Exploring the Impact of Various Interactive Displays on Student Learning in Construction Courses

Mrs. Samaneh Zolfagharian, School of Building Construction, Georgia Institute of Technology

Samaneh Zolfagharian is a PhD student and graduate research assistant at CONECTech lab, Georgia Institute of Technology. Her research focuses on construction education, construction safety, sustainability, utilizing BIM technology, and Interoperability.

Mr. Masoud Gheisari, Georgia Institute of Technology

Masoud Gheisari is a Ph.D. Candidate at the CONECTech Lab in the School of Building Construction at Georgia Tech. He is doing research on establishing the framework for developing next generation technology enhanced solutions to Architecture, Engineering, Construction, and Facility Management (AEC+FM) environment problems by incorporating the cognitive processes of the human component of operations. His Ph.D. dissertation is a multidisciplinary topic and focuses on integrating BIM and Mobile Augmented Reality (MAR) to enhance facility management data access through seamless integration of facility information with the physical environment. As a member of ASEE, he is also involved in research projects using innovative technologies such as Augmented Reality and Tangible Interaction for educational purposes.

Dr. Javier Irizarry P.E., School of Building Construction, Georgia Institute of Technology

Dr. Javier Irizarry is an Assistant Professor in the School of Building Construction at Georgia Tech. He is the Director of the CONECTech Lab which mission is to establish the framework for developing next generation technology enhanced solutions to construction environment problems by incorporating the cognitive processes of the human component of construction operations. Dr. Irizarry's research interests include technology enhanced construction safety, Human Computer Interaction issues in mobile applications for Architecture, Engineering, Construction and Owner/Operator (AECO) information access, interactive visualization systems for AECO education, Building Information Modeling based Augmented Reality applications for AECO, and Unmanned Aerial Vehicle sensing for applications in construction environments. His industry experience includes the planning and construction of multiple types of infrastructure facilities including but not limited to transportation, and parking structures, marine facilities, and residential and commercial structures. Dr. Irizarry is a Licensed Professional Engineer, Certified Green Professional and holds a BS in Civil Engineering from the University of Puerto Rico, a Masters in Engineering Management from the Polytechnic University of Puerto Rico and a PhD in Civil Engineering from Purdue University.

Dr. Pavan Meadati, Southern Polytechnic State University

Exploring the Impact of Various Interactive Displays on Student Learning in Construction Courses

Abstract

A user-friendly interactive model that provides a conducive learning environment is needed to enhance students' learning capabilities. Building Information Modeling (BIM), as a tool for communicating design intent in the architecture engineering and construction (AEC) industry, facilitates development of such knowledge repositories and fosters conducive learning environments. Previous research has explored the use of 3D models in engineering education applications. What has not been considered is the use of an efficient interactive system to enhance not only visualization but also information access and integration with these models along with how they can impact student performance. The aim of this paper is to compare different hardware options and Human Computer Interaction (HCI) modes that may be positively affect BIM related application use in construction education. Interactive display technologies have the potential to provide faculty with a tool that can improve teaching in construction education in a more visual and interactive way and greatly enhance the educational experience of students.

Keywords: BIM, Construction education, Interactive displays, HCI.

Introduction

Two-dimensional (2D) drawings are widely used as pedagogical tools for teaching courses to Architecture, Engineering and Construction (AEC) students. Some of these skills include quantity and cost estimation, developing and analyzing construction operation sequences and schedules, and project safety analysis for site operations. Student interpretation of 2D drawings varies based on their educational background and previous practical experience. However, with advances in computer display technology, it is possible to experience a 3D, full-scale virtual model of a construction project. The use of advanced visual communication and techniques enhances students' understanding and learning about the construction process of complex structures in an active learning manner[1]. The use of digital images provides an active learning environment for students[2], and integration between digital media and the coursework improve productivity and the ability of students to understand more information[3]. Students are required to develop (3D) models mentally by visualizing the different components of the structure. Students with little or no practical experience often face challenges and spend more time developing 3D visual models. With increasing complexity of present-day projects, even experienced professionals misinterpret 2D drawings, which result in increased project cost and duration. The

use of 3D models provides an opportunity to address the challenges faced by students and experienced professionals. Building Information Modeling (BIM) facilitates the use of data-rich digital 3D models and enhances the student's ability to understand the construction process[4-6]. For example, in reinforced concrete design, 3D visualization of concrete members can advance students understanding of reinforcement details and rebar-placement. BIM is a process that provides a framework to develop data rich product models. In this process, real world elements of a structure such as beams, columns, and slabs are represented as objects in a 3D digital model. Besides modeling, it provides a framework that fosters the integration of information from conception to decommissioning of the facility[7].

