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EFFECTS OF MEETING SPACES ON THE PERFORMANCE OF A CONCEPT SELECTION TASK BY ENGINEERING DESIGN TEAMS

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EFFECTS OF MEETING SPACES ON THE PERFORMANCE OF A CONCEPT SELECTION TASK BY ENGINEERING DESIGN TEAMS

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ABSTRACT

Given the increasing importance of collaboration and the resulting use of virtual tools, this research investigates the performance of engineering design teams using a concept selection task in three meeting spaces, face-to-face, 2D online and 3D virtual. Cisco's WebEx and Sun Microsystems' Wonderland were used as the 2D online meeting space and the 3D virtual environment, respectively. Twenty-four two-person design teams were formed and randomly assigned to the meeting spaces. Eight teams performed a cell-phone concept selection task in each meeting space. Four dependent variables were measured: task completion time, team satisfaction, self-evaluated quality and expert-evaluated quality. Following data collection, one-way ANOVA was used to analyze each variable to determine the differences, if any, among the meeting spaces. ANOVA results did not support rejection of the null hypothesis for any variable. These results suggest that 3D virtual environments support design concept selection tasks as well as 2D online meeting spaces and that both of these technologies are viable alternatives to co-located meetings when it is difficult or expensive to bring team members together for a co-located meeting.

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CHAPTER 1

INTRODUCTION

The use of collaboration and distributed teams has become increasingly important as a result of globalization. This trend is especially true for the members of engineering design teams who must interact extensively because of the information and data sharing necessary in the design process. As a result, new communication and data sharing technologies have been developed. While video and audio conferences are still popular, internet-based tools such as e-mail, e-mail groups, discussion boards, video-supported and audio-supported instant messengers and online meeting applications have become increasingly efficient and wide-spread.

However, these applications may lack the immediacy and sense of "presence" required to support current collaboration needs. One area currently receiving much attention is the use of three-dimensional (3D) virtual world applications. An advantage of these worlds is the integration of communication and data-sharing tools. In addition, such 3D virtual worlds as Second Life (SL), Active Worlds and Wonderland mirror the collaboration among team members all physically present, potentially enabling ideas to be shared as effectively among engineers in different places and time zones.

This technology is fairly new and as such, has been the subject of limited research, much of which has investigated its use in education rather than in industry. Given its potential in this area, this study proposes to compare the utility of a 3D virtual meeting room in Sun Microsystems' Wonderland with that of a 2D online meeting tool called WebEx. The potential advantages of using 3D virtual worlds for engineering design teams relative to conventional online meeting tools and traditional meetings that require physical aggregation were investigated using the concept selection task of the engineering design process. The results of the three meeting types were compared based on qualitative and quantitative measurements of the work performed and feedback from the participants forming each team.

CHAPTER 2

LITERATURE REVIEW

2.1 DESIGN PROCESS

The importance of design, one of the essential functions in the product development process, has increased in recent years. As a result, it has become the focus of much research.

Lang, Dickinson & Buchal (2002) define the major steps of the design process:

- Needs analysis/problem clarification
- Information gathering/research
- Ideation/creative thinking
- Information generation/analysis
- Evaluation and optimization.

A more detailed description of this process was provided by Ulrich and Eppinger (2008):

- Identifying customer needs
- Benchmarking of competitive products
- Establishing target specifications
- Generating concepts
- Selecting a concept

- Testing the concept
- Establishing the final specifications
- Planning the project
- Analyzing the cost and the cash flow
- Modeling and Prototyping.

2.2 CONCEPT SELECTION PROCESS

One of the steps requiring a high level of interaction and communication among team members is concept selection. This step involves discussing and evaluating all the concepts developed by the design team and to discuss them during the selection process. Ulrich and Eppinger (p.124, 2008) define the concept selection process as “the process of evaluating concepts with respect to customer needs and other criteria, comparing the relative strengths and weaknesses of the concepts, and selecting one or more concepts for further investigation, testing or development.” Their methodology consists of two stages, concept screening and concept scoring, each using a decision matrix. Sample concept screening and scoring matrices are shown in Figures 1 and 2, respectively. The screening and scoring matrices rate, rank and identify the strongest concept(s). This two-stage process involves the six steps listed as below:

- Preparing the selection matrix
- Rating the concepts
- Ranking the concepts

- Combining and improving the concepts
- Selecting one or more concepts
- Reflecting on the results and the process.

This method is an extension of Pugh's (1990) controlled convergence method, which selects the best concept through the evaluation, elimination, and combination of the current concepts and the addition of the new concepts if appropriate. This approach to concept selection developed by Pugh (1990) is shown in Figure 3 and an evaluation matrix exemplifying Pugh's method is shown in Figure 4.

	Concepts						
Selection Criteria	**A Master Cylinder**	**B Rubber Brake**	**C Ratchet**	**D (Reference) Plunge Stop**	**E Swash Ring**	**F Lever Set**	**G Dial Screw**
Ease of handling	0	0	–	0	0	–	–
Ease of use	0	–	–	0	0	+	0
Readability of settings	0	0	+	0	+	0	+
Dose metering accuracy	0	0	0	0	–	0	0
Durability	0	0	0	0	0	+	0
Ease of manufacture	+	–	–	0	0	–	0
Portability	+	+	0	0	+	0	0
Sum +'s	2	1	1	0	2	2	1
Sum 0's	5	4	3	7	4	3	5
Sum –'s	0	2	3	0	1	2	1
Net Score	2	–1	–2	0	1	0	0
Rank	1	6	7	3	2	3	3
Continue?	Yes	No	No	Combine	Yes	Combine	Revise

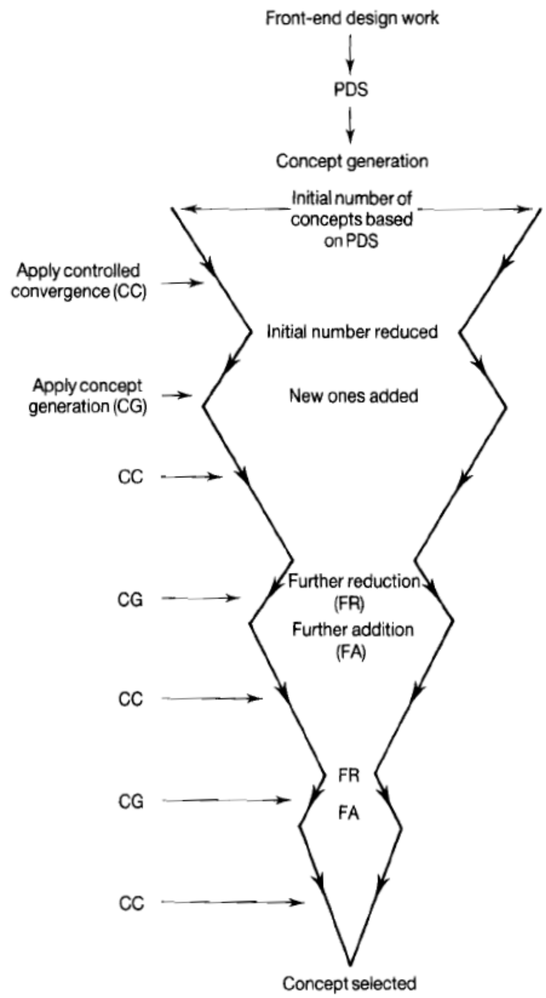
(Ulrich & Eppinger, 2008, p.130)

Figure 1: Concept screening matrix

		Concept							
		A (Reference) Master Cylinder		DF Lever Stop		E Swash Ring		G+ Dial Screw+	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Ease of handling	5%	**3**	0.15	3	0.15	4	0.2	4	0.2
Ease of use	15%	**3**	0.45	4	0.6	4	0.6	3	0.45
Readability of settings	10%	2	0.2	**3**	0.3	5	0.5	5	0.5
Dose metering accuracy	25%	**3**	0.75	3	0.75	2	0.5	3	0.75
Durability	15%	2	0.3	5	0.75	4	0.6	**3**	0.45
Ease of manufacture	20%	**3**	0.6	3	0.6	2	0.4	2	0.4
Portability	10%	**3**	0.3	3	0.3	3	0.3	3	0.3
	Total Score	2.75		3.45		3.10		3.05	
	Rank	4		1		2		3	
	Continue?	No		Develop		No		No	

(Ulrich & Eppinger, 2008, p.134)

Figure 2: Concept scoring matrix



(Pugh, 1990, p.75)

Figure 3: Flexible approach to concept generation and selection

Concept / Criteria											
	1	2	3	4	5	6	7	8	9	10	11
A	+	−	+	−	+	−	D	−	+	+	+
B	+	S	+	S	−	−		+	−	+	−
C	−	+	−	−	S	S	A	+	S	−	−
D	−	+	+	−	S	+		S	−	−	S
E	+	−	+	−	S	+	T	S	+	+	+
F	−	−	S	+	+	−		+	−	+	S
Σ+	3	2	4	1	2	2	U	3	2	4	2
Σ−	3	3	1	4	1	3		1	3	2	2
ΣS	0	1	1	1	3	1	M		1	0	2

(Pugh, 1990, p.77)

Figure 4: Evaluation matrix

2.3 DESIGN TEAMS

One of the significant factors affecting team work is team-size. It is important in terms of interacting, communicating and sharing of responsibility and it is a factor affecting team performance. One study on this subject belongs to Majailan, Kleinman & Serfaty (1992). In this study the researchers compared the performance of individuals, dyads and triads using a distributed computer test-bed called the Team Size Experiment (TEASE). Twelve subjects were recruited. In the first phase of the experiment they read instruction manuals individually. They then completed a 8 hours of training and a task. In the second phase all individuals were assigned to the dyad and triad teams. Three dyads and two triads were formed. These teams were given new instruction manuals. The teams were trained for five hours and then they completed the task. In the third phase all the dyad subjects were assigned to triads and all the triad subjects were assigned to dyads. They were given instructions and then completed the task. Performance was analyzed based on percentages of task completions and failures. The triads achieved the highest task completion percentage and the fewest failures. Individuals performed slightly better than the dyads in terms of task completion and failure percentages. The study concluded that "although larger teams have the advantage of less work through division of labor, a team does not always perform better than an individual because teamwork requires coordination" (p.886).

Another study which compares the performance of larger and smaller teams belongs to Bradner and Mark (2003). They investigated the effects of team size on distributed teams and compared the participation of larger teams' members and smaller teams' members through surveys. They hypothesized that large team size causes lower participation in group activities. In their study smaller teams had 4-9 members and larger teams had 14-18 members. The teams' members responded to a 7-point Likert scale survey that asked questions about their participation. The survey results indicated that smaller teams' members participated more actively on the team and they were more aware of the goals of the team.

