AC 2012-5325: UTILIZING A COLLABORATIVE VIRTUAL REALITY ENVIRONMENT AS A TRAINING TOOL FOR CONSTRUCTION STUDENTS

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Tulio Sulbaran received his Ph.D. in civil engineering from Georgia Institute of Technology with a concentration in construction management and with a minor in computer engineering and strong statistical background. He has more than eight years of work experience in the A/E/C (architecture, engineering, and construction) industry with office and field experience in scheduling, estimating, and project management in the United States and several international locations, including Venezuela, Singapore, Brunei, Malaysia, and Thailand. Sulbaran is an accomplished teacher and has taught a variety of construction courses, including Construction Planning and Scheduling, Construction Project Management, Cost Estimating I, Project Control, Proposal Preparation, and Project Implementation, among others. Sulbaran received the prestigious John Trimmer Award for Excellence in Teaching in 2010. Sulbaran engages students in learning activities inside and outside the classroom continuously advocating hands-on experience and collaborative learning. He has been in the forefront of online teaching, and he was one of the pioneers in delivering online courses in the School of Construction. He established the Study Abroad program in Panama at the University of Southern Mississippi. Sulbaran led the effort to establish the newly created master's of science in logistics, trade, and transportation (MSLTT), and he is currently leading the effort to put the MSLTT fully online to further the educational reach of the university. Sulbaran has the best externally funded projects track record of the School of Construction. He has submitted as PI/Co-PI more than 100 proposals and has been awarded more than 40 externally funded projects, totaling more than $10 million. Additionally, he has been collaborator in multi-million, multi-institution proposals with institutions in the United States and abroad. Sulbaran has received funding from several organizations, such as the National Science Foundation, Mississippi Department of Transportation, Transportation Research Board, Northrop Grumman, Mississippi Development Authority, Army Corp of Engineers, and Department of Health and Human Services among others. Sulbaran founded the Center for Logistics, Trade, and Transportation, and all of his projects have supported and benefit from talented graduate and/or undergraduate students from a variety of academic units in the university. Sulbaran has been very prolific in the area of scholarship and research. He has authored more than 60 peer-reviewed national/international publications, written several books, and made more than 100 professional presentations nationally and internationally. Sulbaran's manuscripts have been published in the International Journal of Technology, Knowledge, and Society, the International Journal of Virtual Reality, the Journal of Marketing Education, the Marketing Education Review Journal, the IEEE- Frontiers in Education, and the American Society of Engineering Education Proceedings, among others. Sulbaran has contributed significantly to his discipline through his service activities. His leadership on several key organizations has reflected very favorably on the university. Sulbaran is the first and only faculty of the University to hold a Board of Trustee position in the American Council for Construction Education. He is also the first and only faculty serving as the Editor for the Associated Schools of Construction proceedings. Sulbaran has served in multiple university committees, such as the I-TECH Customer Service Council, the CoST Research Award Committee, the CoST Scholarship Committee, and the SoC Accreditation Committee, among others.

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Utilizing a Collaborative Virtual Reality Environment as a Training Tool for Construction Students

Abstract

Students graduating from a Construction Management degree or similar entering the industry must know how to properly manage time, materials, personnel and equipment on complex construction projects. Unfortunately, in most cases construction students are not exposed enough to realistic construction project experience during their time at today's universities, leaving them with a preparation that does not fully realize their capability to face the challenges of real-world project management. The purpose of this paper is to describe the results of a pilot project that was carried out in order to address this problem. The project involved designing and creating an interactive learning experience within the Second Life virtual reality environment that gives construction students a realistic experience with construction event sequences and resource management. This project merged the use of virtual reality environments to simulate real-life construction projects with the perspective of using gaming tools as genuine means of education in the university setting. Once a playable interactive learning experience was completed it was tested with the help of a small sample of construction students. Due to the visual interactivity and gaming style, it was hypothesized that the use of a virtual reality environment such as Second Life to design and create an interactive learning experience would prove to be very useful for construction students to learn about and gain experiences in project scheduling. In support of this hypothesis, it was predicted that the results of the experiment would show that the construction students who participated did in fact learn something and gained construction experience from their time using the interactive learning experience. While the technical questions were inconclusive regarding whether or not the students learned anything, the opinion questions showed a very positive outlook. The participants, who each reported that they gained most of their construction experience from onsite work, unanimously agreed that they gained realistic construction project experience from their time using the interactive learning experience and would be interested in using virtual reality environments in the future.

