

**EFFECT OF INFORMATION AND COMMUNICATION TECHNOLOGY (ICT)
ON STUDENTS' PERFORMANCE IN CONSTRUCTION EDUCATION**

A Thesis

by

NIKHIL VIJAY RANKA

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

MASTER OF SCIENCE

Chair of Committee,	John M. Nichols
Committee Members,	Edelmiro Escamilla
	Radhika Viruru
Head of Department,	Joseph P. Horlen

August 2015

Major Subject: Construction Management

Copyright 2015 Nikhil Vijay Ranka

ABSTRACT

The labor productivity of the construction industry has declined or remained stationary over the past 48 years as compared to other non-farm industries. One of the reasons behind this is low adoption rate of technology in construction. Until recent times, most construction firms didn't even have a dedicated IT department. However, over the past years the number has increased with the advent of latest technological advancement in mobile devices and its applications.

Construction document management has advanced in recent years. Slowly, companies are managing these documents electronically. Construction drawings are one of the essential documents used by all the key players during all the phases of construction project, right from preconstruction phase to facilities management. Effective storage and management of drawings is very essential. Drawings are an important communication tool on any construction project. Now, documentation of these drawings has become more sophisticated with the use of mobile applications incorporated with cloud computing technology. However, most of the US colleges still use paper drawings as their pedagogical tool.

The literature review draws some light on the importance of information and communication technology (ICT) in construction education. As the construction industry advances technologically, it becomes imperative to introduce the respective IT tools in the present day curriculum. The following research study was conducted to examine if there is any significant difference in student's performance, as a result of using an IT

tool. Ipad mobile tablet device was used to present construction drawings electronically to a control group and the treatment group was given the traditional paper drawings. Following an instructional lecture, students were asked to give a test based on the provided construction drawings.

The test results show that the use of technology does enhance student' performance, as students who used the IT tool performed better on the test. Statistical analysis showed a statistically significant difference between the two test results. The treatment group answered a usability survey. The usability survey helped in comprehending how students perceived the IT tool in terms of its usability. Students indicated that they would like the use the tool in the future and gave it an SUS score of 71.35. This research study was conducted over a short period of time. Hence, further research involving a longitudinal study with the use of the technology is recommended.

ACKNOWLEDGEMENTS

I would like to convey my sincere thanks to my chair, Dr. John Nichols and my committee members, Dr. Edelmiro Escamilla and Dr. Radhika Viruru. Without their guidance, my thesis wouldn't have been possible.

I would also like to thank my roommates for volunteering for the pilot study, which helped in formulating my research study. Moreover, I am humbled by the help my friends provided by lending me their personal mobile devices, for the purpose of this research study.

Last but not least, I would like to thank my parents for supporting me in my pursuance of my Master's degree at Texas A&M University.

NOMENCLATURE

- 1) Mobile tablet device - A mobile tablet device is a handheld computer device which can be carried around by a person using it. It can be wirelessly connected to Internet and acts as a personal computer. For example, Ipad by Apple Inc.

- 2) Seek and find activity - This is an- class task being given to students which determines their capability to read and interpret construction drawings. It comprises of questions related to construction of a particular building. These questions require students to refer to the respective construction drawings to seek the information being asked.

- 3) PlanGrid - PlanGrid is a construction drawing management application available on mobile computing tablets.

TABLE OF CONTENTS

	Page
ABSTRACT	ii
ACKNOWLEDGEMENTS	iv
NOMENCLATURE.....	v
TABLE OF CONTENTS	vi
LIST OF FIGURES.....	viii
LIST OF TABLES	xi
CHAPTER I INTRODUCTION	1
Background	1
Problem statement	2
Hypothesis	3
Limitations.....	3
CHAPTER II LITERATURE REVIEW	4
Introduction	4
Construction industry at a glance	4
Current use of ICT/IT systems in construction industry	9
Mobile computing technology in construction.....	10
ICT in construction education	12
Technology adoption by students.....	13
Electronic document management through mobile technology	14
System Usability Scale (SUS).....	15
What does individual SUS score mean?.....	16
CHAPTER III METHODOLOGY	17
Introduction	17
Procedure.....	19
Participants	21
Research study setting	21
Construction drawing set.....	22
IT tool	27
Ipad.....	27

PlanGrid application.....	30
Demonstration of measuring tool.....	34
Seek & find activity.....	34
Demonstrations of seek & find activity.....	35
Experimental test.....	42
Lecture schedule and description	46
Lecture schedule.....	46
Lecture description.....	50
Posttest SUS survey.....	54
SUS calculation	55
Data collection and storage	55
 CHAPTER IV RESULTS	 56
Introduction	56
Data results & analysis	57
Exam test.....	57
SUS questionnaire.....	63
Interpretation of individual statements.....	69
Comparison between SUS score and marks obtained of an individual participant.....	73
 CHAPTER V.....	 76
 CONCLUSIONS.....	 76
 REFERENCES.....	 78
 APPENDIX A RESEARCH STUDY TEST QUESTIONS	 85
 APPENDIX B THE SYSTEM USABILITY SCALE (SUS) QUESTIONNAIRE	 87

LIST OF FIGURES

	Page
Figure 1. Shows construction labor productivity, 1964-2012. (From: Teicholz, P., 2013)	6
Figure 2. Shows physical copy of Set1 drawings.....	24
Figure 3. Shows physical copy of Set2 drawings- Francis Hall.....	24
Figure 4. Shows electronic set of drawings through application PlanGrid	26
Figure 5. Shows Set1 drawings- Demonstration.....	26
Figure 6. Shows Set 2 drawings- Francis Hall	27
Figure 7. Shows Ipad mobile device with PlanGrid application.....	28
Figure 8. Shows zoomed out view of drawing A142	32
Figure 9. Shows zoomed in view of drawing A142	32
Figure 10. Shows the hyperlink/callout function helps in jumping to the reference drawing for details.....	32
Figure 11. Shows the annotation of a known length on the drawing necessary to measure any component	33
Figure 12. Shows area box placed on a room	33
Figure 13. Shows step 1A (solution to sample question 1).....	36
Figure 14. Shows step 1B (solution to sample question 1).....	37
Figure 15. Shows step 2A (solution to sample question 1).....	37
Figure 16. Shows step 2B (solution to sample question 1).....	38
Figure 17. Shows step 3&4 (solution to sample question 1).....	39
Figure 18. Shows step 1&2 (solution to sample questyion 2).....	40
Figure 19. Shows step 3 (solution to sample question 2).....	41

Figure 20. Shows pilot test papers with result and reviews marked.	43
Figure 21. Shows the ‘In-Class Task #1’ test papers provided by Prof. Chao Xiao.....	44
Figure 22. Shows the ‘In-Class Task #2 and #3’ test papers provided by Prof. Chao Xiao	44
Figure 23. Shows one of the lecture slides presented to the treatment group	47
Figure 24. Shows participants engaged in drawings while the demonstration of ‘seek and find activity’	48
Figure 25. Shows participants from treatment group (SI) performing the test individually.....	49
Figure 26. Shows participants from treatment group.....	49
Figure 27. Shows one of the participants using PlanGrid features	50
Figure 28. Shows Invigilator handing out the necessary documents while the lecture is being delivered by the researcher.	51
Figure 29. Shows participants from the control group.....	53
Figure 30. Shows participants from the control group during the test.....	53
Figure 31. Shows the probability distribution of the test results.....	61
Figure 32. Shows the raw scores obtained from the SUS questionnaire.....	64
Figure 33. Shows the modified responses and each participants’ SUS score.	65
Figure 34. Shows the mean of all the responses with respect to an individual statement.....	66
Figure 35. Shows the comparison of mean SUS scores by quartile ranges, adjective ratings and acceptability (Bangor et al., 2008).....	68
Figure 36. Shows percentile rankings of SUS scores obtained from Bangor et al. (2008)	68
Figure 37. Shows the statement by statement analysis obtained from study by Bangor et. al. (2008).	73

Figure 38. Shows the matrix plot to determine the correlation between the two variables75

LIST OF TABLES

	Page
Table 1. Shows list of 'Demonstration' architectural drawings (set 1).....	22
Table 2. Shows list of Francis Halls' architectural drawings (set 2).	23
Table 3. Shows the test results of the Treatment group (SI), participants with IT tool ...	58
Table 4. Shows the test results of the control group (SI), participants with traditional paper drawings	59
Table 5. Shows the summary statistics of the treatment group.....	60
Table 6. Shows the summary statistics of the control group.....	60
Table 7. Shows the results of the t-test between two test groups.....	62
Table 8. Shows the results of each student participant and their SUS score.....	74

CHAPTER I

INTRODUCTION

Background

With the fast evolving society there comes challenges to individuals and organizations to develop and sustain the technological skills. The educational institutions need to nurture the future generation (Dede, 2010; Jenkins et al., 2006). As a concurrent to growing demands and shortage of labor it has been maintained that effective technology use by individuals is essential to fruitful performance results (Ertmer & Ottenbreit-leftwich, 2010).

Traditional use of tools in pedagogy includes use of a blackboard, paper notes, textbooks, etc. However, due to the emergence of technology, learning experience has also evolved. For the past 20 years computers have been aiding in teaching and learning experience in school. Moreover, access and sophistication of technologies available has developed, particularly over the past few years. A significant amount of research is available which provides various features of ICT (Information & Communication Technology) in optimizing student learning (Kennewell & Beauchamp, 2007). Kennewell & Beauchamp (2007) talks extensively about intrinsic and constructed features of ICT, which provide potential and structure for classroom activity. A tablet mobile device like Ipad is one such IT tool, which has the potential to enhance the learning experience in a classroom. In a research study, (Conole et al., 2008) analyzed

college students and how they use specific technology in an educational setting. The research enlightens that students were learning effectively as a result of their engagement with various types of technologies to enhance their learning experience. They further affirm that the college students of present generation are expert at using a variety of different technological tools to find and synthesize information in an effective manner (Conole et. al, 2008).

Construction industry has always been resistant to change and in adopting new technologies. There has been a recent paradigm change with the immergence of technologies like use of IT in Construction and BIM (Mihindu & Arayici, 2008). To cope up the industry, students need to reap the same benefits of the technology in an education setting and adapt themselves before entering the industry. Learning environments constructed primarily on interactive program approaches, are increasingly being described in terms of ‘affordances’, which focuses on users perception of the learning environment (Laurillard et al., 2000). Hence, the focus of my research study is to find out if the use of ICT has any significance on students’ performance in construction education? Moreover, the research aims at understanding how students perceive the technology and its usability.

Problem statement

Construction industry has been implementing IT in various facets of construction projects since last few years. Consequently, these IT tools should be introduced in the present day curriculum too. This research aims at analyzing through a case study, if there

is any significant difference in students' performance corresponding to use of ICT in construction education. Moreover, usability of the IT tool used will be determined to understand how students perceived the given technology.

Hypothesis

The following hypothesis will be tested for the study:

1. Statistical difference between the test results of two groups studied, control group and treatment group, will determine the influence of using an IT tool in a construction graphics class.
2. The single SUS score will determine the usability of the IT tool being used.

Limitations

The study limitations are:

1. The research study is conducted with 20 participants in each group.
2. The study was conducted over a span of one day. Students will spend just one lecture time with the IT tool.
3. The research study was conducted in a construction graphics class taught to freshmen at Texas A&M University.
4. The IT tool used in this research study is a mobile tablet device with a drawing management application used to present drawings electronically.

CHAPTER II

LITERATURE REVIEW

Introduction

This chapter outlines the review of literature for this research study. The topics presented in this chapter included the construction industry's labor productivity, recent growth of IT in construction, some research studies, which validate the use of IT/ICT in construction and construction education. The last section talks about the use of the System Usability Scale.

Construction industry at a glance

The division of labor has much importance in the industry with respect to their productivity. With the advent of recent technological advancements and complexity of construction designs, the construction industry is evolving into a complex entity (Tse et.al., 2005).

In the last 50-year era, the construction industry has been attributed to cyclic prosperous and bust phases. This is evident from the labor productivity report by (Teicholz, P., 2013). The Figure 1 below clearly shows how the construction industry's labor productivity has declined over the period of last 50 years, in contrast to the constant growth in labor productivity of other non-farm industries. Construction industry has witnessed a linear decline in its productivity by 0.32%. On the other hand, other non-farm industries have realized a positive output in its labor productivity by 3.06% per

year. The overall impact over the 50-year time period makes it substantial. Numerous factors can be attributed to the reason for consistent decline in the industry's labor efficiency.

Pertaining to the fact that most of the work in construction industry comprises of remodeling and retrofitting of current facilities as opposed to firsthand work, it has become vital to manage construction documents adequately and cost-effectively. One of the reasons mentioned in the report cited above was improper use and management of data based on paper documents. These documents are produced by highly disintegrated group of architects, designers and contractors who operate autonomously. It becomes arduous to examine a problem hence, problematic to manage the job. Substantial costs are incurred in resolving the information using independent sets of plans and documents. These documents are inherited in the process. This has resulted in errors, omissions, additional work and liens (GCR, N., 2004).

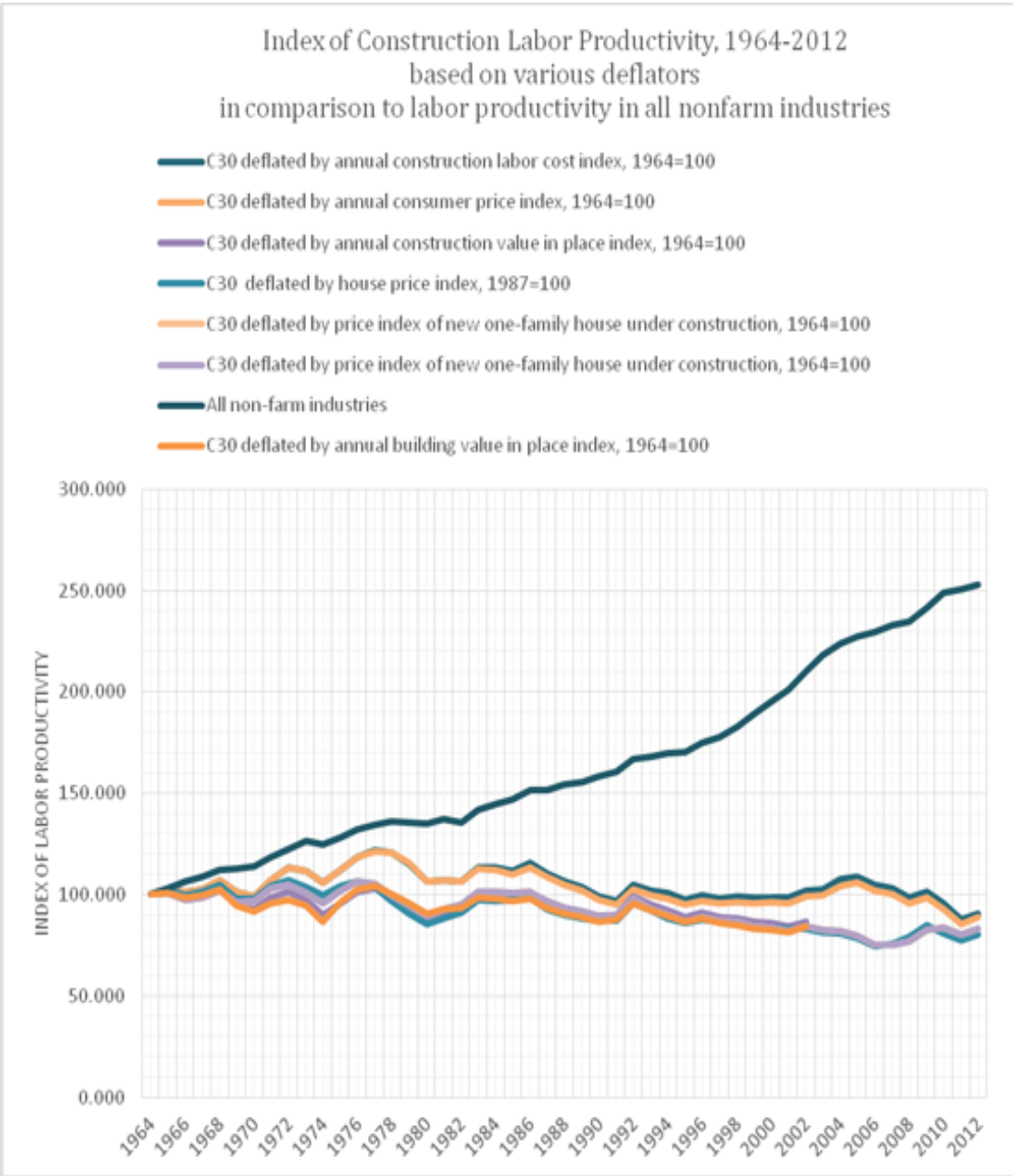


Figure 1. Shows construction labor productivity, 1964-2012. (From: Teicholz, P., 2013)

On a typical construction project designing, architects determine the formulation of sketches and drawings and cost limits. Surveyors manage cost planning and control. Construction engineers are responsible for optimizing the processes used in putting a project together. Superintendents have the responsibility of managing all the field personals like subcontractors, labors, materials and equipment. All these players work and collaborate together to construct a project.

By its nature, the construction industry is multidisciplinary. It is dependent on timely transfer of data and information to and fro amongst all its key players like engineers, architects, contractors, traders and owners (Rojas & Songer, 1999). To accommodate the issue of productivity, all the key players have started incorporating ICT to electronically exchange and record data (Watch, B.,2005; Ruddoch, 2006). In the past few years, the internet has become an essential form of medium for distributing project data and collaborating amongst key project players. Few medium to large construction firms have incorporated electronic document management systems. However, it has been done so for in-house communication only (Sarshar et al., 2002). This draws light to the fact that many small firms are yet skeptical of the benefits IT can bring to the table. Moreover, construction industry has traditionally been very resistant to adoption of new technology.