Most products are designed by a team rather than a single individual. These teams consist of a core team which usually includes a team leader, an industrial designer, a mechanical designer, an electronic designer, a purchasing specialist, a manufacturing engineer, a marketing professional as well as an extended team including the customers, suppliers, operations support and current employees. The former involves those integrally involved in the design process, usually the engineers, and the latter includes such support areas as marketing and production. To work together effectively, the core team usually remains small enough to meet in a conference room, while the extended team may involve dozens, hundreds, or even thousands of members (Ulrich & Eppinger, 2008). To achieve their goals, this varied group of professionals requires a high level of interaction and communication using a variety of technologies (Peña-Mora, Hussein, Vadhavkar & Benjamin, 2000). In particular, design teams that are geographically distributed require highly coordinated collaboration. According to Lang *et al*. (2002), "the support needs of distributed design teams have become an important area of research, though the field remains in its infancy." (p.89)

2.4 COLLABORATIVE DESIGN

Given the current design environment, collaboration on engineering design has become vital especially for global organizations. As a result, researchers have investigated various methods for communication and data sharing on collaborative design. For example, Kirschman and Greenstein (2002) researched the effects of face-to-face, audio, video communication and electronic data sharing on the performance of distributed design teams. They used three meeting conditions: online team meetings with video, online team meetings with audio and without video and face-to-face meetings. They evaluated the effect of these conditions on the performance of three tasks: idea generation, co-editing and negotiation. The last two were subdivided to provide either file transfer or application sharing technologies to support task performance. The results of the study indicate that the distributed teams collaborated more effectively when provided with audio communication and file transfer capability. The experiment and performance evaluation methods employed by Kirschman and Greenstein (2002) are similar to the methods that this research aims to use in terms of using different forms of meeting spaces and comparing performance within these spaces on specific tasks.

Lang *et al.* (2002) provided another study regarding collaborative design. In this study they highlighted the importance of successful and efficient knowledge sharing, negotiation, coordination and activity management. No experiment was conducted to evaluate distributed team performance, but the necessity of interaction between distributed team members and the benefits of virtual meetings are discussed. They also provide a definition of collaboration as they note: “Collaboration is an activity where a large task is achieved by a team.” (p. 191). Their study provides some basic definitions and ideas about collaboration and these are used as initial steps in this research.

Technological developments in communication and meeting tools have expanded the research in this area. Shen, Hao & Li (2008) conducted a study involving computer-supported collaborative design. In this study the concept of computer supported collaborative design is described: “Computer supported collaborative design is the process of designing a product through collaboration among multidisciplinary product developers associated with the entire product lifecycle.” (p. 853). They then present the development of this concept from the 1980’s to today. In the section on today’s computer supported collaborative design, use of web services and technologies is highlighted. Agent-based collaborative design and integration of agent-based technologies for collaborative design are also explained. They note: “In agent-based collaborative design systems, software agents are mostly used for supporting cooperation among designers, enhancing interoperability between traditional computational tools, or allowing better simulations” (p.858). The conclusion of the paper presents some potential research opportunities to achieve more efficient collaboration. The research opportunity they present that is most relevant to this research is that of collaborative intelligent user interfaces; as the authors note: “Designers need to interact with a design system and negotiate with peers via a user interface” (p.860). The study to be proposed intends to use a three dimensional environment to provide better interaction through avatars.

Another study addressing the use of web services for collaborative engineering was reported by Schubert, Kipp & Koller (2008). In this paper, two projects named BREIN and TrustCom are presented. The authors note: “The TrustCom project elaborated the means to create and manage virtual organizations in a trusted and secure manner integrating different providers on-demand. However, TrustCom focused more on the virtual organizations than on the participant, whereas the BREIN project is now enhancing the intelligence of such virtual organizations systems to support even providers with little business expertise and provide them with capabilities to optimize their performance.” (p. 431). This study also describes virtual organizations as a concept which has been developed to describe collaborations using resources exposed to the internet. The relevance of this study to this research is that both are related to collaboration through virtual organizations.

In terms of the development of new systems and methods for collaborative design, some researchers have focused specifically on manufacturing organizations, one example being the study conducted by Fan, Kumar, Jagdish & Bok (2008). This investigation focused on the development of a methodology to enable distributed collaborative design using hybrid grid and peer-to-peer technology, based on a case study dealing with fixture design in a manufacturing environment. The distributed team members working in three companies try to develop a fixture model through a network. After the implementation of the case study the results, which were obtained based on number of processors, computing time and transportation time, indicated the developed system was more flexible and suitable for a fast changing environment than the traditional web-based collaborative system. The relevance of this study and this research is the focus on distributed team members, although the methods and aims are different.

2.5 USE OF VIRTUAL ENVIRONMENTS FOR COLLABORATION

Because of the increasing importance and necessity of collaborative works, investigators have begun to study the use of virtual environments to support such work. Shukla, Vazquez & Chen (1996) conducted one of the early studies using virtual environments. According to them “The aim of virtual reality is to make use of multi-media to generate a perception of a real environment and allow interactive experiences, and facilitate the evaluation of different scenarios with limited expense and effort.”

(p.80). they used various types of multi-media to create “an integrated, synthetic manufacturing environment exercised to enhance all levels of decision and control” in the design of a product. Specifically, they investigated a process planning engineer and a manufacturing engineer simultaneously evaluating and providing feedback early to a product designer physically located in another state or country. This study emphasized the importance of collaboration in engineering that began to be realized during the 1990’s as well as providing information about the technological requirements for virtual manufacturing such as input/output devices, computation and the software. The study concluded that using such virtual reality technologies as CAD and CAM can be expected to enhance the capabilities of many systems used in manufacturing. A similar study was conducted by Jayaram, Connacher& Lyons (1997), focusing on the use of 3D virtual reality technology in assembly techniques during conceptual design phase. They developed a prototype called the “virtual assembly design environment” (VADE) capable of transferring data from CAD, thus allowing a user to see the assembly issues in mechanical systems earlier in the design process. The pilot implementation indicated advantages of virtual assembly, making possible reduced product development time, improved product design and reduced costs for companies.

Pena-Mora *et al.* (2000) developed a system termed “collaborative agent interaction and synchronization” (CAIRO), which provides a virtual meeting environment for design teams. Through this system, which requires its own server and database, members of a design team get together in a virtual meeting room, communicate through a message board and use a whiteboard to share drawings. The study presented a sample meeting session of a four-member structural engineering team discussing a problem about a joint connection in a building being constructed. A meeting session, called a forum, was created, and the team members discussed the problem using text-chat and a white-board, with the team members also being able to view two dimensional photographs. CAIRO is one of the earliest virtual environments developed to support meetings for distributed design teams. Today's web-based meeting tools using the latest technology and enhanced applications for distributed teams are based on the same logic as CAIRO.

The current global manufacturing environment requires more distributed collaboration, due to the increasing number of distributed teams; as a result, researchers have begun exploring real business cases, one example being the case study presented by May and Carter (2001). This study focused on a distributed engineering team, consisting of 40 engineers located in four countries. For this investigation a demonstrator, the Team-based European Automotive Manufacturing (TEAM), was developed, installed on engineering workstations and offered the use of audio and video conferencing tools, a web browser, a shared 2D whiteboard, a product library containing a data management tool for accessing and transferring data, and CAD packages. Evaluation of team performance was conducted through timelines and performance sheets, self-completed by the participating engineers to record brief details of the each collaborative session, observations of selected collaborative sessions, and structured interviews conducted after the final collaborative session. In the case study, collaborative sessions undertaken via the TEAM demonstrator generally consisted of a one-to-one interaction between a development engineer at the automotive manufacturer and a corresponding colleague at the supplier, ranging in duration from 20 to 50 minutes (May & Carter, 2001). Analysis of these sessions indicated that the engineers made the greatest use of the audio tool, the shared whiteboard and the product library. In addition, the satisfaction ratings provided by the engineers indicated that 86% of sessions, they were only partly satisfied and in 14% of the sessions they were very satisfied. These results suggest that the engineers felt that face-to-face meetings were preferable to those using TEAM.

Tseng and Abdalla (2004) proposed a new human-computer system for collaborative design integrating communication media (e.g., E-mail, bulletin board, online list, instant messaging, virtual conference room, 3d viewer) and solid modeling tools. This new system is validated using a case study focusing on marketing information analysis of a product design. In the case study the team members, who were a project manager, various marketing experts and a board of directors evaluated some quantitative information about mobile phone sales in Europe. The results of this study found that using only one interface, the team members collaborated on idea generation, concept development and testing, marketing strategy, business analysis, product development, test marketing, and commercialization.

More recently, the virtual team concept has received increased attention. For example Anderson, McEwan, Bal & Carletta (2007) focused on the communication dimension of virtual teams, because of the relationship between communication and performance. Using TEAM technology, virtual teams formed of 70 participants who work in a supply chain used videoconferencing, a shared whiteboard and web-based product libraries to achieve virtual meetings to collaborate on a real life event between an automotive original equipment manufacturer and its suppliers. During the experiment participants were given written instructions outlining the problem scenario, with each virtual meeting session lasting approximately ninety minutes. The researchers then analyzed the meetings in terms of communication, content and amount of interaction to understand more fully the utility of the virtual meeting tools. To analyze the meetings full transcriptions were taken of the discussions, defined as the time from when one person began to speaking until he/she paused and listened to someone else. The study concluded that for virtual collaboration to be effective proper supporting tools are needed, the team members need appropriate training, and facilities are required to encourage open and inclusive patterns of communication across the distributed locations.

Researching communication among the members of a virtual team in a field experiment, Lin, Standing, & Liu (2008) investigated a famous BBQ restaurant with issues involving the inability to manage customer orders, the use of an inappropriate stock ordering system, and difficulties in managing human resources. For this experiment 200 students were recruited and 25 eight-member teams created. Team members were allowed to communicate only through MSN messenger to find potential solutions for the problems of the restaurant. Following the completion of the field experiment, a survey was given to the members of each team to measure the effectiveness of relationship building, cohesion, coordination, performance, satisfaction and communication. Then the performance of each team was evaluated in terms of the survey and the messaging system logs were analyzed for the average number of sentences and words posted by each of the team members to determine individual contributions. The results of the study indicated that the amount of communication had no significant direct impact on the effectiveness of the virtual teams. In addition virtual teams were focused more on social dimensional factors than task-oriented factors, with these social factors only affecting the satisfaction of virtual teams indirectly.

2.6 USE OF CURRENT THREE DIMENSIONAL VIRTUAL WORLDS

Since three dimensional environments have become feasible, researchers have studied their use in such areas as education and collaboration. Most of these investigators have used Second Life (SL) because it involves the most virtual residents. According to Linden Labs, its developer, 12,942,144 avatars are registered. According to McNeese, Pfaff, Santoro & McNeese (2008) virtual worlds are simulated, immersive, multimedia environments accessed by multiple users through computer networks; one advantage of 3D virtual worlds is that they allow study of methods to enhance team performance. Traum's study (2007) focused specifically on the potential use of SL in engineering. His results found that engineers believed SL to be an efficient tool for design. Based on these comments, comparisons among two-dimensional drawings, CAD, and SL were made, with the latter being found to excel in the use and creation of 3D models, interaction between model and avatar, and accessibility for both designers and user.

SL has also been used in education. Lucia, Francese, Passero & Tortora (2008) characterized 3D virtual environments in terms of presence, awareness, communication and belonging to a community. In their discussion of the creation of a virtual classroom using SL, they conducted lectures in this classroom with students participating through their avatars; then, they evaluated the virtual classroom in terms of design and context, preparation and material, and execution. The evaluation of the classroom was based on the responses to questionnaires on presence, communication, awareness and social awareness, perceived sociability, and comfort with the virtual environment. The results of the study indicate that the virtual environment successfully supports synchronous communication and social interaction; in addition, teachers who lectured in SL found the students motivated.

