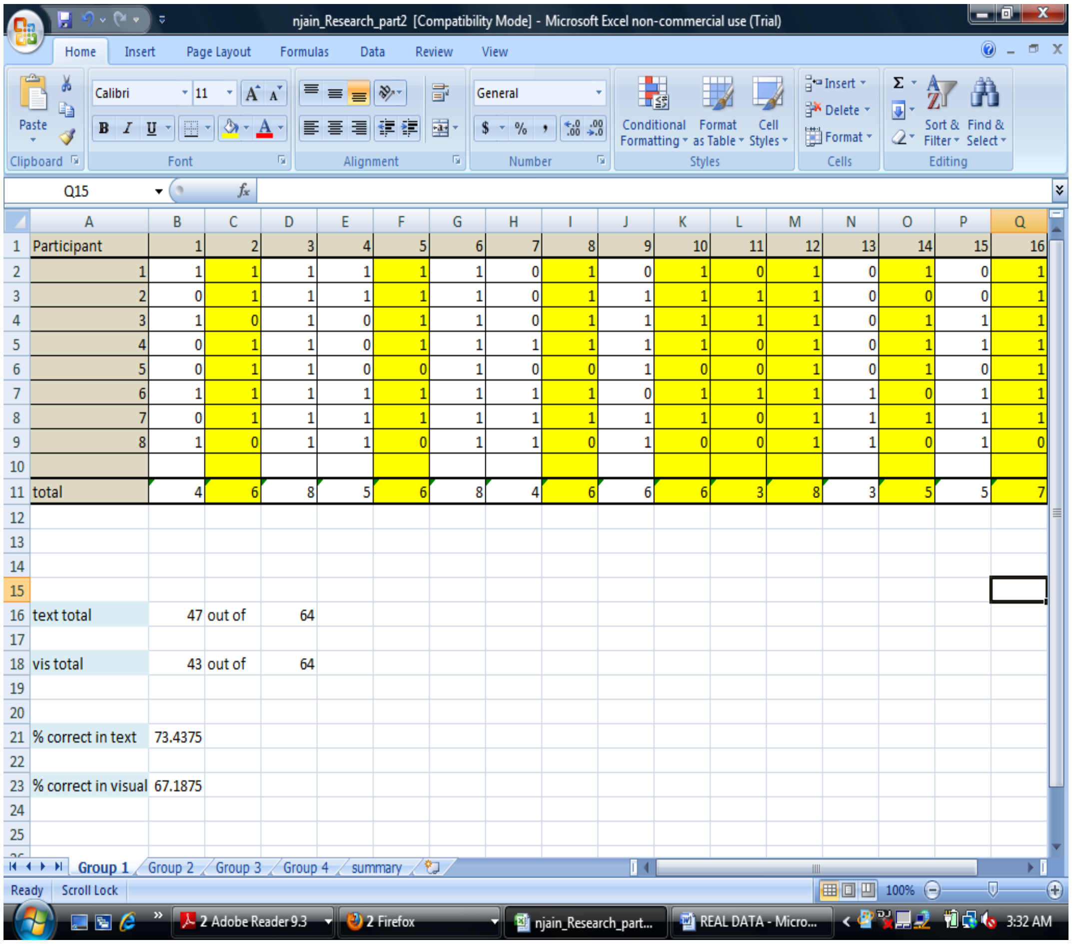


FIG. 7.7. Graph of training method preference

Fig 7.7, shows the total of the exit question graphically, which was 29 out of 32 (90.63%).

7.2 Knowledge Retention

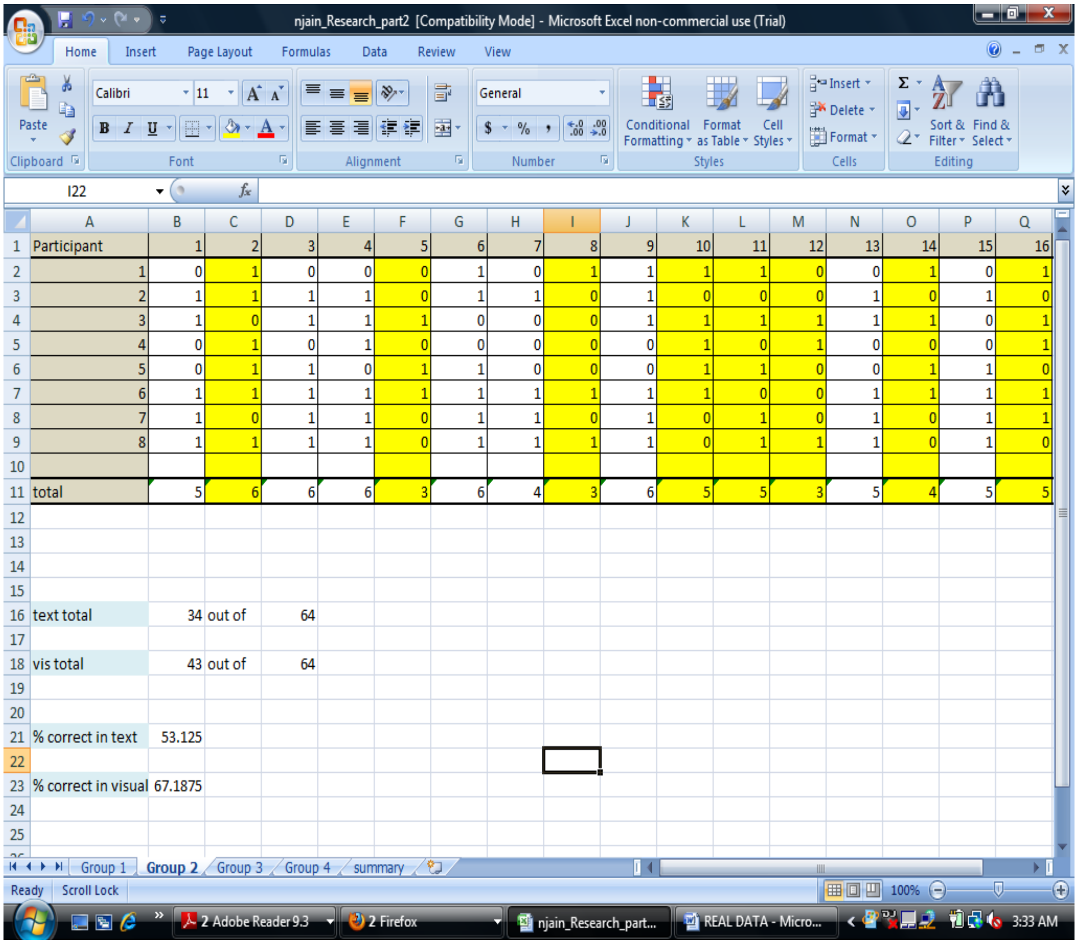
As mentioned earlier, the participants were given a questionnaire on the 7th day to test the knowledge retention from visual and textual training. The questions were randomly arranged. The same questions were asked as the first test, but they were not in the same order. And secondly, the options for the answers were also shuffled. After all the participants answered the questionnaire, the data was entered in an excel sheet in the same manner as it was done for the data collected for knowledge dissemination.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	1
3	2	0	1	1	1	1	1	0	1	1	1	1	1	0	0	0	1
4	3	1	0	1	0	1	1	0	1	1	1	1	1	0	1	1	1
5	4	0	1	1	0	1	1	1	1	1	1	0	1	0	1	1	1
6	5	0	1	1	0	0	1	0	0	1	0	0	1	0	1	0	1
7	6	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1
8	7	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
9	8	1	0	1	1	0	1	1	0	1	0	0	1	1	0	1	0
10																	
11	total	4	6	8	5	6	8	4	6	6	6	3	8	3	5	5	7
16	text total	47	out of	64													
18	vis total	43	out of	64													
21	% correct in text	73.4375															
23	% correct in visual	67.1875															

FIG. 7.8. Screenshot of excel sheet showing data collected from group1 for knowledge retention

