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FACTORS IMPACTING USAGE PATTERNS OF COLLABORATIVE TOOLS DESIGNED TO SUPPORT GLOBAL VIRTUAL DESIGN PROJECT NETWORKS

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EDITOR: Turk Z.

Josh Iorio, Post-Doctoral Research Scientist
Columbia University, Project Network Dynamics Lab
ji2175@columbia.edu

Gabriel Peschiera, Research Assistant
Columbia University, Dept of Civil Engineering and Engineering Mechanics
gsp2107@columbia.edu

John E. Taylor, Assistant Professor
Columbia University, Dept. of Civil Engineering and Engineering Mechanics
taylor@civil.columbia.edu

Lasse Korpela, Technical Assistant
Helsinki University of Technology, SimLab Enterprise Simulation Laboratory
lasse.korpela@tkk.fi

SUMMARY: *The purpose of this paper is to highlight some of the competing factors that impact the usage patterns and adoption of collaborative tools designed to support global virtual collaborative work. Through an analysis of frequency data and recorded interactions, we present findings from a semester-long study of design collaboration in the CyberGRID (Cyber-enabled Global Research Infrastructure for Design), a virtual collaborative space developed in Second Life to support design work in global virtual networks. We discuss tools designed to facilitate the collaborative interaction of seven global virtual networks of designers composed of students from The University of Twente (The Netherlands), Columbia University (United States), the University of Washington (United States), The Indian Institute of Technology – Madras (India) and the Helsinki University of Technology (Finland). Each domestic team was responsible for one component of an integrated design task including the creation of a work schedule, 3D building model, 4D model mapping the work schedule to the 3D model, and a cost estimate. We demonstrate that a number of factors impact tool usage patterns and adoption, including the simplicity of the tool, whether the tool promotes group cohesion, the emergent need for the tools, and local factors specific to the experiences of the domestic teams. We conclude with a discussion of the viability of Second Life as a platform for virtualizing the engineering workforce and highlight challenges of researching and developing tools to support global virtual networks of designers executing complex projects.*

KEYWORDS: *collaboration, design, project networks, virtual teams, virtual worlds*

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1. INTRODUCTION

A growing number of engineering firms are outsourcing complex design work to international vendors (Joseph 2005; Messner et. al. 2007; Nayak and Taylor 2009). Due to the significant geographic distances that can separate clients from vendors in global design networks, much of this work is executed in virtual teams. International design teams are thus faced with the challenge of achieving effective virtual collaboration across spatial and cultural boundaries on projects of increasing complexity. In order to address the intricate interdependencies associated with these collaborative design efforts, teams must be able to synthesize diverse perspectives, leverage cross-disciplinary ideas, transfer knowledge, and understand design decisions that influenced the design development (Fischer 2006).

Moreover, teams must have adequate tools to successfully manage and execute project complexities in parallel. In order to facilitate complex interdependent tasks, technologies must be capable of supporting frequent interactions and meetings (Daft & Lengel 1986); participant awareness of, access to, and relation to the design work of others to their own (Fischer 2006); and real-time activities that enhance the work of co-located designers such as informal, spontaneous, or coincidental exchanges of information that are lacking in globally distributed work (Kraut et al. 2002). In fact, real time distributed virtual interaction is critical for timely and rapid iterative design, brainstorming and problem solving tasks (Fruchter 2005). To date, very few technological options exist that provide *all* of these functionalities to distributed networks.

Commonly used tools such as email, instant messaging, and teleconferencing do not provide a framework for interaction that fully satisfies the demands of geographically distributed projects. For instance, tele- or web-conferencing facilitates real-time interaction between participants working in distributed networks, but meetings are typically formal and planned in advance, which does not afford the type of “ubiquitous and serendipitous” interactions that Ruikar, Anumba & Duke (2008:167) argue is important for effective construction project delivery. Email and other asynchronous communicative modes facilitate informal knowledge exchange, but do not afford spontaneous real-time interactional capability, which Hinds & Mortensen (2005) argue is critical for resolving conflicts between teams working in distributed networks. Synchronous chat platforms provide for informal and spontaneous collaboration, but because network participants interact solely through text, shared context is difficult to establish, which negatively impacts the development of shared understanding (Rennecker 2004). Crucially, the types of collaborative tools that have been employed to facilitate distributed work do not support the development of trust fundamental to the success of global networks executing complex, interdependent tasks (Sonderegger 2007; Child 2001). They also do not afford the ability to use descriptive gestures, which provides network participants with a feeling of being in a cohort (Johnson, Heimann & O’Neill 2001).

In efforts to develop better systems of global collaboration that answer some of these deficiencies, many companies are leveraging virtual worlds to facilitate distributed design work. Besides proving attractive to corporations, virtual environments also provide researchers with the opportunity to record and analyze the complex and nuanced interactions of global virtual collaborations. The resolution of data on interactions in virtual worlds far exceeds what can be practically tracked in non-digital spaces, even when project team members are collocated. Bainbridge (2007) notes that virtual worlds provide great sites for social, behavioural, economic and human-computer interaction research finding that “a number of organizations hold meetings in SL [Second Life], from IBM to informal friendship groups, but it is unclear what enhancements are needed to make it a really good environment for serious distributed collaborations of the kinds often undertaken by scientists” (2007: 475).

Second Life (SL) is the overwhelming platform choice of virtual world developers in a variety of industries including education (Warburton 2009), medicine (Boulos, Hetherington & Wheeler 2007), psychology (Gorini et al. 2008), business (Cagnina & Poian 2009), and AEC (Traum 2007). SL is an appealing choice for researchers and industry members interested in employing virtual workspaces as spaces for distributed work because the platform allows for relative ease in customizability and the availability of already existing collaborative tools such as virtual whiteboards, voice and text chat, and scheduling agents. However, it is not the case that conducting distributed work in SL is without its challenges. A number of studies report that while SL is easily customizable, users often face significant learning curves (e.g. Chang et al. 2009, Bessiere, Ellis & Kellogg 2009), which negatively impact the ability of the distributed network to function efficiently. In spite of the protracted learning curves associated with SL, it retains its market dominance as the most viable, open-source virtual workspace application. Based on a survey of educators using virtual worlds in their instruction, the New Media Consortium reports that 95% (207 out of 219 respondents) use SL as the virtual learning environment (NMC 2010). Our motivation for the project described in this paper is to develop and study Second Life (SL) enhancements in support of global virtual design collaborations.

A vast amount of literature has examined what is required to develop and maintain high performing distributed virtual teams (Avolio & Kahai 2003; Priest et al. 2006; Zacarro et al. 2004; Zacarro & Bader 2003; Zigurs 2003). However, research on virtual organizations and global virtual teams has focused largely on *asynchronous team interactions* (e.g., via email) or *short-term synchronous interactions* (e.g., via web conferences) while generally neglecting the potential of extended synchronous collaboration possible through virtual workspaces. It is these types of long-term interactions that are typical in industry settings. Conversely, efforts have been made to understand the nature of avatar interactions in virtual environments like SL but little research has investigated how geographically distributed teams could use the environment in support of project collaboration (Friedman et al. 2007; Bailenson et al. 2003; Benford et al. 1995). Researchers have examined the dynamics of interactions in these worlds, the potential for these spaces as settings for qualitative behavioural studies, and the underlying technology of virtual worlds but there has not been a concerted effort to understand how global virtual design workers can best exploit collaborative tools employed in the virtual space, and furthermore, what kind of technology needs to be in place so that researchers can extract valuable conclusions on the nature of virtual collaboration (Castronova 2005; Castronova & Falk 2008; Markham & Baym 2008; Orgad 2008; Priest et al. 2006; Rennecker 2004).