A second study investigating education in virtual environments was conducted by Greenstein, Hayes, Stephens, & Peters (2008), who researched the use of SL as a supplement to text-based materials in educational applications. Ten undergraduate students were asked to study two topics: tsunamis and schizophrenia. The teams studied one of the topics first through an SL experience and then using a handout. They then studied the second topic using a handout alone. Following this learning process, participants were given an exam and their learning performance was evaluated. When the students completed both a SL experience and a handout on a topic, they achieved higher exam scores and rated the learning experience more engaging than when they completed the handout alone. The authors concluded that "virtual worlds are a useful instructional supplement to academic readings." (p.623)

In their study, McNeese *et al.* (2008) compared the effectiveness of audio teleconferencing, face-to-face communication and the use of a virtual world (SL) using 96 participants divided into 32 teams, 10 being assigned to face-to-face communication, 10 to audio teleconferencing communication and 12 groups to SL. The teams were to use a video story about how to rescue a missing eagle. All teams were given 40 minutes to complete the task. The interaction of the face-to-face teams was video recorded; the interaction of the audio conferencing team was audio recorded, and the text chats of the SL teams were saved. At the conclusion of the task, the participants completed individual post task surveys; the results of the study indicated no significant differences among the three communication conditions on overall team performance.

One of the most recent developments in 3D environments is Sun Microsystems' Wonderland. An open-source toolkit for creating virtual worlds, it offers such capabilities as high-fidelity communication between avatars, shared applications and the ability to conduct collaborative meetings. Sun's Wonderland is a multi-user environment, robust in security, scalability, reliability and functionality that organizations can rely on as a place to conduct business (Sun Microsystems, 2008). Sun Microsystems' Wonderland will be used in this study because it is an open source tool and because it offers such features as the integration of Microsoft office tools, applications and collaborative browsers, important for a concept selection task like the one that will be used here.

CHAPTER 3

RESEARCH HYPOTHESES

To compare the effectiveness of current online meeting technologies with traditional co-located meetings, the following research hypotheses will be tested.

H1: Concept selection tasks are completed more quickly in Wonderland than in WebEx, and a traditional meeting is quicker than Wonderland.

Since previous research has found that time is a significant element in design collaboration, it is important to determine which type of space is more efficient, 2D online, 3D online or traditional meeting space. In a 3D virtual environment, it is hypothesized that team members do not need to transfer data or upload documents, meaning they can use the meeting time more effectively for collaboration, especially with the avatars identifying the person communicating.

H2: The outcome quality of the concept selection task performed in Wonderland is not significantly different from that obtained using a traditional co-located meeting space and WebEx.

Researchers have found that the level of comfort in a virtual meeting space is similar to that of a traditional face-to-face one. For example McNeese *et al.* (2008) compared the communication performance of face-to-face, audio conferencing and 3D virtual environments, and did not find any significant differences in task performance.

Thus, using a 3D or 2D online space is hypothesized to produce the same quality of work as co-located meetings while affording convenience for distant team members.

H3: User satisfaction with the experience of meeting in Wonderland is greater than that achieved through the use of WebEx, and it is not significantly different from that achieved through use of traditional meeting rooms.

The concept screening process requires co-operation among team members as they discuss concepts, eliminating some while adding new ones before deciding on the best one. All of these activities require high-level interaction. In Wonderland, team members can interact with the same web browsers, white-boards, and applications, in addition to seeing one another's avatars so they can feel as though they are physically together. On the other hand, they do not have to receive e-mails or download or upload files during the meeting, helping them to focus easily on the task and thereby increasing their satisfaction. Such past research as De Lucia *et al*. (2008) has found that participants are comfortable in a 3D virtual world and that they are motivated to perform well.

CHAPTER 4

METHODOLOGY

The study will compare the efficacy of three meeting space environments for engineering design teams, a traditional meeting room in which people meet together physically, WebEx, a web-based application providing data-sharing and communication support, and Wonderland, a three-dimensional virtual environment through which people interact via avatars. In each space eight, 2-person teams performed the same concept selection task. Sample screens that belong to WebEx and Wonderland meetings are presented in Figures 5 and 6. In these figures documents were controlled by the team members.

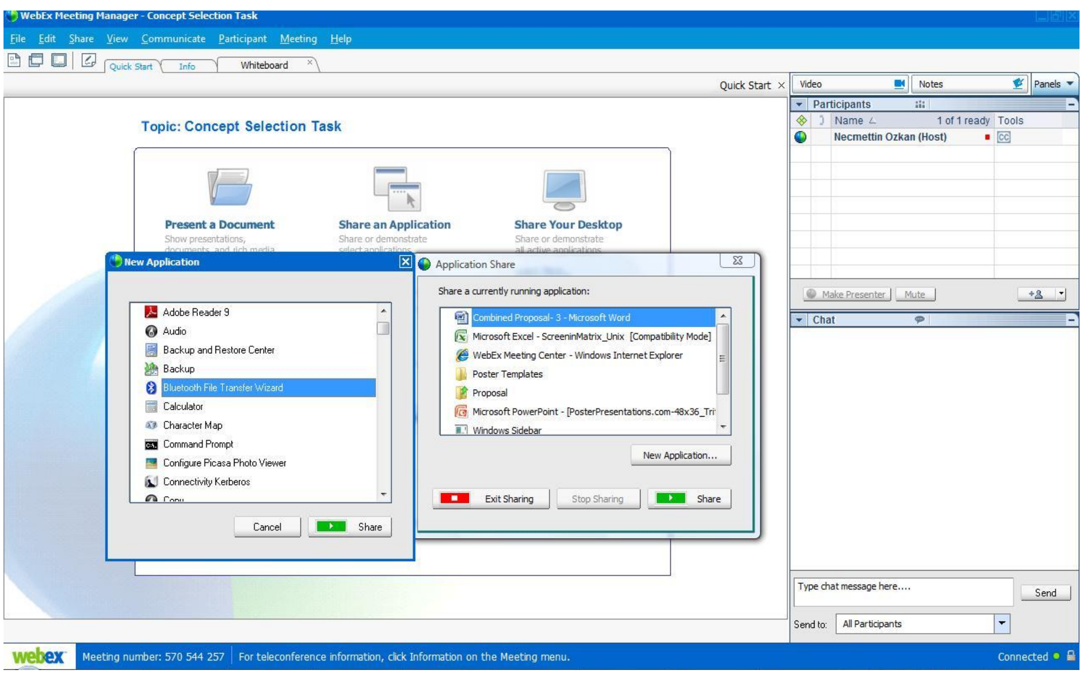


Figure 5: WebEx meeting screen

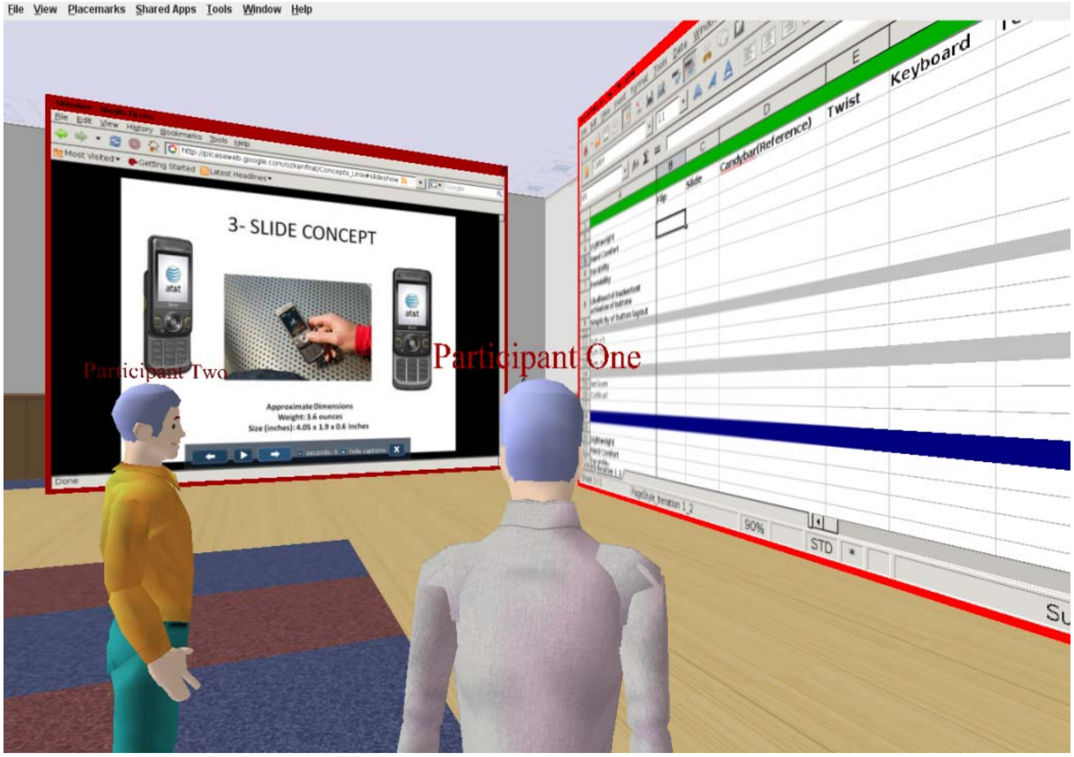


Figure 6: Wonderland meeting screen

Before the meetings all participants were given the same instructions, which are presented in Appendix A. After the participants read the instructions the co-investigator explained how to use the meeting space, trained them until they were able to manage the meeting tools by their selves and let them get familiar with the meeting space until they declared they were ready to start the meeting. All meetings were observed and the observation check list, which is presented in Appendix B, was filled out. The duration of the meetings was recorded. Following the completion of the task, the participants completed questionnaires concerning their background and experience (Appendix C), satisfaction with the meeting space (Appendix D) and their process (Appendix E). The tasks performed by the teams were also evaluated by a design process expert. The evaluator was not aware of the experimental conditions with which the teams were associated. The three meeting spaces were then compared based on the results of the questionnaires, the team task completion times and the evaluations of the expert.

4.1 PARTICIPANTS

Forty-eight Clemson University Industrial Engineering graduate and under-graduate students who had completed a course in design methodology and were familiar with Ulrich and Eppinger’s concept screening method were recruited. Nineteen of the participants were female and twenty-nine of them were male. The age range of the participants was 19-32. All of the participants were familiar with computers and none of them were extremely experienced with 2D or 3D virtual worlds.

4.2 INDEPENDENT VARIABLES

The independent variable of the study was the meeting space where the teams performed the concept selection task. This independent variable was tested for the following environments: the traditional face-to-face meeting room, the web-based 2D meeting tool WebEx and the 3D virtual world Wonderland.

The traditional meeting room included a table, 2 chairs, one whiteboard, one computer and other supplemental materials such as board markers, pens and paper.

WebEx, one of the most popular current online meeting tools supporting collaboration, was developed in 1995 especially for business and it was acquired by Cisco in 2007. Using WebEx, team members met together online, shared their documents by uploading them, shared applications such as Microsoft office programs, used a shared whiteboard and shared their own computer desktops. This tool also enabled the use of audio and text-based communication. To use WebEx, one computer with internet access was required for each participant. In a WebEx meeting one of the participants must be the presenter initially. Only the presenter can manage the shared documents during the meeting but the presenter role can be changed among the team members and also team members other than the presenter can manage the documents by sending a request to the presenter for permission to take control.