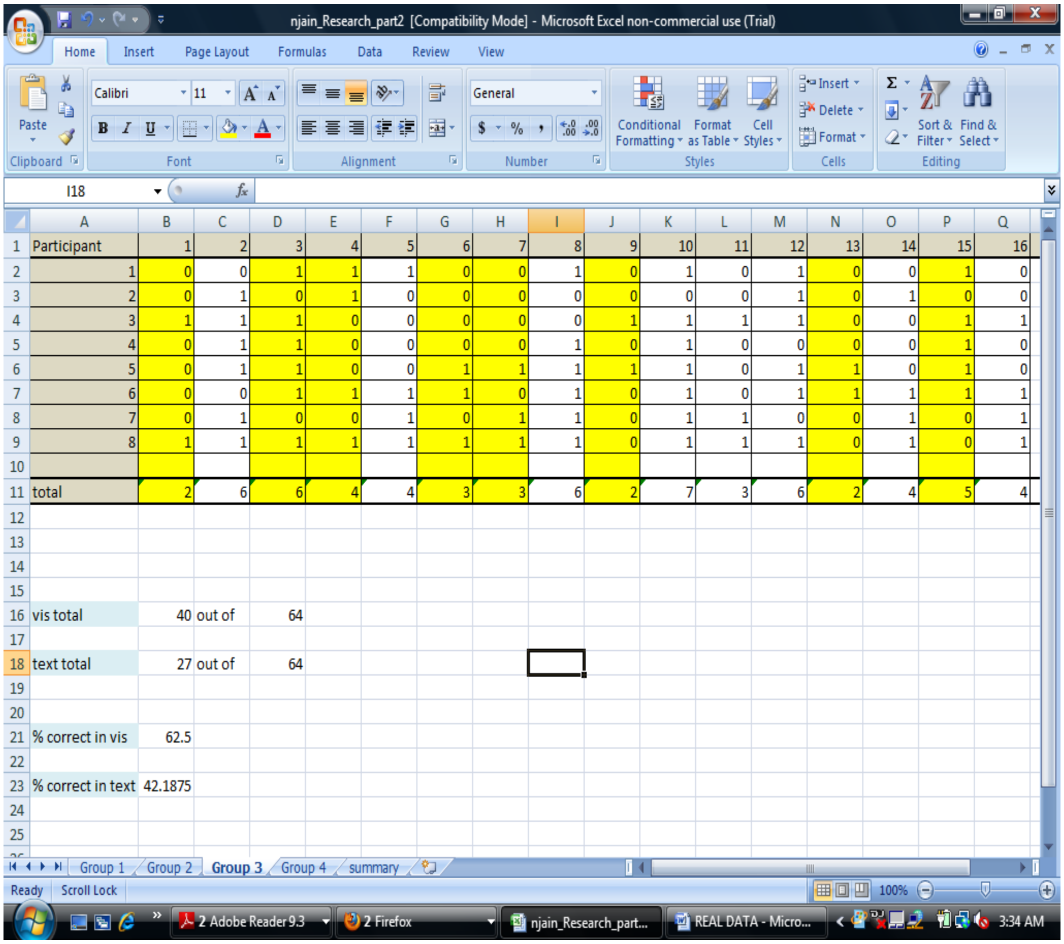
From Fig 7.8, for group 1 (Table 5-1), the total correct answers for questions based on text-based training were 47 out of 64 (73.44%) and that for visual-based training were 43 out of 64 (67.19%).



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	1	0	1	0	0	0	1	0	1	1	1	1	0	0	1	0	1
3	2	1	1	1	1	0	1	1	0	1	0	0	0	1	0	1	0
4	3	1	0	1	1	1	0	0	0	1	1	1	1	1	1	0	1
5	4	0	1	0	1	0	0	0	0	0	1	0	1	0	0	0	1
6	5	0	1	1	0	1	1	0	0	0	1	1	0	0	1	1	0
7	6	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1
8	7	1	0	1	1	0	1	1	0	1	0	1	0	1	0	1	1
9	8	1	1	1	1	0	1	1	1	1	0	1	1	1	0	1	0
10																	
11	total	5	6	6	6	3	6	4	3	6	5	5	3	5	4	5	5
16	text total	34	out of	64													
18	vis total	43	out of	64													
21	% correct in text	53.125															
23	% correct in visual	67.1875															

FIG. 7.9. Screenshot of excel sheet showing data collected from group2 for knowledge retention

From Fig 7.9, for group 2 (Table 5-1), the total correct answers for questions based on text-based training were 34 out of 64 (53.13%) and that for visual-based training were 43 out of 64 (67.19%).

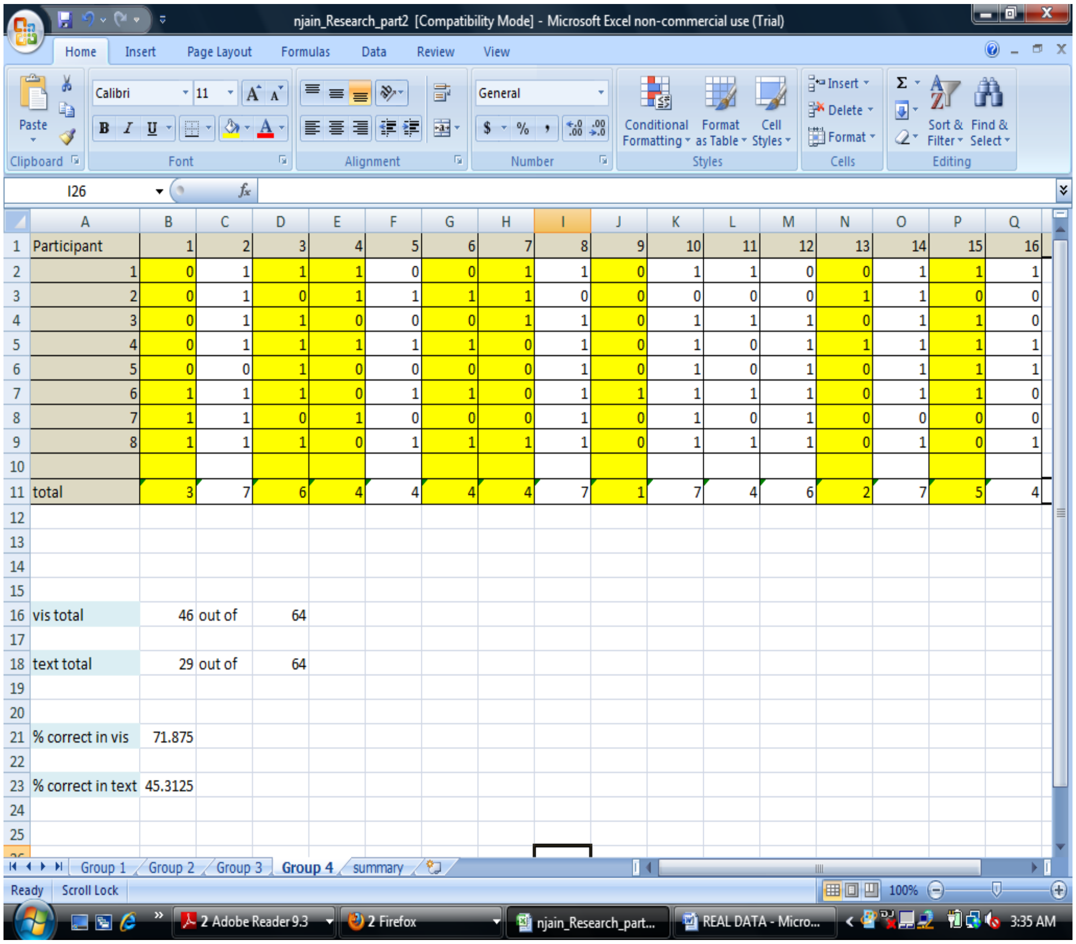


Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0	1	1	1	0	0	1	0	1	0	1	0	0	1	0
2	0	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0
3	1	1	1	0	0	0	0	0	1	1	1	1	0	0	1	1
4	0	1	1	0	0	0	0	1	0	1	0	0	0	0	1	0
5	0	1	1	0	0	1	1	1	1	1	0	1	1	0	1	0
6	0	0	1	1	1	1	0	1	0	1	0	1	1	1	1	1
7	0	1	0	0	1	0	1	1	0	1	1	0	0	1	0	1
8	1	1	1	1	1	1	1	1	0	1	1	1	0	1	0	1
total	2	6	6	4	4	3	3	6	2	7	3	6	2	4	5	4

vis total	40	out of	64
text total	27	out of	64
% correct in vis	62.5		
% correct in text	42.1875		

FIG. 7.10. Screenshot of excel sheet showing data collected from group3 for knowledge retention

From Fig 7.10, for group 3 (Table 5-1), the total correct answers for questions based on text-based training were 27 out of 64 (42.19%) and that for visual-based training were 40 out of 64 (62.5%).