Tse & Choy (2005) had formulated a theoretical model in one of their research work. The study implied that IT training, to some extent, could upsurge the labor efficiency. However, lack of sufficient investment in IT training could hinder its optimal

use rendering firms inefficient despite the use of the best technology available.

Moreover the conclusions from a Finnish survey conducted by (Hjelt and Bjork, 2007) suggest the same. The study states that users who are incompetent with computer skills posed a high impediment to adoption of IT. This is attributed to insufficient prior IT training at educational level. As a consequence, it results in suboptimal use of the offered technology along with users' disappointment. Implementation of IT solutions cannot alone solve the problem of effective collaboration. It is imperative to even focus on its use by people and issues faced by organizations in its implementation. How to harness the technology, available at hand effectively is an important inquiry (Shelbourn et al., 2007). Hence, timely feedback from the technology users is important to validate the technology and for consistent improvement. As ICT advances, it is required by users to make the best use of it by avoiding the pitfalls.

Pertaining to the above stated problem, the research study aims at justifying if the use of an IT tool in a construction education class can be beneficial. As a case study, a mobile technology will be introduced in Construction Graphics class offered at Texas A&M University. Traditionally, students use hard copy of construction drawings in the class. The effect on students' performance will be examined through this research case study. Moreover, for the purpose of elucidating constructive feedback from the user regarding their use of the technology a usability survey was conducted.

Current use of ICT/IT systems in construction industry

IT can act as a strategic weapon by offering novel prospects. IT can be used to alleviate inefficiency, enhance performance, offer competitive advantage over other players and open new and sophisticated methods for managing and organizing the data. Furthermore, help formulating innovative business ventures. Manufacturing industry has always been in the forefront in its application. The advancement in the manufacturing industry is evident.

It is now known that the heart of the issues within construction industry lies in the flow of data (Tse and Choy, 2005).

Construction projects in general are temporary, barely similar, multi-faceted and involves different organizations. Thus, being disposed to communications failure. Hence, through extended use of IT, construction industry can be benefited more than other industries.

Mak (2001) in a study contends that the industry is reluctant to explore the benefits of IT to manage projects. However, some construction companies in the past have utilized an extended electronic document management system (EDMS) for collaborating amongst project players for accessing and sharing information of construction drawings and documents (Lam et. al., 2009).

A subsequent survey study conducted by Wong (2007) found the premier reasons behind adoption of ICT in construction by professionals. His finding suggest that predominant reasons were

- (1) Effective communication and collaboration amongst its team members,
- (2) Competitiveness

One of the old applications of technology in construction engineering and design, which shifted the paradigm of the construction industry is Computer- Aided Design (CAD) drafting tools. CAD was used to accurately draft construction drawings. CAD is a typical illustration of successful IT use in construction history (Tse & Choy, 2005). Now there is a need for managing the prepared CAD drawings on field. Drawings are prepared on CAD applications, printed and used as major reference material on any project. Now these drawings can be accessed electronically through mobile devices. Moreover, with the use of mobile applications, currently available, they can be modified, edited, annotated, and modified online.

Mobile computing technology in construction

Improvement in interchange of information for the purpose of improving productivity is construction engineers' major concern. However, transference of site information becomes difficult with harsh weather conditions, large construction site and dispersed resources.

With the recent development in smart phones and mobile devices, this interchange of information has become more structured and manageable. With the use of technology even the minute detail can be accounted for. Project managers have used mobile devices in the past.

Personal digital assistant (PDA) is one such mobile device, which was used by Navarrete (1999) for assimilating inspectional data from site. The information was fed in the device straight from the construction site. Effective sharing of information through PDAs has been documented by (Pena-Mora & Dwivedi, 2002) in their research study. Wang (2008) in his research study utilized radio frequency identification (RFID) technology integrated with mobile devices for quality control management. It showed that mobile technology can has the potential to improve construction processes. Other studies conducted by Lipman, (2004), shin et al. (2008) and Zurita et al. (2008) have shown similar successes in implementing mobile devices to optimize construction processes.

The above-cited research studies demonstrate the potential of mobile computing devices. However, the mobile devices of present generation have opened new avenues for the construction industry (Kim et. al., 2011).

JBKnowledge, Inc. conducted the first annual Construction Technology (CT) Survey in 2012. This is a yearly report, which compares the technological advancement in construction over the period of the years. It includes responses from 1000 participants representing all the major professionals in the construction industry from Architects to executives.

Nearly 60% of companies surveyed have an IT department. Participants were asked how important mobile technology is. Over the span of three years from 2012 through 2014, number of participants who think mobile devices are important or very

important has increased from 30.1% to 47.9%. In other words, construction professionals who said mobile technology is “not important” have decreased since 2012. Consequently, more companies provide mobile applications now with their integrated desktop software solution. Moreover, participants were asked to indicate top mobile applications they use. Out of 20 mobile stand-alone mobile applications, indicated by the participants as used in the industry, PlanGrid was one of them. PlanGrid is the mobile application being used for the purpose of this research study. The report claims that the industry will realize more sophisticated web-based and mobile-first solutions in coming years (JBKnowledge, 2014).

ICT in construction education

Two-dimensional (2D) drawings are widely used teaching tools used in construction education. They are widely used to teach students in development of various skills like estimating, scheduling, job safety analysis, and etc. Considering the complexity of construction projects now, even well experienced professionals are susceptible to misinterpretation of 2D drawings (Irizarry & Meadati, 2009). Generally, these drawings are presented in the paper format or hard copy. Electronic copy of construction drawings is used only for transferring and printing purposes. However, with the recent development of multiple, document management computer and mobile applications, the 2D drawings can be presented, modified and used a media of communication.

Recent data shows, US construction industry has been adopting mobile

computing devices, such as Ipad (Van Hampton, 2011). Currently, only 33% of the US college population uses such devices. However, Companies often assume that there is no need for any instructional-based program for students as they use these technologies in their daily life (Smith et al., 2009). Students need technology based instructional programs to make them familiar with their use. It should be incorporated in their regular curriculum. This way, students will get well nurtured before they enter the industry.

With rapid technological advancement in IT for construction, it has become imperative to introduce these technologies in the curriculum. One such way is to remove use of printed construction drawings with mobile devices such as tablets for accessing the drawing documents electronically. Apart from being handy, these devices can help save numerous resources wasted on printing documents, making the construction industry more sustainable. Besides, students lack the application knowledge of these technologies in enhancing the construction process (Reyes et. al., 2009). The primary concern is to keep the curriculum in line with the industry to train students in developing the required skillset, as the industry demands (Casey, 2008). Moreover, positive outcomes of tablet devices in an educational setting have been documented by Mock (2004). They claim it to be an effective learning tool and has shown improved results.

Technology adoption by students

College students, who reached young adulthood around the year 2000's, were born around evolutionary technologies. They tend to be more comfortable with novel technologies as compared to older generation (Oblinger & Oblinger, 2005). Most of

them used computers since their childhood and are considered more literate technologically. They are accustomed to understand a wide range of IT tools without much training (Jones, 2008).

Conole et al. (2008) analyzed students using present day technologies in a classroom environment revealed that students tend to learn better with technology. Similar results were found in some of the previous cited research studies. Hence, it is clear that IT has the potential to improve the way students learn, at least the way present day generation learns.

Electronic document management through mobile technology

Traditionally, paper drawings have been widely used on fields and offices to perform all the activities relate to construction of a project. Until very recent, paper drawings are the core form of media used on site by field personnel. Hence, construction field data management is of utmost important since now we have the technology to manage and store them. Construction documents can be easily stored over a wireless cloud and access through Internet. There is no need to store thousands of drawing sheets and documents at the construction site. Moreover, drawings get changed often as a result of change orders.

Now, tablets and cloud computing technology has made management of all types of construction documents with a flick and click of a hand, even from a remote location. All that is required is an Internet connection. Collaboration amongst key players situated borders apart is a reality now. For example, PlanGrid eradicates the burden of printing

paper drawings and storage issues associated with it. Besides, saving huge resources, otherwise spent on printing and reprinting documents, as result of change orders, it keeps all the information updated. This information can be updated by one and accessed at the same time by all the project players involved in the project (Knight, 2015). This can help company aim towards a more sustainable construction and reduce cost as a result of reprography

In conclusion, the above-discussed IT solutions are ever growing. Few large companies are using them on construction site. They are aware how it can automate the process and help manage documents in a better way, all done electronically (Cline & Davis, 2013).Hence, it becomes imperative to introduce these IT solutions in the present day curriculum to accustom students with their application.

System Usability Scale (SUS)

For the purpose of this study, SUS was adopted as a survey to measure the usability of the IT tool being used as a part of the research study. This survey helped us in comprehending various features of the IT tool, how student perceived the technology use. This has further opened avenues for further research.

Brooke had developed the SUS questionnaire as a “quick and dirty” way to determine the usability to a given technology or system. Despite of other alternatives to measure the usability of system, SUS has numerous characteristics, which make it a very robust survey tool for determining the usability of any system (Brooke, 2013)

Originally, the SUS questionnaire consists of 10 statements, which are scored, based on a 5-point likert scale, ranging from 1(complete disagreement) to 5(complete agreement). Over the years, the SUS has been modified to fit any particular user or system. However, for the purpose of this research study, the original SUS questionnaire was used.

The survey participants' response were recorded, tabulated in an Excel spreadsheet and interpreted to give a single usability score. This usability score is compared with the population mean of all the assimilated data available. Since 1996, 2324 surveys have been completed and put together to give the population mean. As a result of the surveys, the mean SUS score has been determined as 69 with the range from 30-93.39. Previously, SUS has been used over a broad range of interfaces. It includes various software applications, mobile devices, networking instruments and other similar IT tools (Bangor et. al, 2008).

What does individual SUS score mean?

A score of 70, means the system being analyzed is passable. Better systems tend to score in mid-70's and 80's. Any exceptional tool would score 90 or above. If a system has a score below 70, it means the system wasn't perceived as usable and it calls for improvement (Brooke, 1996).

A detailed description of its calculation, percentile rankings and various mean values are stipulated in the methodology section of this research study.

CHAPTER III

METHODOLOGY

Introduction

This chapter outlines the detailed account of the procedures performed during the research work. The main objective of this research study was to study the effect of using IT in the Construction Graphics class. The construction graphics class is taught to freshmen at the Construction Science Department of Texas A&M University. This class syllabus outlines reading and interpretation of construction drawings. A mobile device application for managing construction drawing documents on Ipad was incorporated as an IT tool.

The study comprised of comparing two sections of the class. Different professors teach both the sections. However, the syllabus requirement was the same for both the course. Each section of the class comprised of 24 students. However, the participants group comprised of only 20 randomly selected students in each section. This comparative study was conducted between the two sections of Construction Graphics class. The number of participants in both the section was the same. The Institutional Review Board of the institute approved the study and the participation of the students was completely voluntary. Moreover, the outcome of the respective study had no influence on the course grade.

The research study was completed on a single day of class. The study was conducted towards the end of the semester. Both the classes were conducted on the same

day, as per the class schedule. The participants of the first section were provided with electronic drawings. The electronic drawings were provided on a mobile device application called PlanGrid. PlanGrid is a construction document management application available on an array of mobile devices for subscription. It is been popularly used in the industry since its inception in 2012. The mobile device used was Ipad.

The second section of the class was provided with the traditional paper format of the same construction drawings. The researcher delivered a structured lecture demonstrating the plan reading /seek & find activity. Post lecture, the participants were given a test comprising of 9 questions related to the plan reading activity presented earlier that day. The drawing document set and the test was the same for both the sections of the class. Moreover, the class, which acted as a treatment group, was asked to fill out the System Usability Scale (SUS) questionnaire to express their experience with the new technology for the respective class activity. All the participants had to perform individually and were invigilated by the professors, the researcher and a randomly selected invigilator.

The Primary objective of this research study is to determine if there is any significant difference in the students' performance as a result of using Information Technology in Construction Graphics class.

The test result will be statistically analyzed. The second objective of the research study is to determine the usability of the technology introduced in the class.

Procedure

The research study was conducted as a part of the COSC 175 Construction Graphics class. The research study was conducted as a part of the sections offered in the spring semester, 2015. This class is offered every semester. It is a freshmen class and it is mandatory for all the students pursuing Bachelors in Construction Science offered by the Department of Construction Science at Texas A&M University, College Station. The class enrollment predominantly has freshmen students with few sophomores and very few seniors. The class has various sections. All the sections have the same syllabus requirement. However, a different professor teaches each section. Moreover, only two sections were selected for the purpose of this study.

The two sections selected for the purpose of this research study are-

1. COSC 175-Section 902 Construction Graphics offered by Instructor: Segner Jr, Robert O. (Treatment Group SI)
2. COSC 175-Section 903 Construction Graphics offered by Instructor: Escamilla Jr, Edelmiro E (Control group EI)

The following points outline the objective of the COSC 175 class. The syllabus is consistent among all the sections of the class. The following outlines the objective of the course as stated in the syllabus-

1. Visualization, interpretation and communication of graphical geometry in construction design and engineering
2. Graphical analysis of problems
3. Engineering drawing sketching fundamentals & applications.

4. Introduction to computer aided design
5. Difference between various construction drawings and their guidelines.
6. Introduction to common quantitative tools in construction.

Throughout the class students are taught how to read and interpret construction drawings. Initially students are introduced to engineering drawing and sketching concepts. As the course progresses students are introduced to various kinds of Construction drawings and standards used in the industry. As per the research requirement, the research study was conducted towards the end of the course.

The research study was coincided with the introduction of Architectural construction drawings of a construction project. In the second week of April, the instructors had introduced the students with concepts of architectural drawings and their use. For the purpose of this research the study was conducted after the students were familiarized with the basic plan reading concepts of Architectural drawings. Both the sections of the class had completed the same amount of course requirement at the time of the research study. The research study was conducted on the same day; both the sections had their classes scheduled on the same day. The research study was conducted on Monday, 27th April. As a part of the syllabus, the instructor introduces the students with the Construction drawings of the Francis Hall, Department of the Construction Science, Texas A&M University. Hence, the research study was conducted along with the introduction of Architectural drawings of the Francis Hall.

Participants

The participants were randomly selected from each section of the class for the research study. 20 participants were selected in each section. However, the class comprises of 24 students in each section. Due to unavailability of sufficient resources, Ipads, only 20 participants were accommodated in the research study. The participants were randomly selected. On the day of the research study, the first 20 students who showed up for the class had the option to participate in the research study. This was done to randomize the participant pool. All the students agreed with the research study requirements and signed the consent form indicating their interest in the research study. The remaining students had an option either to attend or miss the class. The participants from the first section were assigned the group name 'SI'. Consequently, the participants from the second section were assigned the group name 'EI'. The first section of the class, group SI, acted as a treatment group. The participants from the second section, EI, acted as a control group.

Research study setting

The study was conducted as per the class protocol. The research study was conducted during the regular class hours. The study was conducted in lecture room 105 of the Francis Hall. Both the sections had been previously conducted in same room and hence during the day of the research study.

Construction drawing set

The students were introduced to a set of Architectural drawings of the Francis Hall, which is the new department building for the Construction Science Department at Texas A&M University. Students were given two sets of drawings, Demonstration (Set1) and Francis Hall (Set2) as shown in Table 1 and Table 2. Below is the list of all the drawings with respect to their sets. Figure 1 and Figure 2 show the pictures of the drawing sets used for the research.

Table 1. Shows list of 'Demonstration' architectural drawings (set 1).