Using Wonderland, team members met in a virtual meeting room provided with such virtual meeting tools as an integrated collaborative whiteboard, a presentation screen and a Microsoft Excel spreadsheet. Using these tools, the team members made presentations, discussed ideas and shared documents. In addition, the team members used text and audio chat tools through their avatars. While in WebEx only one presenter can manage the documents at a time, in Wonderland all members can manage them simultaneously. Only one user can modify a document at a time, but any user can assume control of a document without asking or receiving permission from others.

4.3 TASKS

All teams, regardless of the meeting technology, performed a concept selection task using the concept screening methodology outlined by Ulrich and Eppinger (2008). The task involved selecting the best concept for a cell-phone starting from the initial concepts of candy bar, flip, slide, twist, keyboard and touch screen, based on the same given selection criteria (Appendix F). These criteria included weight, hand comfort, likelihood of inadvertent activation of buttons, simplicity of button layout, durability and portability. Based on Ulrich and Eppinger's concept screening methodology, concept screening matrices were created to compare these concepts. During the creation of these matrices, the teams interacted, discussed the advantages and disadvantages of each concept, added new concept ideas and/or combined current ones. All teams in every meeting space used an MS Excel sheet for the creation and computation of the matrices. Finally, each team determined the best cell phone concept in their different meeting spaces. Figure 7 depicts the series of concept screening matrices produced by one team in their application of the methodology.

	Flip	Slide	Candybar(Reference)	Twist	Keyboard	Touch Screen
Lightweight	-	-	0	+	-	-
Hand Comfort	0	+	0	-	+	0
Durability	-	-	0	-	-	-
Portability	0	0	0	+	0	0
Likelihood of inadvertent activation of buttons	+	+	0	+	-	0
Simplicity of button layou	0	0	0	-	+	+
Sum +'s	1	2	0	3	2	1
Sum 0's	3	2	6	0	1	3
Sum -'s	2	2	0	3	3	2
Net Score	-1	0	0	0	-1	-1
Continue?	no	yes	yes	yes	yes	no

	Slide(Reference)	candybar	Twist	Keyboard
Lightweight	0	+	+	-
Hand Comfort	0	0	-	+
Durability	0	+	-	+
Portability	0	0	+	0
Likelihood of inadvertent activation of buttons	0	-	-	-
Simplicity of button layout	0	0	-	+
Sum +'s	0	2	2	3
Sum 0's	6	3	0	1
Sum -'s	0	1	4	2
Net Score	0	+1	-2	+1
Continue?	yes	yes	no	yes

	slide+keyboard'	candybar(Reference)
Lightweight	0	0
Hand Comfort	+	0
Durability	-	0
Portability	0	0
Likelihood of inadvertent activation of buttons	+	0
Simplicity of button layout	+	0
Sum +'s	3	0
Sum 0's	2	6
Sum -'s	1	0
Net Score	+2	0
Continue?	yes	no

Figure 7: Concept screening matrices created by one of the teams

4.4 DEPENDENT VARIABLES

The dependent variables of this study were task completion time, self-evaluated quality, expert-evaluated quality and team satisfaction.

Task completion time indicated the total amount of meeting time for the team. Satisfaction was measured with a questionnaire based on a ten-point Likert scale with questions addressing the ease of completing the task, the ease of learning how to use the meeting space, the ease of communication and the ease of data sharing. Team members completed this satisfaction questionnaire individually, and the overall satisfaction score per team was obtained by averaging their responses. The satisfaction questionnaire can be seen in Appendix D. Expert-evaluated-quality was measured based on the process used by the teams as evaluated by an expert against a performance rubric to determine if the team executed the concept selection process properly. To measure the self-evaluated-quality, teams were given a questionnaire to determine the steps of the selection process used. Team members completed this questionnaire together. This task questionnaire can be seen in Appendix E.

These dependent variables were statistically analyzed using one-way ANOVA to determine whether there was any difference between meeting spaces and if the null hypothesis of the ANOVA was rejected, the results were tested using the LSD (least significance difference) test to compare the performance of the teams and to determine the validity of the hypotheses concerning the effectiveness of the different meeting spaces.

CHAPTER 5

RESULTS

Once the data were collected, the time, satisfaction and quality results were analyzed using MINITAB 15 statistical software. Basic descriptive results, illustrative graphs, correlation analyses and one-way ANOVA were used to determine the potential differences among the three meeting spaces.

5.1 DATA COLLECTION

To compute the team satisfaction score, the average of the individual responses was calculated. Since three of the ten questions on the satisfaction questionnaire were negative, the values on these questions were reversed before they were included in the sums of the scores. The maximum score on this questionnaire was 100. To determine the self-evaluated quality score, the task questionnaire responses to each question were totaled; the highest score possible was 100. To determine the expert-evaluated quality score the screening matrices prepared by the teams were submitted to the design expert. The expert evaluated these documents without knowing the meeting space involved, giving a score of 1 to 100 as a quality score. All the data obtained for the experiment for each meeting space are presented in Tables 1-3.

Table 1: Data from the co-located meeting space

Meeting Space	Team #	Task Completion Time (minutes)	Team Satisfaction (%)	Self-evaluated-quality (%)	Expert-evaluated-quality (%)
Co-Located	1	62.05	87.50	92.00	80.00
Co-Located	2	31.52	86.00	88.00	65.00
Co-Located	3	62.62	92.50	82.00	75.00
Co-Located	4	22.53	91.50	82.00	70.00
Co-Located	5	22.28	88.00	92.00	70.00
Co-Located	6	37.67	80.50	100.00	80.00
Co-Located	7	47.15	82.00	86.00	80.00
Co-Located	8	22.15	75.50	83.00	60.00

Table 2: Data from the WebEx meeting space

Meeting Space	Team #	Task Completion Time (minutes)	Team Satisfaction (%)	Quality (Self) (%)	Quality (Expert) (%)
WebEx	1	22.43	70.50	90.00	65.00
WebEx	2	43.58	67.50	93.00	60.00
WebEx	3	49.98	89.00	80.00	65.00
WebEx	4	20.82	78.50	100.00	75.00
WebEx	5	37.58	71.00	65.00	65.00
WebEx	6	36.12	81.00	83.00	55.00
WebEx	7	42.80	71.00	86.00	70.00
WebEx	8	24.07	86.50	88.00	65.00

Table 3: Data from the Wonderland meeting space

Meeting Space	Team #	Task Completion Time (minutes)	Team Satisfaction (%)	Self-evaluated-quality (%)	Expert-evaluated-quality (%)
Wonderland	1	64.78	79.50	94.00	75.00
Wonderland	2	31.03	81.50	87.00	70.00
Wonderland	3	21.62	90.00	69.00	65.00
Wonderland	4	62.50	73.50	90.00	70.00
Wonderland	5	22.02	83.50	93.00	60.00
Wonderland	6	31.45	73.00	98.00	70.00
Wonderland	7	46.13	86.00	100.00	60.00
Wonderland	8	29.60	71.50	89.00	65.00

5.2 DESCRIPTIVE STATISTICS

Descriptive statistics including the task completion times, the team satisfaction scores and the meeting quality scores for each meeting space are presented in Table 4 and Figure 8. The descriptive statistics for the combined data from the three meeting spaces including the time, satisfaction and quality variables are shown in Table 5, with histograms of each variable being presented in Figures 9 -12.

Table 4: Descriptive statistics for each meeting space

Meeting Space	Variable	N	Mean	Std.dev.	Minimum	Maximum
Co-Located	Task Completion Time	8	38.50	17.10	22.15	62.62
WebEx	Task Completion Time	8	34.67	10.99	20.82	49.98
Wonderland	Task Completion Time	8	38.64	17.18	21.62	64.78
Co-Located	Team Satisfaction (%)	8	85.43	5.77	75.50	92.50
WebEx	Team Satisfaction (%)	8	76.87	8.08	67.50	89.00
Wonderland	Team Satisfaction (%)	8	79.81	6.70	71.50	90.00
Co-Located	Self-evaluated Quality (%)	8	88.13	6.29	82.00	100
WebEx	Self-evaluated Quality (%)	8	85.63	10.35	65.00	100
Wonderland	Self-evaluated Quality (%)	8	90.00	9.56	69.00	100
Co-Located	Expert-evaluated Quality (%)	8	72.50	7.56	60.00	80.00
WebEx	Expert-evaluated Quality (%)	8	65.00	5.98	55.00	75.00
Wonderland	Expert-evaluated Quality (%)	8	66.88	5.30	60.00	75.00

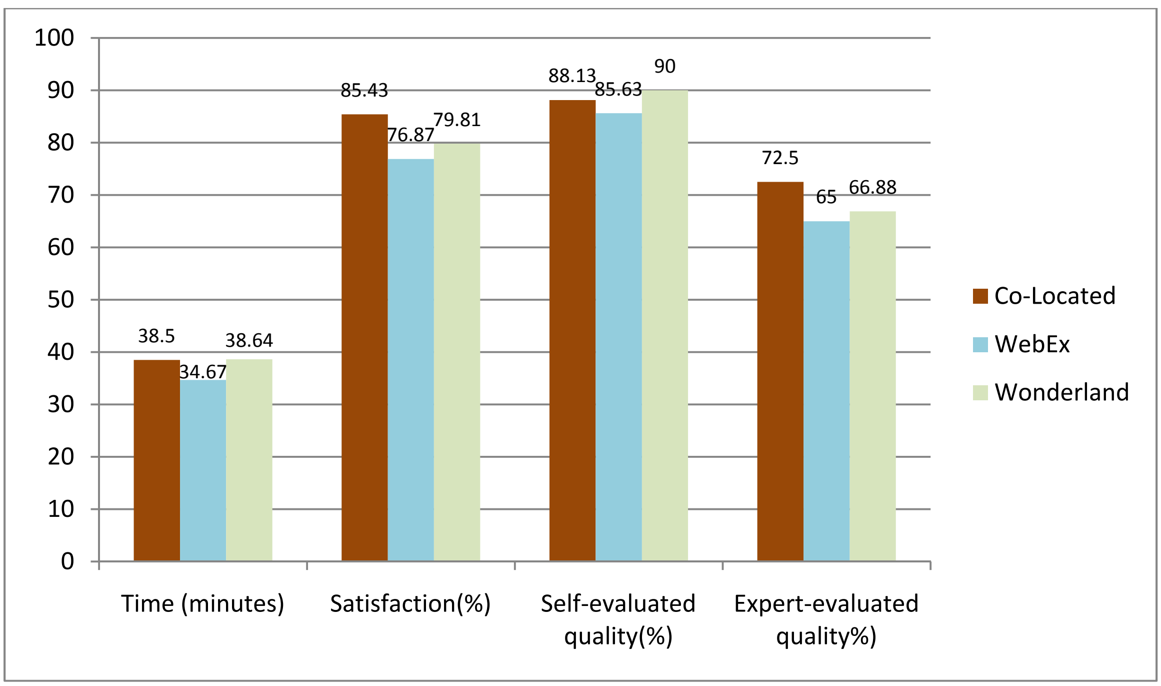


Figure 8: Means of variables in three meeting spaces

Table 5: Overall descriptive statistics of variables

Variable	N	Mean	Std.dev.	Minimum	Maximum
Task Completion Time (minutes)	24	37.27	14.80	20.82	64.78
Team Satisfaction Score (%)	24	80.71	7.54	67.5	92.5
Meeting Quality (Self) (%)	24	87.92	8.71	65.00	100.00
Meeting Quality (Expert) (%)	24	68.13	6.89	55.00	80.00