Previous research has explored the use of 3D models in engineering education applications. What has not been considered is the use of an efficient interactive system to enhance not only visualization but also information access and integration with these models. These interactive systems based on BIM have the potential to provide faculty with a tool that can improve teaching Civil and Construction Engineering and Management courses in a more visual and interactive way and greatly enhance the educational experience of students., The AEC students will have greatly improved access to the increasing amount of information via using BIM models in the civil engineering and construction fields.

On the other hand, interactive display technology is been adopted at an increasing rate. This technology was initially used in first generation tablet computers but failed to gain popularity for mass adoption. More recently, the education environment has also increased use of interactive display technologies and tablet computers to the point that many institutions have started providing these devices to students[8]. The benefits of interactive displays in the form or interactive whiteboards have been studied in the K-12 and higher education environments with promising results[9-13]. Most noticeable benefits are ease of use, increased learning, use of diagrams/visuals, interactivity, and use for software demonstration.

It is important to understand the usability implications of using these interactive screen devices in the education environment in order to maximize the benefits that they may offer. The aim of this paper is to compare different hardware options and Human Computer Interaction (HCI) modes which may be positively affect the use of BIM related applications in construction education. Through this comparison, the hardware type and the HCI mode that can positively affect student satisfaction when performing tasks similar to what students could perform in BIM applications will be investigated. Students' higher satisfaction of using 3D models in an efficient interactive system allows them to have better understanding and performance of a task.

BIM as a Teaching Tool

Teaching AEC courses by addressing students' different learning styles is a challenging task. Traditional lecture is one of the styles that widely used for teaching AEC courses. Sometimes, the lecture format style is complemented by including construction site visits. This teaching style provides an auditory and visual learning environment. However, inclusion of site visits within the course schedule is not always feasible due to reasons such as unavailability of construction sites meeting the class needs, class schedule conflicts, and safety issues[14]. Additionally, lack of laboratory and training facilities are impeding the creation of kinesthetic learning environments. Sometimes the traditional lecture teaching style also falls short to serve as an effective communication tool for transferring knowledge to students. Due to the lack of a conducive learning environment, which stimulates auditory, visual, and tactile senses, currently AEC students struggle to gain the required skills to solve real world problems. A user-friendly interactive BIM model that provides a conducive learning environment is needed to enhance students' learning capabilities. BIM serves as an excellent tool for data management. Some of the BIM characteristics such as easy access to the information, visualization, and simulation capabilities allow auditory, visual, and kinesthetic learning environments to emerge. Students' access to 3D models provides them with a more efficient learning environment and facilitates learning at their own pace. These environments allow students to discover strengths and weaknesses of their learning practices and facilitate self-improvement. However, BIM has the potential to greatly enhance the educational experience of AEC students in acquiring skills related to different areas and will provide faculty with a tool that can improve teaching different courses in a more visual and interactive way.

The characteristics, which help BIM to serve as a better learning and teaching tool, are accessibility to information and visualization enhancement. Educational institutions in many countries are introducing BIM applications in their curricula[15]. BIM models not only can be used to represent the geometry of a building, it also shows the types of materials and construction details required for scheduling the construction process. Moreover, different users with varied background can collaborate together on one BIM model of a building [16]. Students can learn about the architectural design features with BIM in addition to engineering and construction processes, so there is a need for research and development of educational methods supported by BIM and related technologies[15].

Traditionally the construction sequence is taught by using 2D drawings and critical path method (CPM) bar charts. Students find more success when they are able to visualize and conceptualize the construction sequence in their minds using 3D models to correlate the relationships between different components and schedule activities. Lack of 3D model visualization skills limits the students' ability to comprehend the construction sequence[1]. The shortcomings of these traditional methods can be addressed by using four-dimensional (4D) modeling (3D model + schedule)[17, 18]. BIM facilitates integration of 3D with schedule for 4D modeling. This 4D simulation helps to

explain and communicate the construction process better than 2D drawings and CPM bar charts alone.