Participant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	1	1	1	0	0	1	1	0	1	1	0	0	1	1	1
2	0	1	0	1	1	1	1	0	0	0	0	0	1	1	0	0
3	0	1	1	0	0	0	1	1	0	1	1	1	0	1	1	0
4	0	1	1	1	1	1	0	1	0	1	0	1	1	1	1	1
5	0	0	1	0	0	0	0	1	0	1	0	1	0	1	1	1
6	1	1	1	0	1	1	0	1	1	1	1	1	0	1	1	0
7	1	1	0	1	0	0	0	1	0	1	0	1	0	0	0	0
8	1	1	1	0	1	1	1	1	0	1	1	1	0	1	0	1
total	3	7	6	4	4	4	4	7	1	7	4	6	2	7	5	4

vis total	46	out of	64
text total	29	out of	64
% correct in vis	71.875		
% correct in text	45.3125		

FIG. 7.11. Screenshot of excel sheet showing data collected from group4 for knowledge retention

From Fig 7.11, for group 4 (Table 5-1), the total correct answers for questions based on text-based training were 29 out of 64 (45.31%) and that for visual-based training were 46 out of 64 (71.88%).

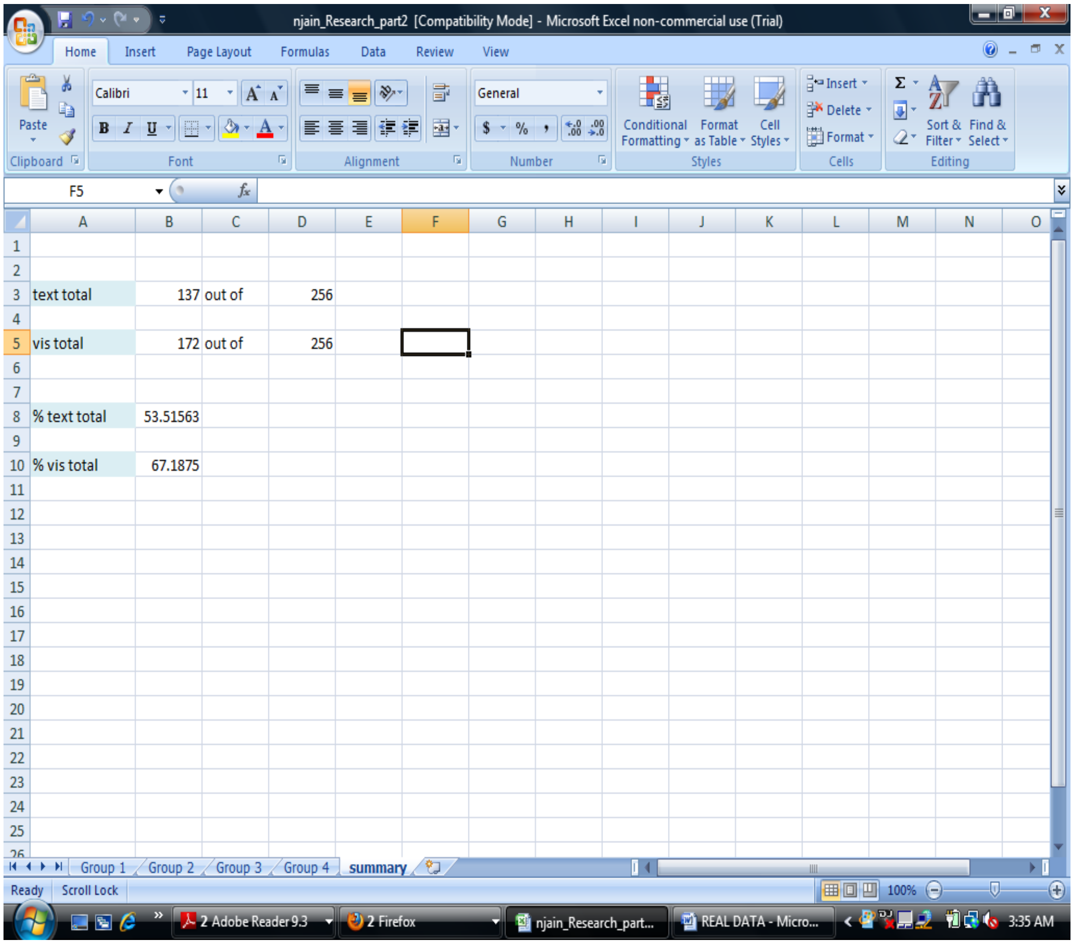


FIG. 7.12. Screenshot of excel sheet showing summary of data collected for knowledge retention

From Fig 7.12, for the entire knowledge retention test, the total correct answers for questions based on text-based training were 137 out of 256 (53.52%) and that for visual-based training were 172 out of 256 (67.19%).

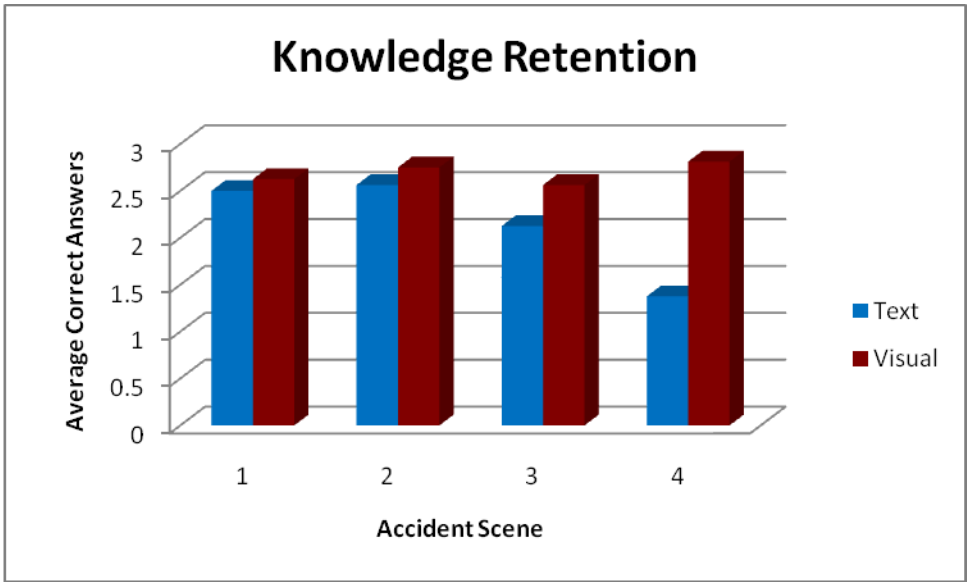


FIG. 7.13. Graph of knowledge retention data based on accident scenes

Fig 7.13 shows the comparison between the average correct answer per student for every accident scene for text-based training and visual training for the second test.

FIG. 7.14. Graph of knowledge dissemination and retention data based on accident scenes

Fig 7.14 shows the comparison between the average correct answer per student for every accident scene for text-based training and visual training in the first test and the second test.

All this data was then tested statistically.

8. DATA ANALYSIS

8.1 Comparison of Data Collected from Textual and Visual Training

8.1.1 For the first day test (Knowledge dissemination)

The total of the correct answers for questions based on text and questions based on game for participant were calculated. This data was arranged accident wise. This data was used to check whether the two samples are statistically different or not for each accident scene.

To check whether the samples were statistically different or not we had to conduct two sample t-test. But for that the data has to be normal. So the normality test had to be done. We conducted the Shapiro-Wilk test to check normality. If the data would be normal then two sample t-test could be used but if data was not normal then we had to do the Wilcoxon Rank-Sum test to check whether samples were statistically different.

The statistical analysis was done using SAS 9.2 software.

8.1.1.1 Accident Scene1

The correct answers, obtained from the first day test, between textual and visual training for accident scene1 was compared.