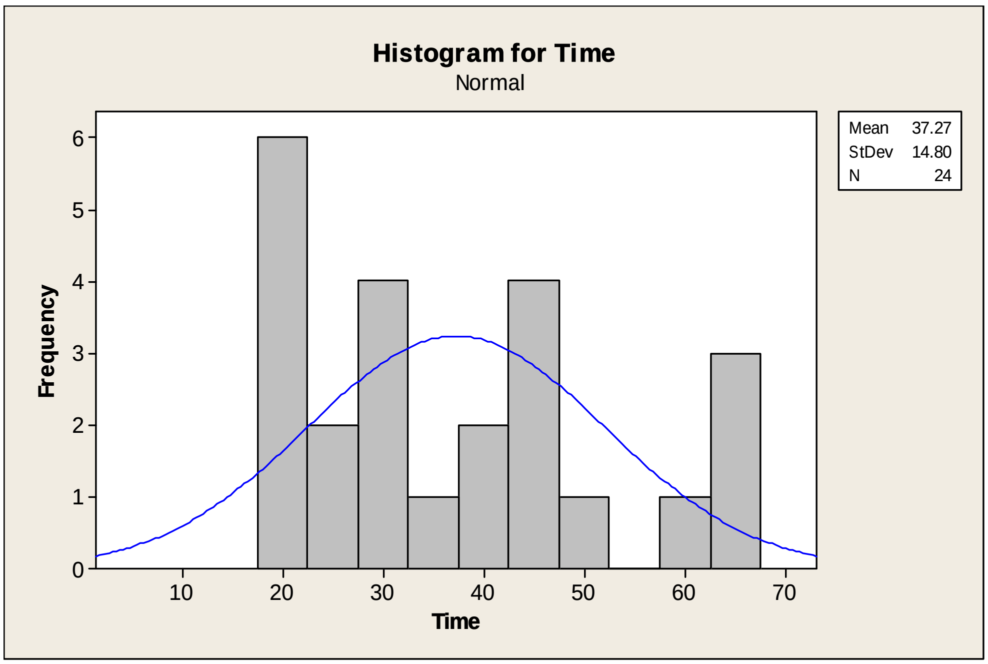


Figure 9: Histogram of task completion time variable

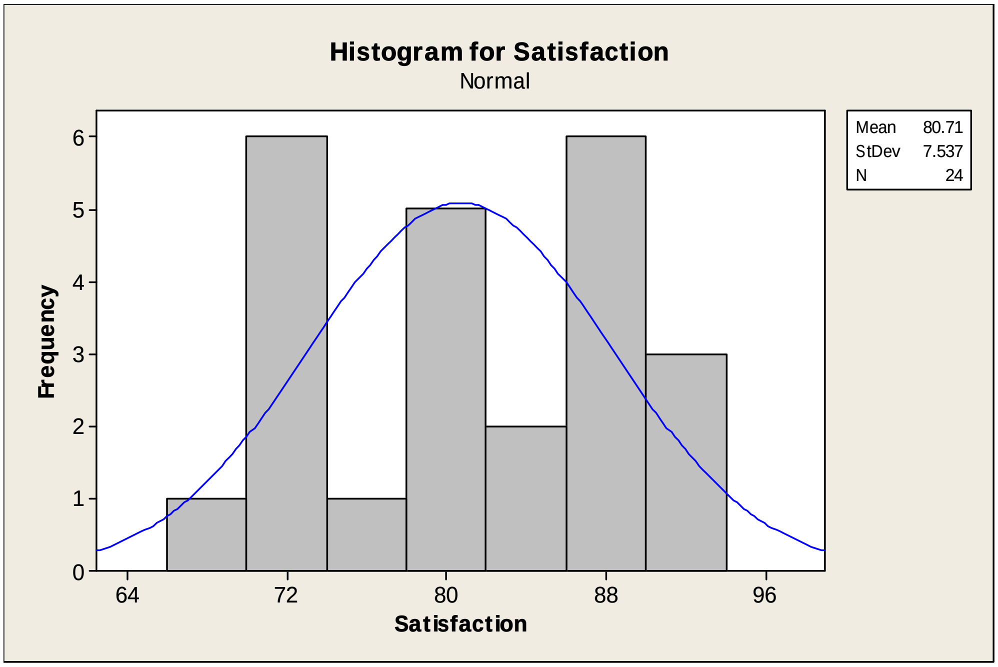


Figure 10: Histogram of team satisfaction variable

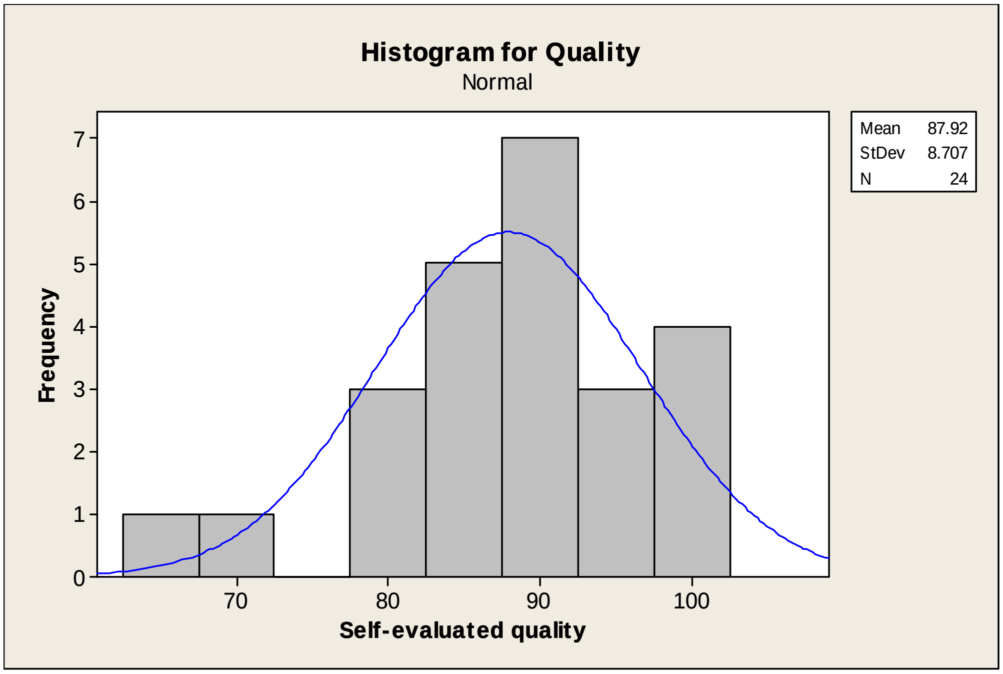


Figure 11: Histogram of self-evaluated task quality

Figure 12: Histogram of expert-evaluated task quality

5.3 NORMALITY TESTS

Before ANOVA was conducted, the variables were tested to determine if they were normally distributed using the Anderson-Darling normality test in MINITAB. The null hypothesis of this test indicates that the distribution is normal at a 95% confidence interval, meaning that if the p-value is larger than 0.05 the distribution is considered normal. The results of the tests for the variables of time, satisfaction, self-evaluated quality and expert-evaluated quality are presented below in Figures 13-16.

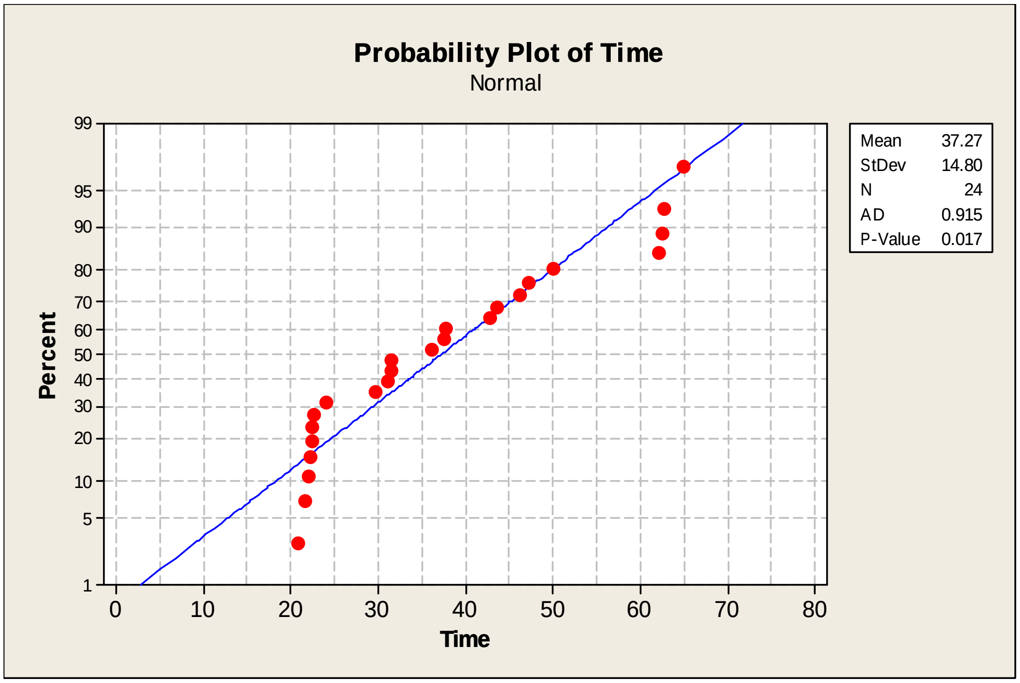


Figure 13: Normality test result of time variable

As the probability plot and p-value (0.017) in Figure 13 show, the null hypothesis is rejected, and the task completion time variable does not exhibit a normal distribution.