There is a great deal of potential for virtual world tools that satisfy the needs of globally distributed networks of engineers working on increasingly complex projects while enabling refined research analysis on global virtual collaboration. Yet there has been little research focused on examining how tools developed in support of global networks are used, and perhaps more fundamentally, how we can encourage their adoption. For instance, Chang et al. (2009: 14-15) report that participants had positive experiences using collaborative tools in SL because the virtual setting and supporting tools afforded "scheduling flexibility" and "saved on travel time", but the authors do not provide an analysis of the relationship between the functionality afforded by the tools and how the tools were used to facilitate the collaborative process. However, the authors admit that they had difficulty in developing "user-friendly collaboration tools". This statement implies that use of the collaborative tools may have been problematic for project participants, but that their overall experience in the virtual context was positive. This example is consistent with other approaches to studying collaboration in virtual teams in that researchers typically focus effort on analysing the experience of distributed network participants with little consideration for how specific tools utilized in the virtual workspace either contribute to or detract from effective collaborative practices. To address this gap in the literature, Shneiderman (2007: 26) suggested that researchers move past "old strategies of controlled studies and short-term usability testing to embrace ethnographic styles of observation, long-term case studies, and data logging to understand patterns of usage". By understanding the relationship between patterns of usage and effective work practices, researchers gain insight into how distributed networks can best be supported through the evolution of collaborative tools designed to address many of the interactional deficiencies of virtual workspaces.

This paper will examine how a suite of collaborative tools are used by global network participants to support distributed work and perhaps more fundamentally, how to encourage tool adoption. This paper will examine the use of a suite of tools developed to support globally distributed networks of design teams in the CyberGRID (Cyber-enabled Global Research Infrastructure for Design), a virtual collaboration and research environment in SL. The CyberGRID was developed as a joint effort between the Helsinki University of Technology's *Computer Science and Information Networks Department* (SimLab) and Columbia University's *Project Network Dynamics Lab*. It was designed to support synchronous and asynchronous collaboration across globally distributed networks where teams engage in iterative design processes. Teams were composed of students enrolled in graduate level design courses in 4 countries. While the CyberGRID was developed to support the work of geographically distributed *design* networks, the collaborative tools integrated into the CyberGRID can be employed by a variety of disciplines where effective collaboration is dependent on the ability of team members to share points of reference in space. For instance, geographically distributed project managers creating a process map must be able to refer to stages of the map and be assured that their collaborators share the same point of reference. Without the ability to bring the map into the virtual space, collaborators must create alphanumeric designations for each stage of the project and refer to stages by these designations. When maps are imported into the virtual space, collaborators can "point" to the relevant stage, thus more efficiently creating a shared reference. Similarly, in designing a 3D CAD model, designers can refer to the north-facing exterior wall of a particular building design through a visual indication as opposed to describing the orientation of the wall in detail to assure a shared reference. One of the key motivations in designing the CyberGRID enhancements to SL was to allow users to create a shared point of reference in the virtual space, which is critical in developing a sense of shared context that Hinds & Mortensen (2005) argue facilitates effective conflict management in distributed teams.

Developers of virtual collaboration tools make assumptions about how they expect tools to be used, especially when the tools are designed in response to existing research that motivates their development. Armed with research that demonstrates a need for a particular type of functionality that a tool will provide and because these functionalities have been demonstrated to facilitate effective collaboration, designers expect these tools to be adopted by users engaged in collaborative endeavours. For instance, CyberGRID developers understood the challenges that differing time-zones pose for distributed collaboration. Thus, they assumed that collaborators would use an integrated web-based calendaring agent to facilitate the management of scheduling conflicts that can potentially occur when project team members are distributed across a wide variety of international time zones. Yet, this calendaring tool was never used throughout the semester-long testing phase. In this case, the expectations for tool use by the developers mismatched the observed tool use among the collaborators. Since the functional need to manage schedules across time-zones existed and had to be addressed, participants opted to use email to manage scheduling discrepancies as opposed to the scheduling agent. It is through an analysis of tool use patterns that researchers can develop a better understanding of why certain tools are adopted while others are rejected. Research on technology adoption posits that a variety of factor types impact adoption of new technologies including social factors (Vannoy & Palvia 2010) and factors related to perceived usefulness and ease of use (Davis 1989). It is clear through this simple example that the functional value that developers and researchers place on particular tools may be at odds with usage patterns as users to play a more active role in developing their own norms for technological use (Baron et al. 2006). By studying how tool use diverges from expectation and the processes through which usage norms emerge, we enhance our understanding of virtual collaboration more broadly as we explore how tools are adopted and potentially adapted by users to meet their interactional and collaborative needs.

This paper is primarily concerned with answering the following research question: What factors impact the use of tools designed to support virtual collaboration of globally distributed networks of engineers executing complex design projects?

2. DEVELOPING VIRTUAL TOOLS FOR COLLABORATION AND RESEARCH

The previous section discussed: 1) the need for virtual tools to support global networks of designers, and 2) a lack of research on tools designed to support long-term, synchronous design collaborations. We developed the CyberGRID, a virtual suite of collaboration and research tools based on the SL platform, in order to study how best to support geographically distributed cross-cultural design work. The SL Platform has a number of advantages. First, the open-source, highly modifiable virtual space allows for developers to begin from an already existing framework as opposed to building all of the basic virtual functionality from scratch (e.g. voice chat, walking, camera, GUI). SL offers relative flexibility for developers as well as easy installation and space navigation for users. However, as we will demonstrate, many of the positive aspects of building virtual workspaces in SL are counterbalanced by limitations of the SL platform, particular in regard to use of collaborative tools.

After a year of development and testing, five faculty members from universities in four countries agreed to integrate the CyberGRID into their engineering and architecture courses in Spring 2010. These courses were attended by 88 undergraduate and graduate students at *Columbia University* and *The University of Washington* in the United States, *Helsinki University Technology* in Finland, *The Indian Institute of Technology – Madras* in India, and *The University of Twente* in The Netherlands. Seven global virtual project networks were assigned by faculty and were composed of student teams from each of the participating universities. The purpose of the collaboration was to investigate how geographically dispersed cross-cultural networks of designers used the CyberGRID to complete a complex design project. Each global project network of designers was assigned a project that could only be successfully completed through collaboration between the domestic teams. The projects required global networks of designers to create building designs that consisted of four interdependent components: 1) a work schedule that was created through collaboration with a local industry sponsor, 2) a 3D model of the building, 3) a 4D model that maps the schedule to the 3D model, and 4) a cost-estimate of the construction process. Because modification to any component necessarily requires modification to all or some of the other components, this research setting is ideal to investigate how collaboration is mediated through the CyberGRID tools. Within each global project network, domestic teams of designers were each responsible for one component of the task, e.g. the Columbia University teams were responsible for creating the work assignment schedule in their global project network while the Indian Institute of Technology team was responsible for developing the 3D model. As domestic teams worked locally on their project components, the assembled global project network comprised of the domestic teams met weekly for two hours in the CyberGRID to collaborate on task integration. This paper reports on emergent barriers to adoption during these collaborations.

The SL platform contains a number of built-in collaborative features such as text and voice chat, which provide the synchronous communication modalities that Kraut et. al. (2002) argue are required for effective virtual collaboration on complex interdependent tasks. In addition to standard SL features, we developed and integrated new features into the CyberGRID that are designed to facilitate the complex design work of the assembled global project network more effectively. These tools focus on providing globally distributed designers with the ability to: 1) visualize their designs in the virtual space, 2) share documents, 3) organize meetings, and 4) hold effective discussions. Moreover, the tools are designed to provide designers with two macro-level functionalities that are crucial to successful virtual collaboration: 1) social functionality and 2) communicative functionality. Social functionality serves to aid teams in building rapport and minimizing interpersonal conflicts while communicative functionality aids teams in effectively transferring knowledge between members. Sections 2.1 through 2.3 describe the development and implementation of these collaborative tools.

2.1 Team Screen

A *Team Screen* was developed so that local teams could share visual information in real-time within the virtual work rooms. The tool serves both as a project information portal and as a virtual world version of the overhead projector. Through this interface, students can share screenshots, broadcast their own screen, and share quick sketches. *Fig. 1* is a screenshot of a Simvision schedule projected from a user's desktop onto the Team Screen in a CyberGRID meeting room.

Successful collaboration on complex design work requires the designers to be able to have a shared view and point of reference when referring to their designs. Ideally, 3D models could be imported into the virtual environment as a shared focus of discussion. However, one of the drawbacks to the SL platform is that it does not support the straightforward import of 3D and 4D models into the virtual space. While *programmers* familiar with SL can import these models into the virtual space, *typical users* cannot. It is this type of shared visualization functionality that has been absent from previous studies of global collaboration.