First the normality test was done.

Shapiro-Wilk test was conducted to check the normality. For this, the null Hypothesis H0 was the data is normal and the alternative hypothesis, Ha was the data is not normal.

The code used for the test was

```
proc univariate data=SASUSER.NJAIN_RESEARCH_DISSEMINATION normal;
var Des_acc1_text Des_acc1_vis
run;
```

The following output was received.

TABLE 8-1. Normality test result for text data for accident scene1

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.835989	**Pr < W**	0.0085

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0085 (Table 8-1) which is less than 0.05, the data is not from a normal population.

TABLE 8-2. Normality test result for visual data for accident scene1

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.878056	**Pr < W**	0.0362

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0362 (Table 8-2) which is less than 0.05, the data is not from a normal population.

And now, as we have proved that the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_DISSEMINATION4 wilcoxon;
class Type_dis_acc1;
var Score_dis_acc1;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.9678 (Table 8-3) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-3. Wicoxon rank-sum test, p value for accident scene1 –knowledge dissemination

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	**0.9678**

Therefore, the samples were not statistically different.

8.1.1.2 Accident Scene2

The correct answers, obtained from the first day test, between textual and visual training for accident scene2 was compared.

First the normality test was done.

Shapiro-Wilk test was conducted to check the normality. For this, the null Hypothesis H0 was the data is normal and the alternative hypothesis, Ha was the data is not normal. The code used for the test was

```
proc univariate data=SASUSER.NJAIN_RESEARCH_DISSEMINATION normal;
var Des_acc2_text Des_acc2_vis
run;
```

The following output was received.

TABLE 8-4. Normality test result for text data for accident scene2

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.762456	**Pr < W**	0.0009

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0009 (Table 8-4) which is less than 0.05, the data is not from a normal population.

TABLE 8-5. Normality test result for visual data for accident scene2

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.859276	**Pr < W**	0.0187

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0187 (Table 8-5) which is less than 0.05, the data is not from a normal population.

And now, as we have proved that the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_DISSEMINATION4 wilcoxon;
class Type_dis_acc2;
var Score_dis_acc2;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.8734(Table 8-6) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-6. Wicoxon rank-sum test, p value for accident scene2 –knowledge dissemination

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.8734

Therefore, the samples were not statistically different.

8.1.1.3 Accident Scene3

The correct answers, obtained from the first day test, between textual and visual training for accident scene3 was compared.

First the normality test was done.

Shapiro-Wilk test was conducted to check the normality. For this, the null Hypothesis H0 was the data is normal and the alternative hypothesis, Ha was the data is not normal. The code used for the test was

```
proc univariate data=SASUSER.NJAIN_RESEARCH_DISSEMINATION normal;
var Des_acc3_text Des_acc3_vis
run;
```

The following output was received.

TABLE 8-7. Normality test result for text data for accident scene3

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.884444	**Pr < W**	0.0455

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0455 (Table 8-7) which is less than 0.05, the data is not from a normal population.

TABLE 8-8. Normality test result for visual data for accident scene3

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.878421	**Pr < W**	0.0367

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0367 (Table 8-8) which is less than 0.05, the data is not from a normal population.

And now, as we have proved that the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_DISSEMINATION4 wilcoxon;
class Type_dis_acc3;
```

```
var Score_dis_acc3;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.0306 (Table 8-9) which is less than 0.05, that is H0 does not hold true at 95% CI.

TABLE 8-9. Wicoxon rank-sum test, p value for accident scene3 –knowledge dissemination

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.0306

Therefore, the samples were statistically different. Now to see which one out of the two – text and visual is was better, we compared the mean score calculated using the Wilcoxon Rank-Sum Test.

TABLE 8-10. Wicoxon rank-sum test, mean score for accident scene3 –knowledge dissemination

Wilcoxon Scores (Rank Sums) for Variable Score_dis_acc3 Classified by Variable Type_dis_acc3	
Type_dis_acc3	**Mean Score**
Text	13.031250
Visual	19.968750

From the mean score (Table 8-10) we can say that, the number of correct answers for Visual is much higher than Textual training for immediate knowledge dissemination for accident scene3. That is Visual training is better in comparison to Textual training, statistically.

8.1.1.4 Accident Scene4

The correct answers, obtained from the first day test, between textual and visual training for accident scene4 was compared.

First the normality test was done.

Shapiro-Wilk test was conducted to check the normality. For this, the null Hypothesis H0 was the data is normal and the alternative hypothesis, Ha was the data is not normal. The code used for the test was

```
proc univariate data=SASUSER.NJAIN_RESEARCH_DISSEMINATION normal;
var Des_acc4_text Des_acc4_vis
run;
```

The following output was received.

TABLE 8-11. Normality test result for text data for accident scene4

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.763405	**Pr < W**	0.0009

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0009 (Table 8-11) which is less than 0.05, the data is not from a normal population.

TABLE 8-12. Normality test result for visual data for accident scene4

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.796845	**Pr < W**	0.0025

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0025 (Table 8-12) which is less than 0.05, the data is not from a normal population.

And now, as we have proved that the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_DISSEMINATION4 wilcoxon;
class Type_dis_acc4;
var Score_dis_acc4;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.0033(Table 8-13) which is less than 0.05, that is H0 does not hold true at 95% CI.

TABLE 8-13. Wicoxon rank-sum test, p value for accident scene4 –knowledge dissemination

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.0033

Therefore, the samples were statistically different. Now to see which one out of the two – text and visual is was better, we compared the mean score calculated using the Wilcoxon Rank-Sum Test.

TABLE 8-14. Wicoxon rank-sum test, mean score for accident scene4 –knowledge dissemination

Wilcoxon Scores (Rank Sums) for Variable Score_dis_acc4 Classified by Variable Type_dis_acc4	
Type_dis_acc4	**Mean Score**
Text	11.81250
Visual	21.18750

From the mean score (Table 8-14) we can say that, the number of correct answers for Visual is much higher than Textual training for immediate knowledge dissemination for accident scene4. That is Visual training is better in comparison to Textual training, statistically.

8.1.1.5 Total

The correct answers, obtained from the first day test, between textual and visual training for all accident scenes (total) was compared.

First the normality test was done.

Shapiro-Wilk test was conducted to check the normality. For this, the null Hypothesis H0 was the data is normal and the alternative hypothesis, Ha was the data is not normal. The code used for the test was

```
proc univariate data=SASUSER.NJAIN_RESEARCH_DISSEMINATION normal;
var Des_tot_text Des_tot_vis
run;
```

The following output was received.

TABLE 8-15. Normality test result for text data for all accident scenes

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.902128	**Pr < W**	<0.0001

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0001 (Table 8-15) which is less than 0.05, the data is not from a normal population.

TABLE 8-16. Normality test result for visual data for all accident scenes

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.8754 19	**Pr < W**	<0.000 1

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0001 (Table 8-16) which is less than 0.05, the data is not from a normal population.

And now, as we have proved that the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_DISSEMINATION4 wilcoxon;
class Type_dis_tot;
var Score_dis_tot;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.0035 (Table 8-17) which is less than 0.05, that is H0 does not hold true at 95% CI.

TABLE 8-17. Wicoxon rank-sum test, p value for all accident scenes –knowledge dissemination

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.0035

Therefore, the samples were statistically different. Now to see which one out of the two – text and visual is was better, we compared the mean score calculated using the Wilcoxon Rank-Sum Test.

TABLE 8-18. Wicoxon rank-sum test, mean score for all accident scenes –knowledge dissemination

Wilcoxon Scores (Rank Sums) for Variable Score Classified by Variable Type	
Type	**Mean Score**
Text	55.18750
Visual	73.81250

From the mean score(Table 8-18) we can say that, the number of correct answers for Visual is much higher than Textual training for immediate knowledge dissemination for all accident scenes. That is Visual training is better in comparison to Textual training, statistically.

8.1.2 For the seventh day test (Knowledge retention)

The total of the correct answers for questions based on text and questions based on game for participant were calculated. This data was arranged accident wise. This data was used to check whether the two samples are statistically different or not for each accident scene.