Sr. no.	Drawing sheet number	Drawing sheet description
1	G003	Legends and code information
2	A103	Third Floor Plan
3	A111	First floor reflected ceiling plan
4	A113	Third floor reflected ceiling plan
5	A142	Enlarged plans
6	A213	Interior elevations
7	A214	Interior elevations

Table 2. Shows list of Francis Halls' architectural drawings (set 2)

Sr. no	Drawing sheet number	Drawing sheet description
1	G001	Title sheet
2	G002	Index of drawings
3	G003	Legends and code information
4	A001	Architectural site plan
5	A002	Architectural site details
6	A101	First floor plan
7	A102	Second floor plan
8	A103	Third floor plan
9	A141	Enlarged plans
10	A142	Enlarged plans
11	A201	Exterior elevations
12	A211	Interior elevations
13	A212	Interior elevations
14	A213	Interior elevations
15	A214	Interior elevations
16	A321	Vertical circulation
17	A322	Vertical circulation

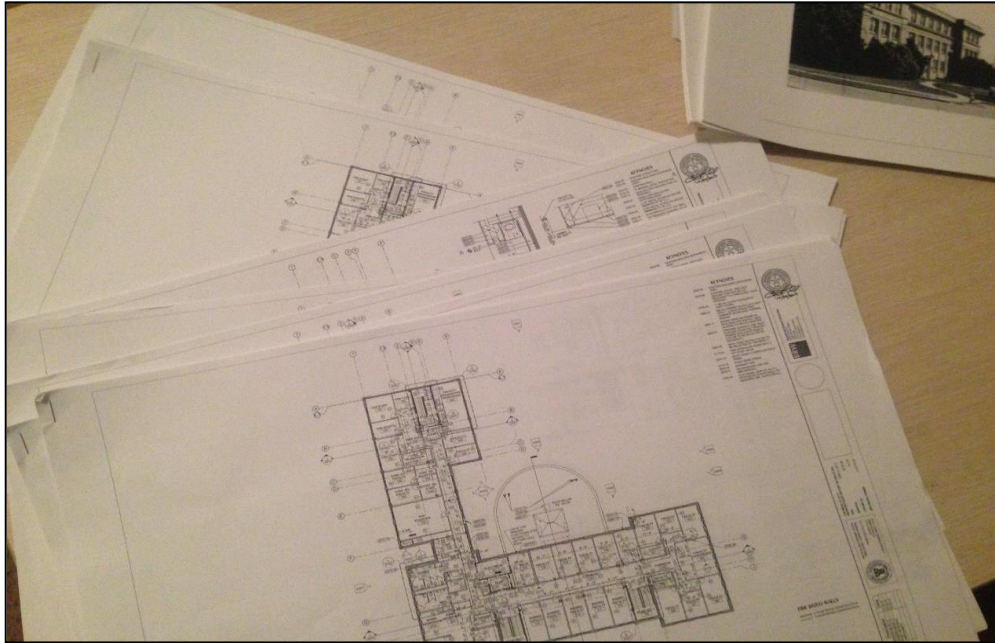


Figure 2. Shows physical copy of Set1 drawings

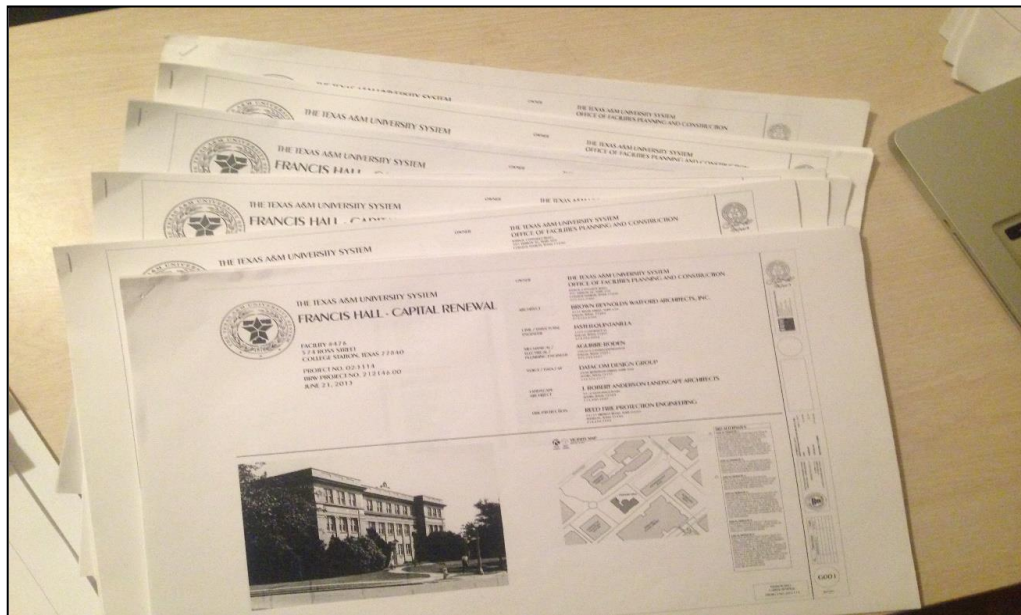


Figure 3. Shows physical copy of Set2 drawings- Francis Hall

The above drawings were selected for the research study from the 75 available Architectural drawings of Francis Hall. Participants of the treatment group, SI, were given the electronic form of drawings. The students were provided with the Ipad. The drawings were accessed through the application called 'PlanGrid'. Participants of the control group, EI, were taken the traditional paper format of the drawings. The size of the paper drawings complied with the ones, which have been historically used during the Construction Graphics class. The size of the Paper drawings was 17" by 14". The two sets of drawings provided to the participants had different purposes each. The 'Demonstration (Set1)' drawings had six drawings involving the details of the third floor of the Francis Hall. The 'Francis Hall (Set2)' drawings had the drawings, which mainly covered the details of the first two floors of the Francis Hall building. The purpose of providing different sets of drawings separately was to differentiate between drawings used to demonstrate 'seek & find' activity and to answer the test questions. Students used Set1 during the lecture to get familiar with the Francis Hall drawings, seek & find activity and the usability of PlanGrid, in case of treatment group SI. On the other hand, Set2 drawings were used to answer the questions on the test, followed by the lecture. Figure 4, Figure 5, Figure 6 are the snapshots of the PlanGrid application showing the electronic drawings.

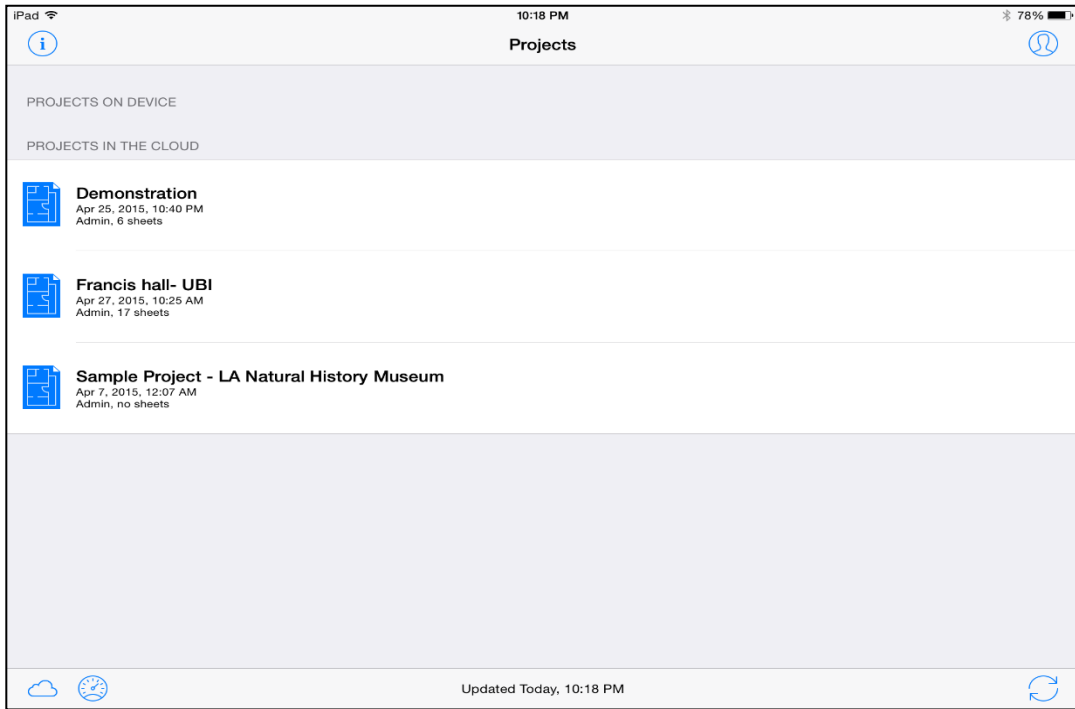


Figure 4. Shows electronic set of drawings through application PlanGrid

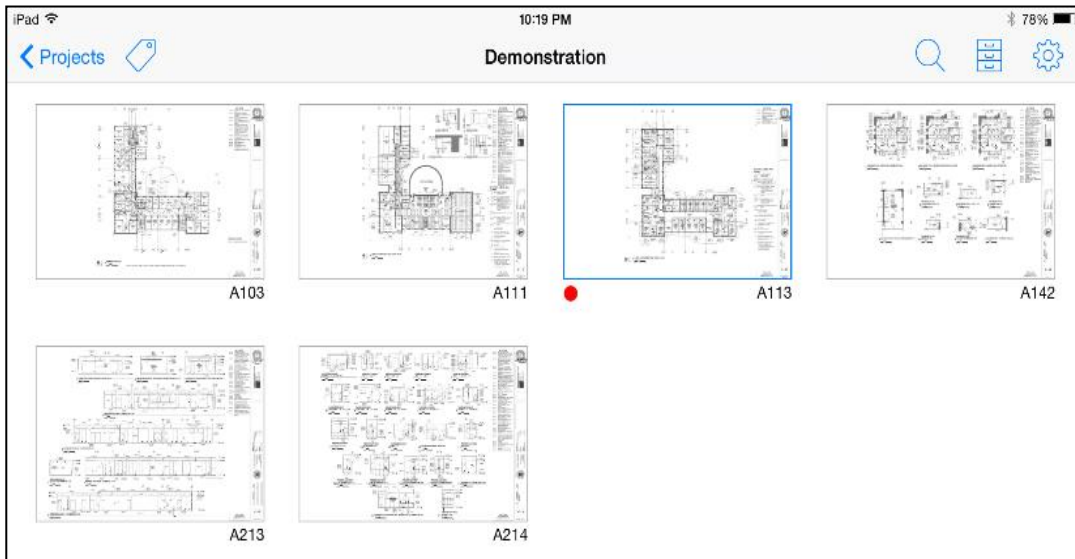


Figure 5. Shows Set1 drawings- Demonstration

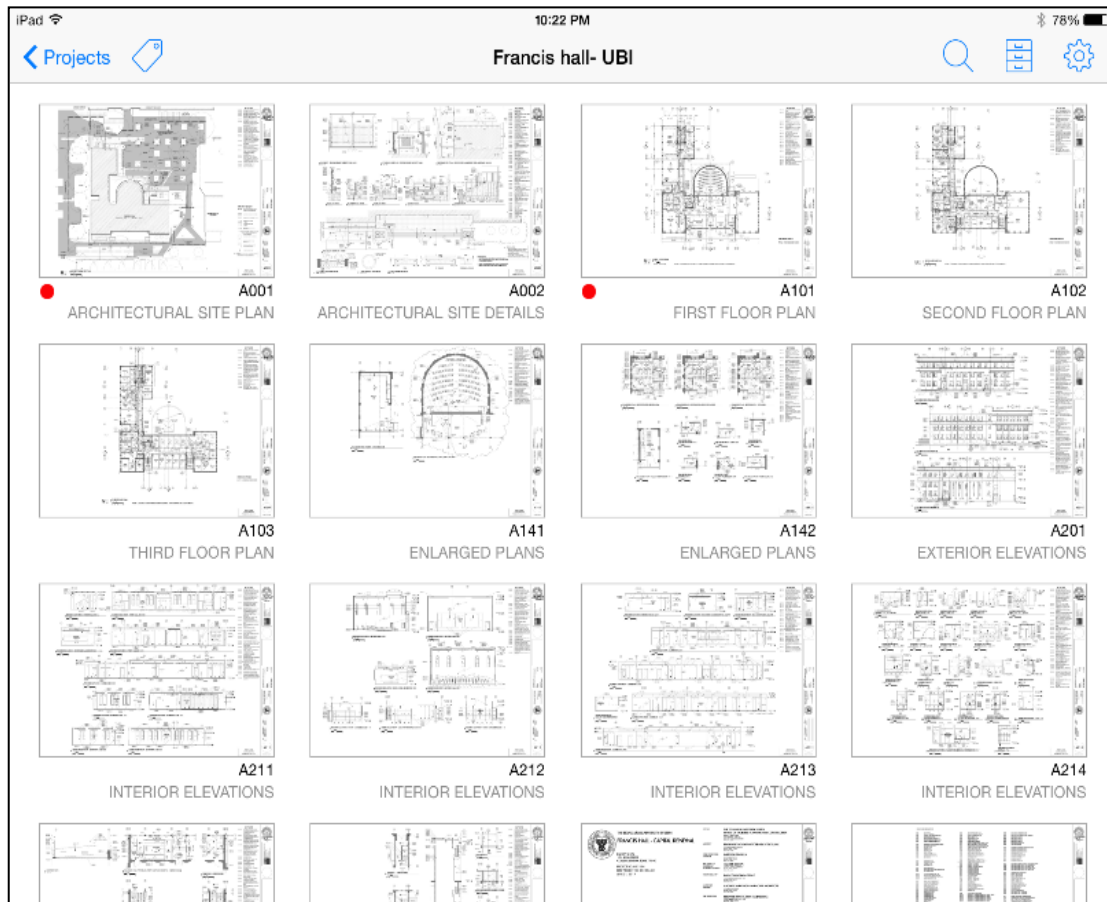


Figure 6. Shows Set 2 drawings- Francis Hall

IT tool

Ipap

The participants from the treatment group were provided with Apple Ipads as they sat down and agreed to the terms and conditions of the research study. Apple Ipads were chosen over other mobile/tablet devices working on Android Operating System (OS). The reason being, PlanGrid application was not available on any other OS other than iOS (Apple devices). Initially, PlanGrid was developed for iOS platform only. It

was not until the month of May, 2015 that PlanGrid application was developed and available for android OS. Moreover, it was easier to assimilate Apple Ipads through friends and college recourses for this research study.



Figure 7. Shows Ipad mobile device with PlanGrid application

All the Ipads were collected from different sources for the purpose of this study. Due to limited resources, even after exhausting all the possibilities, only 21 Ipads could be collected. However, only 20 participants were chosen from a section of the class to avoid any discrepancies, which could have occurred. The collected Apple devices had different versions of Ipads. There were 3 Ipad air, 5 Ipad mini and the remaining were Ipad 2nd & 3rd generation. Figure 7 shows one of the Ipad mini. However, there wasn't any significant difference between their usability. The only difference was the display

size. It varied from 7.9 inches for Ipad mini to 9.7 inches for Ipad 2nd & 3rd generation. Due to insignificant difference between the various Ipads available for the research study, all the Ipads were approved for the research study. After collecting the Ipads, the PlanGrid application was installed on each Ipad successfully. The researcher had made an account with PlanGrid. All the selected drawing documents were uploaded on the cloud from the PlanGrids' website. Later on, both the drawing sets were downloaded individually on each Ipad. The PlanGrid downloads all the uploaded documents from the cloud through Internet. Once downloaded, the documents can be reviewed or edited without any Internet connection. However, the application needs an Internet connection to update any information, which needs to be fed in. All the drawing sets were updated for the last time on the weekend before the day of the research study.

This study was conducted to investigate the effect on student's performance in using IT technology in Construction Graphics class. Ipads with PlanGrid application was the IT tool used to view the construction drawings electronically.

There are few other mobile applications, which are available and manage construction blueprints. Fieldwire and Procore are some of those few applications, which are similar to PlanGrid. However, PlanGrid was chosen based on its simplicity and versatility. Moreover, the other applications are more complex and just one day 20 minute lecture isn't sufficient for students to get familiarized with the software application. PlanGrid was found to be more relevant and apt for the research study.

PlanGrid application

PlanGrid is a construction mobile application, which aids AEC industry professionals to collaborate with their project plan, specifications and photos from the construction site, not just office, through a mobile device. The basic version of the software application comes free with the liberty to manage up to 50 drawing sheets. Since, the research didn't require utilizing more than 25 sheets, the application could be used for the research for free. How it works is, one just has to upload the PDF drawings on PlanGrid.com and the service provider automatically synchronizes and makes the drawings communicable. The modified drawings can be shared with all the teammates working on a particular project. Moreover, one can use markup tools to modify the drawings and send updates to anyone associated with the project. PlanGrid even has the capability to generate RFI's, track issues and add photos to any particular location or a component on a drawing. The platform provides real-time updates and seamless file synching over Wi-Fi and cellular networks. PlanGrid can replace cost of paper in a construction project considerably.

PlanGrid is a versatile application for managing construction drawing documents. Some of its key features are enlisted below-

Features:

1. Automatic leaf-in and versioning of new plan revisions
2. Convenient and fast zoom-in and zoom-out of a drawing
3. Automatic and manual hyperlinking of all detail callouts.

4. Cloud based annotations, markups sync to the team
5. Automatic punch lists that sync and become searchable.
6. Quick field takeoff and estimating tools.
7. Markup your drawings with our full annotation suite.
8. Manage all the project drawings separately through a single application.
9. Take progress photos and pin them to your blueprints.
10. Automatic uploading and tracking of progress photos .
11. Construction management tools like RFI posting and submittal distribution

Out of the above listed features, only features 3, 4 and 7 were used by the participants as tools to aid in answering the questions related to the drawings based on seek & find activity. Figure 8, Figure 9, Figure 10, Figure 11 and Figure 12 demonstrate some of above listed features.