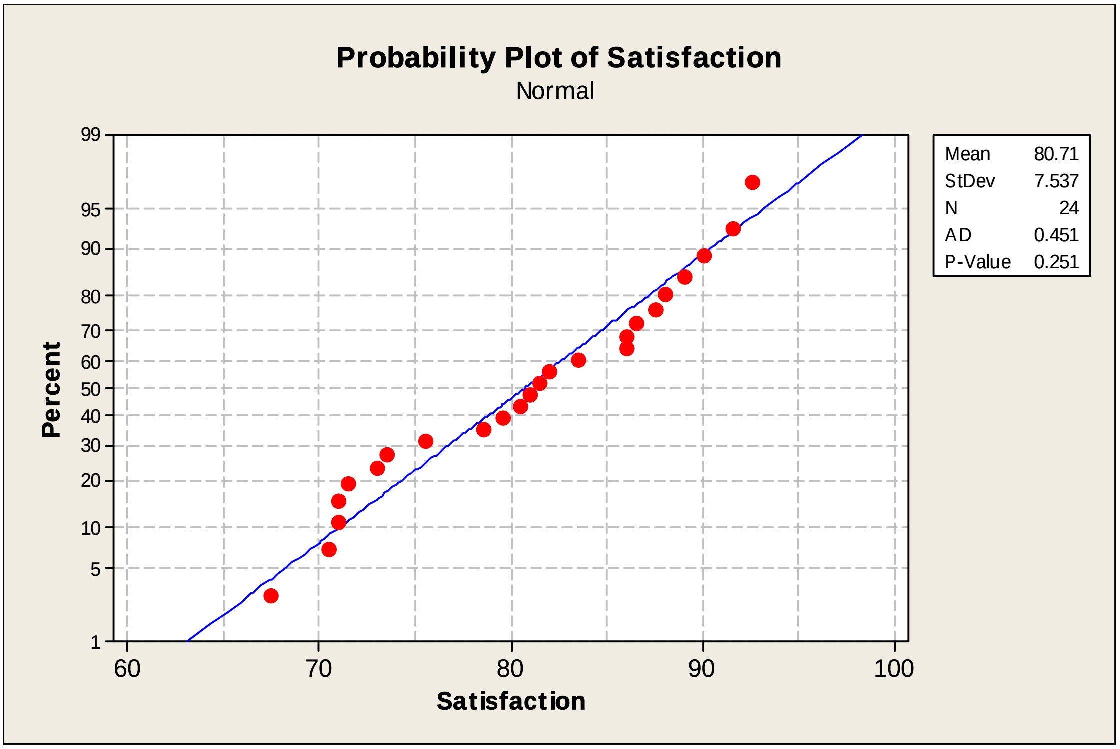


Figure 14: Normality test result of satisfaction variable

As the the probability plot and the p-value (0.251) in Figure 14 show, the null hypothesis is not rejected, meaning that the satisfaction variable exhibits a normal distribution.

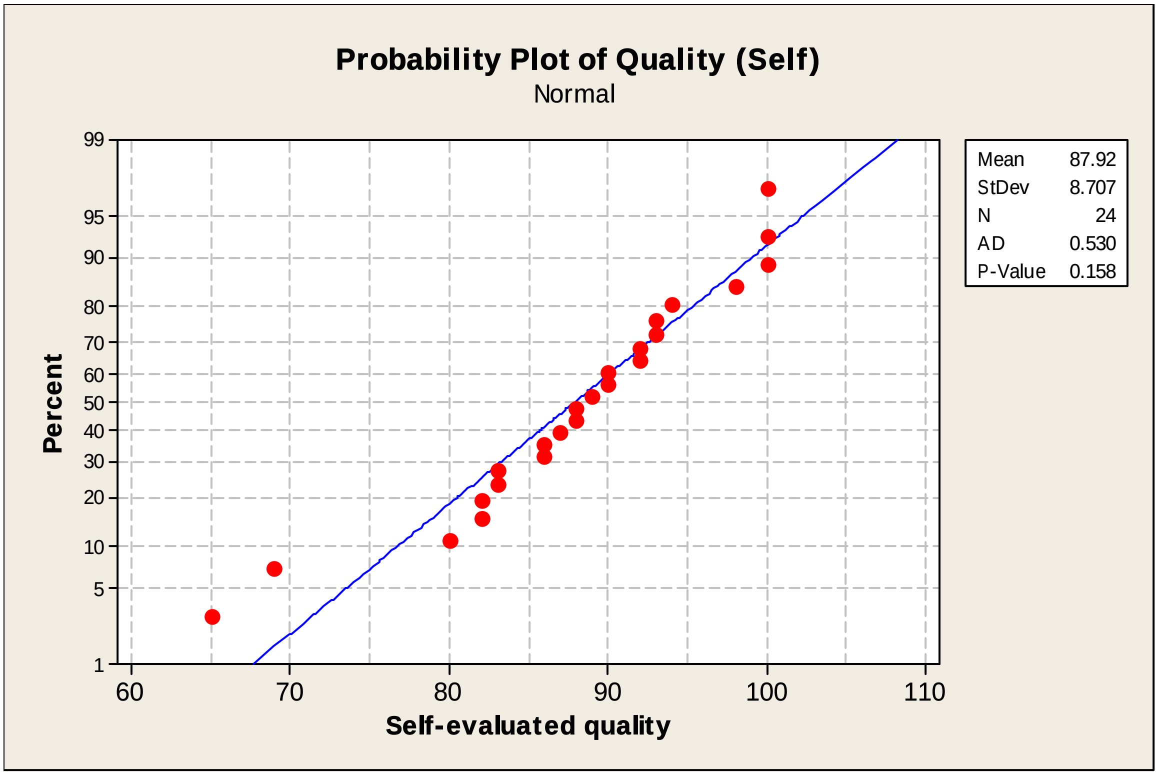


Figure 15: Normality test result of self-evaluated quality variable

As the probability plot and the p-value (0.158) in Figure 15 show, the null hypothesis is not rejected, meaning that the self-evaluated quality variable exhibits a normal distribution.

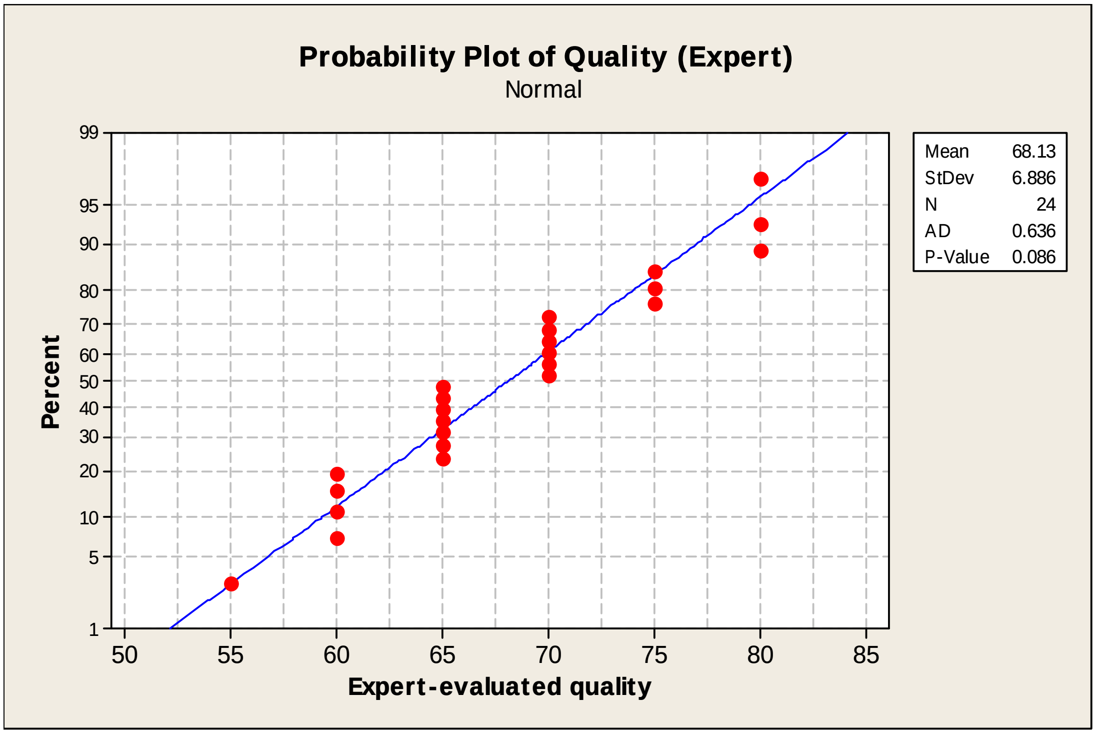


Figure 16: Normality test result of expert-evaluated quality variable

As the probability plot and the p-value (0.086) in Figure 16 show the null hypothesis is not rejected, meaning that the expert-evaluated quality variable exhibits a normal distribution

5.4 NATURAL LOGARITHM TRANSFORMATION

Since the time data did not exhibit a normal distribution, they required a normalization procedure before a one-way ANOVA could be conducted. There are several methods. The one used here was MINITAB's natural log function. This function transforms the data by calculating logarithms to the base e. For this study, the time data were transformed to its natural logarithm and a new time data set appropriate for

ANOVA was obtained. The transformed data are shown in Table 6 with the normality test result for these transformed data presented in Figure 17.

Table 6: Transformed time data

Meeting Space	Task Completion Time	Natural Log Time
Co-Located	62.05	4.12794
Co-Located	31.52	3.45052
Co-Located	62.62	4.13703
Co-Located	22.53	3.11500
Co-Located	22.28	3.10384
Co-Located	37.67	3.62878
Co-Located	47.15	3.85333
Co-Located	22.15	3.09784
WebEx	22.43	3.11055
WebEx	43.58	3.77467
WebEx	49.98	3.91169
WebEx	20.82	3.03575
WebEx	37.58	3.62656
WebEx	36.12	3.58675
WebEx	42.80	3.75654
WebEx	24.07	3.18083
Wonderland	64.78	4.17105
Wonderland	31.03	3.43506
Wonderland	21.62	3.07346
Wonderland	62.50	4.13517
Wonderland	22.02	3.09180
Wonderland	31.45	3.44840
Wonderland	46.13	3.83154
Wonderland	29.60	3.38777

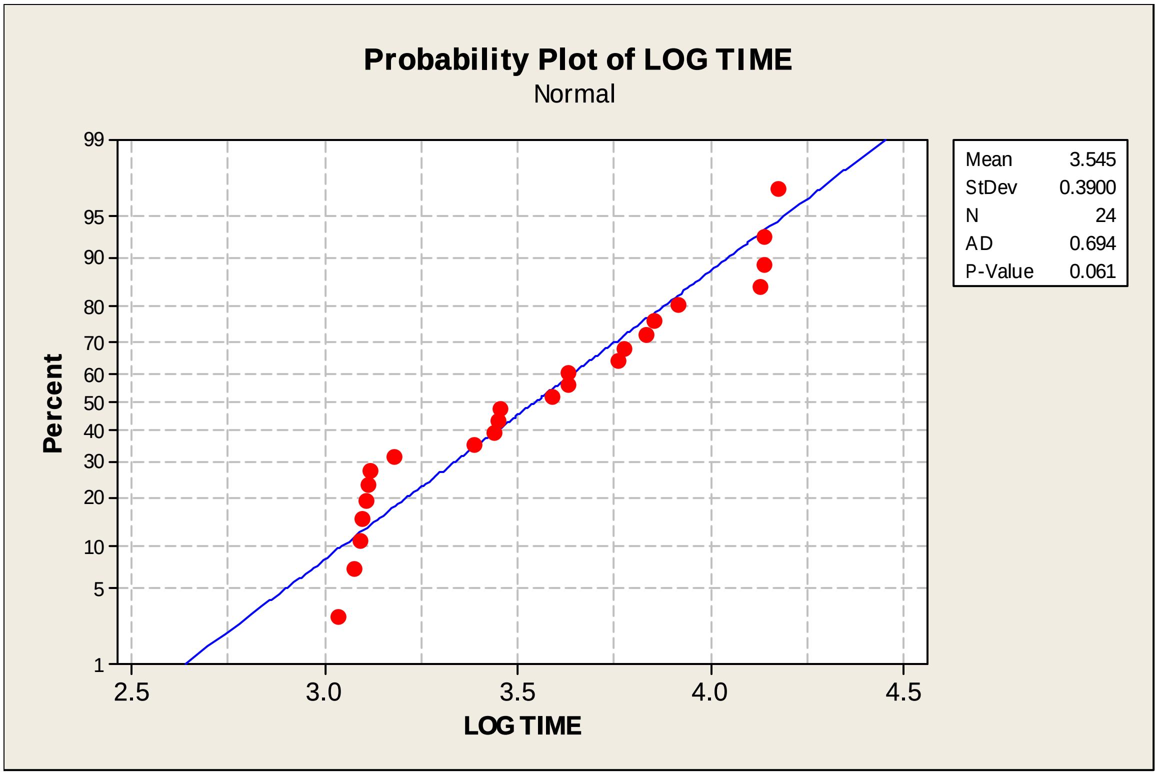


Figure 17: Normality test result of transformed time data

As the probability plot and the p-value (0.061) in Figure 17 show, the transformed time data exhibits a normal distribution.