Many other applications of BIM as a teaching and learning tool can be explored. Visualization of construction processes can be integrated with safety standards, operation procedures, and material or product data sheets. The continuous evolution of computing hardware allows such applications to be used even in mobile platforms. This facilitates any-time access to BIM models and creates an efficient learning environment for AEC students. Besides using proper software for construction education and training, appropriate hardware and HCI modes can also enhance student engagement and motivate them towards learning. Thus, it is essential to provide an appropriate usage and preference of technology to improve the effectiveness of education.

Methodology

In this study, different interfaces and interaction modes were chosen to carry out the experiment, including Touch screen Desktop computer using Finger as an interaction mode (DTouch+F), Touch screen Tablet using Finger as an interaction mode (TTouch+F), and Touch screen Tablet using Stylus as an interaction mode (TTouch+S)- (see Figure 1). In addition, the modeling program SketchUp was selected as a representative modeling application with a low level of difficulty in which user interface does not vary between computing platforms or operating systems. The user interface for SketchUp is very consistent between the Windows operating system and the Apple Mac OS X operating system used in the study.

(a) DTouch+F (b) TTouch+F (c) TTouch+S

Figure 1: The hardware used in the experiment

A between-subjects experimental approach was used to investigate the effects of HCI mode and screen size on student performance and satisfaction when using a 3D modeling tool for performing simple drawing tasks. Each participant would perform a 3D drawing task and do the task using only one of the interfaces. The participants were randomly assigned to perform the tasks on one of the equipment types. The task was to draw a 3D model of a building element with a low level of difficulty in a predetermined amount of time (see Figure 2). Then the results from each participant were compared to each other to examine differences-in the accuracy to accomplish the given task by using the different interactive displays. The reason of choosing 3D

models for the experiments is that these models provide a number of advantages compared to 2D drawings. Three-Dimensional visualization of construction models will be useful to students for better understanding of complex construction design and details, while gaining required experience in analyzing that type of information. In general, working with 3D models significantly improves the level of knowledge disseminated and increases the speed of absorption, because students are able to see ideas develop in 3D right in front of them[19]. Using 3D models assists students to think in 3D, and then, from the 3D model, they can easily understand all the necessary 2D information[19].

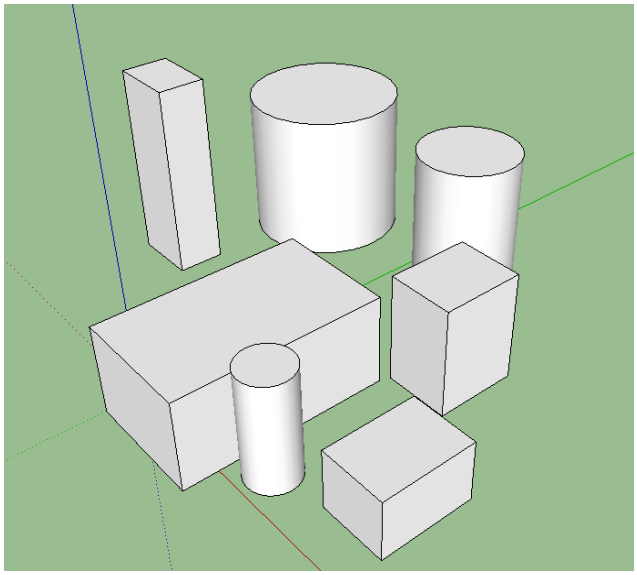

Figure 2: A screenshot of 3D modeling

In addition, a three-section questionnaire was designed for the study. The first section of the questionnaire covered demographic information including age, gender, class rank, work experience, experience with software used in the experiment, experience with HCI mode used in experiment, and ownership of touch screen devices. The second section of the questionnaire was developed based on the IBM Post-Study System Usability Questionnaire (PSSUQ) [20] in combination with other qualitative variables. The questionnaire consisted of questions adopted from the PSSUQ and questions were based on some qualitative issues that were of interest to the research group (e.g. "The interface of this system was pleasant."). Through the answers to the questionnaire, system usability and interface quality were evaluated. Since the use of seven response categories is relatively easy to use, preferred by respondents, and lead to more reliable participant responses[21, 22], the questionnaire were developed by using a seven-point Likert scales. The third section of the questionnaire was developed to get participants' feedback and comments on their specific interaction mode and interface type.