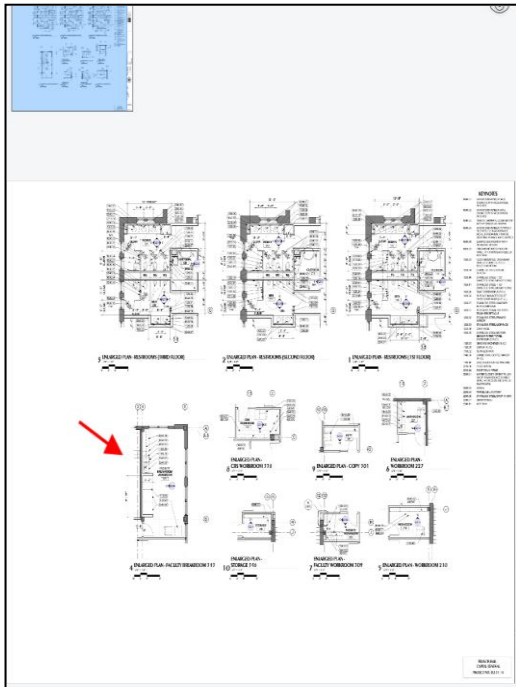


Figure 8. Shows zoomed out view of drawing A142

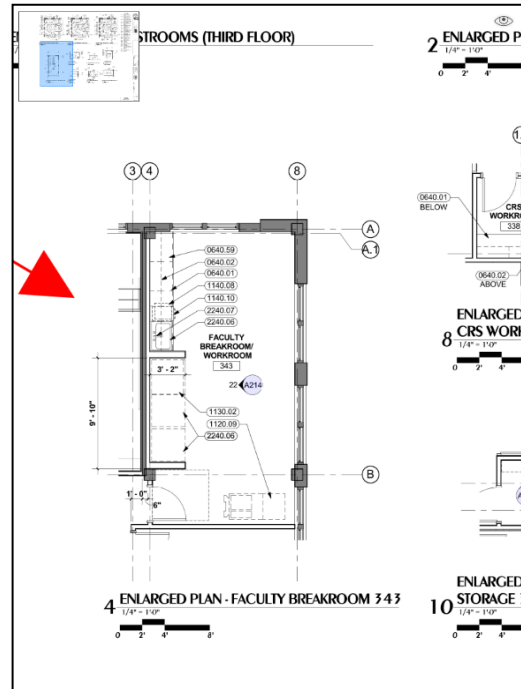


Figure 9. Shows zoomed in view of drawing A142

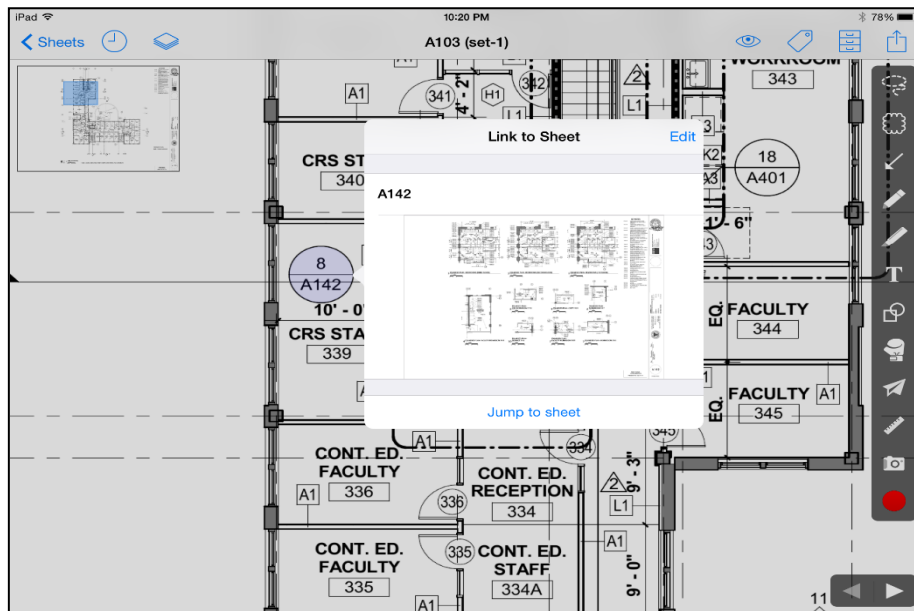


Figure 10. Shows the hyperlink/callout function helps in jumping to the reference drawing for details

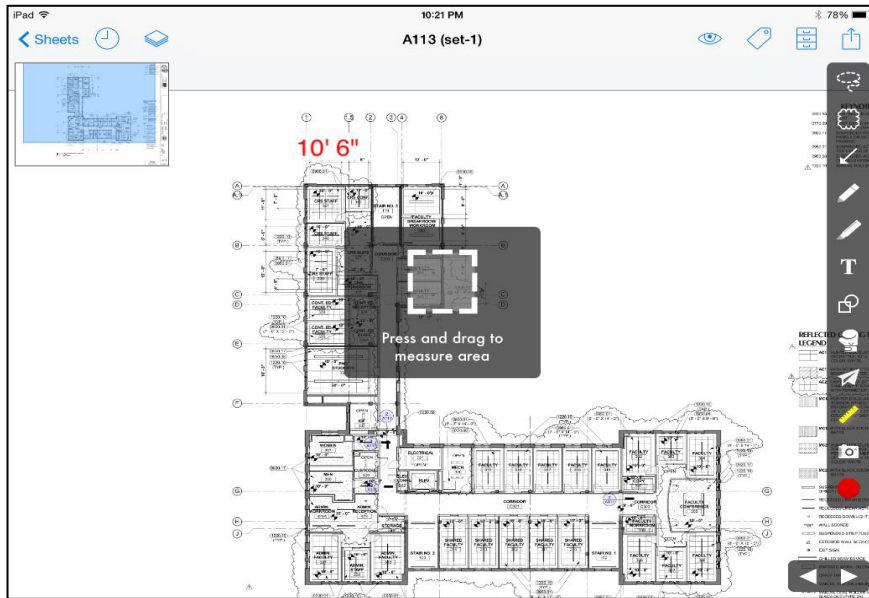


Figure 11. Shows the annotation of a known length on the drawing necessary to measure any component

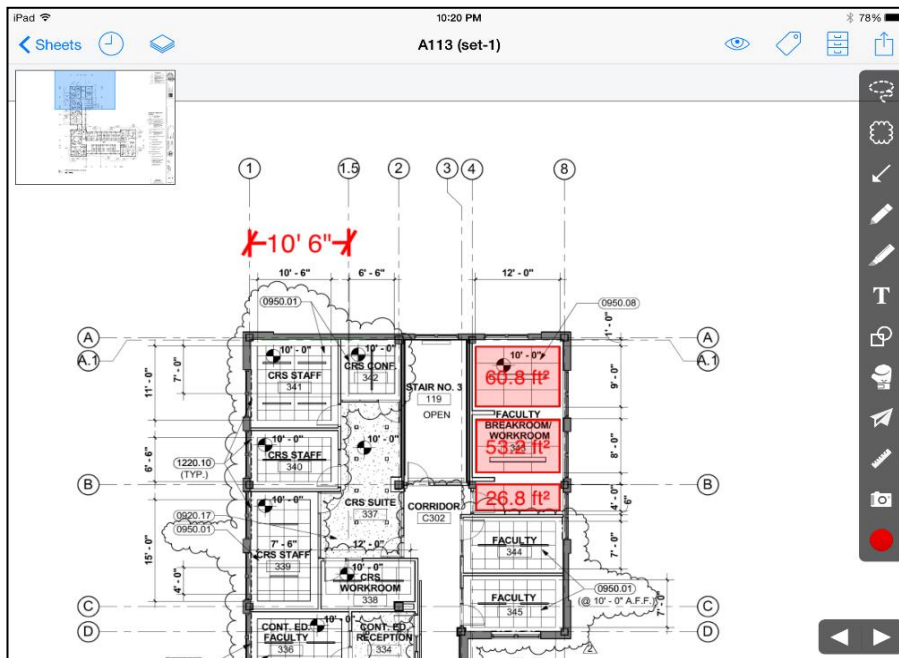


Figure 12. Shows area box placed on a room

Demonstration of measuring tool

To measure any area, first a known length is required to be annotated for the application to calculate any other measurements. The annotation acts as a measuring reference. Hence, the accuracy of your estimation depends on the accuracy of your annotation.

Seek & find activity

The terms seek & find activity has been referred to an in-class task, which have been given to students of the same class in previous year sections. This in-class task resembles basic problem solving questions, which are faced in the construction industry on daily bases. Estimators, Project Managers, Superintendents have to review construction drawings on daily bases to solve problems, which develop on construction site.

In this class activity, students are given drawing documents of a project. They are required to answer some questions based on the drawings provided. A typical question requires the student to seek for the right drawing and extricating the right information. It requires students to understand how the drawings are interlinked and used as a communication tool. For example, a particular room in Francis Hall might have more than one drawing referring to its details. Depending upon the detail required to be found out, students would have to seek the right drawing and hence the right information. For this purpose, right call outs and reference drawings are used to find the information.

Effective reading and comprehension of construction drawings as a communication media aids in such problem solving activity. Students need to learn the various signs, symbols and abbreviations, which are used for intra-drawing communications.

Demonstrations of seek & find activity

The answer to the question is found in set1 drawings or Demonstration, as named in PlanGrid

Sample Question 1: What is the elevation of the light fixture present in the Faculty room 309?

Solution steps: - The solution is virtually represented through Figure 13, Figure 14, Figure 15, Figure 16 and Figure 17.

1. The faculty room 309 is found on the third floor. Hence refer third floor plan A103. Find room 309.
2. Referring to the detail bubble for room 309. Click the callout circle (7 A142). 7th section of the drawing A142 shows the detail of room 309.
3. Refer to the interior elevation of the room 309. Click the callout circle (17 A214). 17th section of drawing A214 shows the light fixture.
4. The elevation of the light fixture is annotated on the right, 9'.

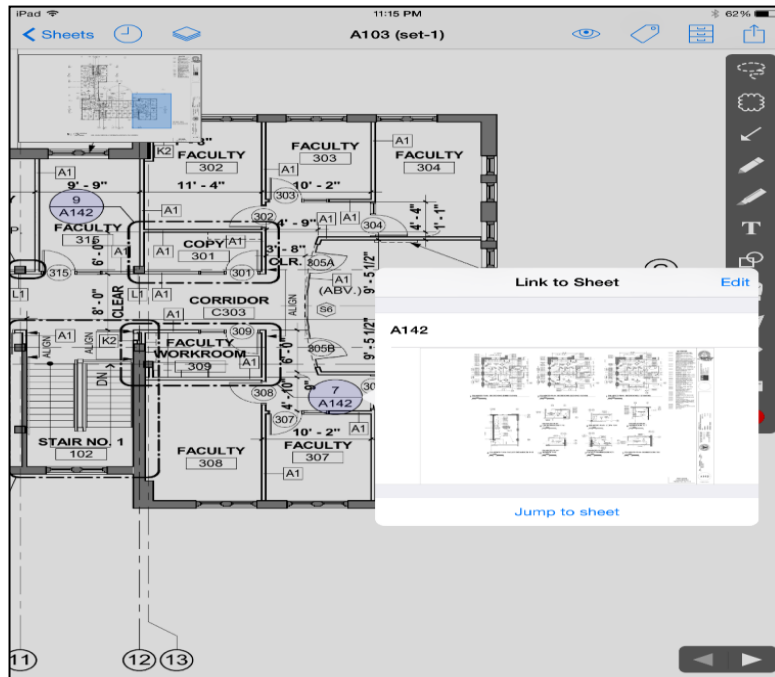


Figure 14. Shows step 1B (solution to sample question 1).

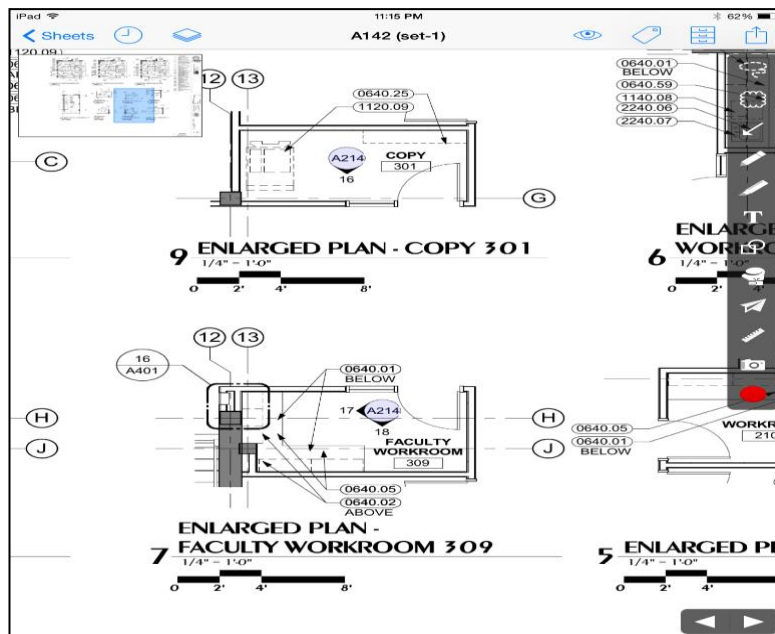


Figure 15. Shows step 2A (solution to sample question 1).

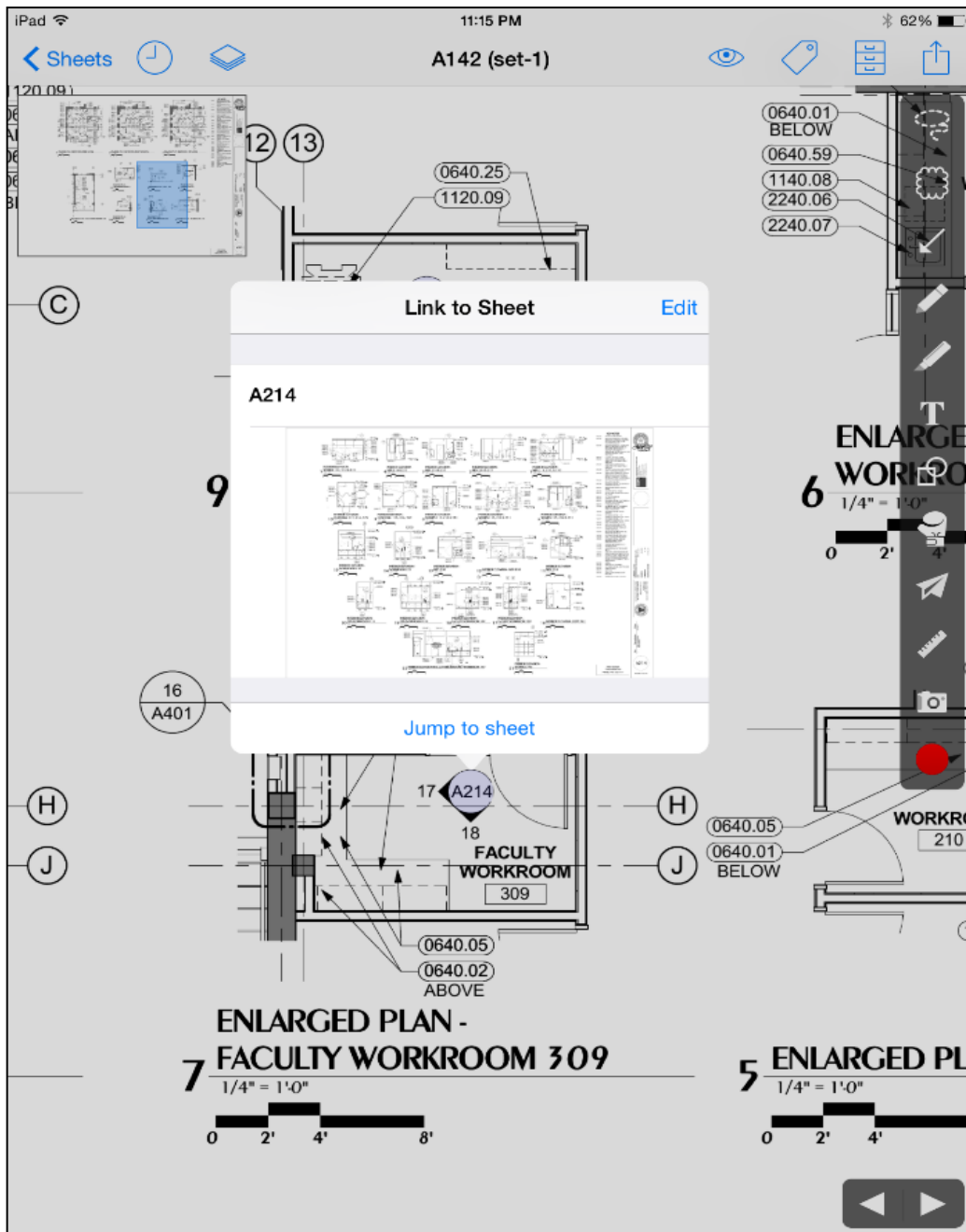


Figure 16. Shows step 2B (solution to sample question 1).

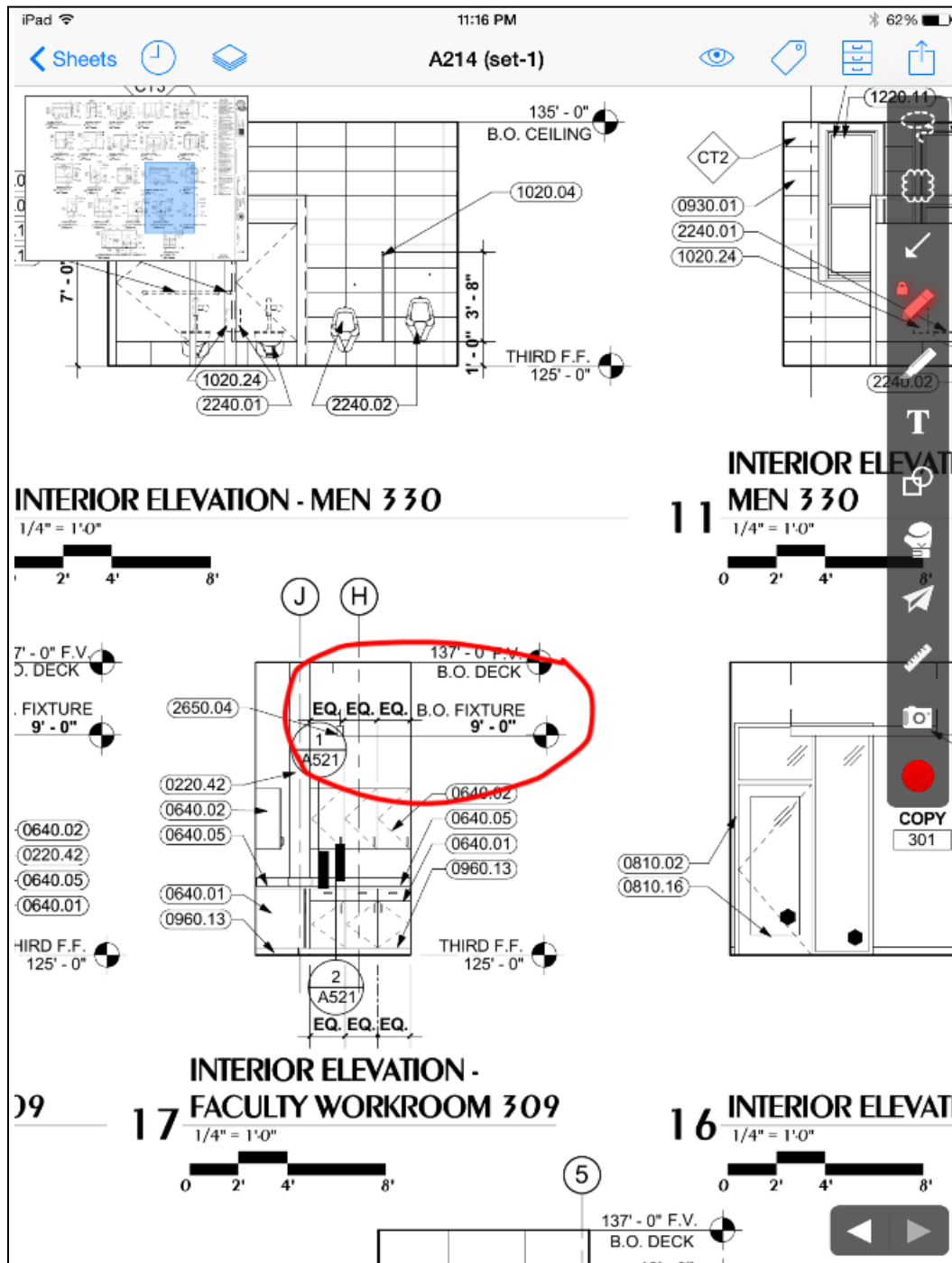


Figure 17. Shows step 3&4 (solution to sample question 1).