In order to provide participants with the ability to reference a shared image, we created functionality for the Team Screen that allows for near-synchronous sharing of a user's desktop. This functionality allows the user to play a 4D model on their desktop, which is then broadcast onto the Team Screen in the virtual meeting room.

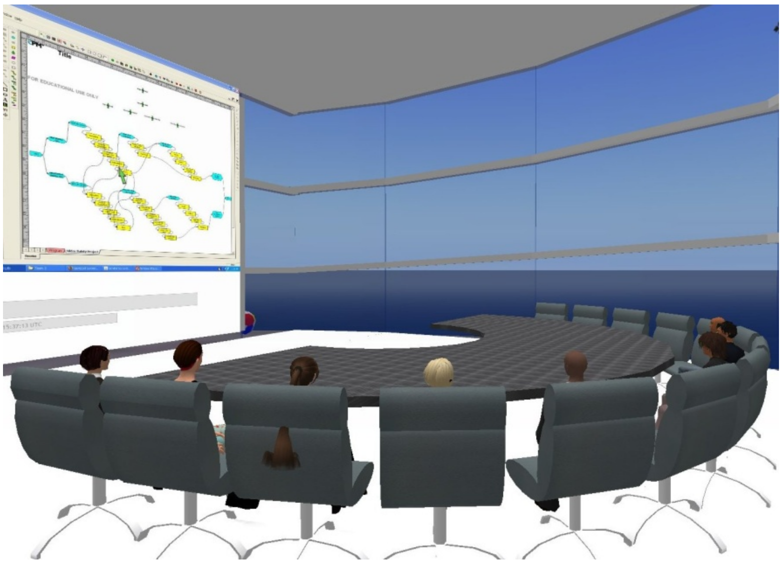

Fig. 1: Team Screen Desktop Broadcast of a Simvision Model

A larger Team Screen was also incorporated into the meeting rooms to accommodate a *process map*. The process map was modifiable and allowed facilitators to: 1) establish project timelines and milestones, 2) reference the relevant position in the timeline with a user-controlled pointer arrow, and 3) ensure that each of the domestic teams understood how their component contributed to the overall goals of the global design network. *Fig 2*. is a screenshot of a CyberGRID meeting room, including the Team Screen (center) and Process Map (right).

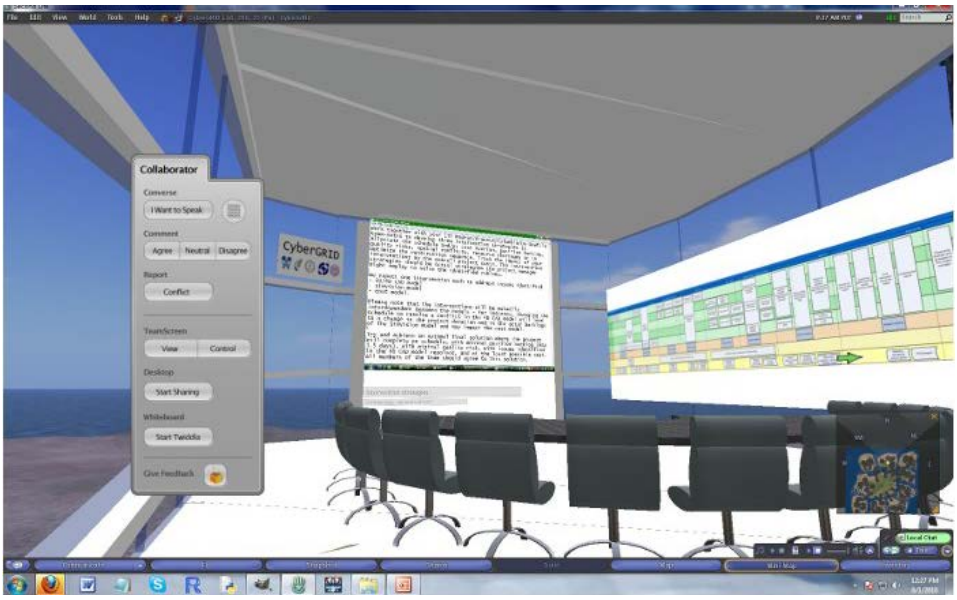

Fig. 2: Screenshot of CyberGRID Meeting Room

2.2 Collaborator

The *Collaborator* (c.f. *Fig. 2* and *Fig. 3*) is a Heads-Up Display (HUD) object we created that has been incorporated into each participant's SL interface. The Collaborator provides a number of functionalities designed to facilitate collaboration in the virtual space. First, through the Collaborator, users control the Team Screen, allowing them to share their own desktop and view other users' shared desktops. Additionally, the Collaborator allows for anonymous feedback to be sent to the design team, allowing for the user to contribute to the iterative development of future versions of the tool.

Fig. 3: Collaborator Tool HUD

The Collaborator also allows users to access four *thought bubbles*, which each indicate a different notion. When pressed, the *I want to speak* button causes a white thought bubble to appear over an avatar's head (see *Fig. 4*), which is the virtual equivalent to raising one's hand in a classroom or a meeting in physical space. The longer the bubble is active, the faster it spins, which gives other meeting attendees a visual indicator about who has waited the longest to speak. The purpose of this bubble is to help establish turn-taking norms in the virtual space, as physical indicators such as eye-contact and other body gestures that are typically used to facilitate turn-taking in physical settings (Gurevitch 1998) are absent.

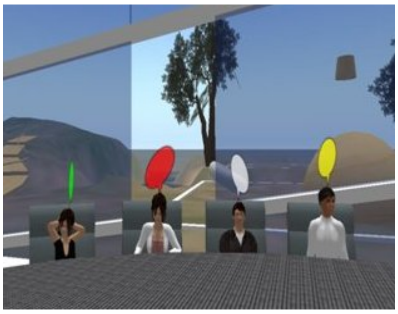

Fig. 4: Thought Bubbles

The Collaborator also allows users to voice an opinion through a traffic light system of thought bubbles. In this system, a green bubble indicates agreement and red indicates disagreement. Yellow indicates neutrality. *Fig. 4* shows how the different thought bubbles are graphically distinguished in the CyberGRID. Because the bubbles are easily distinguished and visually represented, they serve to facilitate quick decision-making as users can indicate their agreement or disagreement with a particular course of action, inclusion of a suggested design element, or strategy for resolving conflicts between interdependent tasks. Through the use of the thought bubbles, users are able to visually indicate a point-of-view, which allows the participating group of designers to quickly assess the level of consensus about a particular topic, thus enhancing collaborative efficiency.

2.3 External Services

Both the Team Screen and Collaborator were designed by the CyberGRID research team because existing tools lacked the functionality for virtual workers to share their designs in real-time. However, a number of either free and/or open-source collaborative tools were already developed for collaboration on the internet, so many of these tools were incorporated into the CyberGRID. These add-ons were chosen in order to provide functionality critical to successful complex design work, e.g. document sharing, shared real-time note-taking and sketching, and longer-term meeting organization and scheduling functionality. The remainder of Section 2.3 describes these add-on services and discusses their intended use.

Team members created *Digital Dropbox* (http://www.dropbox.com) accounts so that users could share documents associated with the domestic and global tasks. Dropbox is a free, web-based file sharing tool that supports versioning and document storage up to 2GB. Larger storage quotas can be purchased for a fee. When the Dropbox software is installed, the program allows for the synchronization of documents across users' hard drives, which ensures that the accessed version is the most current. This type of functionality is crucial for designers working collaboratively and iteratively to create documents or designs because it allows for different members to work on documents at different times without having to create a versioning system from scratch.

Twiddla (http://www.twiddla.com) was introduced to provide the participants with whiteboard functionality. Users are able to share and collaborate on sketches in their web browsers, which is projected in real-time onto the room's Team Screen. Simple text can also be created in Twiddla, which allows for meeting notes to be projected and saved. Notes can then be uploaded to the Dropbox for archiving or review. Since the assembled networks of designers were engaged in complex *design* tasks, the whiteboard functionality allowed users to draw simple objects and have the objects projected in the virtual space for a shared point of reference during a discussion.