To check whether the samples were statistically different or not we had to conduct two sample t-test. But for that the data has to be normal. So the normality test had to be done. We conducted the Shapiro-Wilk test to check normality. If the data would be normal then two sample t-test could be used but if data was not normal then we had to do the Wilcoxon Rank-Sum test to check whether samples were statistically different.

The statistical analysis was done using SAS 9.2 software.

8.1.2.1 Accident Scene1

The correct answers, obtained from the seventh day test, between textual and visual training for accident scene1 was compared.

First the normality test was done.

Shapiro-Wilk test was conducted to check the normality. For this, the null Hypothesis H0 was the data is normal and the alternative hypothesis, Ha was the data is not normal. The code used for the test was

```
proc univariate data=SASUSER.NJAIN_RESEARCH_RETENTION normal;
var Ret_acc1_text Ret_acc1_vis
run;
```

The following output was received.

TABLE 8-19. Normality test result for text data for accident scene1

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.880963	**Pr < W**	0.0402

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0402 (Table 8-19) which is less than 0.05, the data is not from a normal population.

TABLE 8-20. Normality test result for visual data for accident scene1

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.869889	**Pr < W**	0.0271

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0271 (Table 8-20) which is less than 0.05, the data is not from a normal population.

And now, as we have proved that the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_RETENTION wilcoxon;
class Type_ret_acc1;
var Score_ret_acc1;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.9222(Table 8-21) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-21. Wicoxon rank-sum test, p value for accident scene1 –knowledge retention

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.9222

Therefore, the samples were not statistically different.

8.1.2.2 Accident Scene2

The correct answers, obtained from the seventh day test, between textual and visual training for accident scene2 was compared.

First the normality test was done.

Shapiro-Wilk test was conducted to check the normality. For this, the null Hypothesis H0 was the data is normal and the alternative hypothesis, Ha was the data is not normal. The code used for the test was

```
proc univariate data=SASUSER.NJAIN_RESEARCH_RETENTION normal;
var ret_acc2_text ret_acc2_vis
run;
```

The following output was received.

TABLE 8-22. Normality test result for text data for accident scene2

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.8793 26	**Pr < W**	0.0379

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0379 (Table 8-22) which is less than 0.05, the data is not from a normal population.

TABLE 8-23. Normality test result for visual data for accident scene2

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.8787 90	**Pr < W**	0.037 2

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0372 (Table 8-23) which is less than 0.05, the data is not from a normal population.

And now, as we have proved that the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_RETENTION wilcoxon;
class Type_ret_acc2;
var Score_ret_acc2;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.7699(Table 8-24) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-24. Wicoxon rank-sum test, p value for accident scene2 –knowledge retention

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.7699

Therefore, the samples were not statistically different.

8.1.2.3 Accident Scene3

The correct answers, obtained from the seventh day test, between textual and visual training for accident scene3 was compared.

First the normality test was done.

Shapiro-Wilk test was conducted to check the normality. For this, the null Hypothesis H0 was the data is normal and the alternative hypothesis, Ha was the data is not normal. The code used for the test was

```
proc univariate data=SASUSER.NJAIN_RESEARCH_RETENTION normal;
var ret_acc3_text ret_acc3_vis
run;
```

The following output was received.

TABLE 8-25. Normality test result for text data for accident scene3

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.826562	**Pr < W**	0.0063

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0063 (Table 8-25) which is less than 0.05, the data is not from a normal population.

TABLE 8-26. Normality test result for visual data for accident scene3

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.855332	**Pr < W**	0.0163

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0163 (Table 8-26) which is less than 0.05, the data is not from a normal population.

And now, as we have proved that the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_RETENTION wilcoxon;
class Type_ret_acc3;
var Score_ret_acc3;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.2367(Table 8-27) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-27. Wicoxon rank-sum test, p value for accident scene3 –knowledge retention

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.2367

Therefore, the samples were not statistically different.

8.1.2.4 Accident Scene4

The correct answers, obtained from the seventh day test, between textual and visual training for accident scene4 was compared.

First the normality test was done.

Shapiro-Wilk test was conducted to check the normality. For this, the null Hypothesis H0 was the data is normal and the alternative hypothesis, Ha was the data is not normal. The code used for the test was

```
proc univariate data=SASUSER.NJAIN_RESEARCH_RETENTION normal;
var ret_acc4_text ret_acc4_vis
run;
```

The following output was received.

TABLE 8-28. Normality test result for text data for accident scene4

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.845581	**Pr < W**	0.0117

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0117 (Table 8-28) which is less than 0.05, the data is not from a normal population.

TABLE 8-29. Normality test result for visual data for accident scene4

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.844622	**Pr < W**	0.0114

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0114 (Table 8-29) which is less than 0.05, the data is not from a normal population.

And now, as we have proved that the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_RETENTION wilcoxon;
class Type_ret_acc4;
var Score_ret_acc4;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.0025(Table 8-30) which is less than 0.05, that is H0 does not hold true at 95% CI.

TABLE 8-30. Wicoxon rank-sum test, p value for accident scene4 –knowledge retention

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.0025

Therefore, the samples were statistically different. Now to see which one out of the two – text and visual is was better, we compared the mean score calculated using the Wilcoxon Rank-Sum Test.

TABLE 8-31. Wicoxon rank-sum test, mean score for accident scene4 –knowledge retention

Wilcoxon Scores (Rank Sums) for Variable Score_ret_acc4 Classified by Variable Type_ret_acc4	
Type_ret_acc4	**Mean Score**
text	11.56250
visual	21.43750

From the mean score (Table 8-31) we can say that, the number of correct answers for Visual is much higher than Textual training for knowledge retention for accident scene 4. That is Visual training is better in comparison to Textual training, statistically.

8.1.2.5 Total

The correct answers, obtained from the seventh day test, between textual and visual training for all accident scenes (total) was compared.

First the normality test was done.

Shapiro-Wilk test was conducted to check the normality. For this, the null Hypothesis H0 was the data is normal and the alternative hypothesis, Ha was the data is not normal. The code used for the test was

```
proc univariate data=SASUSER.NJAIN_RESEARCH_RETENTION normal;
var ret_tot_text ret_tot_vis
run;
```

The following output was received.

TABLE 8-32. Normality test result for text data for all accident scenes

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.889639	**Pr < W**	<0.0001

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0001 (Table 8-32) which is less than 0.05, the data is not from a normal population.

TABLE 8-33. Normality test result for visual data for all accident scenes

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.872235	**Pr < W**	<0.0001

If p >0.05 at 95% confidence interval (CI) then H0 holds true. And, since p = 0.0001 (Table 8-33) which is less than 0.05, the data is not from a normal population.

And now, as we have proved that the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_RETENTION wilcoxon;
class Type_ret_tot;
var Score_ret_tot;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.0147(Table 8-34) which is less than 0.05, that is H0 does not hold true at 95% CI.

TABLE 8-34. Wicoxon rank-sum test, p value for all accident scenes –knowledge retention

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.0147

Therefore, the samples were statistically different. Now to see which one out of the two – text and visual is was better, we compared the mean score calculated using the Wilcoxon Rank-Sum Test.

TABLE 8-35. Wicoxon rank-sum test, mean score for all accident scenes –knowledge retention

Wilcoxon Scores (Rank Sums) for Variable Score Classified by Variable Type	
Type	**Mean Score**
text	56.718750
visual	72.281250

From the mean score (Table 8-35) we can say that, the number of correct answers for Visual is much higher than Textual training for knowledge retention for all accident scenes. That is Visual training is better in comparison to Textual training, statistically.

8.2 Comparison of data collected on first day and seventh day

8.2.1 For textual training

The total of the correct answers for questions based on textual training obtained from the first day and seventh day test were calculated for each participant. This data was arranged accident wise. This data was used to check whether the two samples are statistically different or not for each accident scene.

To check whether the samples were statistically different or not we had to conduct two sample t-test. But for that the data has to be normal. So the normality test had to be done. We had already conducted the Shapiro-Wilk test to check normality in the previous tests. Referring back to those tests we were able to conclude whether the data was normal or not. If the data would be normal then two sample t-test could be used but if data was not normal then we had to do the Wilcoxon Rank-Sum test to check whether samples were statistically different.

The statistical analysis was done using SAS 9.2 software.