Keywords: Construction Scheduling, Second Life, Training Tool, Virtual Reality

Introduction

This paper will focus on the problem of construction students not gaining enough realistic construction project experience during their time at today's universities. The construction industry, including engineering and architectural design, represents about 4% of the United States Gross Domestic Product (US GDP) [2]. Poor understanding of the complexity of construction projects contributes to the fact that approximately 15% of all construction projects are over-budget and/or delayed [5]. The US GDP is approximately $14.26 trillion. At 4% of this, the construction industry makes up about $570 billion. If 15% of all construction projects are over-budget and/or delayed, then this means that an estimated $85.5 billion is compromised in some form or fashion.

A key member of all construction projects is the construction manager. In most instances construction managers have university degrees offered by multiple education programs across the country. However, education techniques used in universities today do not provide students with enough realistic construction project experience, whether it is hands-on or simulated [1]. Thus, students do not rise to their full potential at the universities, leaving them unprepared to face the challenges of real-world project management.

Objective

In order to address this lack of realistic experience among young engineers, the performed project proposed the use of a new educational medium known as "virtual reality environments" to create an interactive learning experience. Virtual reality environments, if used correctly, help to immerse a person into the virtual world where they can interact with their surroundings. The focus of this paper is to describe the interactive learning experience that was designed and created, and to share the experimental results obtained from it.

Approach

The virtual reality environment this research project used is known as "Second Life." Developed by a company called Linden Lab, Second Life provides its users with the ability to design, build and script their own virtual objects, allowing for limitless creative expression [4]. Learning these creation techniques and the scripting language was required to carry out the research project. The capabilities of Second Life were used to create an interactive learning experience that gives the students a realistic experience with construction event sequences and resource management.

The interactive learning experience asks the player to select from a set of construction tasks in the correct order. Each construction task is represented by a button on a heads-up display. If the construction tasks are selected in the correct order then they disappear from view and a building appears part-by-part in the virtual reality environment.

ID#	Construction Task	Predecessors
1	Excavate Foundation	-
2	Place Foundation Rebar	1
3	Place Concrete for Foundation	2
4	Formwork Slab on Grade	3
5	Vapor Barriers	4
6	Place Rebar and Wire Mesh	5
7	Place Concrete for Slab on Grade	6
8	Remove Slab Formwork	7
9	Frame House Walls	8
10	Frame Roof	9
11	Decking	10
12	Sheathing	10
13	Doors	12
14	Brick	13
15	Windows	14
16	HVAC Ducts	11, 12
17	Rough Electrical	11, 12
18	Rough Plumbing	11, 12
19	Hang Dry Wall	16, 17, 18
20	Finish Interior Walls	19
21	Finish Interior Floors	20
22	Plumbing Finishes	19
23	Electrical Finishes	20
24	HVAC Finishes	20
25	Front Deck	14
26	Landscaping	25
27	Fire Place	13

Figure. 1. List of the construction tasks involved and their predecessors.

If a button is selected at an incorrect time, it will progressively turn red (yellow, then orange, then red) in accordance to the amount of times it is wrongly chosen. If a button that has already turned red is selected at an incorrect time then the player loses and everything resets to the beginning of the interactive learning experience. The goal is to give the player experience with the correct event sequences of a simple building.