Sample question 2: What is the thickness of the gypsum board (ceiling) provided in the corridor C303?

Solution steps: - The solution is virtually represented through Figure 18 and Figure 19.

1. Refer the drawing A113, Third floor ceiling plan, since the question asks us to provide the ceiling material detail.
2. Click the callout circle (2 A111) for the ceiling detail.
3. Look for the gypsum board ceiling in the section 2 of drawing A111. Every component on a drawing has reference number. The keynotes have the list of all the reference number. Refer to the keynotes provided on top right side of the drawing. Look for reference number 0920.08. It is a gypsum board with thickness 5/8” thickness.

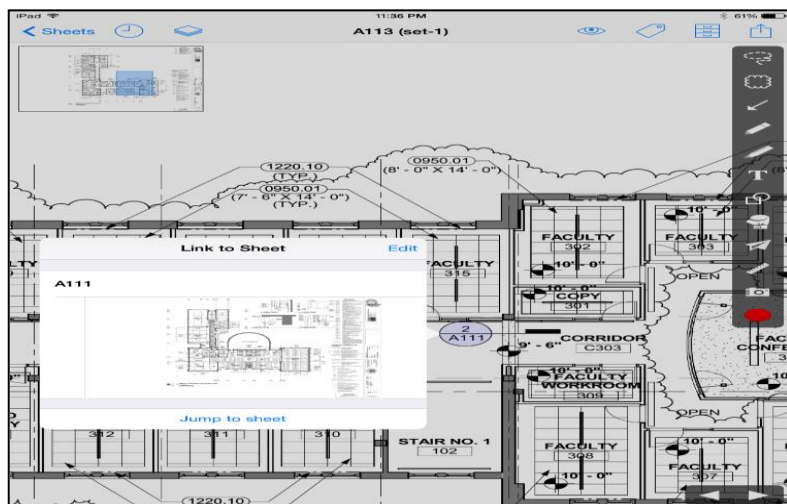


Figure 18. Shows step 1&2 (solution to sample question 2).

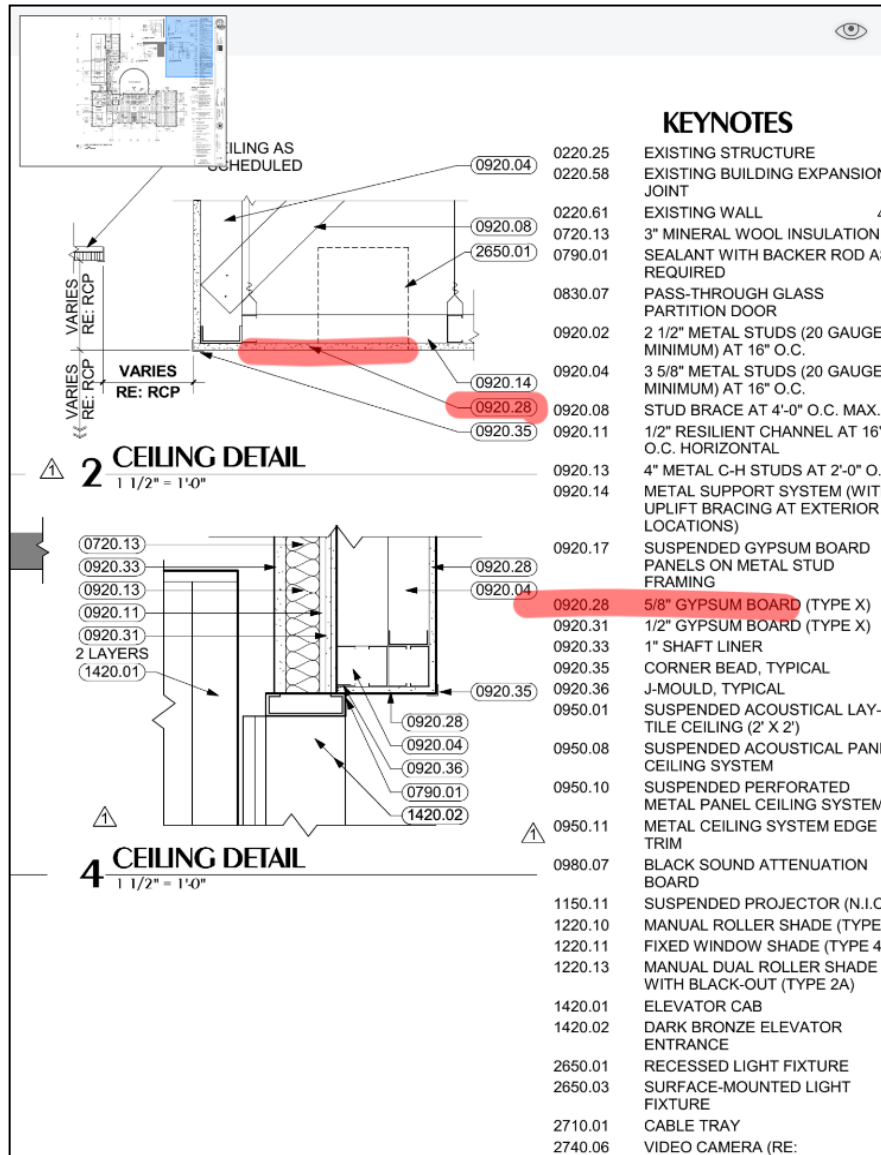


Figure 19. Shows step 3 (solution to sample question 2).

Two more similar questions were discussed before students began the test. In section EI, control group, students were asked to flip, instead of clicking the callout circle, to the referred drawing for the details.

In the past, Francis hall drawings have been part of the syllabus to perform this ‘seek & find activity’ in class. It is introduced towards the end of the class, when students have learned much about plan drawing and reading. Before the day of the research study, participants of any section had not been given any test on this seek & find activity. However, similar concepts and its application had been discussed. For this purpose, this activity was used as a factor for differentiation between the two study groups.

The questions in the test paper, were based on these seek & find tasks. The questions were inspired from the questions attained from the sections of previous class. During the presentation, some of the questions, excluded from the test, were used to demonstrate how to seek & find the right information. Hence, students were familiarized with what they were required to do. As mentioned earlier, no such tasks were yet introduced in any sections of the class until the day of research study. Hence, the researcher holds confidence that there was no significant difference in the capability of the participants to perform better or worse on the test.

Experimental test

The questions on the test were inspired form the In-Class Task #1, #2, #3 activity (refer Figure 21 and Figure 22), which has been taught in the class in a previous year’s section. The material was provided by Prof. Chao Xiao form her class in 2014. A set of 15 questions was formulated. Three pilot tests were run to determine the difficulty level of the question, simplicity of the questions and the time required to solve them

individually. Two gave using the traditional paper drawings and one using an Ipad. All the pilot tests took more than 40 minutes to seek the answers. The pilot test participants were the researcher's class mates who helped in the test formulation. 9 questions were short-listed considering the limitation of the test time. Figure 20 below shows the pilot tests.

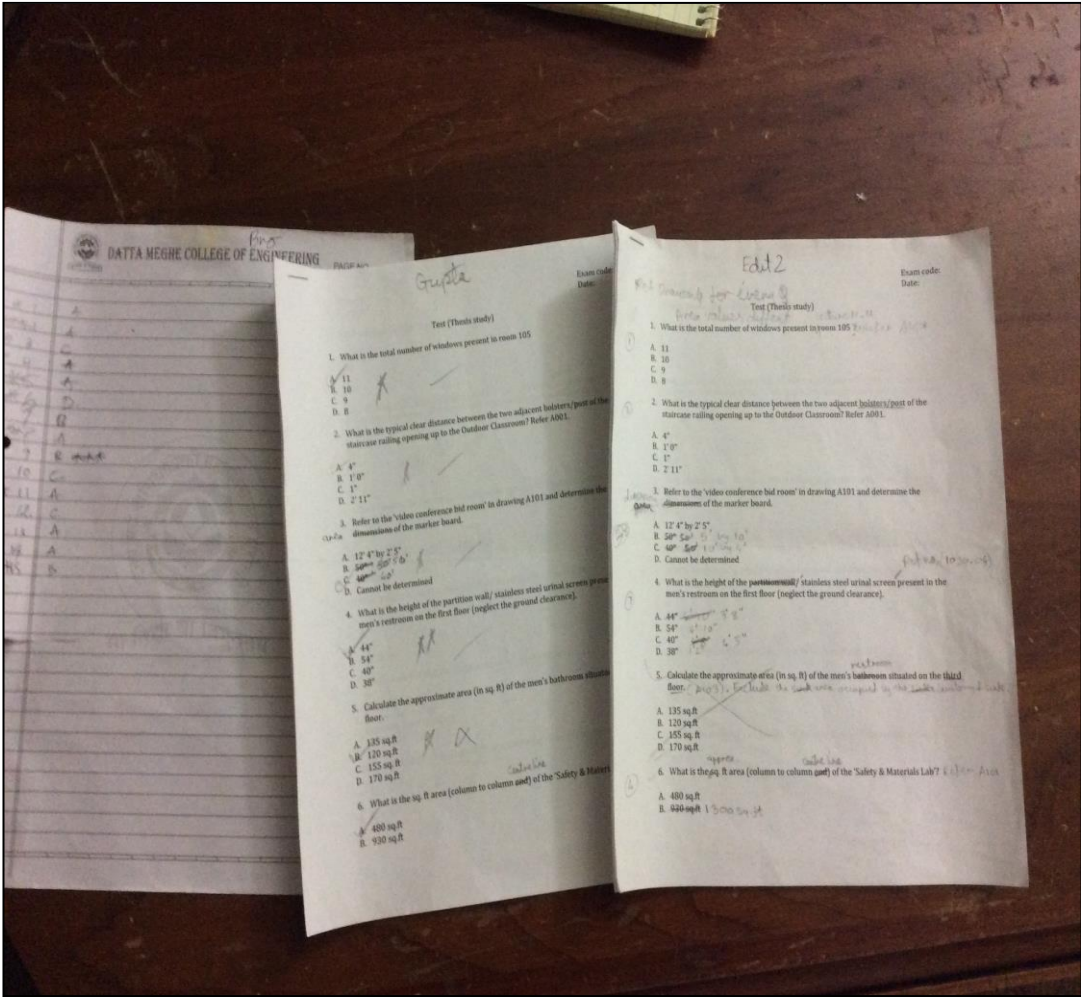


Figure 20. Shows pilot test papers with result and reviews marked.

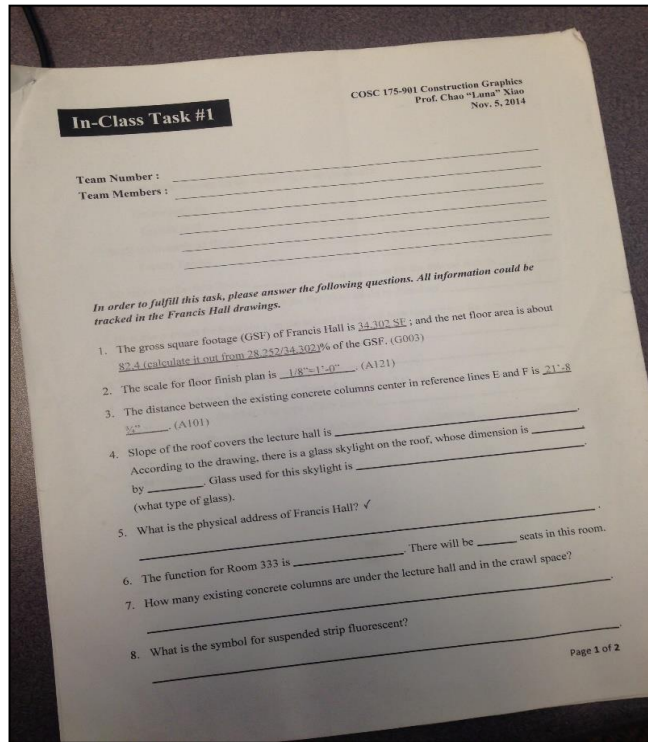


Figure 21. Shows the ‘In-Class Task #1’ test papers provided by Prof. Chao Xiao

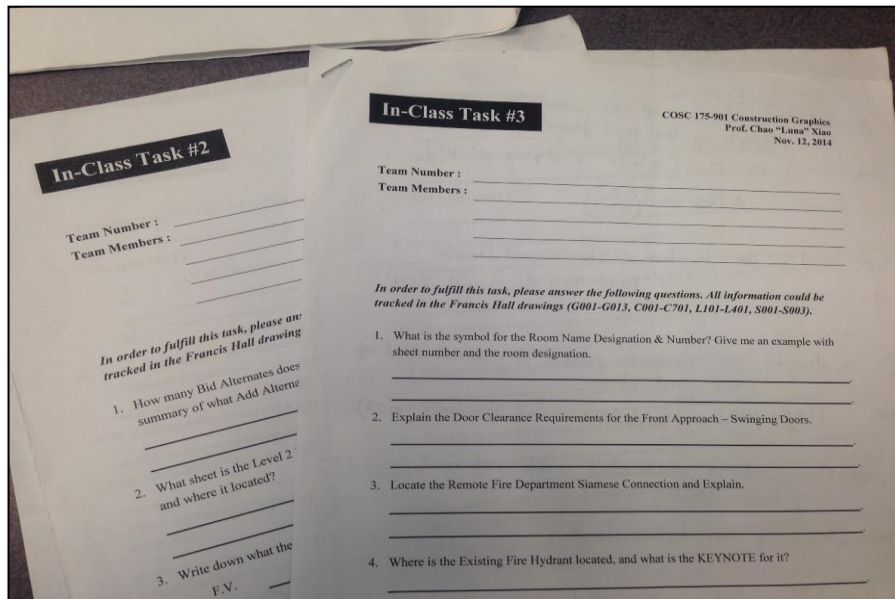


Figure 22. Shows the ‘In-Class Task #2 and #3’ test papers provided by Prof. Chao Xiao

The test paper, which was given to the participants of both the section of class, was identical. The test had 9 questions, based on the 'seek & find activity'. The allotted time for the test was 18 minutes. An average question was prepared to be able to be solved in 2 minutes. The prepared questions had varied level of difficulty. The first four questions, on the test were comparatively easy and straightforward as compared to other five questions. The purpose was to determine if the participants could seek the required information within the allotted time. Time was one of the factors, however, for the purpose of the study, participants weren't timed individually. However, a general observation was made and noted down to differentiate the percentage of student who finished the test before time. Once the time was up, those students who had not yet turned their test in were considered to go over time. Students were strictly asked to not mark any answers, which they couldn't find the answers to or didn't have sufficient time available. Participants were also requested to move on to the other question if they got stuck at any time to come back to the question later on. The purpose of doing this was to mitigate the augmentation of random data result due to random marking.

The researcher holds confidence in the accuracy of the data collected as random marking of answers was eradicated. Apart from this, students were given incentive to perform to their best ability. The student who scored the highest in a section was awarded a \$25 Starbucks gift card. Due to this, the participant's best performance on the test was elucidated.

Lecture schedule and description

Lecture schedule

The following outlines the planned time- lapse of both the section of class on the day of research study.

Time Lapse of Prof. Segner's Class (Group SI)

3:00 – get everything set up and seat students

3:05 – Introduction to the study, consent form sign up

3: 08 – Presentation

3: 13 – Reading drawings (G003- Plan grid)

3: 16 – Plan grid functions

3: 20 – Demonstration of seek & find

3: 30 – Test

3: 48 - Usability questionnaire

3: 50- Collect Test papers & the questionnaire

Time Lapse of Dr. Escamilla's Class (Group EI)

4:10 – setting things and student's seating

4:15 – introduction to the study, consent form sign up

4:20 – Presentation

4:23 - Reading Drawings (Goo3- physical drawings)

4:25 – Demonstration of seek & find.