8.2.1.1 Accident Scene1

The correct answers, obtained from the textual training, on the first day and seventh day for accident scene1 was compared.

First the normality was to be checked and referring to the previous normality tests the data was not normal.

And since the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_TEXT wilcoxon;
class Type_txt_acc1;
var Score_txt_acc1;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.8729 (Table 8-36) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-36. Wicoxon rank-sum test, p value for accident scene1 – textual training

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.8729

Therefore, the samples were not statistically different.

8.2.1.2 Accident Scene2

The correct answers, obtained from the textual training, on the first day and seventh day for accident scene2 was compared.

First the normality was to be checked and referring to the previous normality tests the data was not normal.

And since the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_TEXT wilcoxon;
class Type_txt_acc2;
```

```
var Score_txt_acc2;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.3652 (Table 8-37) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-37. Wicoxon rank-sum test, p value for accident scene2 – textual training

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.3652

Therefore, the samples were not statistically different.

8.2.1.3 Accident Scene3

The correct answers, obtained from the textual training, on the first day and seventh day for accident scene3 was compared.

First the normality was to be checked and referring to the previous normality tests the data was not normal.

And since the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_TEXT wilcoxon;
class Type_txt_acc3;
var Score_txt_acc3;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.1848 (Table 8-38) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-38. Wicoxon rank-sum test, p value for accident scene3 – textual training

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.1848

Therefore, the samples were not statistically different.

8.2.1.4 Accident Scene4

The correct answers, obtained from the textual training, on the first day and seventh day for accident scene4 was compared.

First the normality was to be checked and referring to the previous normality tests the data was not normal.

And since the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_TEXT wilcoxon;
class Type_txt_acc4;
var Score_txt_acc4;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.8868 (Table 8-39) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-39. Wicoxon rank-sum test, p value for accident scene4 – textual training

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.8868

Therefore, the samples were not statistically different.

8.2.1.5 Total

The correct answers, obtained from the textual training, on the first day and seventh day for all accident scenes was compared.

First the normality was to be checked and referring to the previous normality tests the data was not normal.

And since the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_TEXT wilcoxon;
class Type_txt_tot;
var Score_txt_tot;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.8619(Table 8-40) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-40. Wicoxon rank-sum test, p value for all accident scenes – textual training

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.8619

Therefore, the samples were not statistically different.

8.2.2 For visual training (Game-based)

The total of the correct answers for questions based on game-based training obtained from the first day and seventh day test were calculated for each participant. This data was arranged accident wise. This data was used to check whether the two samples are statistically different or not for each accident scene.

To check whether the samples were statistically different or not we had to conduct two sample t-test. But for that the data has to be normal. So the normality test had to be done. We had already conducted the Shapiro-Wilk test to check normality in the previous tests. Referring back to those tests we were able to conclude whether the data was normal or not. If the data would be normal then two sample t-test could be used but if data was not normal then we had to do the Wilcoxon Rank-Sum test to check whether samples were statistically different.

The statistical analysis was done using SAS 9.2 software.

8.2.2.1 Accident scene1

The correct answers, obtained from the visual training, on the first day and seventh day for accident scene1 was compared.
First the normality was to be checked and referring to the previous normality tests the data was not normal.

And since the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_VIS wilcoxon;
class Type_vis_acc1;
var Score_vis_acc1;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.9842 (Table 8-41) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-41. Wicoxon rank-sum test, p value for accident scene1 – visual training

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.9842

Therefore, the samples were not statistically different.

8.2.2.2 Accident Scene2

The correct answers, obtained from the visual training, on the first day and seventh day for accident scene2 was compared.

First the normality was to be checked and referring to the previous normality tests the data was not normal.

And since the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_VIS wilcoxon;
class Type_vis_acc2;
var Score_vis_acc2;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that $p = 0.6037$ (Table 8-42) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-42. Wicoxon rank-sum test, p value for accident scene2 – visual training

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.6037

Therefore, the samples were not statistically different.

8.2.2.3 Accident Scene3

The correct answers, obtained from the visual training, on the first day and seventh day for accident scene3 was compared.

First the normality was to be checked and referring to the previous normality tests the data was not normal.

And since the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_VIS wilcoxon;
class Type_vis_acc3;
var Score_vis_acc3;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.8729 (Table 8-43) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-43. Wicoxon rank-sum test, p value for accident scene3 – visual training

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.6690

Therefore, the samples were not statistically different.

8.2.2.4 Accident Scene4

The correct answers, obtained from the visual training, on the first day and seventh day for accident scene4 was compared.

First the normality was to be checked and referring to the previous normality tests the data was not normal.

And since the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_VIS wilcoxon;
class Type_vis_acc4;
var Score_vis_acc4;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.6495 (Table 8-44) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-44. Wicoxon rank-sum test, p value for accident scene4 – visual training

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.6495

Therefore, the samples were not statistically different.

8.2.2.5 Total

The correct answers, obtained from the visual training, on the first day and seventh day for all accident scenes was compared.

First the normality was to be checked and referring to the previous normality tests the data was not normal.

And since the data is not normal, we have to run the wilcoxon rank-sum test. For the wilcoxon rank-sum test the following code was run.

```
proc npar1way data=SASUSER.NJAIN_RESEARCH_VIS wilcoxon;
class Type_vis_tot;
var Score_vis_tot;
run;
```

The null Hypothesis for this test is H0: The samples are not different. Whereas, the alternative hypothesis is Ha: The samples are statistically different. The output received showed that p = 0.8124 (Table 8-45) which is greater than 0.05, that is H0 holds true at 95% CI.

TABLE 8-45. Wicoxon rank-sum test, p value for all accident scenes – visual training

Wilcoxon Two-Sample Test	
Two-Sided Pr > |Z|	0.8124

Therefore, the samples were not statistically different.

9. 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.

Statistically, when we compared the textual and visual data for knowledge dissemination (first day test), for two accident scenes the correct answers were statistically different and visual training had more correct answers in comparison to Textual training. And for the total correct answers collected from the first day test it was concluded that visual training had more correct answers in comparison to text. On comparing correct answers of text and game method for knowledge retention (seventh day test), it was scene that only once accident scene had statistically different number of correct answers. And for that scene again visual was better that text. In this case also the total had significant difference and Visual was better than text.

Then we compared knowledge dissemination and retention in case of textual training for all accident scenes and also for the total correct answers, but there was no statistical difference. It was the same in case of visual training also.

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. We can definitely say that the knowledge dissemination in case of visual was better than text for the overall accidents. 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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APPENDIX A

A.1 Text Description of Accidents

Accident#1

The U.S. Occupational Safety and Health Administration(OSHA) proposed fines of $72,000 fine against Fake Construction Corp., a concrete subcontractor, "for alleged repeat and serious" safety violations related to an accident in which a worker fell 10 ft on a high-rise jobsite. The firm, which could not be reached for comment, has 15 days to appeal. OSHA says its jobsite inspection found "several fall-related hazards." Fake's clients include building contractors. The firm was cited by OSHA earlier also for similar hazards at a separate high-rise site, at which a crane collapse, killed two workers.

There were many safety violations at the job site. The worker who fell from the high rise building was not given prompt medical attention. Whereas according to OSHA, Provisions shall be made prior to commencement of the project for prompt medical attention in case of serious injury. And Proper equipment for prompt transportation of the injured person to a physician or hospital, or a communication system for contacting necessary ambulance service, shall be provided. Moreover the guardrails were not meeting the requirement of OSHA. According to OSHA, Guardrail systems shall be so surfaced as to prevent injury to an employee from punctures or lacerations, and to prevent snagging of clothing. And from the records, OSHA personnel came to know that there was no safety monitor at the site at the time of accident. OSHA requires that the employer shall designate a competent person to monitor the safety of other employees. And, the safety monitor shall be on the same walking/working surface and within visual sighting distance of the employee being monitored and the safety monitor shall not have other responsibilities which could take the monitor's attention from the monitoring function. Also, there was no danger sign on the open edges of the floors of the building.

OSHA says Danger signs shall be used where an immediate hazard exists. And Danger signs shall have red as the predominating color for the upper panel; black outline on the borders; and a white lower panel for additional sign wording.