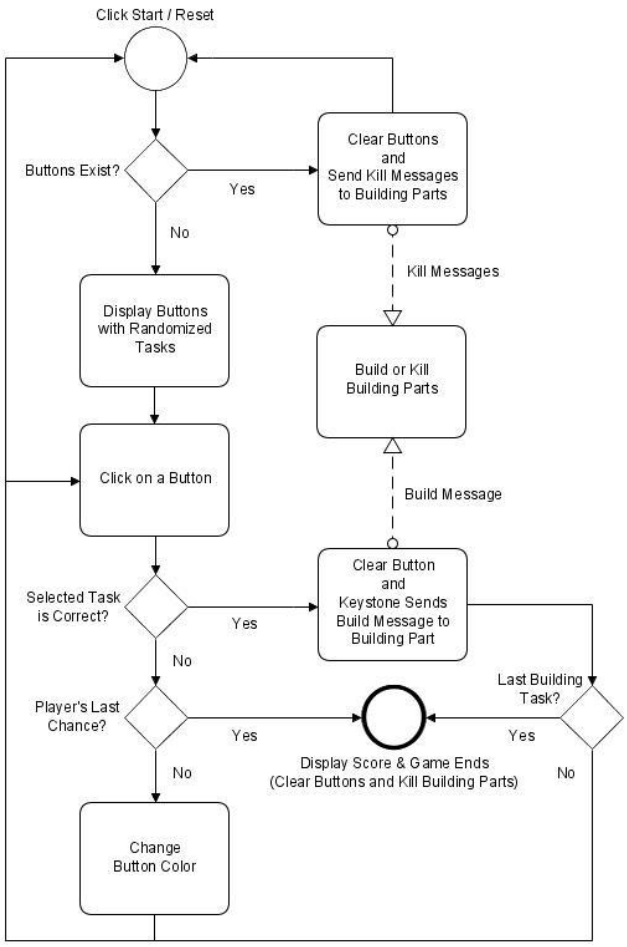

Figure. 2. Workflow chart for the entire process of the interactive learning experience. Created using an online tool called Gliffy [3].

The purpose of the experiment that was run for this research project was not only to evaluate whether or not construction students can learn from this interactive learning experience within the Second Life virtual reality environment, but also to see if the students feel on a personal level that they have gained realistic construction project experience. In preparation for the experiment several things were created and carried out. First, five instances of the interactive learning experience were setup in Second Life.

Next, five Second Life accounts were created for the sole purpose of giving each experiment participant an account they can login to play with. Each account was prepared with the HUD already attached to the avatars and the avatars were placed in front of their assigned interactive learning experience instances. To help the participants keep track of where they should be, standing pads were created and given a hover-text script that caused text to hover above it stating which station number it was. These station numbers corresponded to the numbers in the participants' Second Life names.

The experimental data was gathered through the use of a pre-test and post-test to be administered before and after the participants used the interactive learning experience respectfully. There were nine construction students who participated, but only seven fully completed both the pre-test and post-test. The first five questions were the same on both tests and were aimed at evaluating whether or not the participants learned anything new. The remaining questions were different on either test and were aimed at evaluating how the participants personally felt about the Second Life virtual reality environment, virtual reality environments in general, and their experience with the interactive learning experience.

Results

The following results are based on seven pre-test and seven post-test samples. The first five questions were technical questions based on the information being taught by the interactive learning experience. The remaining questions were personal questions based on the participants' opinions. The following charts include five charts based on the number of correct and incorrect answers for each of the first five questions before and after the participants used the interactive learning experience, a breakdown of those five charts, and then eight charts based on the second five questions before and after using the interactive learning experience. The questions and their possible answers can be viewed in the Appendix.

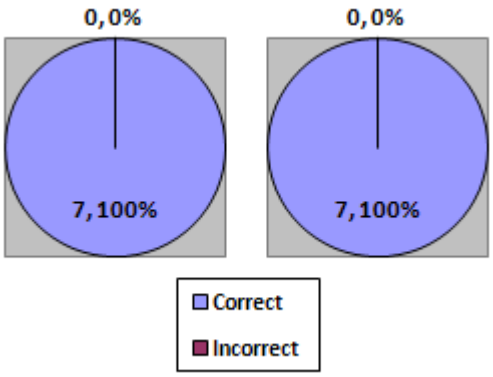

Figure 3. Question 1 before and after using the interactive learning experience. Question: "When should the Remove Slab Formwork task be performed?"

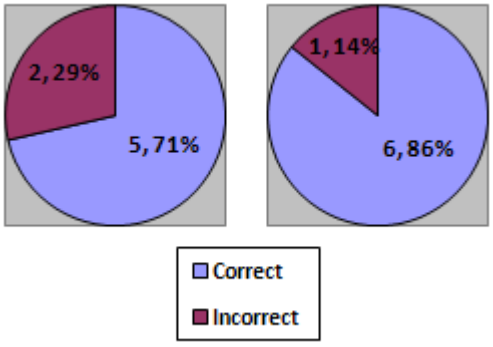

Figure 4. Question 2 before and after using the interactive learning experience. Question: "Which task should be completed first?"