4:35 – Test

4:53 – collect the Test papers

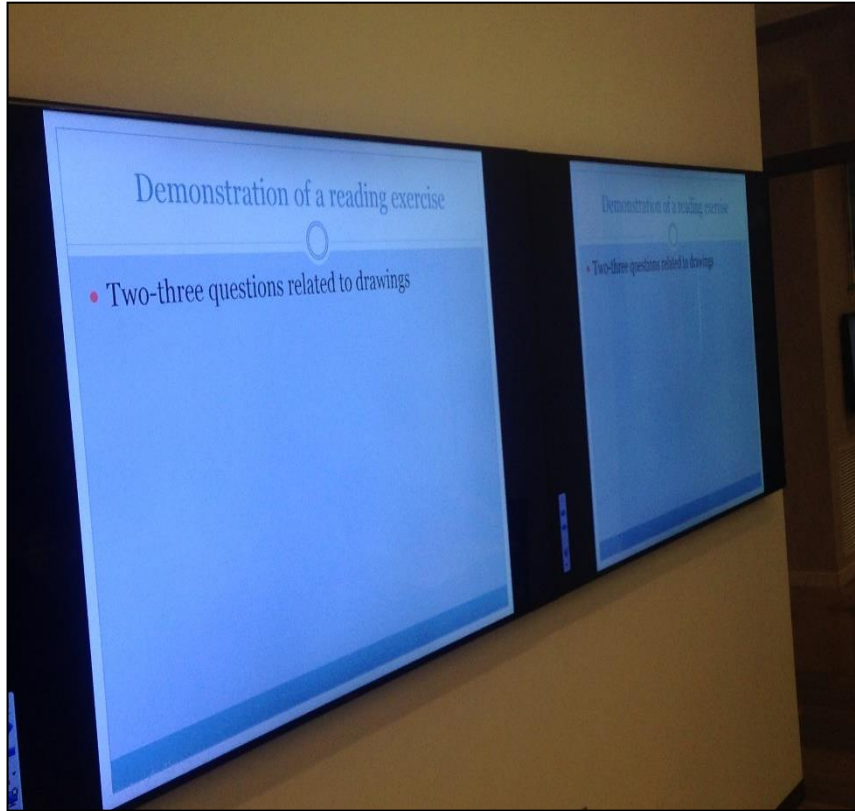


Figure 23. Shows one of the lecture slides presented to the treatment group

Despite rigorous planning, some contingencies are bound to occur. On the day of the research study, everything went according to the plan. However, Professor Segner needed 10 minutes with his class before the researcher could take over the class. This situation was unprecedented. In spite of that, the research study was not compromised. The 20-minute break time, between the two sections was used effectively to make up for

the loss time. It was important to provide sufficient time for demonstrating the plan grid features and seek & find activity for the purpose of the research study. The above time schedule was just shifted by 10 minutes to accommodate the whole lecture. Students were requested to spare 10 more minutes of their time to which they agreed happily. Just to mention, students were in fact excited to be part of the study. The second section of the class, group SI, went as scheduled without any interferences.

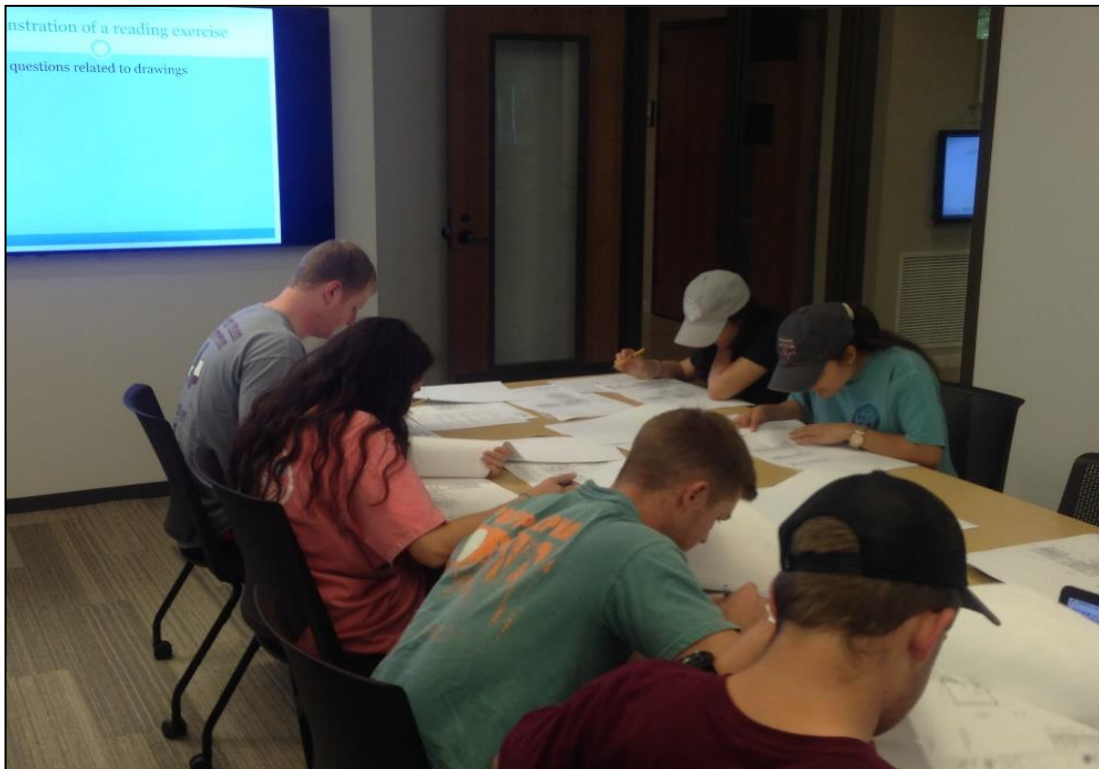


Figure 24. Shows participants engaged in drawings while the demonstration of ‘seek and find activity’



Figure 25. Shows participants from treatment group (SI) performing the test individually.



Figure 26. Shows participants from treatment group

Lecture description

On the day of the study, the researcher, Dr. Escamilla and a randomly selected invigilator were the first one to be present in the class. The invigilator was the researchers' classmate and agreed to help upon request. Students had started showing up before the class time. Figure 28 shows the invigilator handing out the consent forms and the drawing sets to the participants. To randomize the study group, first 20 students were handed over the Consent forms. This indicated their selection for the research study. If they didn't agree with the terms of the consent form, the immediate next student would have been eligible for the study. None of the students disagreed with the terms and conditions of the consent form.



Figure 27. Shows one of the participants using PlanGrid features

After the consent form was handed out, Prof. Segner took over the class for 10 minutes. At roughly 3:10pm, students were introduced to the study, the researcher and Principal Investigator (PI). Dr. John Nichols is the primary PI of the research study. However, due to his unavailability, Dr. Escamilla was given the responsibility on the day off. Dr. Escamilla is a member on the researchers' committee. Consequently, the participants were presented with some basic fundamentals of construction drawings as shown in Figure 23. Followed by demonstration of the PlanGrid application and its features relevant to the test activity. Relevant features of PlanGrid as mentioned under section 'IT tool' were individually demonstrated within the allotted time. More detailed description on working of the features has been explained in the previous sections.

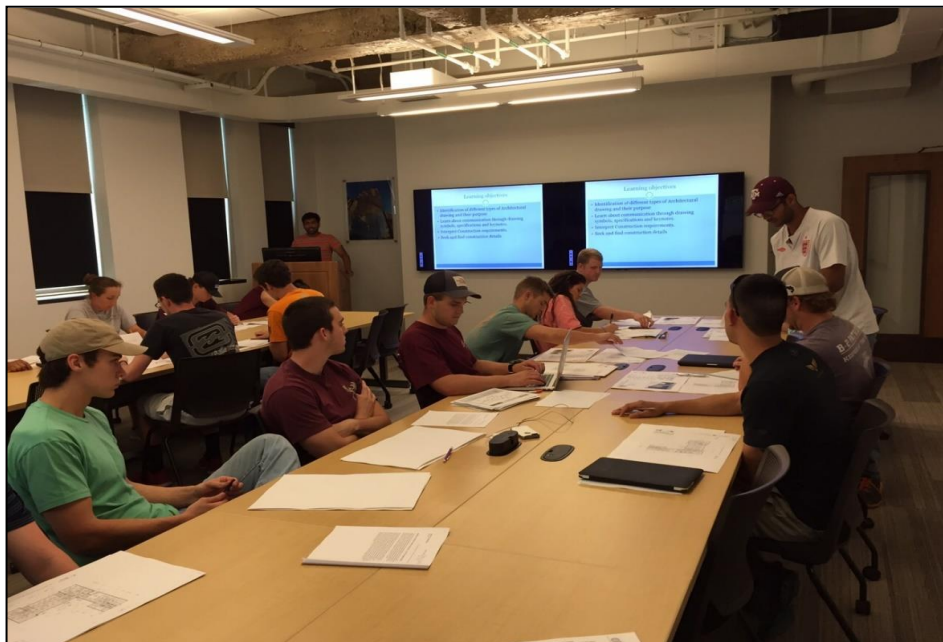


Figure 28. Shows Invigilator handing out the necessary documents while the lecture is being delivered by the researcher.

As the lecture progressed, the invigilator handed over necessary drawing sets to the participants. Before handing over the test papers, the students were demonstrated the 'seek & find' activity through sample questions. The questions solved during the demonstration were not part of the test. Students were asked to follow the lecturer's instruction with going to the required drawing for seeking the information. The researcher's Ipad was connected to the class display screen. This aided the researcher to demonstrate the essential features of PlanGrid effectively. Four questions were solved using the Set1 drawings. Those four questions were sufficient to familiarize students with the seek & find activity', which the test is based on. Participants were given time to ask questions to resolve their difficulties. After the discussion, students were given the test papers. Students were told about the Starbucks gift card before the commencement of the test. After the test, group SI participants were asked to fill in the SUS questionnaire. They were told about the importance of the questionnaire and how it will help in measuring the usability of the tool. The survey didn't explicitly mention the likert scale. Hence, the students were told that number 5 corresponds to complete agreement and number 1 corresponds to complete disagreement with the statement. Post questionnaire, students were appreciated for their time and effort that day and all the test papers, questionnaires and Ipads were collected. Participants from the control group are shown in Figure 24, Figure 29 and Figure 30. While, participants from the treatment group are shown in Figure 25, Figure 26 and Figure 27.



Figure 29. Shows participants from the control group.

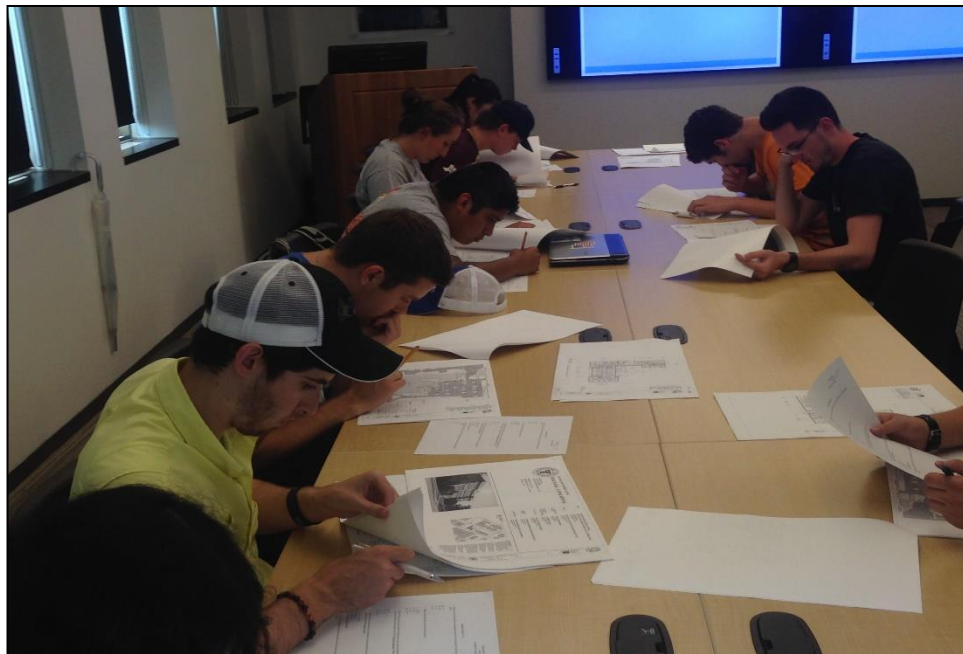


Figure 30. Shows participants from the control group during the test

In case of group SI, the lecture protocol remained the same. Since, Dr. Escamilla was the class instructor of that class, there was no time crunch unlike in the previous section. The only difference in the presentation was that the 'seek & find activity was demonstrated using the Paper drawings. Since, the participants represented the control group, they weren't given the SUS questionnaire. Instead of Ipads, participants were given Set1 and Set2 of drawings separately as paper drawings. Relatively, few extra minutes were taken to demonstrate the 'seek & find activity to the participants of group EI.

Posttest SUS survey

SUS is a 10-statement survey with a five point likert scale of agreement/disagreement. The likert scale varies from negative (1) to positive (5) response with respect to the statement. More than often, the SUS questionnaire is slightly modified to cater a particular product, service or technology (Bangor et. al., 2008). However, for the purpose of this research study, the original SUS questionnaire has been used. The questionnaire should be given to the respondents immediately after they have reviewed the technology, rather than contemplating about it for a long time. Moreover, the survey should be filled in promptly (Brooke, 1996).

Only in the section SI of the class, the posttest survey questionnaire was given to the participants along with their test. They were asked to fill it in after the completion of the test. The following is the Questionnaire, which was given to the participants.

SUS calculation

SUS is a versatile and a robust instrument. It is reliable and has become an industry standard in determining the usability of a system. It is very easy to use and it generates a reliable single score that estimates the usability of a product. With the grace of sufficient ancient test scores, the score can be compared to the average mean of the plethora of test scores accumulated over the years, as in the article (Bangor et. al., 2008).

First step in calculating the single usability score is to calculate the scores of individual statements. The raw score of odd questions (1,3,5,7,9) is reduced by 1 and added up. The raw score of the even numbers (2,4,6,8,10) is subtracted from 5 and added up together. No individual score can be greater than 4 or less than 0. 10 individual scores corresponding to 10 statements are added together to give a value. Multiply the calculated value by 2.5 to give a SUS score for individual participant. Similarly, 20 individual SUS score were obtained corresponding to every questionnaire filled and normalized to give a single usability score. It is compared with the average population mean score, which is 69. This mean is a result of thousands of SUS survey data assimilated over the years (Brooke, 1996). The then obtained survey responses were fed in Excel document for statistical analysis.

Data collection and storage

All the test papers, signed consent forms and questionnaire responses from the treatment group SI were collected in a box, sealed and stored in the PI's office. Later on the data was fed in an Excel document to perform the necessary statistical analysis

CHAPTER IV

RESULTS

Introduction

This section summarizes the data obtained and its analysis. The test results obtained from the two group studies were compared. As observed, there is significant difference between the mean averages of the two groups. The population mean of the treatment group, $\mu_{SI} = 5.95$, is greater than mean of the control group, $\mu_{EI} = 5.00$, suggesting there is a significant difference in the students' performance with respect to the use of IT in Construction Education. A two-tail t-test was performed to measure for any significant difference between the two populations data sets. The participants who used electronic drawings performed better than the participants who used paper drawings. Participants might have performed well with the use of technology. However, it was suggested through the survey results that many students thought they needed more time to get familiar with the technology. Students even strongly expressed their interest to use the same technology in the future, suggesting such construction document tools should be incorporated in the curriculum.

The usability of the technology was measured through the SUS survey. The single usability score was just above the mean average of all the SUS results accumulated over the years since its inception. The usability score of the research study was 71.375, just marginally surpassing the average of 68. A SUS score of 68 is said to be the average score and has the percentile of 50. SUS score of individual statements

were also calculated and compared with the population mean of individual statements from years old data. Moreover, the survey data was also compared with the participant's performance. Every participant's test score from the treatment group was compared against their SUS score. The results suggest that the results were correlated. The students, who scored less than average of the whole class, tend to have perceived the technology as difficult to use, contrasting to their students who scored better. Their usability score was less than the population average of 68. The Pearson's product movement correlation coefficient, denoted as r , was found to be 0.583558741. This indicates that the two variables are moderately correlated. Students who couldn't effectively understand the technology had a tough time in performing well on the test.

Data results & analysis

The following section displays the marks obtained on the test by the participants of each group, followed by the raw data of the survey. In the consequent section, the calculated overall SUS score, individual SUS score of every participant and average mean of each statement is also exhibited. The later section contains the summary statistics of each group. The probability distribution curve of test results of both the section were calculated.

Exam test

Every test paper was assigned a test code, which stated the group name and the corresponding test number. For example, SI13- 13th test paper form treatment group (SI).

Each participant got one mark for every correct answer marked, i.e. the maximum one could obtain is 9. The test results are shown in Table 3 and Table 4. Table 5 and Table 6 below contain the summary statistics of the test results obtained from the study groups.