Discussion and Results

The experiments took place at various locations throughout the Georgia Institute of Technology's Atlanta, Georgia campus and the Southern Polytechnic State University's Marietta University, Georgia campus in Spring and Fall semesters of 2011. Given that this was a between-subjects study, 149 adult participants (66% male and 34% female) were recruited from the Georgia Institute of Technology's Atlanta University (n=94) and Southern Polytechnic State University's Marietta University (n=55) communities. The experiment lasted approximately fifteen minutes per participant. After performing the requested tasks, participants were asked to fill out the questionnaire to get their feedback and comments on their specific interaction mode and interface type. A statistical analysis was performed on the outcome of the questionnaires. Analysis of the data includes reporting descriptive statistics of the data collected via the questionnaire and then the data were analyzed using either by Brown-Forsythe Robust Test of Equality of Means or One-Way ANOVA based on their Levene's test of Homogeneity of Variance result and alpha level of p = .05. Table.1 shows the results of the questionnaire analysis.

Table1: Descriptive Statistics of the Questionnaire

		Interaction Mode - Interface Type		
No.	**Variables**	**DTouch+F (N=35)**	**TTouch+F (N=48)**	**TTouch+S (N=66)**
		Mean (SD)	**Mean (SD)**	**Mean (SD)**
1	Overall Usability	3.03 (1.18)	3.15 (1.58)	2.65 (1.08)
2	Interface Quality	2.43 (1.45)	3.12 (1.65)	2.17 (1.11)
3	How mentally demanding was the task?	5.20 (1.37)	5.38 (1.63)	5.35 (1.60)
4	How physically demanding was the task?	5.37 (1.91)	5.94 (1.36)	5.94 (1.48)
5	How successful were you in accomplishing what you were asked to do?	2.71 (1.52)	2.94 (1.77)	2.77 (1.71)
6	How hard did you have to work to accomplish your level of performance?	4.86 (1.46)	5.23 (1.60)	5.47 (1.55)

The results showed that 29% of the participants had used 3D modeling tools previously and 84% of the participants had owned or used touch screen devices before. Among the participants who

had used touch screen, 25% used DTouch+F, 34.5% used TTouch+F before, and the rest of them used TTouch+S.

The outcome of the statistical analysis revealed that on average, although, the participants were satisfied using all three interfaces, they coincided in that TTouch+S was more useable (mean response out of 7, M = 2.65) than DTouch+F (3.03) and TTouch+F (3.15). They expressed that the interface of the DTouch+F (2.43) and the TTouch+S (2.17) had better quality compared to the TTouch+F (3.12). Even though, the general pattern of the results is almost similar, the participants showed a more positive response using the TTouch+S compared to the two other interfaces. Some of the participants declared that tool icons were too small to touch using fingers in the TTouch+F interface and some of them showed a higher accuracy while interacting with the TTouch+S interface.

Overall, participants were more satisfied using the TTouch+S interface; however, they made some positive as well as negative comments about its usability. For instance, they stated “it’s too sensitive and hard to select an object” as a negative comment, or “it’s user-friendly and quick to learn the interaction method with the system” as a positive comment. There were also some negative comments about the DTouch+F interface, such as “it’s intuitive but requires practice and time” and “it’s quick and easy [but] only for simple tasks”, and “cumbersome”.

In the case of mental and physical demand, participants preferred the TTouch+S (mentally demanding = 5.35 & physically demanding = 5.35) and the TTouch+F (mentally demanding = 5.38 & physically demanding = 5.94) slightly better than the DTouch+F (mentally demanding = 5.20 & physically demanding = 5.37). In addition, the scores indicated that the participants believed they performed the task more successfully using the TTouch+S mode (5.29) compared to the TTouch+F (4.94) and the DTouch+F (4.74). Overall, participants rated the TTouch+S (6.08) better than the DTouch+F (5.89) and the TTouch+F (5.69). Figure.3 shows the results of the questionnaire analysis.