Accident#2

Design deficiencies draw the most fire in the government engineer's report on the fatal collapse of a parking garage under construction. The U.S. Occupational Safety and Health Administration released a report in response to a Freedom of Information Act request by the newspaper. One construction worker was killed and 23 others were injured, when the six-level, 39,000-sq-ft, post-tensioned parking garage for the condominium complex collapsed during concrete placement on the top level. OSHA cited contractors for nine safety violations and proposed a total of $192,800 in penalties. Five of 11 conclusions in the report are completely blacked out and three others are partially obscured. The conclusions that are visible cite failures by the subcontractor for vertical concrete, formwork and shoring, and by the threshold inspector. Cited elsewhere in the report is honey combing and voids at the beam-column joints. One eyewitness informally interviewed told OSHA "that a crack extended diagonally across the post-tensioning cables through the entire depth of the 20-in.-thick slab on the third level." The report describes elements of the structure itself as "under-designed" and "deficient as per the prescribed codes." But one beam, SB-5 on the third level, comes in for special scrutiny. At one end, the 60-in.-wide beam tied into a 14-in.-wide column. "Thus only a few top reinforcements could develop their full strength in the column," says the report. Only three of six #8 continuous top and bottom bars fell within the column. "The post-tensioning cables were placed at the center of gravity of the T-beam, and thus could not be expected to provide continuity of the beam with the column," states the report. At its other end, the beam joined with a column 28 in. wide, but the top reinforcements did not continue into an adjoining span, and the post-tensioning cables dead-ended on the column grid line. The demand at the time of collapse was 20% higher than its design strength. Report says the shortcomings indicate "deficient design" by the structural engineer of record. The report says, "It is considered unlikely that the failure could have occurred at the loads placed on the C4 column at the time of the incident."The report analyzes the shoring and reshoring on the day of the collapse, "was the first time that concrete was being cast on elevated slabs without reshores extending down to the [first] level." Reshores below the third level had been removed. Why Fake removed the reshores remains unclear. General Counsel for the general contractor, says, "We disagree that our subcontractor removed any shoring improperly."

The major mistake by the contractor according to OSHA was that none of the construction workers at the job site were wearing helmets. Whereas OSHA requires that Employees working in areas where there is a possible danger of head injury from impact, or from falling or flying objects, or from electrical shock and burns, shall be protected by protective helmets. Moreover there was no rescue plan for the injured workers. But according to OSHA, The employer shall provide for prompt rescue of employees in the event of a fall or shall assure that employees are able to rescue themselves. The edges of the parking garage were left open without any safety sign or warning lines. And OSHA says that the warning line shall be erected around all sides of the roof work area and it shall be flagged at not more than 6-foot (1.8 m) intervals with high-visibility material. When OSHA personnel were investigating, they found out that there was no fire extinguisher in the entire site. Whereas the requirement is that a fire extinguisher, rated not less than 2A, shall be provided for each 3,000 square feet of the protected building area, or major fraction thereof. Travel distance from any point of the protected area to the nearest fire extinguisher shall not exceed 100 feet.

Accident #3

One week after an 11th-floor scaffold collapsed at a 21-story apartment construction project, killing three workers, local contractor Fake Construction Services has resumed work on the $40-million structure with "some limitations for the exterior," says a spokesperson for the owner. It eventually will house students and faculty from the nearby University. Four men were working on a scaffold between the building's 11th and 13th floors when part of it collapsed. Two men fell about 100 ft to the ground and were pronounced dead at the scene. Another fell onto the roof of a seven-story parking garage and died a few hours later in a hospital. The fourth workers hung onto the scaffold until rescued and received minor injuries. Fake Construction and its scaffolding manufacturer and rental firm, Bogus Mast Climbers, declined comment, as did the U.S. Occupational Safety and Health Ad- ministration, citing ongoing investigations. It is unclear whether the scaffolding was erected, maintained and inspected by the rental firm or the contractor. The cause of the accident has not been determined yet, but one scaffolding expert who viewed TV footage believes it was likely due to improper erection or overloading of the platforms, rather than a manufacturer's defect. President of Mock Scaffold says the scaffold's main mast remained attached to the building, while only one section fell. "The way these mast climbers are designed, the mast section is supported from the ground and goes up the side of the building and is tied into the building at different height intervals," he explains, noting that it is a very secure design.

According to report developed by OSHA the major problems were in the scaffolds. The load on the scaffolds was much more than the design load. The platform placement on the scaffolds was also incorrect. The actual requirement of scaffolds expects that each scaffold and scaffold component shall be capable of supporting, without failure, its own weight and at least 4 times the maximum intended load applied or transmitted to it. And Scaffolds shall be designed by a qualified person and shall be constructed and loaded in accordance with that design. And On scaffolds where platforms are overlapped to create a long platform, the overlap shall occur only over supports, and shall not be less than 12 inches (30 cm) unless the platforms are nailed together or otherwise restrained to prevent movement. Moreover on further investigation, OSHA personnel came to know that none of the workers working on the scaffold were trained. Whereas, it is clearly mentioned in OSHA that The employer shall have each employee who is involved in erecting, disassembling, moving, operating, repairing, maintaining, or inspecting a scaffold trained for The nature of scaffold hazards; The correct procedures for erecting, disassembling, moving, operating, repairing, inspecting, and maintaining the type of scaffold in question; The design criteria, maximum intended load-carrying capacity and intended use of the scaffold. Also, the caution signs were colored incorrectly. OSHA says Caution signs shall be used only to warn against potential hazards or to caution against unsafe practices and shall have yellow as the predominating color; black upper panel and borders: yellow lettering of "caution" on the black panel; and the lower yellow panel for additional sign wording. Black lettering shall be used for additional wording.

Accident#4

Two of three firms cited by the U.S. Dept. of Labor in a fatal pedestrian bridge collapse will contest the citations. Fake Construction Co., Bogus Erection Co., and Mock Access, were fined a total of $26,250 for the collapse of the 600-ft-long, 40-ft-tall bridge that was under construction. One worker died and 17 were injured as a result. According to the U.S. Occupational Safety and Health Administration, Fake and Bogus Erection were cited for inadequate formwork design, fabrication, erection, support and bracing. Construction-materials loads on the bridge for a routine repaving job were also a factor in the collapse. Engineers should develop guidelines to prevent this.

In their reports, OSHA personnel said that there were no safety nets on the bridge site. But as per OSHA Safety nets shall be installed as close as practicable under the walking/working surface on which employees are working, but in no case more than 30 feet (9.1 m) below such level. And when nets are used on bridges, the potential fall area from the walking/working surface to the net shall be unobstructed. It is also a requirement that Defective nets shall not be used and Safety nets shall be inspected at least once a week for wear, damage, and other deterioration. The personal fall arrest systems used on the site were not in compliance with OSHA. According to OSHA it should be rigged such that an employee can neither free fall more than 6 feet (1.8 m), nor contact any lower level and it should bring an employee to a complete stop and limit maximum deceleration distance an employee travels to 3.5 feet (1.07 m).Also, The attachment point of the body belt shall be located in the center of the wearer's back and The attachment point of the body harness shall be located in the center of the wearer's back near shoulder level, or above the wearer's head.