Table 3. Shows the test results of the Treatment group (SI), participants with IT tool

Treatment group (SI)	
Exam number	Marks obtained
SI 01	5
SI 02	2
SI 03	7
SI 04	7
SI 05	7
SI 06	7
SI 07	7
SI 08	4
SI 09	8
SI 10	7
SI 11	8
SI 12	5
SI 13	4
SI 14	3
SI 15	7
SI 16	7
SI 17	7
SI 18	6
SI 19	5
SI 20	6

Table 4. Shows the test results of the control group (SI), participants with traditional paper drawings

Control group (EI)	
Exam number	Marks obtained
EI 01	3
EI 02	4
EI 03	5
EI 04	5
EI 05	3
EI 06	9
EI 07	4
EI 08	6
EI 09	5
EI 10	4
EI 11	2
EI 12	5
EI 13	8
EI 14	5
EI 15	4
EI 16	5
EI 17	5
EI 18	4
EI 19	7
EI 20	7

Table 5. Shows the summary statistics of the treatment group

Parameter	Value
Mean	5.95
StDev	1.66938375
95 % LCI	5.045485599
95 % UCI	6.854514401
CV	28.05686975
Min	2
Median	7
Max	8
Skewness	-0.968581499
Kurtosis	0.151540161
Sum	119
Count	20
Autocorrelation Coefficient	0.133405636

Table 6. Shows the summary statistics of the control group

Parameter	Value
Mean	5
StDev	1.716790151
95 % LCI	4.06979961
95 % UCI	5.93020039
CV	34.33580301
Min	2
Median	5
Max	9
Skewness	0.693431396
Kurtosis	0.518907563
Sum	100
Count	20
Autocorrelation Coefficient	-0.111788618

The summary statistics indicates the differences between the two study groups. Both the study groups have similar standard deviation across its respective mean values. The coefficient of variation (CV) states that both the variables are well dispersed about its mean value. CV for the treatment group is 28.05 and that for the control group is 34.33. The population distribution curve validates the difference in the two group studied. The treatment group is skewed negatively while the control group is skewed positively. The maximum marks obtained by a participant from the treatment group are 8 and maximum from the control group is 9. It means, that someone managed to score the full marks from the treatment group, which was given the paper drawings. The distribution curves of the test results significantly differ as shown in Figure 31.

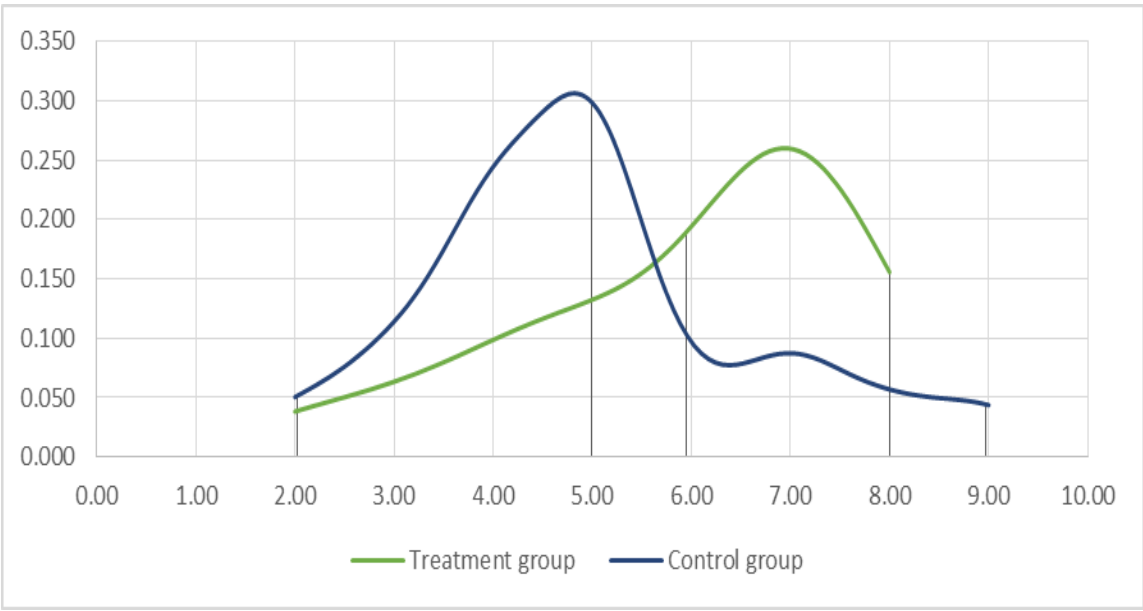


Figure 31. Shows the probability distribution of the test results

Two tailed t-test: -

A simple two-tail t-test was performed to compare the test results of the two groups. The t-test results are tabulated in the following section. The probability distribution curve shows there is significant difference between the two test results. The difference between the mean was realized as 0.95. It means that the treatment group performed better than the control group on the test by 0.5 marks out of 9.

Table 7. Shows the results of the t-test between two test groups.

Parameter	Treatment group	Control group
Mean	5.95	5
Variance	2.576315789	2.947368421
Observations	20	20
Hypothesized Mean Difference	0	
df	38	
t Stat	1.807690943	
P(T<=t) one-tail	0.039287721	
t Critical one-tail	1.68595446	
P(T<=t) two-tail	0.078575443	
t Critical two-tail	2.024394164	

The t-test was performed between the two variables with the assumption of unequal variances. The results clearly convey the significant difference in the student's performance.

SUS questionnaire

The raw data obtained from the participants that day through a 5-point likert scale was tabulated in Excel sheet for statical analysis. The raw data obtained was converted into numbers as per the SUS questionnaire protocol for further interpretation. Odd statements indicate positive impact and even statements consider the negative impact of the technology. Response to odd statements is reduced by 1 to give a score number. Response to even statements is reduced from number 5 to give a score number corresponding that statement. The scores for one test are added up and cannot be greater than 40 or less than 0. That score is the individual SUS score of that single SUS questionnaire. Similarly, the average mean of the 20 SUS scores was calculated to be 71.375. This score is called the single SUS score of the study.

	Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	Q 7	Q 8	Q 9	Q 10
SI 01	2	4	2	4	4	1	3	4	2	4
SI 02	4	2	4	2	3	1	3	3	3	3
SI 03	5	1	4	3	5	1	5	5	5	5
SI 04	5	1	4	1	4	2	4	2	4	3
SI 05	5	1	4	2	3	2	4	2	4	2
SI 06	5	2	4	2	4	2	4	3	4	1
SI 07	5	1	5	2	5	1	3	1	5	2
SI 08	5	2	3	1	4	3	3	4	4	3
SI 09	5	2	5	2	4	2	3	4	4	2
SI 10	5	2	4	1	3	2	4	3	4	2
SI 11	5	2	4	1	4	1	4	2	4	2
SI 12	4	2	3	2	4	2	3	2	4	3
SI 13	5	3	3	2	3	2	4	3	2	3
SI 14	5	3	4	2	4	1	5	5	4	5
SI 15	5	2	3	1	4	2	3	1	4	4
SI 16	4	2	4	2	3	2	4	2	4	2
SI 17	4	2	4	3	4	2	5	2	5	2
SI 18	4	2	4	2	5	1	4	1	4	1
SI 19	5	3	5	2	3	2	3	2	3	4
SI 20	5	2	3	1	4	1	4	3	2	5

Figure 32. Shows the raw scores obtained from the SUS

The individual raw scores from the table above were modified to give SUS score for each participant. Moreover, mean score of every statement is also tabulated for comparative analysis. The next table shows the individual SUS from every respondent. . The SUS score of individual participant is highlighted in light maroon color. The following table summarizes the mean of responses for every statement. The mean of every statement response is highlighted in light green. This detailed analysis to every

statement response measures each individual factor of the technology use. Every statement asked on the SUS questionnaire considers different aspect of the technology.

Participant	Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	Q 7	Q 8	Q 9	Q 10	Total (out of 40)	Single SUS score
SI 01	1	1	1	1	3	4	2	1	1	1	16	40
SI 02	3	3	3	3	2	4	2	2	2	2	26	65
SI 03	4	4	3	2	4	4	4	0	4	0	29	72.5
SI 04	4	4	3	4	3	3	3	3	3	2	32	80
SI 05	4	4	3	3	2	3	3	3	3	3	31	77.5
SI 06	4	3	3	3	3	3	3	2	3	4	31	77.5
SI 07	4	4	4	3	4	4	2	4	4	3	36	90
SI 08	4	3	2	4	3	2	2	1	3	2	26	65
SI 09	4	3	4	3	3	3	2	1	3	3	29	72.5
SI 10	4	3	3	4	2	3	3	2	3	3	30	75
SI 11	4	3	3	4	3	4	3	3	3	3	33	82.5
SI 12	3	3	2	3	3	3	2	3	3	2	27	67.5
SI 13	4	2	2	3	2	3	3	2	1	2	24	60
SI 14	4	2	3	3	3	4	4	0	3	0	26	65
SI 15	4	3	2	4	3	3	2	4	3	1	29	72.5
SI 16	3	3	3	3	2	3	3	3	3	3	29	72.5
SI 17	3	3	3	2	3	3	4	3	4	3	31	77.5
SI 18	3	3	3	3	4	4	3	4	3	4	34	85
SI 19	4	2	4	3	2	3	2	3	2	1	26	65
SI 20	4	3	2	4	3	4	3	2	1	0	26	65

Figure 33. Shows the modified responses and each participants' SUS score.

Participant	Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	Q 7	Q 8	Q 9	Q 10
SI 01	1	1	1	1	3	4	2	1	1	1
SI 02	3	3	3	3	2	4	2	2	2	2
SI 03	4	4	3	2	4	4	4	0	4	0
SI 04	4	4	3	4	3	3	3	3	3	2
SI 05	4	4	3	3	2	3	3	3	3	3
SI 06	4	3	3	3	3	3	3	2	3	4
SI 07	4	4	4	3	4	4	2	4	4	3
SI 08	4	3	2	4	3	2	2	1	3	2
SI 09	4	3	4	3	3	3	2	1	3	3
SI 10	4	3	3	4	2	3	3	2	3	3
SI 11	4	3	3	4	3	4	3	3	3	3
SI 12	3	3	2	3	3	3	2	3	3	2
SI 13	4	2	2	3	2	3	3	2	1	2
SI 14	4	2	3	3	3	4	4	0	3	0
SI 15	4	3	2	4	3	3	2	4	3	1
SI 16	3	3	3	3	2	3	3	3	3	3
SI 17	3	3	3	2	3	3	4	3	4	3
SI 18	3	3	3	3	4	4	3	4	3	4
SI 19	4	2	4	3	2	3	2	3	2	1
SI 20	4	3	2	4	3	4	3	2	1	0
Mean	3.6	2.95	2.8	3.1	2.85	3.35	2.75	2.3	2.75	2.1

Figure 34. Shows the mean of all the responses with respect to an individual statement

Interpretation of SUS score: -

The SUS was developed more than 25 years ago and has been picked for many usability evaluations. Consequently, there is a plethora of information on its use and the importance of its score. (Bangor et. al., 2008) have assimilated SUS data of over 3500 results for over more than 10 years. They formulated a grading scale based on the

similarity of the responses from the survey results. Figure 35 below states that a good SUS score lies between 70 and 100.

The adjective ratings for different SUS scores are

- 0-60- F
- 60-70- D
- 70-80- C
- 80-90- B
- 90-100- A

They even gave an acceptable range for an SUS score. If the SUS score lies below 60, it is said to be unacceptable. The average SUS score of all studies ever conducted is 69. A score of 70 is said to be just the average SUS score. SUS score of 70 doesn't have a 70% percentile, rather 50% percentile. If the SUS score is more than 60, it lies in the acceptable range. The SUS score for this study was 71.34, which lies in the acceptable range. However, it lies in the marginal range of acceptance. Moreover, the usability of the technology is not the 'best imaginable', as perceived by the participants. Students indicated their interest in using the technology in future but had difficulties in using the technology. This could be attributed to the limited time spent by the participants in using the technology.

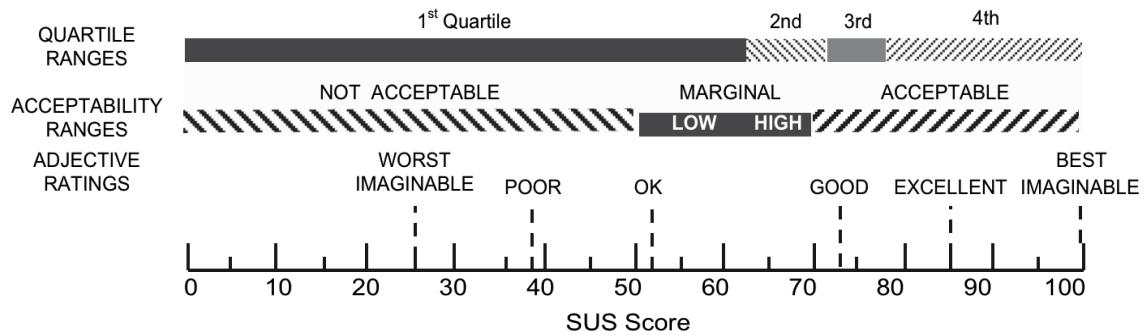


Figure 35. Shows the comparison of mean SUS scores by quartile ranges, adjective ratings and acceptability (Bangor et al., 2008)

Moreover, Sauro (2011) has made conclusions based on 5000 SUS observations. He provided some principles aiding the analysis of SUS data. He gave a percentile ranking of SUS scores, similar to Bangor, Kortum and Miller’s grade scale, based on the approximate distribution of all the SUS scores available readily. The percentile rankings are categorized in the Figure 36 below.

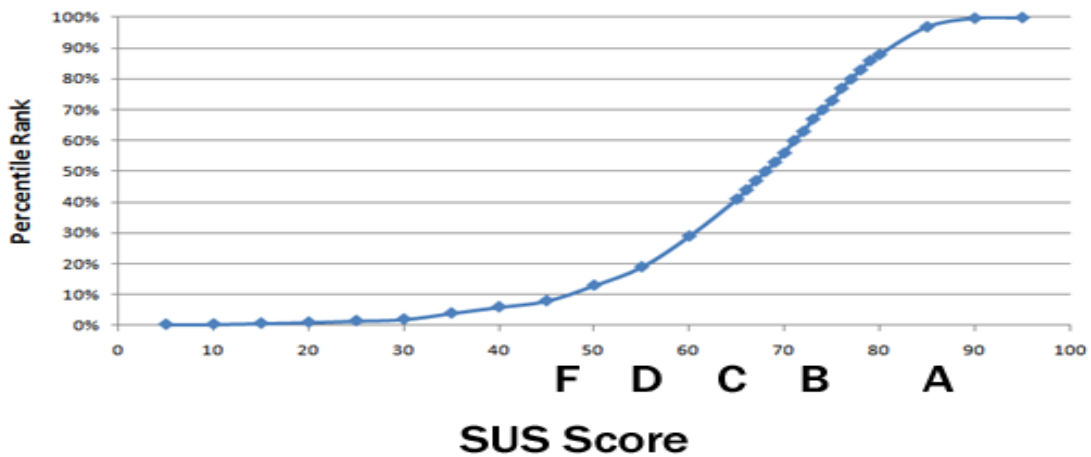


Figure 36. Shows percentile rankings of SUS scores obtained from Bangor et al. (2008)

Interpretation of individual statements

Individual statements' mean values are compared. (Bangor et. al., 2008) performed a statement-by-statement analysis of 206 SUS studies comprising of more than 2000 surveys. The mean values of each statement from this study are compared to the population mean of response to each statement as shown in the figure below. This helps in interpreting the students' perception regarding different aspects of the technology. Statements 1, 3,5,7,9 are positive statements. On the contrary, statements 2, 4, 6,8,10 are negative. A higher score corresponds to strong agreement and vice-versa. The population mean of all individual statements is shown in the Figure 37.

Statement by statement analysis: -

Statement1: - I think that I would like to use this system.

The raw mean score of all the responses to this statement was 4.6 out of 5. The population mean is 3.68. The participants indicated their strong interest in using the IT tool studied in the future. Such document management tools should be introduced in the general curriculum.

Statement2: - I found the system unnecessarily complex.

The raw mean score of all the responses to this statement was 2.05. The population mean is 2.34, above the mean of this study. Participants disagreed to the statement if the tool was unnecessarily complex. The tool was perceived as being less complex as compared other technology studied in the past.

Statement3: - I thought the system was easy to use.

The raw mean score of all the responses to this statement was 3.8. The population mean is 3.69. Participants didn't strongly agree if the system was easy to use. They scored the tool very close the population mean. The tool was perceived as being a little difficult to use. This can be attributed to the less time the participants had spent with the tool. There are many features in the application, which the participants weren't introduced to. Integration of features which participants were not aware of could have rendered the tool difficult to use.

Statement4: - I think that I would need the support of a technical person to be able to use this system.

The raw mean score of all the responses to this statement was 1.9. The population mean is 1.83. Participants indicate that they agree that they wouldn't need a support of a technical person to be able to use this system. However, they scored the tools technical complexity just below the population average.

Statement5: - I found the various functions in the system were well integrated.

The raw mean score of all the responses to this statement was 3.85. The population mean is 3.62. Participants agree with the integration of various functions in the tool. They scored the tool higher than the population mean by a marginal value.

Statement6: - I thought there was too much inconsistency.

The raw mean score of all the responses to this statement was 1.65. The population mean is 2.12. Participants disagreed to this statement affirming that the tool was not inconsistent. Participants scored this statement below the population mean by a significant difference. Students perceived the tool as being very consistent. Students

could use this tool more efficiently once they got hang of it. The tool is very agile and responsive in its functioning, which adds to its consistency.

Statement7: - I would imagine that most people would learn to use this system very quickly.

The raw mean score of all the responses to this statement was 3.75. The population mean is 3.82. Participants agreed that most other people would learn to use this system quickly. The students' response is in consistent with the simplicity of the tool. However, students did not very strongly to the statement, it means the tool was simple but not as simple as other similar technologies are perceived.

Statement8: - I found the system very cumbersome to use.