5.5 CORRELATION ANALYSIS

To determine the relationship among the variables and to explore the possible effects of meeting spaces on the relationships between variables, a correlation analysis was conducted using MINITAB. First a correlation analysis was performed on the variables for each meeting space; then a second was performed with the combined data from all three meeting spaces for each variable. Correlation coefficients from 0 to 0.2 were interpreted as weak correlations, 0.2 to 0.5 as moderate correlations and over 0.5 as strong correlations (Giventer, 2008). The results from the first analyses are shown in Tables 7 through 9. Those from the second combined correlation analysis are shown in Table 10.

Table 7: Correlations between variables in co-located meeting space

	Transformed Time	Satisfaction	Quality (Self)
Satisfaction	0.255		
Quality (Self)	0.113	-0.248	
Quality (Expert)	0.736*	0.225	0.473

*p < 0.05, **p < 0.01

Table 7 shows that for the co-located meeting space, the correlation between expert-evaluated quality and time is strongly positive. The correlations between satisfaction and time, between expert-evaluated quality and satisfaction, and between expert-evaluated quality and self-evaluated quality are moderately positive. The correlation between self-evaluated quality and satisfaction is moderately negative. The correlation between self-evaluated quality and time is weakly positive.

Table 8: Correlations between variables in WebEx

	Transformed Time	Satisfaction	Quality (Self)
Satisfaction	-0.043		
Quality (Self)	-0.496	-0.019	
Quality (Expert)	-0.395	-0.022	0.312

*p < 0.05, **p < 0.01

Table 8 shows that for the WebEx meeting space, the correlations of satisfaction with time, self-evaluated quality with satisfaction and expert-evaluated quality with satisfaction are weakly negative. The correlation between expert-evaluated quality and self evaluated quality is moderately positive. The correlation between expert-evaluated quality and time and between self-evaluated quality and time are moderately negative.

Table 9: Correlations between variables in Wonderland

	Transformed Time	Satisfaction	Quality (Self)
Satisfaction	-0.340		
Quality (Self)	0.474	-0.432	
Quality (Expert)	0.493	0.098	-0.037

*p < 0.05, **p < 0.01

Table 9 shows that for the Wonderland meeting space, the correlations of satisfaction with time and self-evaluated quality with satisfaction are moderately negative and the correlations of expert-evaluated quality with time and self evaluated quality with time are moderately positive. The correlation between expert-evaluated and self-evaluated quality is weakly negative and the correlation between expert-evaluated quality and satisfaction is weakly positive.

Table 10: General correlations between variables

	Transformed Time	**Satisfaction**	**Quality (Self)**
Satisfaction	-0.017		
Quality (Self)	0.064	-0.135	
Quality (Expert)	0.354	0.186	0.244

*p < 0.05, **p < 0.01

Table 10 indicates that expert-evaluated quality has moderately positive correlations with time and with self-evaluated quality, and a weakly positive correlation with satisfaction. Self-evaluated quality has a weakly positive correlation with time and a weakly negative correlation with satisfaction, while satisfaction has a weakly negative correlation with time.

Surprisingly all of the correlations between self-evaluated quality and satisfaction are negative. This suggests that the participants tended to give themselves more credit for the quality of their work when they were not satisfied with the meeting space.

5.6 ONE-WAY ANALYSIS OF VARIANCE

For each dependent variable a one-way ANOVA was conducted to determine the statistically significant differences among the meeting spaces. A confidence level of 95% was used. None of the ANOVA results has a p-value less than alpha (0.05), meaning the null hypothesis, equating all the means cannot be rejected. As a result, Least Significant Difference tests were not performed. The results of the ANOVAs are presented in Tables 11 through 14.

Table 11: ANOVA for transformed time

Source	SS	DF	MS	F-value	P-value
Meeting Space	0.0264	2	0.0132	0.08	0.923
Error	3.4716	21	0.1653		
Total	3.4981	23			

R-Sq = 0.0076

Because $F_{(2, 21)} = 0.08$, $p > 0.05$, the meeting spaces did not differ in terms of time.

Table 12: ANOVA for satisfaction

Source	SS	DF	MS	F-value	P-value
Meeting Space	302.90	2	151.45	3.17	0.063
Error	1003.56	21	47.79		
Total	1306.46	23			

R-Sq = 0.2318

Because $F_{(2, 21)} = 3.17$, $p > 0.05$, the meeting spaces did not differ in terms of satisfaction.

Table 13: ANOVA for self-evaluated quality

Source	SS	DF	MS	F-value	P-value
Meeting Space	77.08	2	38.54	0.49	0.622
Error	1666.75	21	79.37		
Total	1743.83	23			

R-Sq =0.0442

Because $F_{(2, 21)} = 0.49$, $p > 0.05$, the meeting spaces did not differ in terms of self-evaluated quality.

Table 14: ANOVA for expert-evaluated quality

Source	SS	DF	MS	F-value	P-value
Meeting Space	243.75	2	121.88	3.02	0.070
Error	846.88	21	40.33		
Total	1090.63	23			

R-Sq = 0.2235

Because $F_{(2, 21)} = 3.02$, $p > 0.05$, the meeting spaces did not differ in terms of expert-evaluated quality.

CHAPTER 6

DISCUSSION

The statistical results from this study indicate that there is not enough evidence to support the conclusion that the meeting spaces investigated achieve different levels of performance or satisfaction. For this reason descriptive statistics, meeting observation notes, and participants' comments are used to explore possible explanations for this situation.

The lack of any statistically significant differences among the meeting spaces was no doubt in part due to the low statistical power of the study. Although the study included 48 participants, the sample size of the study in terms of teams was eight. The number of qualified potential participants was limited because only students familiar with Ulrich and Eppinger's concept screening methodology were considered for participation in the study.

6.1 TASK COMPLETION TIME

The first research hypothesis addresses the potential difference in task completion time among the three meeting spaces. According to this hypothesis, concept selection tasks are completed more quickly in Wonderland than in WebEx and more quickly in a traditional meeting than in Wonderland. The one-way ANOVA results (Table 11) show that the task completion time did not significantly differ among the three meeting spaces. However, the data collected and the descriptive statistics indicate that the shortest meetings took place in WebEx (Mean = 34.67 minutes). Co-located (Mean = 38.50 minutes) and Wonderland (38.64 minutes) meetings were similar in length and somewhat longer than those in WebEx. It was observed that 6 of the 8 co-located teams did not use a computer, preferring to prepare, fill and compute the screening matrices manually. This may have caused the co-located teams to take more time than expected to complete the task.

6.2 OUTCOME QUALITY

The second research hypothesis suggests that there is no significant difference in the quality variables among the meeting spaces. This hypothesis is supported by the ANOVA results shown in Tables 13 and 14. Although the difference is not significant, both the team members and the expert rated the quality of the results from the WebEx meetings to be the lowest (Figure 8). While quality and task completion time were positively correlated for the co-located and Wonderland meetings, they were negatively correlated for WebEx meetings (Tables 7, 8, 9). That is, for the WebEx meetings alone longer meetings tended to be associated with lower quality results.

6.3 SATISFACTION

The third research hypothesis addresses differences in team satisfaction among the three meeting spaces. The third hypothesis suggests that user satisfaction with a meeting in Wonderland is greater than that achieved through the use of WebEx, but is not significantly different from that achieved through use of traditional meeting rooms. The one-way ANOVA results (Table 12) show that the satisfaction did not significantly differ among the three meeting spaces. The results of this ANOVA ($p = 0.063$) approach significance, however, with the co-located meetings achieving the highest satisfaction ratings of the three meeting spaces (Figure 8), with a mean satisfaction score of 85.43. Wonderland meetings (Mean = 79.81) achieved somewhat higher satisfaction scores than WebEx meetings (Mean = 76.87). The participants' written comments on the subjective satisfaction questionnaires suggest that one advantage of the co-located meeting space is its familiarity. The participants in the WebEx meetings indicated that it was easy to use and facilitated interaction but that the users missed not being able to see each other and did not like having to resize and manage multiple documents to enable everyone to view each other's inputs. Figure 18 shows an arrangement of multiple documents in a WebEx meeting. In contrast Wonderland offered a separate screen for each document, so there was no need to resize and move documents on the screen to make room for others. Figure 19 shows an arrangement of multiple documents in a Wonderland meeting

The level of familiarity and experience of the participants virtual worlds may also have had an impact on satisfaction. All of the participants indicated that they were familiar with computers. None indicated that they were experienced with either virtual worlds or online meetings.