A *Virtual Knowledge Repository* (ViKR) was created using *Proboards* (http://www.proboards.com), a free, web-based message board service. The ViKR affords participants with the ability to communicate asynchronously. Because sub-teams are located in different time-zones, it is important that they are not bound to interactions at only certain, pre-defined points of the day. By providing asynchronous communicative modes like the ViKR, participants are able to pose questions, add items to an agenda, or suggest a revision to a document regardless of the local time for their global collaborators. While past research (Hinds & Mortensen 2005) has demonstrated that asynchronous communication modes are insufficient for effective collaboration on complex design work, these modes have not been investigated as means to *support* work conducted primarily through other modalities.

All of the external services used to complement the functionality built into the CyberGRID are either open-source or free of charge. While industry applications of similar tool suites may require more control over the 3D environment, for many research programs, open-source software is preferable to proprietary options because open-source tools can be extended, updated, and revised by *all* other scholars interested in studying global virtual collaboration, regardless of whether they have received funding for long-term research and development into global virtual collaborative spaces. In effect, using open-source development tools allows the design of virtual collaborative spaces that can be easily replicated, which is a first step toward theorization of how complex design work is enacted in virtual spaces.

To this point, the discussion has focused on CyberGRID functionality that is designed to support collaboration between global virtual networks of designers executing complex projects. Our other focus is on tool development that facilitates *research* on global virtual collaborative interactions that occur within the CyberGRID. We turn now to a discussion of the functionalities designed to aid in the collection and analysis of data produced in the CyberGRID.

2.4 Automated Recording System

In addition to the collaborative tools designed for the CyberGRID, research tools were also designed to aid in the collection, processing, and analysis of the data generated. One of our goals in designing the CyberGRID is to be able to develop effective new methods of studying network interactions of globally distributed engineers in virtual environments. Virtual environments have the advantage over physical environments as research sites because data can be collected *automatically* and with relative ease. Because of these two points, research on virtual interaction has the potential to produce very large data sets. The findings reported below are based on 112 hours of virtual interactions. In order to effectively research global virtual design collaborations, the data collection process has to be controlled because of the potential for collecting large amounts of “empty” data, i.e. data that is either uninterpretable or unrelated to the research questions. Accordingly, the research tools described below all serve to automatically reduce the amount of data that eventually are analyzed by the researcher.

An automated system of audio and video recording was developed to record avatar interactions without storing all of the inactive time in the CyberGRID when users were not present. This system is activated by avatar movement. When two avatars enter the meeting area, the recording server is triggered. Because the system is designed to selectively record interaction, the total amount of analyzable video and audio recordings is reduced, which makes coding more efficient for researchers.

Recorded interactions include both audio and video of the virtual space as well as additional information about the users and avatars that is recorded in a searchable and sortable database.

2.5 Tool Use Database

The *Tool Use Database* identifies every instance when one of the Collaborator tools is clicked and makes a notation in a MySQL (http://www.mysql.com/) database. Each use of the Collaborator tool is associated with a time stamp that corresponds to the time in the audio/video recording when the tool was used. Specifically, the database contains entries for the following:

- Chat logs
- Logout/login for each avatar
- Location of the avatar in the virtual space
- Gaze, i.e. 3D coordinates indicating the direction the avatar is looking
- Thought Bubbles
- Team Screen usage
- Uploaded screenshots

In other words, the tool use database maps any action taken by avatars in the virtual space with the timeline present in the video recordings, which allows researchers to make associations between the quantitative tool use frequency counts noted in the database and socially or organizationally meaningful interactions identified through qualitative analysis of the video data. Researchers are able to first scan the database looking for potentially interesting patterns between interaction and tool use, which then focuses any subsequent analyses on specific points in the video data identified through the database scan. This process facilitates an efficient approach to managing the data created through virtual collaborative interaction.

2.6 Research Interface

Once all of the data has been collected, the tool use database is synchronized with the audio/video recordings to port all of the collected data into a web-based *research interface*. The research interface was developed to display and analyze recorded information in its video and audio context. This interface shows meeting videos associated in real-time with information in the database as it is occurring in the recorded interaction. For example, *Fig. 5* shows a screenshot of the research interface as it maps a user-reported conflict and thought bubble use with the video at the top of the screenshot. Researchers are able to play the video and observe as the interface reports relevant entries from the database.

Fig. 5: Screenshot of Web-based Research Interface

As with automated recording, the research interface serves to organize and pre-process the large amount of data collected in the CyberGRID. The interface facilitates both qualitative and quantitative analyses because it maps the qualitative data of the recorded videos to the quantitative frequency data stored in the database.

3. COLLABORATIVE TOOL USE IN THE CYBERGRID

Having described the collaboration and research tools developed for the CyberGRID, we turn now to a discussion of tool use with a focus on explaining why certain tools were successfully adopted while others were rarely or never used. We present qualitative accounts of tool use based on end-of-semester reports that included reflection on tool use and researcher review of the virtual interactions combined with quantitative tool use frequency data extracted from the database. Though both qualitative and quantitative analyses of interactions in the CyberGRID, we will discover the patterns of tool utilization by the global virtual design project networks and how they developed norms for tool usage. We will also discover some of the challenges that exist for designing tools to research the collaborative interactions.

From a generalized perspective, all of the teams were successful in that they submitted four completed sub-components of the project (i.e. work schedule, 3D model, 4D model, and cost estimate). *Fig. 6* shows designs created by four project groups through their collaborative interactions in the CyberGRID. The quality of the models suggests that the suite of CyberGRID tools achieved its purpose, i.e. that the tools helped to facilitate the global virtual collaborative process.

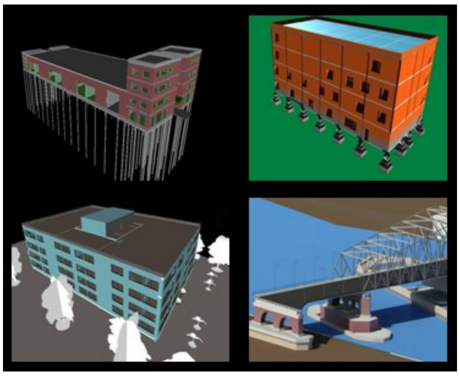

Fig. 6: Models Created by Global Design Project Networks in the CyberGRID

3.1 Finding 1: Tool use may be based on an emergent functional need.

In most cases, the functionality afforded by a particular tool is directly related to its intended use. In these cases, tools are typically adopted early in the lifespan of the collaboration. For instance, the assigned projects required the ability to share documents, so Digital Dropbox was adopted from the first day of interaction as the normative method for doing so. In other cases, tool adoption emerged over time. We turn now to an example of how the designers adopted new communication tools to address needs that arose based on challenges introduced by working in a virtual context. We describe how participants adopted the use of text chat as a response to the periodic difficulties with voice technology.

The CyberGRID has basic voice and text communicative modalities built into the SL platform. Through these two modalities, users are able to speak with each other or exchange *synchronous* text messages. In Section 2.3, we discussed our efforts to augment these communicative modalities by introducing a third modality, i.e. the *asynchronous* textual functionality afforded by the ViKR message board. The purpose of introducing the asynchronous option was to help support the resolution of scheduling conflicts that could emerge because of differences in the local times between the domestic teams. Additionally, the asynchronous option was incorporated into the CyberGRID so that students could share knowledge at any point throughout their day, regardless of the local time for other participants.

Based on analyses of the chat logs that are automatically recorded into the CyberGRID database combined with the manually extracted ViKR message board posts, it is evident that participants are using the two modalities to serve different functions. *Table 1* shows the top five trigrams for the asynchronous and synchronous text modes. *Trigrams* are contiguous three word strings in a text that when ranked, allow researchers to develop an understanding of the themes or topics that are associated with a given text (e.g. Conway et. al. 2009). While the rankings on their own hold little meaning, when compared to another set of rankings for a different text, trigram rankings can tell us whether one text is topically different from another (Archer 2009). If the rankings demonstrate that the topics are distributed differently, we can imply that the two modalities serve different interactional functions.