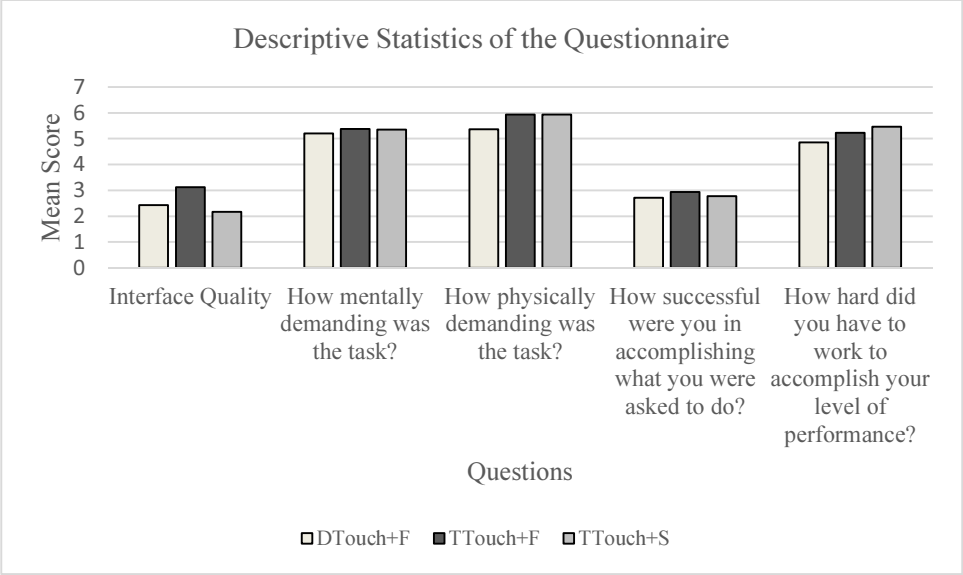

Figure 3: Descriptive Statistics of the Questionnaire

Conclusions

There is a need to improve construction education and training by incorporating advances in simulation, modeling and semantic web, and software engineering [23]. The ability to visualize the built environment and learn the building construction processes is critical for students in the architecture, engineering, and construction disciplines. Therefore, AEC education programs should update their teaching methods to include new tools of visual communication in civil and construction engineering and management courses, such as using new graphic resources or interactive simulations. The main objective of this study was to investigate if HCI mode used affected student satisfaction when performing BIM related tasks.

This study used a between-subjects experimental approach to investigate the effects of HCI mode and screen size on student performance and satisfaction when using the 3D modeling program for performing simple drawing tasks. The between- subjects experimental design avoids problems due to practice and carryover effects. In addition, by randomly assigning participants to different conditions, extraneous variables across the groups are balanced in the between-subjects design. The experiment was performed by participants under three different conditions:

i) Touch screen Desktop computer using Finger as an interaction mode (DTouch+F);
ii) Touch screen Tablet using Finger as an interaction mode (TTouch+F); and
iii) Touch screen Tablet using Stylus as an interaction mode (TTouch+S).

The outcome of the statistical analysis revealed that the interface quality between different conditions of the experiment was statistically significant and the usability of different system was almost significant. The results statistically and practically supported the hypothesis that the hardware type and the HCI mode used affect student satisfaction when performing BIM related tasks. The results of the experiment indicated that the participants were more satisfied using the

touch screen tablet using stylus and they provided more positive responses such as "easy to create shape", "intuitive", "accurate", "smooth and simple [interaction mode]", "quick to learn the interaction method with the system [interface]" under the touch screen tablet using stylus . Performing this experiment did provided valuable feedback about the selection of hardware options, which can positively affect students' attention and concentration, and can also lead to better understanding of construction processes when BIM applications are used. The findings of this study illustrate the application of different HCI modes can be extremely useful for AEC education practice by improving students' satisfaction and learning in the BIM-embedded construction education environment.