The raw mean score of all the responses to this statement was 2.7. The population mean is 2.09. Participants indicated here that they weren't sure if the system was cumbersome to use or no. Students don't agree nor disagree that the tool was cumbersome to use. However, they rated the tool higher than the population mean, signifying that they found this tool more cumbersome then other technologies perceived in the past. The response to this statement is a little inconsistent with the response of the participants to other statements with respect to the technology. This could be attributed to inconsistency in presenting the lecture and demonstrating the features and use of the tool. If the lecture was delivered by one of the professors from the class, this factor could have been mitigated.

Statement9: - I felt very confident using the system.

The raw mean score of all the responses to this statement was 3.75. The population mean is 3.64. Participants indicated that they felt confident using this system. They scored this tool above the population mean. This coincides with the students' performance on the test. Students felt confident in seeking and finding information from the drawings.

Statement10: - I needed to learn a lot of things before I could get going with this system.

The raw mean score of all the responses to this statement was 2.9. The population mean is 2.03. Participants agreed to this statement more than the population average by a big margin. Participants indicate that they needed to learn a lot of things before they got comfortable with the tool. This confirms that the participants should have been given more time to use the technology. Moreover, more time should be given in demonstrating all the features and application of the tool. However despite the initial difficulty, overall, students performed well on the test and were confident in using the system. This indicates that the tool is easy to learn, if sufficient time is spent with it.

<i>Statement</i>	<i>M</i>	<i>SD</i>	<i>Absolute</i>	<i>Standardized</i>	<i>Standard SD</i>
1. I think that I would like to use this product frequently.	3.68	1.15	3.68	-0.18	0.99
2. I found the product unnecessarily complex.	2.34	1.21	3.66	-0.16	0.89
3. I thought the product was easy to use.	3.69	1.15	3.69	-0.13	0.73
4. I think that I would need the support of a technical person to be able to use this product.	1.83	1.16	4.17	0.47	0.94
5. I found the various functions in the product were well integrated.	3.62	1.05	3.62	-0.28	0.90
6. I thought there was too much inconsistency in this product.	2.12	1.12	3.88	0.10	0.88
7. I imagine that most people would learn to use this product very quickly.	3.82	1.15	3.82	-0.01	0.92
8. I found the product very awkward to use.	2.09	1.22	3.91	0.16	0.85
9. I felt very confident using the product.	3.64	1.19	3.64	-0.20	0.83
10. I needed to learn a lot of things before I could get going with this product.	2.03	1.24	3.97	0.23	0.97

Figure 37. Shows the statement by statement analysis obtained from study by Bangor et. al. (2008).

Comparison between SUS score and marks obtained of an individual participant

Results: -

Each participants test results from the treatment group (SI) were compared against their SUS score to interpret if there is any correlation between them. The two variables were analyzed to determine the correlation coefficient. Participants who scored less than the average (5.95) on the test are indicated in red. Their corresponding SUS score is also marked.

The following section displays marks obtained plotted against the corresponding SUS score and the calculation of its correlation coefficient.

Table 8. Shows the results of each student participant and their SUS score.

Participants	Marks obtained	SUS score
SI 01	5	40
SI 02	2	65
SI 03	7	72.5
SI 04	7	80
SI 05	7	77.5
SI 06	7	77.5
SI 07	7	90
SI 08	4	65
SI 09	8	72.5
SI 10	7	75
SI 11	8	82.5
SI 12	5	67.5
SI 13	4	60
SI 14	3	65
SI 15	7	72.5
SI 16	7	72.5
SI 17	7	77.5
SI 18	6	85
SI 19	5	65
SI 20	6	65

Analysis: -

The test results were plotted against the SUS score of individual participants. The results and the corresponding SUS scores associated with them are shown in

. The matrix plot showing the correlation data is shown in Figure 38. The data of participant's who scored less than the class average are marked in red. In clear observation, the table above indicates that students who scored less on the test, gave a lower SUS score to the IT used as a part of the research study. However, the scatter matrix displayed below suggests that the results and the SUS score are moderately correlated but not very strongly. The results show the variables are positively correlated. The coefficient of correlation obtained from the scatter plot matrix is 0.583. Correlation (R) greater than 0.8 is generally described as strong, whereas value of R less than 0.5 is generally described as weak (Statistics 2, 2015). This indicates that better understanding of the technology can do wonders for students. However, if right use of a technology is not effectively communicated to the students, the technology can be rendered useless.

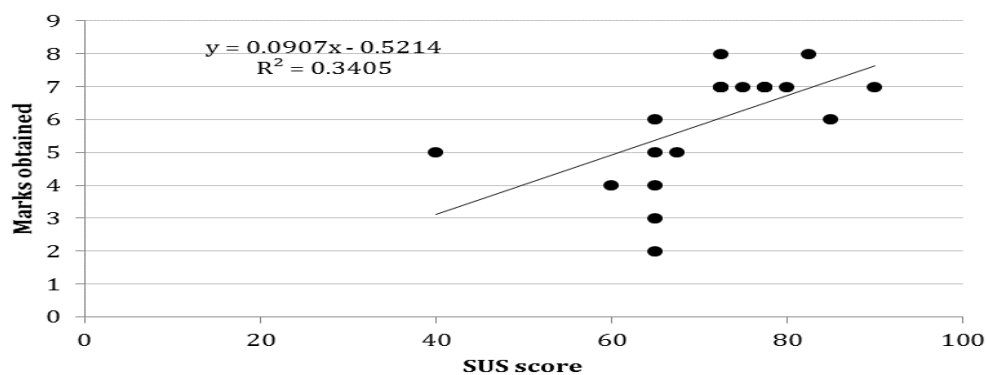


Figure 38. Shows the matrix plot to determine the correlation between the two variables

CHAPTER V

CONCLUSIONS

The construction industry is the United States' one of the largest industries which comprises of 10% of United States' GDP. It provides employment to about 10 million workers (Nunnally, 2004). It's imperative that construction industrys' productivity needs to improve. With the recent development in IT in construction, the paradigm shift is more likely. Companies at the forefront of the technology will advance and reap great benefits in the coming years. Currently, there is a generation gap between the workforces in the industry. The construction workforce is getting older. In 2001, the average age of a construction personnel remained about 40 years, Moreover, over the last 10-year period, this had been layered by 1.5 years (Worker Health Chart book, 2004). On the positive side, the youth in construction is technologically literate. The youngster of this millennia will optimize the construction processes with the latest technology.

The test results of the research study indicate that students, Treatment group (SI), who used the IT tool to answer the test performed better than the students, Control group (EI), who used traditional paper drawings to answer the same test. The statistical analysis and the two- tail t- test demonstrate significant difference between the two groups. Moreover, the students from the treatment group gave an SUS usability score of 71.35 to the IT tool. This value is just above the average mean of the data set available form SUS data of past 10 years. This indicates that the students didn't perceive the technology as very easy to use. Statement-by statement analysis revealed helped

decipher different aspects of the tool and the research study. In the first statement, students suggested that they strongly want to use to use this tool again in the future. However, they though they needed to spend more time with the tool, to get familiar with all its features. Some students found the application to be cumbersome too. This is attributed to the limited time given to the participants to use the technology. Moreover, the lecture wasn't delivered very effectively. Hence, some students had to struggle initially to get accustomed with the tool, which could have been the reason why the participants indicated that they needed to learn more things before they could get going with the tool (statement 10). The average mean of the last statement was 2.9 as compared to population average of 2.03. However, student indicated that they found the features of the tool well integrated and thought that most people would learn to use it easily. This calls for further research. A longitudinal study comprising of at least 4-5 sessions with the IT tool should be conducted in the future.

Moreover, participants marks on the test and their SUS score was compared for any correlation. The matrix plotted between the two variables, indicated that there was positive correlation between the two variables. The two variables had a Pearson product-moment correlation coefficient (r) of 0.583, which signifies some correlation between the two variables studied. However, it suggests that the two variables are moderately correlated.

REFERENCES

- Bangor, A., Kortum, P. T., & Miller, J. T. (2008). An empirical evaluation of the system usability scale. *Intl. Journal of Human-Computer Interaction*, 24(6), 574-594.
- Brooke, J. (1996). SUS-A quick and dirty usability scale. *Usability evaluation in industry*, 189(194), 4-7.
- Brooke, J. (2013). SUS: a retrospective. *Journal of Usability Studies*, 8(2), 2940.
- Casey, M. J. (2008, October). Work in progress: How building informational modeling may unify IT in the civil engineering curriculum.
- Cline, R. C., & Davis, K. A. (2013). Using mobile technology in a construction management "Hands-On" laboratory.
- Conole, G., De Laat, M., Dillon, T., & Darby, J. (2008). 'Disruptive technologies', 'pedagogical innovation': What's new? Findings from an in-depth study of students' use and perception of technology. *Computers & Education*, 50(2), 511-524.
- Davis, K. A. Introducing mobile technology into the construction management classroom.

- Dede, C. (2010). Comparing frameworks for 21st century skills. 21st century skills: Rethinking how students learn, 20, 51-76.
- Ertmer, P. A., & Ottenbreit-leftwich, A. T. (2010). Teacher technology change: how knowledge, confidence, beliefs, and culture intersect. Journal of Research on Technology in Education, 42(3), 255–284.
- GCR, N. (2004). Cost analysis of inadequate interoperability in the US capital facilities industry. National Institute of Standards and Technology (NIST).
- Hjelt, M., & Björk, B. C. (2007). End-user attitudes toward EDM use in construction project work: Case study. Journal of computing in civil engineering, 21(4), 289-300.
- Irizarry, J., & Meadati, P. (2009, April). Use of interactive display technology for construction education applications. In American Society for Engineering Education Southeastern Section Annual Conference (pp. 5-7).
- JBKnowledge (2014). Construction Technology Report Survey. Retrieved on June 12, 2015, from <http://jbknowledge.com/2014-construction-technology-report-survey>.

- Jenkins, H., Purushotma, R., Clinton, K., Weigel, M., & Robison, A. (2006). Confronting the challenges of participatory culture: Media education for the 21st century. The MacArthur Foundation.
- Jones, S. (2008). Internet goes to college: How students are living in the future with today's technology. DIANE Publishing.
- Kennewell, S., & Beauchamp, G. (2007). The features of interactive whiteboards and their influence on learning. *Learning, Media and Technology*, 32(3), 227-241.
- Kim, C., Lim, H., & Kim, H. (2011). Mobile computing platform for construction site management. In *Proceedings of 28th International Symposium on Automation and Robotics in Construction*, Seoul, Korea (pp. 1164-1169).
- Knight, T. (2015, March 30). 3 ways to cut costs on your next construction project. Retrieved June 12, 2015, from <http://blog.plangrid.com/3-ways-to-cut-costs-on-your-next-construction-project>.
- Lam, P. T., Wong, F. W., & Kenny, T. C. (2009). Effectiveness of ICT for construction information exchange among multidisciplinary project teams. *Journal of Computing in Civil Engineering*.

- Laurillard, D., Stratfold, M., Luckin, R., Plowman, L., & Taylor, J. (2000). Affordances for learning in a non-linear narrative medium. *Journal of Interactive Media in Education*, 2000(2).
- Lipman, R. R. (2004). Mobile 3D visualization for steel structures. *Automation in Construction*, 13(1), 119-125.
- Mak, S. (2001). A model of information management for construction using information technology. *Automation in Construction*, 10(2), 257-263.
- Mihindu, S., & Arayici, Y. (2008). Outlook of building information modeling within UK construction Industry. Greater Manchester, UK: School of Built Environment University of Salford.
- Mock, K. (2004). Teaching with Tablet PC's. *Journal of Computing Sciences in Colleges*, 20(2), 17-27.
- Navarrete, G. (1999). In the palm of your hand: Digital assistants' aid in data collection. *Journal of Management in Engineering*, 15(4), 43-45.
- Nunnally, S. W., & Nunnally, S. W. (2004). *Construction methods and management* (p. 325). Pearson Prentice Hall.

- Oblinger, D., & Oblinger, J. (2005). Is it age or IT: First steps toward understanding the next generation. *Educating the next generation*, 2(1-2), 20.
- Pena-Mora, F., & Dwivedi, G. H. (2002). Multiple device collaborative and real time analysis system for project management in civil engineering. *Journal of Computing in Civil Engineering*, 16(1), 23-38.
- Reyes, M. D., Perrenoud, A. J., & Goldman, J. A. (2009). Teaching plan reading to construction students: the effect of using tablet computers.
- Rojas, E. M., & Songer, A. D. (1999). Web-centric systems: a new paradigm for collaborative engineering. *Journal of Management in Engineering*.
- Ruddock, L. (2006). ICT in the construction sector: Computing the economic benefits. *International Journal of Strategic Property Management*, 10(1), 39-50.
- Sarshar, M., Tanyer, A. M., Aouad, G., & Underwood, J. (2002). A vision for construction IT 2005–2010: two case studies. *Engineering Construction and Architectural Management*, 9(2), 152-160.
- Sauro, J. (2011). Measuring usability with the system usability scale. URL: <http://www.measuringusability.com/sus>. Php and procedure (9.4. 2012.).

- Shelbourn, M., Bouchlaghem, N. M., Anumba, C., & Carrillo, P. (2007). Planning and implementation of effective collaboration in construction projects. *Construction Innovation*, 7(4), 357-377.
- Shin, Y., An, S. H., Cho, H. H., Kim, G. H., & Kang, K. I. (2008). Application of information technology for mass customization in the housing construction industry in Korea. *Automation in Construction*, 17(7), 831-838.
- Smith, S., Salaway, G., & Borreson Caruso, J. (2009). The ECAR study of undergraduate students and information technology, 2009 (Research Study, Vol. 6). Boulder, CO: EDUCAUSE Center for Applied Research.
- Statistics 2 - Correlation Coefficient and Coefficient of Determination (n.d). Retrieved June 12, 2015, from <http://mathbits.com/MathBits/TISection/Statistics2/correlation.html>.
- Teicholz, P. (2013). Labor-productivity declines in the construction industry: causes and remedies (another look). *AECbytes Viewpoint*, 67.
- Tse, R. Y., & Choy, L. (2005). Is IT training in construction industry useful? *Journal of Construction Research*, 6(01), 1-13.

- Van Hampton, T. (2011). Tablets take off. ENR: Engineering News-Record, 267(7), 20-23.
- Wang, L. C. (2008). Enhancing construction quality inspection and management using RFID technology. *Automation in construction*, 17(4), 467-479.
- Wong, C. H. (2007). ICT implementation and evolution: Case studies of intranets and extranets in UK construction enterprises. *Construction innovation*, 7(3), 254-273.
- Watch, B. (2005). ICT and Electronic Business in the construction Industry, IT adoption and e-business activity in 2005. The European e-Business market watch. European Commission, Enterprise and Industry Directorate General.
- Worker Health Chart-book. (2004, September 1). Retrieved June 12, 2015, from <http://www.cdc.gov/niosh/docs/2004-146/pdfs/2004-146.pdf>.
- Zurita, G., Baloian, N., & Baytelman, F. (2008). A collaborative face-to-face design support system based on sketching and gesturing. *Advanced Engineering Informatics*, 22(3), 340-349.

APPENDIX A

RESEARCH STUDY TEST QUESTIONS

1. What is the total number of windows present in the Lecture Hall (room 105)? Refer A101
 - A. 11
 - B. 10
 - C. 9
 - D. 8
2. What is the elevation of the third Finish floor?
 - A. 112' 6"
 - B. 125'
 - C. 25'
 - D. 31' 7"
3. What is the typical clear distance between the two adjacent bolsters/post of the staircase railing, which opens up to the 'Outdoor Classroom'? Refer A001.
 - A. 4"
 - B. 1' 0"
 - C. 1"
 - D. 2' 11"
4. Refer to the 'video conference bid room' in drawing A101 and determine the dimensions of the marker board.
 - A. 12' 4" by 2' 5"
 - B. 5' by 10'
 - C. 10' by 4'
 - D. Cannot be determined
5. What is the number of hardwood veneer wall cabinets present in the Workroom (210)?

- A. 4
- B. 8
- C. 3
- D. 5

6. What is the approximate sq.ft area (column to column end) of the 'Safety & Materials Lab'?

- A. 480 sq.ft
- B. 850 sq.ft
- C. 1350 sq.ft
- D. 2350 sq.ft

7. What is the height of the stainless steel urinal screen (1020.04) present in the men's restroom on the first floor (neglect the ground clearance).

- A. 44"
- B. 54"
- C. 40"
- D. 38"

8. What is the height of the suspended light fixture present in the BIM computer lab? Refer drawing A102.

- A. 8' 11"
- B. 9' 6"
- C. 10' 5"
- D. 12' 5"

9. In the elevator Hoist way there is a mechanical sump pump below the crawl space. What is the area of the space, which stores the sump pump? Refer Elevator's detail bubble.

- A. 10 ½" by 10 ½"
- B. 9' 4" by 9' 4"
- C. 1 ½' by 1 ½'
- D. 2' by 2'

APPENDIX B

THE SYSTEM USABILITY SCALE (SUS) QUESTIONNAIRE

Please answer the following questions to evaluate the usability of the PlanGrid application, described as a system. It would help in measuring the usability and learnability of the system.

The SUS Survey

			1	2	3	4	5
1	I think that I would like to use this system.		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2	I found the system unnecessarily complex.		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3	I thought the system was easy to use.		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4	I think that I would need the support of a technical person to be able to use this system.		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5	I found the various functions in the system were well integrated.		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6	I thought there was too much inconsistency in this system.		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7	I would imagine that most people would learn to use this system very quickly.		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8	I found the system very cumbersome to use.		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9	I felt very confident using the system.		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10	I needed to learn a lot of things before I could get going with this system.		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>