Table 1: Top 5 Trigrams for Asynchronous and Synchronous Text-Based Modalities

Rank	Asynchronous (n = 22,039)	Synchronous (n = 5,176)
1	“would like to”	“I can hear”
2	“the meeting on”	“can you hear”
3	“agenda for the”	“not able to”
4	“proposed agenda for”	“can u hear”
5	“the meeting notes”	“you hear us”

The trigram analysis presented in *Table 1* shows that the asynchronous ViKR and the synchronous in-world text chat are used for different purposes. The message board is used more typically for scheduling, organizing the meetings in the virtual space, and managing meeting notes, while the text chat is used primarily to troubleshoot the voice functionality. After reviewing the quality of the recorded video data, it became evident that many of the groups had difficulty managing the extensive sound options on their own computers, in the CyberGRID, and in SL. The complexity of audio options frequently led to uncertainty about whether or not their voice was broadcasting into the virtual space. Thus, the functionality afforded by the text chat may not have been expected during the CyberGRID development stage, but it served as an alternative mode of communication in the case of an aural mode failure.

It is important to note that the use of the ViKR and the text chat typically complemented interactions that primarily occurred through voice. The message board was used to exchange scheduling information diachronically while the text chat was used to synchronically solve audio issues. Through the trigram analysis, we have seen evidence that users are adopting collaborative tools based on afforded functionality, whether the functionality was designed into the tool by the developers or whether it emerged from circumstances that arose over time. In this case, the synchronous and asynchronous modalities of the two communication tools were strong factors in the adoption of tools to serve two discrete interactional functions.

3.2 Finding 2: Tools that promote group cohesion are used more frequently.

Each of the collaborative tools was used to differing degrees by the participants. Some tools such as the green thought bubble were used extensively while other tools like the Twiddla whiteboard were hardly used. Along with Davis (1989), we have demonstrated that tools are adopted based on a particular functionality that they provide. Additionally, we demonstrate that the need for a particular functionality, such as the ability to troubleshoot voice technology, can emerge through the experiences in the virtual space. We turn now to a discussion of how a tool's emergent social function impacts adoption. Based on data extracted from the tool use database, we demonstrate how green bubble use developed a social function over the course of the semester by the global virtual design project networks.

Fig. 7 shows the total number of tool uses by tool type. Tool uses were recorded in the database when a user clicked on the Collaborator tool. The frequency data demonstrates that the green thought bubble was used considerably more frequently than any of the other bubbles.

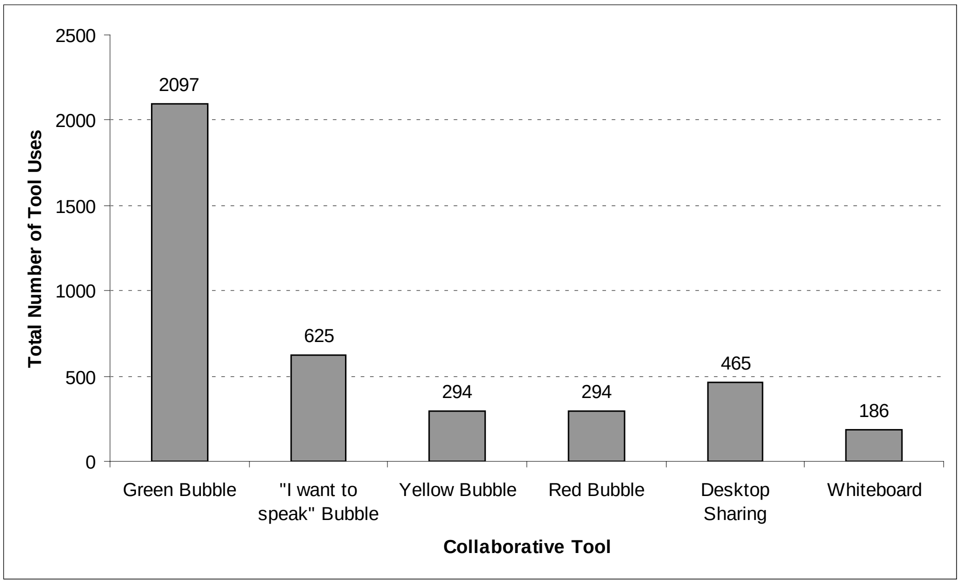

Fig. 7. Total Number of Tool Uses by Tool Type

The crucial difference between the green bubble and other bubbles is in the range of functions that have developed for the green bubble compared to the other three. The green bubble serves three distinct functions: 1) voting affirmatively, 2) showing agreement, and 3) back-channelling. The green bubble was originally intended to indicate a vote of “yes”. The intended use was then extended such that the bubble was interpreted as being more positive and supportive than for either the red or yellow bubbles. Students may have been hesitant to openly disagree with another student by using the red bubble, whereas use of the green bubble in agreement may have served to strengthen the interactional and social cohesion. Use of the green agreement bubble may also indicate the use of *back-channelling* (White 1989). Back-channelling is common linguistic practice in most of the world’s languages that involves the use of short groups of sound segments (e.g. in English, “ah”, “mm hmm”, “ok”, “right”, etc.) or gestures (e.g. head nodding, eye contact, etc.) that are inserted at different points during or between conversational turns. The function of back-channelling is to demonstrate that a speaker is following along with a conversation and comprehends the speech stream. It typically influences conversational fluidity, and its absence in virtual settings can be conversationally problematic (Herring 1999). Back-channelling is also gestural, including eye-contact and head nodding for some groups. One participant notes the value that the green bubble has for Network 3: “Second Life has a substantial issue as a meeting space in that the forum does not allow one to observe or interpret expressions and body language. [The green bubble] restores the ability to gauge your audience in Second Life.”

The red bubble was intended to be used to signal a vote of “no”, and through extension, associated with disagreement. The yellow bubble was intended to indicate a vote of “neutral”, and was extended to indicate a question or as a proxy for the white “I want to speak” bubble. The use of the yellow bubble has not been made normative as one group describes in their reflection: “Some of our teammates tried to use the [yellow] bubble in the beginning, but nobody really paid attention or could identify its proper use.” While the green bubble is used for a variety of interactional functions (e.g. agreement, back-channelling, affirmative voting), the yellow and red bubbles served less well-defined purposes. This may explain why the green bubble was used more frequently than the other bubbles. Crucially, the yellow and red bubbles were described by participants as being used less frequently because of either the ambiguous (yellow) or negative (red) social implications.

3.3 Simple tools are used more frequently.

The data related to the propensity of green bubble use suggests that when a tool serves to foster group cohesion, it may be adopted more consistently compared to tools like the yellow or red bubbles which have either narrowly defined, socially negative, or unclear functions. By examining the data related to the use of the Team Screen combined with data on the frequency of tool use, we find evidence that users tend not to adopt tools that are complicated to use.

The data presented in *Fig. 7* indicate that desktop sharing was used 465 times during the roughly 112 hours of recorded CyberGRID interaction. Based on review of the recorded video, the ratio of desktops shared per hour is extremely inflated. By reviewing the reflections of participants in their end of semester reports, we discovered that many of the groups had difficulty in sharing their desktops, i.e. they had difficulty operating the tool effectively. They noted that it was difficult to zoom in on a specific part of the Team Screen or to adjust their view to be square with the screen. In order to successfully interact in the environment, users have to be able to manipulate their view to toggle between looking at the screen and looking at other users. In physical settings, this is analogous to looking from an overhead projector screen while commenting on a presentation point and then scanning the audience to see if there are any questions. In the CyberGRID, this is a complex task. Some participants found the Team Screen to be difficult to use and, when properly displaying a user’s desktop, it was difficult to see and use while interacting with their collaborators.