References

1. J. I. Messner, S. C. M. Yerrapathruni, A. J. Baratta and V. E. Whisker, presented at the Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition, 2003 (unpublished).
2. A. Aydilek, Digital Image Analysis in Geotechnical Engineering Education, Journal of Professional Issues in Engineering Education & Practice, Jan2007 133 (1), 38-42 (2007).
3. S. Pitt, C. Updike and M. Guthrie, Integrating Digital Images into Art and Art History Curriculum, Journal of Library Administration 39 (2/3), 29-42 (2003).
4. S. Azhar, A. Sattineni and M. Hein, (2010), Retrieved November 22, 2011, http://ascpro.ascweb.org/chair/paper/CEUE200002010.pdf.
5. D. M. Gier, in ASC International Proceedings of the 44th Annual Conference (Retrieved October 22, 2011 from http://ascpro0.ascweb.org/archives/cd/2008/paper/CEUE179002008.pdf, 2008).
6. J. M. Taylor, J. Liu and M. F. Hein, Integration of Building Information Modeling (BIM) into an ACCE Accredited Construction Management Curriculum, Retrieved on November 22, 2011, https://fp.auburn.edu/heinmic/Pubs/ASC%202008-Integration.pdf (2008).
7. J. D. Goedert and P. Meadati, Integration of construction process documentation into Building Information Modeling, Journal of Construction Engineering and Management 134 (7), 509-516 (2008).
8. W. Hu, Math That Moves: Schools Embrace the iPad, http://cmapspublic3.ihmc.us/rid=1L3024L5Z-5B9PBH-104R/iPadsLaptopsinSchool.pdf (2011).
9. R. Hertz-Lazarowitz and N. Miller, Interaction in cooperative groups: the theoretical anatomy of group learning. (Cambridge: University of Cambridge Press, 1992).
10. M. A. Bell, Teachers' Perceptions Regarding the Use of the Interactive Electronic Whiteboard in Instruction, http://downloads01.smarttech.com/media/sitecore/en/pdf/research_library/higher_education/teachers_perceptions_regarding_the_use_of_the_interactive_electronic_whiteboard_in_instruction.pdf (1998).
11. C. Singhanayok and S. Hooper, The effects of cooperative learning and learner control on students' achievement, option selections, and attitudes, Educational Technology Research and Development 46, 117-133 (1998).
12. E. Howse, D. Hamilton and L. Symons, Retrieved November 17, 2011, http://downloads01.smarttech.com:80/media/sitecore/en/pdf/research_library/higher_education/the_effect_of_a_smart_board_interactive_whiteboard_on_concept_learning_generation_of_ideas_group_processes_and_user_interaction_satisfaction.pdf (2000).
13. B. Somekh, M. Haldane, K. Jones, C. Lewin, S. Steadman, P. Scrimshaw, S. Sing, K. Bird, J. Cummings, B. Downing, T. H. Stuart, J. Jarvis, D. Mavers and D. Woodrow, 2007.
14. M. E. Haque, in The 2nd International conference on Virtual Learning, ICVL 2007, Retrieved November 12, 2010 (http://www.cniv.ro/2007/disc2/icvl/documente/pdf/met/2.pdf, 2007).
15. P. T. I. Lam and F. W. H. Wong, Improving building project performance: how buildability benchmarking can help, Construction Management and Economics 27 (1), 41 - 52 (2009).

16. D. Thomson and R. Miner, BIM contractual risks change with technology, Construction Executive, 60-64. Available at: http://www.constructionexec.com/Files/69.07Issue.pdf (2007).
17. B. Koo and M. Fisher, Feasibility study of 4D CAD in commercial construction, Journal of Construction Engineering and Management 126 (4), 251-260 (2000).
18. H. J. Kang, B. Lho and J. Kim, presented at the Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition, 2004 (unpublished).
19. Autodesk, 2007.
20. J. Lewis, IBM computer usability satisfaction questionnaires: Psychometric evaluation and instructions for use, International Journal of Human-Computer Interaction 7 (1), 57-78 (1995).
21. E. P. Cox, The optimal number of response alternatives for a scale: a review, Journal of Marketing Research 17, 407-422 (1980).
22. L. J. Weng, Impact of the number of response categories and anchor labels on coefficient alpha and test reliability, Educational & Psychological Measurement 64 (6), 956-972 (2004).
23. J. Goedert, Y. Cho, M. Subramaniam, H. Guo and L. Xiao, A framework for Virtual Interactive Construction Education (VICE), Automation in Construction 20 (1), 76-87 (2011).