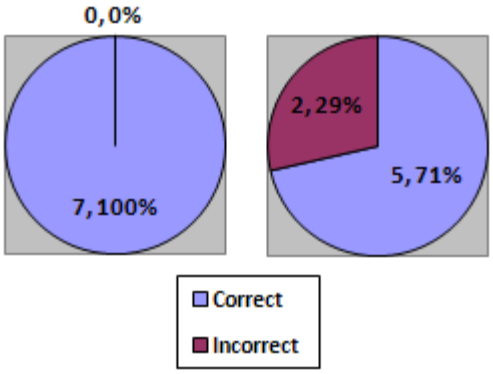

Figure 5. Question 3 before and after using the interactive learning experience.
Question: "Which three tasks should be completed just before the Hang Dry Wall task?"

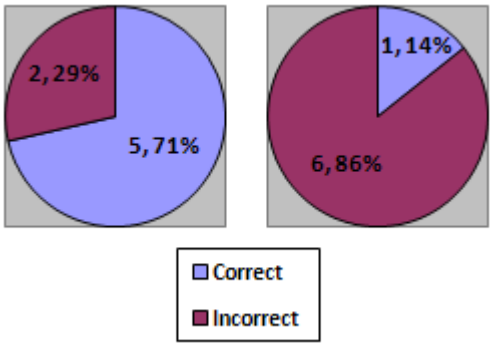

Figure 6. Question 4 before and after using the interactive learning experience.
Question: "Which of the following is a correct sequence of construction tasks?"

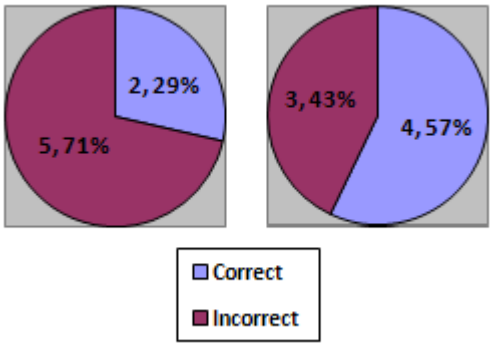

Figure 7. Question 5 before and after using the interactive learning experience.
Question: "Which of the following is a correct sequence of construction tasks?"

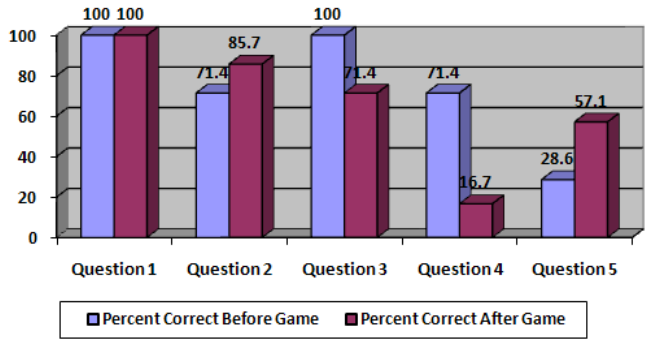

Figure 8. Breakdown of the preceding five figures based on the change in the percent of correct answers for each question before and after using the interactive learning experience.

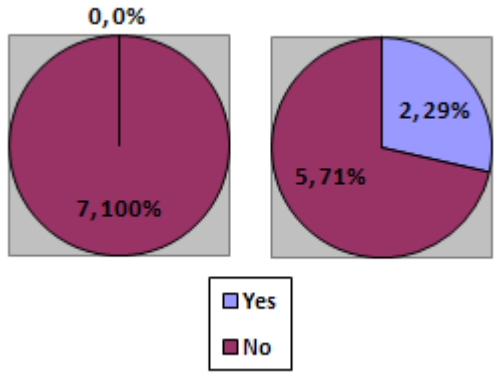

Figure 9. Personal questions 1 and 2 before using the interactive learning experience.
Question 1: "Have you ever used Second Life before?" Question 2: "Have you ever used a VRE similar to Second Life?"