If we sort the frequency data by specific global project design network, we see that in *Fig. 8*, the use of the tools collectively varies. While most of the global project networks were actively using the tools, Networks 2 and 7 used the tools nearly half as frequently as the others. Based on review of the recorded videos, both global project networks had difficulty throughout the semester operating the desktop sharing functionality. Aside from their lack of success in operating the Team Screen, Networks 2 and 7 are not unique in relation to the other groups. Early in the semester, both groups agreed to develop new ways of sharing visual information in the virtual space by emailing documents before a meeting and asking attendees to open the documents on their desktops. The other groups may have devoted more time to overcoming the tool learning curve and thus successfully developed strategies for using the tools appropriately.

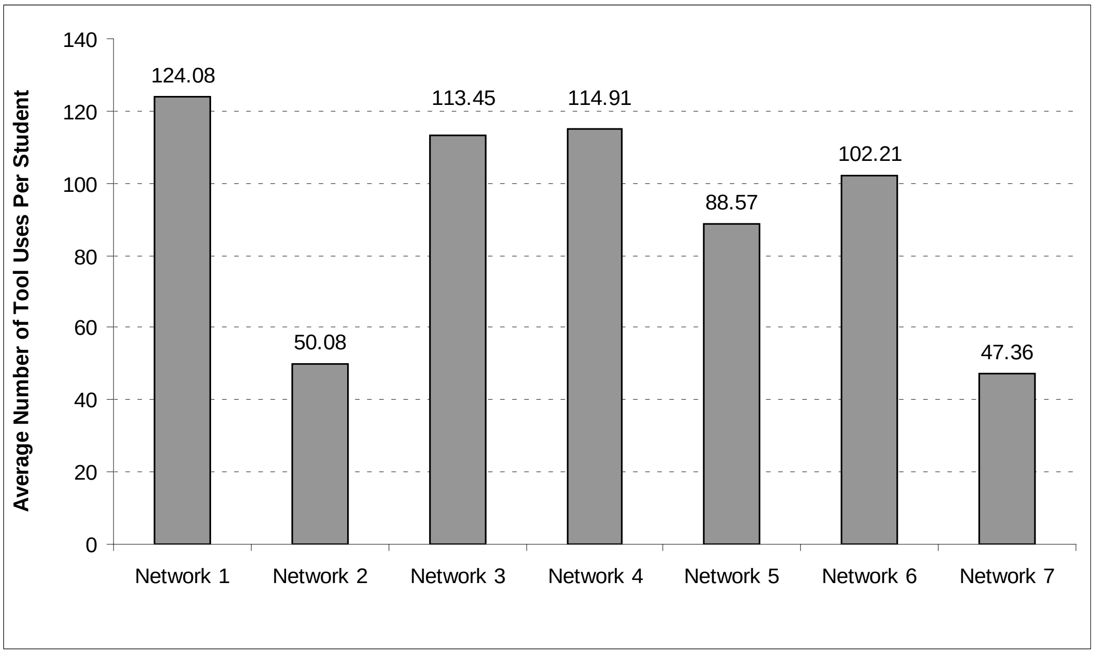

Fig. 8: Average Frequency of Tool Use by Global Project Network

Both Networks 2 and 7 noted in their reflections that the Team Screen was difficult to use. In their reflection, Network 7 indicated that "the sharing screen was not entirely clear. The images seen on the screen were sometimes blurry and made visualization difficult for the team members trying to follow the explanations". If we return to the database and examine tool frequency use for the desktop sharing functionality of the Team Screen by global networks of designers (*Fig. 9*), Networks 2 and 7 use the desktop sharing functionality less frequently than the other groups. This pattern in desktop sharing use confirms that the tool was difficult to adopt, which, coupled with the group's reflection on the difficulty they had using the tool appropriately, suggests that the complexity of operating the desktop sharing functionality of the Team Screen proved to be a barrier to adoption.

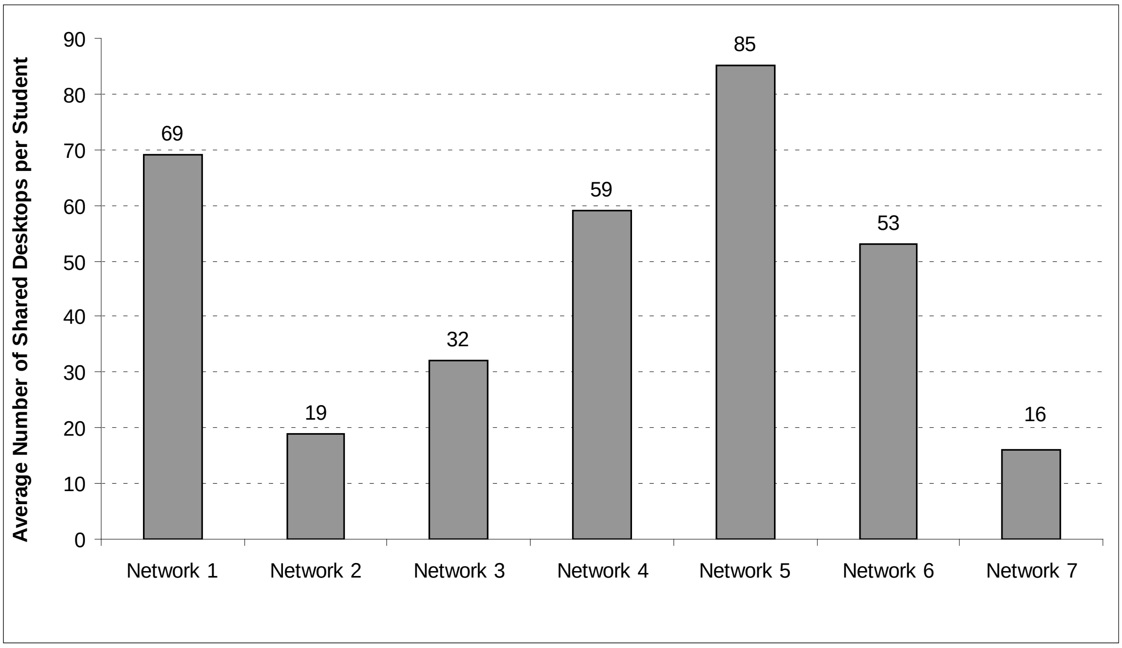

Fig. 9: Average Frequency of Desktops Shared by Global Project Network

3.4 Finding 4: Local factors impact tool use.

Local factors, such a particular group's value system or a user's access to a reliable, high-bandwidth connection also influenced tool adoption. Given that the each global project network was constituted by a number of local (i.e. nationally co-located) teams, local motivations and influences may be powerful influences on tool use. For instance, the students from the United States were repeatedly encouraged by their professors to experiment with the tools, while the faculty in The Netherlands were more interested in observing *whether* practices would emerge surrounding tool use and did not seek to influence student experimentation with the tools. This is one example of how *intra-team* factors can impact tool use. By sorting the tool use frequency data by a user's country of origin, the impact of these localized practices and meanings can be assessed in terms of tool adoption.

The data presented in *Fig. 10* indicate that the Finnish students use the CyberGRID collaborative tools with more frequency than the students from other countries. Given that a Finnish Technical Assistant was responsible for developing a large portion of the CyberGRID, his influence in the local setting encouraged use by the Finnish students. Moreover, the Finnish students were assigned the role of facilitator in each global project network. In this role, the Finnish students were in a unique position to leverage the hypothesized collaborative power of the CyberGRID tools, which may help to explain their increased adoption. The Indian students were roughly one third as active as the Finnish students in using the collaborative tools in the CyberGRID. One contributing factor to the relatively low frequency of Indian student tool use relates to the communication infrastructure available to the Indian students. Throughout the course of the semester, the Indian students had difficulty with internet connectivity, which resulted in at times distorted audio, avatar lag, and in some cases, an inability to log in to the CyberGRID. Moreover, the Indian students reported long wait times for document downloads. All of these examples suggest that the Indian students may not have been as active in using the collaborative tools because periodically they experienced difficulties in getting the tools to work, through no fault of their own.