A.2 Questionnaire First Test

Group ____

Questions

1. Employees working in areas where there is a possible danger of head injury shall be protected by _____ .
   i) hats
   ii) helmets
   iii) wooden boards
   iv) safety glasses

2. Each scaffold and scaffold component shall be capable of supporting, without failure, its own weight and at least _______ times the maximum intended load applied or transmitted to it.
   i) 2
   ii) 3
   iii) 4
   iv) 5

3. Danger signs shall have _____ as the predominating color.
   i) green
   ii) black
   iii) yellow
   iv) red

4. In no case shall safety nets be installed more than ___ below the working level.
   i) 10 feet
   ii) 20 feet
   iii) 30 feet
   iv) 40 feet

5. Travel distance from any point of the protected area to the nearest extinguisher shall not exceed ______.
   i) 100 ft
   ii) 150 ft
   iii) 200 ft
   iv) 250 ft

6. Safety nets shall be inspected _____.
   i) Once a day
   ii) Once a week
   iii) Once every fifteen days
   iv) Twice a week

7. _______ shall be so surfaced as to prevent snagging of clothing.
   i) Warning line
   ii) Safety Net
   iii) Safety glass
   iv) Guardrail system

8. On scaffolds where platforms are used, the overlap shall ____.
   i) Occur only over supports
   ii) Not be allowed
   iii) Occur anywhere where platform ends
   iv) Occur only after every three platforms

9. Personal fall arrest system, when stopping a fall shall bring an employee to complete stop and limit maximum deceleration distance an employee travels to ______ .
   i) 2.5 ft
   ii) 3.0 ft
   iii) 3.5 ft
   iv) 4 ft

10. _____ shall provide for prompt rescue of workers in the event of a fall.
    i) Other workers
    ii) Employer
    iii) Safety Monitor
    iv) Nearest Hospital

11. The employer shall have each employee who is involved in erecting a scaffold trained in ____. (Select which statement is **false**)
    i) The proper handling of materials on the scaffold
    ii) The nature of scaffold hazard
    iii) The design criteria of the scaffold
    iv) The correct procedure for erecting a scaffold

12. For personal fall arrest system, the attachment point of the body harness shall be located ___ .
    i) In the center of the wearer's back
    ii) In the center of the wearer's back near shoulder level
    iii) In the center of the wearer's back or above the wearer's head
    iv) In the center of the wearer's back near shoulder level or above the wearer's head

13. Caution signs shall be used ________ .
    i) For safety instructions
    ii) To caution against unsafe practices
    iii) Where an immediate hazard exists
    iv) ii & iii

14. The warning line shall be flagged at no more than ___ intervals with high-visibility material.
    i) 3 ft
    ii) 4 ft
    iii) 5 ft
    iv) 6 ft

15. The safety monitor ____________ . (Select which statement is **false**)
    i) Shall be close enough to communicate orally with the employee.
    ii) Shall be within visual sighting distance of the employee being monitored.
    iii) Shall not necessarily be on the same walking/working surface as the employee being monitored.
    iv) Shall not have other responsibilities which could take the monitor's attention from the monitoring function.

16. Provision for prompt medical attention in case of serious injury should be made ___ .
    i) As soon as the injury occurs
    ii) Prior to commencement of the project
    iii) Prior to commencement of a task which could lead to serious injury
    iv) No such provision is required

Exit Question :

If you had to receive training which method would you prefer:

i) Text
ii) Visual (Computer game)

A.3 Questionnaire Second Test

Group ____

Questions

1. The employer shall have each employee who is involved in erecting a scaffold trained in ____. (Select which statement is **false**)
   i) The correct procedure for erecting a scaffold
   ii) The design criteria of the scaffold
   iii) The proper handling of materials on the scaffold
   iv) The nature of scaffold hazard

2. Danger signs shall have ______ as the predominating color.
   i) yellow
   ii) green
   iii) Red
   iv) black

3. On scaffolds where platforms are used, the overlap shall ____.
   i) Occur only after every three platforms
   ii) Not be allowed
   iii) Occur only over supports
   iv) Occur anywhere where platform ends

4. Safety nets shall be inspected _____.
   i) Once every fifteen days
   ii) Once a day
   iii) Twice a week
   iv) Once a week

5. Provision for prompt medical attention in case of serious injury should be made ___ .
   i) No such provision is required
   ii) Prior to commencement of a task which could lead to serious injury
   iii) As soon as the injury occurs
   iv) Prior to commencement of the project

6. In no case shall safety nets be installed more than ___ below the working level.
   i) 40 feet
   ii) 30 feet
   iii) 10 feet
   iv) 20 feet

7. Caution signs shall be used _______ .
   i) To caution against unsafe practices and Where an immediate hazard exists
   ii) To caution against unsafe practices
   iii) For safety instructions
   iv) Where an immediate hazard exists

8. Travel distance from any point of the protected area to the nearest extinguisher shall not exceed ______.
   i) 250 ft
   ii) 200 ft
   iii) 100 ft
   iv) 150 ft

9. Personal fall arrest system, when stopping a fall shall bring an employee to complete stop and limit maximum deceleration distance an employee travels to ______ .
   i) 3.5 ft
   ii) 2.5 ft
   iii) 4.0 ft
   iv) 3.0 ft

10. _______ shall be so surfaced as to prevent snagging of clothing.
    i) Safety glass
    ii) Warning line
    iii) Guardrail system
    iv) Safety Net

11. The safety monitor _____________ . (Select which statement is **false**)
    i) Shall not have other responsibilities which could take the monitor's attention from the monitoring function.
    ii) Shall be within visual sighting distance of the employee being monitored.
    iii) Shall be close enough to communicate orally with the employee.
    iv) Shall not necessarily be on the same walking/working surface as the employee being monitored.

12. Employees working in areas where there is a possible danger of head injury shall be protected by ______ .
    i) hats
    ii) helmets
    iii) safety glasses
    iv) wooden boards

13. For personal fall arrest system, the attachment point of the body harness shall be located ___ .
    i) In the center of the wearer's back near shoulder level or above the wearer's head
    ii) In the center of the wearer's back near shoulder level
    iii) In the center of the wearer's back
    iv) In the center of the wearer's back or above the wearer's head

14. _____ shall provide for prompt rescue of workers in the event of a fall.
    i) Other workers
    ii) Employer
    iii) Nearest Hospital
    iv) Safety Monitor

15. Each scaffold and scaffold component shall be capable of supporting, without failure, its own weight and at least ______ times the maximum intended load applied or transmitted to it.
    i) 2
    ii) 3
    iii) 5
    iv) 4

16. The warning line shall be flagged at no more than ___ intervals with high-visibility material.
    i) 3 ft
    ii) 4 ft
    iii) 6 ft
    iv) 5 ft

THANK YOU

A.4 Instructions to play game

The following instruction sheet was given to participants for reference while testing for the visual method.

TABLE A.4-1. Instructions to play

		Keyboard	Gamepad
1	Move ahead	Up Arrow Key	Y
2	Move back	Down Arrow Key	A
3	Turn right	Right Arrow Key	Left Stick -Right
4	Turn left	Left Arrow Key	Left Stick -Left
5	Look up	A	Left Stick -Up
6	Look down	Z	Left Stick -Down
7	Camera Spring On/Off	S	X
8	Back to starting position	X	Right Stick Press

A.5 Letter of Invitation

Letter of Invitation

Dear Student,

I am conducting a research on "Investigation of feasibility of computer games for training about safety in the construction industry." The purpose of this study is to test the effectiveness of visual graphics/game in efficient knowledge dissemination and retention in the construction industry and to check the feasibility of the application of visual graphics/game for training personnel about safety in the construction industry. You were selected to be a possible participant because of your knowledge and/or experience in the area/field related to construction.

If you agree to participate in this study, you will be asked to play a computer game and read some textual material. Both of them will have information about how to maintain safety on construction sites. You will be given 20 minutes to go through material. After that you will be asked to answer 16 questions based in that information. You will be asked to come again after one week to answer another set of 16 questions. On this day you will not be given any material to read or to play the computer game. This study will take 30 mins on the first day and 15 mins when you come after a week. This study is anonymous and your name or UIN will not be asked when you submit the questions.

The risks associated with this study are minimal, and are not greater than risks ordinarily encountered in daily life. The possible benefits are that you will get to learn about emerging technology and also gain knowledge about maintaining safety at the construction site. And as a result of this research there is a possibility that better training method could be implemented in the construction industries leading to better knowledge dissemination and retention leading to fewer accidents.

Your participation is voluntary. You may decide not to participate or to withdraw at any time without your current or future relations with Texas A&M University being affected. If you have questions regarding this study, you may contact Nidhi Jain at 510-705-3417 or email at : nidhi17@tamu.edu.

Thank you for your time.

Sincerely,
Nidhi Jain

A.5 Email for Invitation

Email for Invitation

Dear Student,

I am conducting a research on "Investigation of feasibility of computer games for training about safety in the construction industry." The purpose of this study is to test the effectiveness of visual graphics/game in efficient knowledge dissemination and retention in the construction industry and to check the feasibility of the application of visual graphics/game for training personnel about safety in the construction industry. You were selected to be a possible participant because of your knowledge and/or experience in the area/field related to construction.

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Thank you for your time.

Sincerely,

Nidhi Jain

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