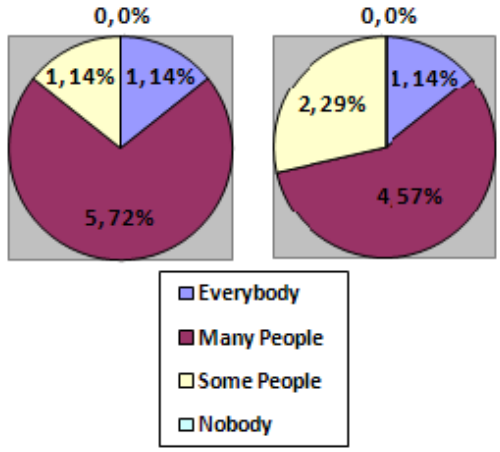

Figure 10. Personal questions 3 and 4 before using the interactive learning experience.
Question 3: "How viable do you think VREs are as a learning tool in a college setting? (Who could learn from them?)"
Question 4: "How viable do you think games are as a learning tool in a college setting? (Who could learn from them?)"

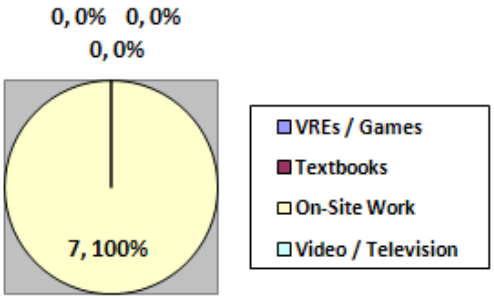

Figure 11. Personal question 5 before using the interactive learning experience.
Question: "In what way do you gain most of your construction experience and understanding?"

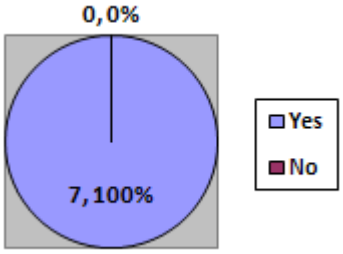

Figure 12. Personal question 1 after using the interactive learning experience.
Question: "Do you feel like you learned anything or gained experience from playing this game?"

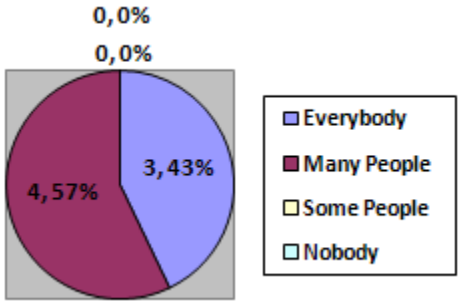

Figure 13. Personal question 2 after using the interactive learning experience.
Question: "How viable do you think VREs are as a learning tool in a college setting? (Who could learn from them?)"

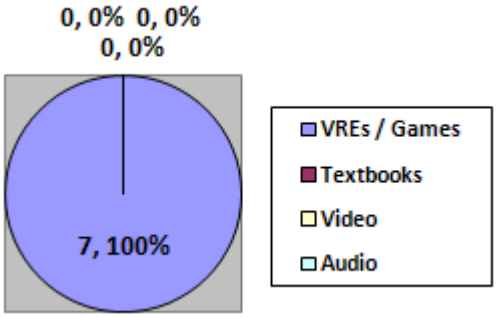

Fig. 14. Personal question 3 after using the interactive learning experience.
Question: "Which media do you think is a better teaching device when it comes to teaching about construction?"

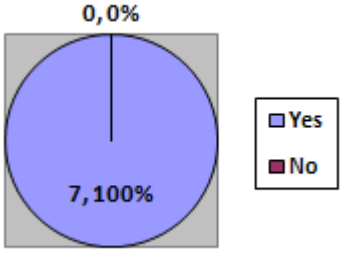

Fig. 15. Personal question 4 after using the interactive learning experience.
Question: "Would you be interested in using VREs to learn more about construction in the future?"

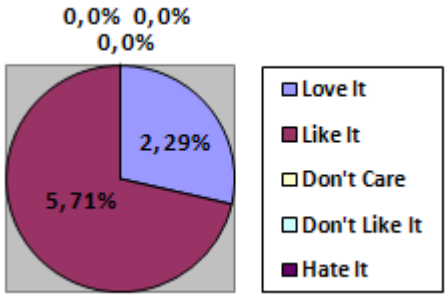

Fig. 16. Personal question 5 after using the interactive learning experience.
Question: "How well do you like the Second Life VRE?"