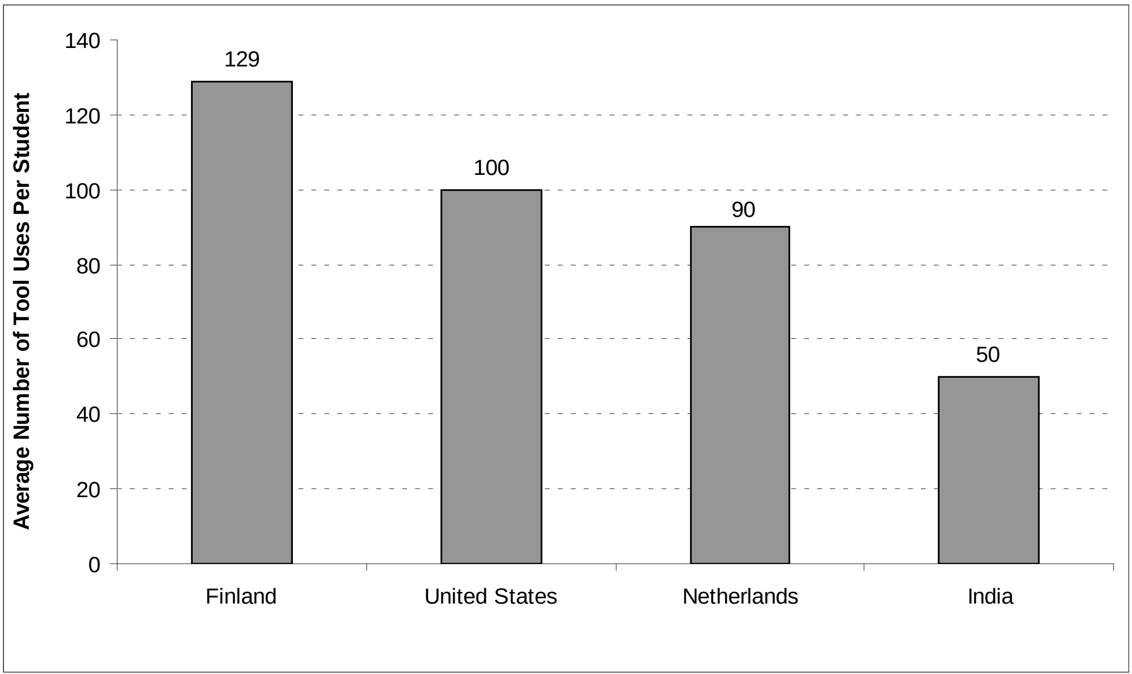

Fig. 10: Average Frequency of Tool Suite Use by Country

Another issue with the Team Screen that students identified as challenging is the necessary five second delay that is designed to accommodate Information Technology (IT) infrastructure at the Indian collaborator site. For instance, Network 7 notes that "although this tool was useful, the sharing screen in the CyberGRID was delayed by five seconds, making the process tedious and somewhat confusing, and therefore more difficult for the person trying to explain the documents or files on his desktop". During the semester it became apparent that the IT infrastructure in at the India site did not support the bandwidth needs of this tool. As a result, the refresh rate of the desktop sharing software had to be limited to 10 seconds. This meant that broadcasting video from a desktop to the Team Screen was not viable even though the tool was used to share PowerPoint presentations and images of 3D models. This is one of many cases where the functionality of a collaborative tool was impacted by differences in communication infrastructure. It is also an example of how modifications to the design of a particular tool trigger new challenges.

The data presented in *Fig. 7* through *Fig. 10* demonstrate that the adoption of collaborative tools is impacted by a variety of social and communicative functions afforded by the tools on both local and global interactional levels. The data also highlights the importance of collecting qualitative data through which to frame the frequency counts automatically recorded in the virtual world research databases.

4. DISCUSSION

The findings discussed above point to a range of factors that impact collaborative tool use in virtual workspaces. Some factors are directly related to the design of the tools, their implementation, and how best to support their use (i.e. tool simplicity and emergent functional need), while other factors are based on socio-contextual aspects of interacting in virtual workspaces (i.e. local practices and group cohesion). In some cases, the hypothesized value of a particular tool was never realized based on the analysis of usage (e.g. desktop sharing). In other cases, emergent value promoted tool use (e.g. green bubbles). The findings suggest that the adoption of collaborative tools in virtual workspaces is a complex interplay between the developers' expectations for tool use and emergent practices based on the functional needs of the network.

Before addressing adoption, we must begin with a discussion of how to effectively study tool adoption in virtual workspaces and lessons learned from the research reported in this paper. Our findings suggest that researchers should combine quantitative descriptions of usage patterns with qualitative accounts of how the tools are used in productive and appropriate ways. Many studies of tool use are based on users' reflections about the value that a particular tool has for their interactions (e.g. Lewis et al. 2007). While these reflections can help to demonstrate that users' attitudes and ideologies about technology can impact their likelihood of adoption, studies based on user reflections may not reflect actual tool usage patterns. By contrast, studying frequency of tool use without any sense of the users' experiences is also problematic. For instance, the data presented in *Fig. 7* indicate that desktop sharing was used frequently. However, the inflated value of desktop sharing frequency can be explained as the repeated attempts by participants to use the technology in interactionally appropriate ways. Users stop the sharing application and then restart, with the intention of resolving image clarity issues in the Team Screen. In the case of the Indian students' tool use, connectivity issues may have been forcing a restart. In each case, this attempt at appropriate use would be noted two or more times in the database, which accounts for the inflation. Thus, a lesson learned here is that while automatically compiled interactional databases of tool use in virtual spaces greatly increase the speed and amount of data collected, the data captured is based on *absolute usage* as opposed to *appropriate usage*. Absolute frequencies are only informative as based on their relationship to appropriate usage. Unfortunately, it is extremely challenging to automate the identification of appropriate usage. Thus, the goal of creating a system of automated data collection on virtual collaboration must be to facilitate the *collection* of data and not be confused with the *analysis* of the data. Identifying appropriate use of a tool falls in the purview of data analysis. This highlights the lack of explanatory power for strictly quantitative approaches to assessing tool adoption. Because of the number of variables impacting adoption, it is crucial for researchers to have access to qualitative recorded data to confirm the patterns that emerge in the quantitative data. Researchers need to have qualitative data because usage alone is insufficient to capture whether tools are being used in meaningful ways.

The interpretation of automatically collected data is problematic without the ability to frame the data in qualitative accounts based on review of the recorded videos. In this sense, the CyberGRID has been successful as a research instrument for studying virtual interaction because it not only records instances of tool use, but it also captures the associated video of the interaction so that researchers can return to these videos in order to accurately contextualize entries in the database. However, there are a number of reasons why the collection and interpretation of virtual interaction data remains challenging to automate. For instance, many of the technological challenges were triggered by diversity in hardware configurations, microphones, and operating systems. However, mandating an approved hardware configuration compromises the broad appeal of the SL-based CyberGRID because it makes participation in the project prohibitively expensive for some users. In contrast, by building a virtual workspace from scratch, developers can make affordances for a range of hardware configurations by including only those tools and functionalities that serve to facilitate collaborative work while ignoring much of the social functionality contained in the SL platform. For instance, SL allows for avatars to present a range of "emotes" or physical gestures. Avatars can be made to laugh, dance, stand on their heads, swing swords, and throw automobiles. While these types of emotes produce humorous interactions between users, they serve little practical purpose in design networks and can lead to distractions or inappropriate behaviours. Moreover, their use in the SL serves to slow down some hardware configurations, thus potentially compromising the functionality of some of the more critical collaborative tools such as voice chat or desktop sharing.