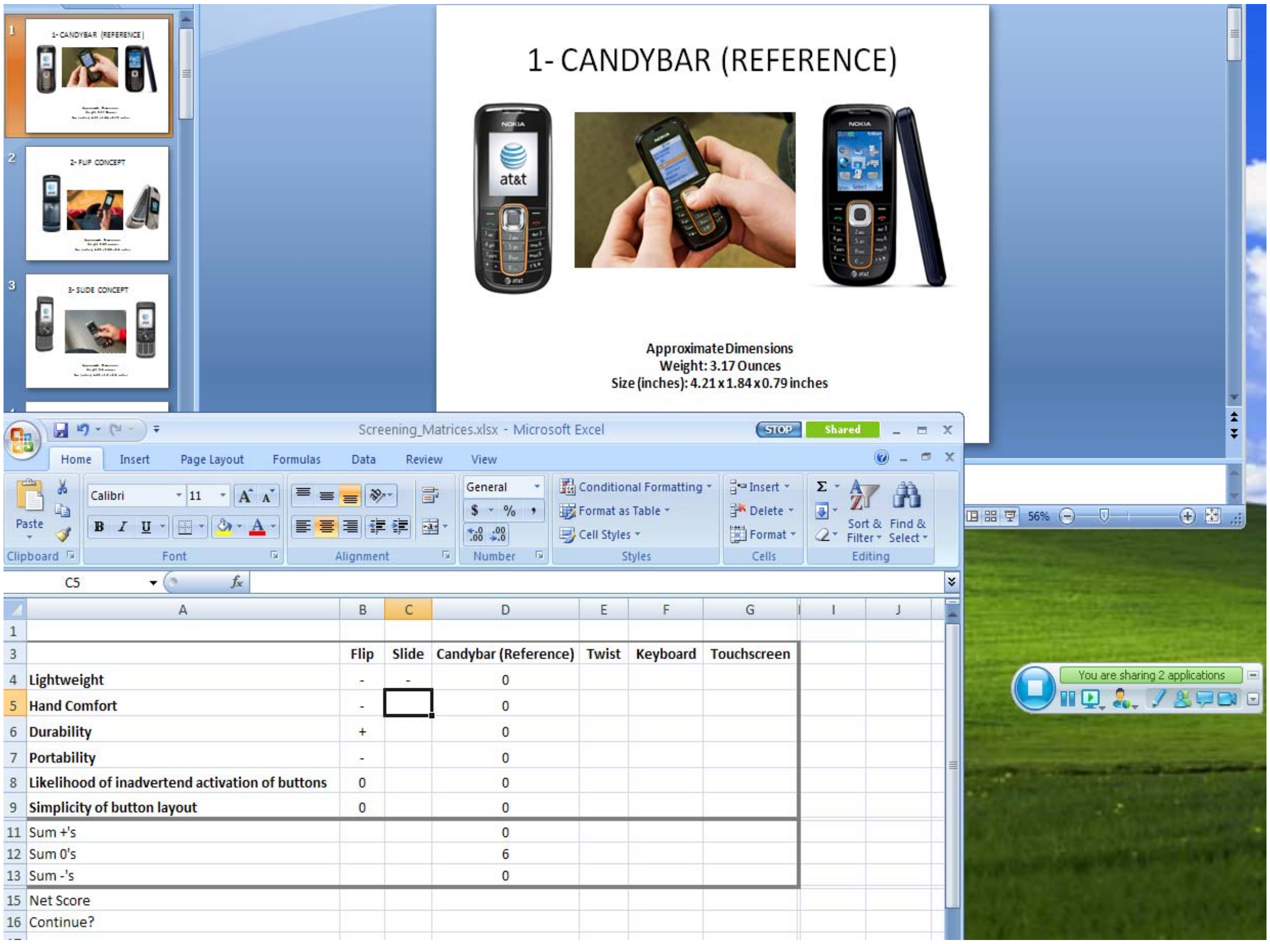


Figure 18: Managing multiple documents in a WebEx meeting

Figure 19: Separate screens for multiple documents in Wonderland

Wonderland participants appeared to enjoy being represented by 3D avatars and liked being able to work on a shared document. They did not like the sluggishness of the application in responding to their inputs, however. This sluggishness was probably due to the computationally intensive nature of 3D virtual worlds relative to 2D applications, such as WebEx.

6.4 IMPLICATIONS

The economic consequences of choosing to meet in one or the other of the meeting spaces investigated in this research depend largely on the locations of the team members and the technological requirements of these meeting spaces.

The most significant cost of face-to-face meetings is travel expenditure. If the team is geographically distributed, the cost may increase dramatically depending on the distances between each team member and the meeting location. If all of the team members are located near the meeting location, the travel cost is not a significant expense. Even in this case, the time required to bring the team members together should be considered as a time cost.

The most significant cost of a WebEx meeting is the cost for a subscription to the service. The service fee of WebEx at the time of the experiment was $69/month per meeting host. Each team member requires a computer and an internet connection, but these are ubiquitous in business today. There is no travel expenditure for WebEx meetings, an advantage for distributed teams.

Wonderland meetings require one computer for each team member and one additional computer for the application. The application, currently in beta, is freely available from Sun Microsystems. Produced as an open source toolkit, Wonderland requires configuration by a programmer if it is to be tuned to provide a specific suite of meeting tools, such as the virtual room, tables, chairs, whiteboard and presentation screen used in this study.

Given the lack of significant differences in performance and satisfaction observed with the meeting spaces investigated in this study, the decision to use one or another may to some extent be dictated by issues of cost and convenience.

CHAPTER 7

CONCLUSIONS AND FUTURE RESEARCH

In this study comparing the effects of three meeting spaces on a concept selection task, statistical analysis did not reveal any significant differences between meeting spaces for the variables of task completion time, satisfaction, self-evaluated quality and expert-evaluated quality.

These results indicate that design teams can perform with similar effectiveness in physical meeting spaces, two-dimensional web spaces and three-dimensional virtual worlds. Thus, 3D virtual worlds can be seriously considered as a collaboration tool to support the work of globally dispersed business and engineering teams.

This study constitutes a first step in the exploration of the application of virtual worlds in business and engineering. Future studies might explore how the effectiveness of these meeting spaces is affected by larger team sizes. How well the different meeting spaces support additional types of group work should also be explored. Variables of the meeting space in a virtual world should also be explored. For example the effect of the use of a shared presentation screen or whiteboard versus providing each team member with their own presentation screens or whiteboards might be studied. In a virtual world, increasing the size of meeting space or the number of tools provided within the meeting space do not add to the cost of constructing the meeting space. These features may be provided solely on the basis of their effect on team performance and satisfaction.

The integration of 3D solid modeling and design tools with virtual worlds might also be explored. With such integration, engineers distributed around the world could conceivably get together in a virtual world meeting room to view, discuss, test and refine 3D virtual prototypes of a proposed product.

Appendix A

Instructions

Task:

1. This is a “concept selection” task, you are asked to select the best cell-phone concept.
2. You will select the concept based on 6 selection criteria.
3. These selection criteria only contain physical features of the cell-phone concepts.
4. Initially, you will be given 6 cell-phone concepts with pictures and approx. dimensions.
5. Please *do not* focus on the brands or technological features of the cell-phone concepts.

Method:

1. You are asked to use *concept screening* matrices to select the best concept.
2. These matrices contain the concepts and selection criteria.
3. One of the concepts is selected as reference.
4. Other concepts are compared to the reference concept for each selection criterion
5. The team rates the concept against the reference concept using ‘+’ for “better than,” ‘0’ for “same as,” and ‘–‘ for “worse than” in order to identify some concepts for further consideration. The reference concept is given (0) for each selection criteria.
6. A relative score of “better than” (+), “same as” (0), or “worse than” (-) is placed in each cell of the matrix to represent how each concept rates in comparison to the reference concept relative to the particular criterion..
7. After rating all the concepts, the team sums the number of (+), (0) and (-) scores and enters the sum for each category in the lower rows of the matrix.
8. Having rated and ranked the concepts, the team should verify that the results make sense and then consider if there are ways to combine and improve certain concepts.
9. Once team members are satisfied with their understanding of each concept and its relative quality, they decide which concepts are to be selected for further refinement and analysis.
10. The team creates another screening matrix including the selected concepts, selects a reference concept and performs the same rating, ranking, combining and improving steps iteratively.

Meeting Space:

Your meeting space will be introduced and explained by the co-investigator of the research via word-of-mouth.

After the Task

Following the completion of the task, you will be given two questionnaires. One of them is a satisfaction questionnaire which asks ten questions about your satisfaction with the meeting space. This satisfaction questionnaire will be filled out by each team member. The other one is a task questionnaire which asks ten questions about your task completion process. The task questionnaire will be filled out by the team.

Thank you for participating in this study.

Appendix B

Concept Selection Process Observation Results

1. Did the team discuss all of the initial concepts? Yes(___)   No(___)

   Number of concepts discussed by the team: ___

   Comment:

2. Did the team look at the negatives of the strong concepts and discuss how to improve them? Yes(___)   No (___)

   Number of concepts discussed by the team: ___

   Comment:

3. Did the team look at the weak concepts and discuss whether it would be possible to improve them? Yes (___)   No (___)

   Number of concepts discussed by the team: ___

   Comment:

4. Did the team decide whether another round of concept screening was appropriate? Yes (___)   No (___)

   Comment:

5. Did the team members discuss whether everybody was comfortable with the outcome?

Yes (___)   No(___)

   Comment:

Appendix C

User Profile

Please provide the following information.

1. Age: _____ years.

2. Gender: Female ☐   Male ☐

3. Have you completed IE 201 or IE 801?

    Yes___   No___

4. Did you learn how to carry out the concept selection (concept screening) process in that course?

    Yes___   No___

5. Have you ever participated in an online meeting?

    Yes___   No___

6. Do you have any experience with three dimensional virtual worlds? (e.g., video games such as World of Warcraft or virtual worlds such as Second Life)

    Yes___   No___

Appendix D

Subjective Satisfaction Questionnaire

Please provide the following information.

1. It was easy to understand how to use this meeting space.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

2. It was easy to interact in this meeting space.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

3. It was easy to share documents in this meeting space.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

4. It was time consuming to get together in this meeting space.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

5. It was easy to adapt to working together in this meeting space.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

6. It was easy to perform the task in this meeting space.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree | Neutral | Strongly Agree

7. It was boring to work in this meeting space.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree | Neutral | Strongly Agree

8. I am satisfied with what the team accomplished by performing its task in this meeting space.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree | Neutral | Strongly Agree

9. I would rather meet using another method.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree | Neutral | Strongly Agree

10. Overall, the team had an efficient and successful meeting and the team accomplished what it set out to do.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree | Neutral | Strongly Agree

If you have additional comments please write them down in the space below.

Appendix E

Concept Selection Process Questionnaire

Please provide the following information.

1. The team discussed all of the initial concepts.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

2. The team established a concept screening matrix which compared the generated concepts, one with the other, in terms of the criteria for evaluation.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

3. Each concept was compared against the reference concept and rated as 'better' (+), 'worse' (-) or 'the same' (0) on each selection criterion.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

4. The individual concept scores were assessed by the team.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

5. The team looked at the negatives of the strong concepts and discussed how to improve them.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

6. The team looked at the weak concepts and discussed whether it would be possible to improve them.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

7. The team combined and improved concepts.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

8. Team members decided which concepts were to be selected.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

9. The team decided whether another round of concept screening was appropriate.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

10. Team members discussed whether everybody was comfortable with the outcome.

0 1 2 3 4 5 6 7 8 9 10

Strongly Disagree — Neutral — Strongly Agree

If you have additional comments please write them down in the space below.

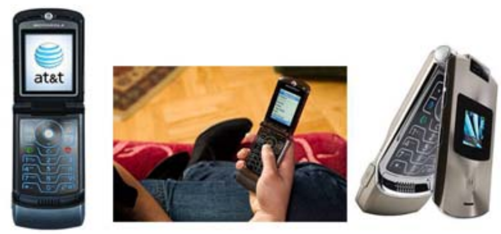
Appendix F

INITIAL CONCEPTS

1- CANDYBAR (REFERENCE)

Approximate Dimensions
Weight: 3.17 Ounces
Size (inches): 4.21 x 1.84 x 0.79 inches

2- FLIP CONCEPT



Approximate Dimensions
Weight: 3.83 ounces
Size (inches): 4.05 x 2.08 x 0.6 inches

3- SLIDE CONCEPT

Approximate Dimensions
Weight: 3.6 ounces
Size (inches): 4.05 x 1.9 x 0.6 inches

4- TWIST CONCEPT

Approximate Dimensions
Weight: 2.5 ounces
Size (inches): 3.3 x 1.18 x 0.78 inches

5- KEYBOARD CONCEPT

Approximate Dimensions
Weight: 4.73 ounces
Size (inches): 4.65 x 2.63 x 0.47 inches

6- TOUCHSCREEN CONCEPT

Approximate Dimensions
Weight: 4.34 ounces
Size: 4.4 x 2.24x 0.52 inches

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