For the first five questions, which were based on technical information that the interactive learning experience was attempting to teach the player, the participants showed improvement overall. As seen in Chart 11, the first question showed no change in the percentage of correct answers before and after the participants used the interactive learning experience, the second and fifth questions showed some improvement, and the third and fourth questions showed a decrease in the percentage of correct answers. The first question can be ignored as it appears that the

participants simply knew the answer beforehand, thus the interactive learning experience had no real effect. However, for the other questions the explanation is not so simple.
One possibility is that the participants did in fact learn from the interactive learning experience as seen with questions two and five, but some of the construction task sequences may have been slightly different from the way the participants were taught and the act of using the interactive learning experience confused their answers for the time being as seen with questions three and four. This possibility is more evident when taking into account that some of the participants suggested more detailed construction tasks and an option to view the construction tasks that have already been performed as ways of improving the interactive learning experience.
Another possibility is that the participants simply happened to choose the correct answers when they did by chance, but this loses credibility when viewing the results of the fourth question. Before using the interactive learning experience, five of the seven participants chose the correct answer, but after using the interactive learning experience only one chose the correct answer. This drop of 54.7% is too steep to be explained away as happening by chance.

Overall, the technical questions show that the teaching capabilities of the interactive learning experience are generally inconclusive. However, the personal questions based on the participants' opinions show another side to the interactive learning experience. All seven participants reported to have never used the Second Life virtual reality environment before, with only two having used some other virtual reality environment, and all seven reported that they gained most of their construction experience from onsite work, yet all seven participants also reported to have felt as if they had learned and gained construction experience as a result of using the interactive learning experience.

All seven participants felt positively about the idea of using virtual reality environments to teach about construction within the college setting, with two participants increasing their choice of how many people they felt could learn from such experiences after using the interactive learning experience. Again, all seven participants reported that they would be interested in using virtual reality environments to learn more about construction in the future, and they all felt positively about the Second Life virtual reality environment in particular. These results are important to the construction industry because they shine a positive light on the use of virtual reality environments as teaching and training tools for construction students in the future. This would increase the students' understanding and experience, and subsequently the productivity of the construction industry as a whole.

Conclusion

Today's universities do not provide students with enough realistic construction project experience. Thus, students do not rise to their full potential and are left unprepared to face the challenges of real-world project management. This research project focused on how virtual reality environments can help construction, engineering and architect students better understand the event sequences and resource management required to successfully complete a complex construction project. An interactive learning experience was designed and created within the virtual reality environment known as Second Life that asked players to select construction tasks in the correct sequences, performing the sequences visually when correctly chosen. An experiment was performed where construction students took a pre-test, used the interactive learning experience, and then took a post-test.

The results of this research project's experiment were generally inconclusive regarding whether or not the construction students learned from the interactive learning experience. However, the results did support the idea that the use of a virtual reality environment for an interactive learning experience would prove to be very useful for construction students to gain experiences in project scheduling, as each student reported positively and enthusiastically about their experience with the environment and using the interactive learning experience. Given these results, work could begin on creating much more complex tools in Second Life or other virtual reality environments that could improve the understanding and experience of construction students even more. As more students graduate with having used these tools, the construction industry would begin to be filled with much more knowledgeable workers, thus increasing the industry's productivity as a whole.

Some work that could be done to extend this particular project in the future include adding more detail to the construction tasks such as contractor and material vendor scheduling, material types and prices (a prototype of this was created but was not fully completed), adding multiplayer features such as having players competing with one another for sub-contractor and material vendor contracts, and having players actually play the roles of sub-contractors and material vendors while others bid for their contracts. The final question on the experiment post-test asked the participants how they thought the interactive learning experience could be improved, and their suggestions mirrored the ones listed above. The conceptual possibilities for improving upon this research project are almost limitless.

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Bibliography

1. Dossick, C., Lee, N., Locsin, S., & Rojas, E. (2007). Defining construction management events in situational simulations. 7th International Conference on Construction Applications of Virtual Reality, pp. 80-89.

2. Economic Growth (2005). Occupational Outlook Quarterly, 49 (4), 45. Retrieved July 2, 2009, from http://www.bls.gov/opub/ooq/ 2005/winter/contents.htm.

3. Gliffy. (2008). Gliffy online. Retrieved April 19, 2009, from http://gliffy.com.

4. Linden Research, Inc. (2007). About Linden Lab. Retrieved November 20, 2007, from http://lindenlab.com/about.

5. Sharma, S. (2003). Construction e-project management. Retrieved December 9, 2007, from http://www.projectmanagement.com/ pm/article.cfm?ID=127864.