The mismatch between the hypothesized value of desktop sharing as a means to create shared reference in the virtual space and its lack of use by the design project networks provides another example of how the underlying functionalities built into SL can be simultaneously beneficial to virtual workspace development and a hindrance. The potential of the Team Screen as a valuable collaborative tool was not realized because it was difficult to use. The technical challenges associated with both the implementation and user mastery of tools proved to undermine many basic CyberGRID functionalities. Many of the challenges to implementation of the tool and its mastery by participants are a product of limitations in SL. In order to activate the desktop sharing functionality, participants had to proceed through the following process: 1) click the "desktop sharing" button on the Collaborator, 2) download a Java client, which opens an in-world internet browser, 3) click "share my desktop" in the browser window, 4) open another in-world internet browser window to view potential desktop streams to be shared, and 5) select the appropriate desktop stream for broadcast on the Team Screen. Additionally, a small "play" button at the bottom of the GUI had to be activated to view any media displayed within the virtual work rooms. While the customizability of SL allowed for desktop sharing to be possible, limitations to the SL client forced the complex and time-consuming implementation of the functionality. When participants were able to share their desktops successfully, it often took more than five minutes to implement the functionality, which proved to disrupt the interactional coherence of the meeting. If participants made an error in any of the five steps listed above, they had to begin the sharing process from the beginning. Ideally, participants should be able to share their desktop with a single click. However, this type of simplified implementation is not currently possible in SL because of the need to install the Java client and stream the desktop via the internet. While having a dedicated IT professional would have ensured that network participants were able to share their desktops, this solution is an ad-hoc response to a more fundamental issue, i.e. that while it is possible to create a number of potentially useful collaborative tools, their seamless implementation into the virtual workspace is problematic because of the need to work within the existing SL architecture.

On the other hand, the architecture of SL afforded for the simple implementation of the stop-light system of bubbles that emerged as an interactionally valuable tool for the network participants. The bubble system was hypothesized to be a tool for project network participants to easily indicate their agreement or disagreement with a particular stance during the course of collaboration. Bubble use was triggered by a single click of a button on the Collaborator and was able to be seamlessly integrated into SL. Because the bubbles were simple to use and performed a valuable collaborative function for network participants, new practices concerning their use emerged (e.g. backchanneling) that served to strengthen the social cohesion of the group. In this case, the ease of implementing the bubbles into the SL architecture supports the assertion that SL is a sufficiently simple and robust platform for the development of virtual workspaces. Because desktop sharing is more complex to implement in SL, the hypothesized value mismatched the applicable value. Because the bubbles were easy to implement and use, their hypothesized value was not only realized, but expanded to address the emergent needs of the interactions. Designers of virtual workspaces should assess the types of tools that are required for effective collaboration and whether or not they can be implemented in ways that allow users to easily access the functionality. For some tools (e.g. bubbles) SL may be an adequate platform from which to begin development. In other cases, while functionality is possible within SL, it may not afford the ease of use required for successful tool adoption.

To aid in the adoption of the tools, a maximally simplified interface helps to improve the learning curve for using the technology as users will have less options to consider when becoming familiar with successfully operating the tools. In its current iteration, users can view and discuss models in the CyberGRID, but then have to load an external web page to post to the ViKR. They must load an additional page to share documents via Dropbox. One student noted that: "Although the Dropbox helped in [the file sharing] process, sharing files directly in the CyberGRID would have been more efficient." One way to accomplish this is to integrate all tools into a single interface. Users should be able to access all of the collaborative functionality from *within* the CyberGRID. This approach makes the interactions more fluid because they are conducted in the same space and also more efficient as users do not have to waste time interacting with external website and applications. This will allow users to effectively “go to work” in the CyberGRID, thus providing a robust interactional platform for global virtual design network collaboration. A simplified interface with built-in document sharing, message boarding, and communicative functionality in addition to the interactional tools like the thought bubbles will provide the best collaborative environment in which to study how global virtual design networks use tools in ways that make their work more efficient and successful.

However, the creation of a unified interface is difficult to implement in SL because developers are constrained to adding to the SL interface without the ability to remove options. In some cases, the overwhelming number of options in the SL interface makes it difficult for users to locate the functionality they need. For instance, if a user is experiencing audio problems (which occurred repeatedly in our study), the user has to sort through 219 different options on the first tier of the interface’s upper toolbar to find the tab that allows the user to modify their input (microphone) volume. Another volume slider is located on the bottom of the GUI that allows the user to modify the level of their audio (speakers). This slider requires no searching and is readily available at all times during the interaction, without the need to search through hundreds of options hidden in a variety of tool bars. Participants in the study frequently attempted to adjust their microphone volume with the audio slider and some were not aware that the input volume slider within the options menu existed. Many of the options built into SL are designed for *social* interaction and serve in many cases to distract from collaborative *work*. For instance, of the 219 options in the upper-toolbar, 76 give users the option to attach or detach objects from their avatars. Users can attach hats and coats as well as basketballs and automobiles. While this functionality is appealing to social users of SL, the inclusion of these options in the SL interface was confusing for participants as much of the social functionality did not perform any collaborative function in relation to their design tasks. Unfortunately, there is currently no way to limit the options available to users in SL. As a platform for building virtual workspaces, the benefit of SL is that developers do not have to create these options from scratch. On the other hand, developers cannot remove these options if they are deemed superfluous or distracting. It is relatively easy to add functionalities to the SL platform, but difficult to remove functionalities already existent in SL.

The adoption of collaborative tools in support of distributed design networks is based on a number of factors that relate ease of use and implementation to functional value. Because the CyberGRID was developed within SL, the SL platform itself plays an important role in either facilitating or constraining the adoption of tools. Therefore, during the initial stages of the tool design process, tool developers and researchers studying tool use must weigh the time saved by building on the already existing SL platform in comparison to the restrictions imposed by the platform, particularly in the case of creating a streamlined, minimal interface design that promotes the simplicity and clarity of appropriate tool use.

5. CONCLUSIONS

By examining the CyberGRID participant user reflections and tool usage data, there is a lot to be excited for in terms of the potential for virtual worlds to enhance collaboration in geographically distributed design networks. However, the direction forward may be away from existing virtual worlds like Second Life which were designed for other purposes. While SL has proven to be a valuable starting point for this project in investigating how to best support global virtual design networks, the lack of customizability, particularly in regard to simplifying the user interface, hampers the developer’s ability to streamline tool presentation and use, and consequently, the researcher’s ability to draw accurate conclusions about how distributed networks leverage collaborative technologies. The successful adoption of the green bubble tool by users suggests that when the tools are available and they meet emergent interactional needs, designers will seize the opportunity to work collaboratively for extended periods of time in virtual workspaces. The unsuccessful adoption of the Team Screen and the desktop sharing functionality suggests that complex tools that are not well-integrated into the user interface will not prove to be useful, regardless of whether the functionality they provide is valuable to network participants. These two examples demonstrate the difficulty in reconciling the customizability of certain aspects of SL with the lack of control over other aspects of the platform. In our case, the lack of control compromised the functionality of many of the critical tools designed to create a virtual workspace with theory-driven interactional advantages over more traditional approaches to performing distributed design work. A possible avenue for further research and development is to use gaming engines with the ability to only include the functionalities that are relevant and valuable for distributed design tasks or other professional tasks that require a shared reference point in space.

Through the research reported in this paper, it is clear that research and development of tools in support of global virtual design project networks are mutually inclusive endeavours. In other words, by researching tool use, we are better positioned to develop tools with robust functionalities to best support the work conducted in these increasingly common global design networks. However, while the research has contributed to our understanding of why certain tools are successfully adopted and others are not, it has also suggested a number of avenues for future research efforts. Future research can fruitfully contribute to our understanding of global virtual design networks by investigating how designers in virtual working environments leverage the collaborative potential of virtual tools to increase their performance in complex design tasks. We currently have *hypothesized* the value of virtual collaborative spaces for globalized networks, but until research can *demonstrate* that distributed networks collaborating in virtual spaces perform as well as co-located networks, the potential of these spaces will be of limited practical relevance within industry. For instance, we know that knowledge system conflicts impact performance in co-located networks, but we have little sense of how collaborative tools like those discussed in this paper are used to handle conflicts that arise in virtual networks. We may find that tools integrated into virtual networks serve to handle conflicts better than tools employed in co-located networks, which would suggest that virtual networks might outperform co-located networks if designed properly. In short, we still know very little about how virtual networks perform in relation to co-located networks, when the virtual networks are supported with appropriate and meaningful tools. If researchers are able to understand how to increase performance in virtual networks, the impact of geographical boundaries on complex design work can be minimized as we gain more nuanced understandings of how to leverage virtuality to increase network cohesion and productivity. Through this type of research, we can develop a more robust understanding of how best to support the collaborative endeavours of global virtual networks executing complex and iterative design tasks, which in turn can make a positive impact on the efficiency of projects in the globalized and increasingly interconnected workplace.

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