Title
Collaboration Strategies Employed in a Virtual World while Performing Distributed Usability Inspections

Author
Koehne, Benjamin

Publication Date
2014

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA,
IRVINE

Collaboration Strategies Employed in a Virtual World while Performing Distributed Usability Inspections

DISSERTATION

submitted in partial satisfaction of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in Information & Computer Science

by

Benjamin Koehne

Dissertation Committee:
Professor David F. Redmiles, Chair
Professor Gary M. Olson
Professor Peter Krapp

2014

DEDICATION

To

my parents Ilse und Hilko Köhne

for their unwavering support and encouragement over the years.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

A great number of individuals have given me their support and encouragement over the past six years. Professor David Redmiles has been a mentor and colleague from the very first day that we met in the garden of my Masters advisor Christian Rathke in Germany. He has given me the chance to start my academic journey at UC Irvine, challenged me intellectually, and gave me the opportunity to meet all the great people during my studies that I would have otherwise never known. I am very grateful that he saw potential in me and I want to thank him for his steady support and guidance.

I would like to thank my dissertation committee of Gary Olson, Peter Krapp, Aditi Majumder, and Walt Scacchi for their support over the past two years as I developed my research ideas into my dissertation. Gary Olson's research has inspired me to look into CSCW and his willingness to share his knowledge of the literature has been immensely helpful. My discussions with Peter Krapp gave me the confidence to peruse my topic ideas and I thoroughly enjoyed talking to him about much more than just work.

Matthew Bietz is an incredibly kind and smart individual who I want to thank for supporting me throughout my time at UC Irvine. He also clearly gives the best hugs in the world. Judith Olson has been a great mentor. I believe I will benefit from her advice for many more years to come. Steve Abrams was the first person to greet me at LAX airport when I arrived in the United States in September 2008. Steve was one of the kindest and most unselfish persons I have ever met. My lab mates and friends at the Department of Informatics have been with me during good and bad times. Although I cannot mention everyone here, I want to particularly thank Oliver Yi Wang, Erik Trainer, Patrick Shih, Leslie Liu, Norman Su, and Bryan Semaan for being great fellow students and for accepting me into their ranks.

I would like to thank Michael Caldera for working with me on the implementation of the INspect-World project. He brought knowledge, skill, and much joy to the CRADL lab. My thanks also goes to my undergraduate student research assistants Grace Pai and Gerardine Montebon who worked with me on the data analysis and system updates of the INspect-World project. I believe we were able to learn from each other. Jingwen Zhang gave me the peace of mind to plan and run my studies at Hana lab.

I would not have been able to complete my Ph.D. without the support of my family. My parents, Ilse and Hilko Köhne, let me venture far away from home to peruse my ambitions - first to London and eventually to Irvine, California. I treasure our weekly video calls and their visits. Thanks to my siblings, Tobias Köhne and Ana Borg, for sharing their lives with me all the way across the Atlantic Ocean.

Ko Nee has been my most important bastion of calm during my everyday life as a Ph.D. student. She is an incredibly understanding, smart, and sweet person and I am incredibly fortunate to have found her in my life. She is truly irreplaceable and I am looking forward to exploring the world with her - wherever life will take us.

CURRICULUM VITAE

Benjamin Koehne

2003-07	B.A./M.S. in Business Information Management Stuttgart Media University, Germany
2008	Technical Consultant, RIB Software UK Ltd. London, United Kingdom
2008-10	M.S., Information and Computer Science University of California, Irvine
2011	Human-Computer Interaction Group, Intern Microsoft Research Asia, Beijing, China
2013	User Experience Research, Intern Google Inc., New York, NY
2014	Ph.D., Information and Computer Science University of California, Irvine

FIELD OF STUDY

Information and Computer Science, Human-Computer Interaction
Informatics, track: Interactive and Collaborative Technology

PUBLICATIONS

Koehne, B., Bietz, M., and Redmiles, D. Identity Design in Virtual Worlds. The Fourth International Symposium on End-User Development (IS-EUD 2013, Copenhagen, Denmark), Springer, 2013.

Koehne, B., Redmiles, D. Envisioning Distributed Usability Evaluation through a Virtual World Platform, The 2012 International Workshop on Cooperative and Human Aspects of Software Engineering (CHASE), held in conjunction with the 34th International Conference on Software Engineering (ICSE 2012, Zurich, Switzerland), June 2012, pp. 73-75

Koehne, B., Shih, P.C., Olson, J.S. 2012. Remote and alone: coping with being the remote member on the team. In Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work (CSCW ’12). ACM, New York, NY, USA, 1257-1266.

Koehne, B., Redmiles, D., Fischer, G. Extending the Meta-Design Theory: Engaging Participants as Active Contributors in Virtual Worlds, The Third International Symposium on End-User Development (IS-EUD 2011, Torre Canne, Italy), June 2011, pp. 264-269.

Koehne, B., Redmiles, D., Fischer, G. Details on Extending the Meta-Design Theory: Results from Participant Observation of Active Contributors in Virtual Worlds, Technical Report UCI-ISR-11-1, Institute for Software Research, University of California, Irvine, CA, March 2011.

Koehne, B., Redmiles, D. Gaze Awareness in Distributed Work Environments , Technical Report UCIISR-10-2, Institute for Software Research, University of California, Irvine, CA, March 2011.

Thies, P. and Köhne, B. (2009). Electronic Glassboard – Conception and Implementation of an Interactive Tele-Presence Application. Proc. HCI International 2009, 19.-24.07.2009. San Diego, CA, USA. Berlin, Heidelberg: Springer LNCS.

ABSTRACT OF THE DISSERTATION

Collaboration Strategies Employed in a Virtual World
while Performing Distributed Usability Inspections

By

Benjamin Koehne

Doctor of Philosophy in Information & Computer Science

University of California, Irvine, 2014

Professor David F. Redmiles, Chair

Geographically distributed collaboration has become the common way to work in many industries. Collaborative tools for supporting distributed work in complex work environments rely on information and communication technology to enable meaningful, rich interactions in the distributed team. Virtual world technology has advanced rapidly in recent years and public virtual worlds draw millions of users. Innovative, natural user interfaces have become more broadly available at lower costs, opening up virtual world technologies to a broader range of applications. The lower barrier to entry creates opportunities in CSCW to apply virtual world technology in collaborative tools for distributed teams. Yet, there are only few systems built specifically for collaborative activities using virtual world technology and our understanding of how users collaborate in virtual world environments is still very limited. In this dissertation I sought to discuss the implementation and evaluation of INspect-World, a collaborative tool for conducting and managing distributed usability inspections. In two empirical qualitative studies I observed, analyzed, and documented collaborative behaviors and strategies performed in the INspect-World virtual world environment. I found

that users developed unique collaborative strategies in the contexts of team building, interacting on a level playing field, using virtual scaffolding mechanisms, and working with rules in the open virtual space. The qualitative findings represent an important stepping stone between the past and the future of applying virtual world technology in collaborative tools for geographically distributed work.

CHAPTER 1: INTRODUCTION

Geographically distributed collaboration has become an integral part of everyday work in businesses, research institutions, and educational programs. The formation of distributed teams has become common business practice (Gibson & Cohen, 2003). Employees and students increasingly work from any location without necessarily requiring a physical office. The development of information and communication technology (ICT) for supporting geographically distributed work practices needs to keep pace with the increasing demands from practitioners for distributed collaboration systems in specialized industry areas such as software engineering or product design. Implementing available ICT into organizational processes and individual work practices, companies and individuals need to develop collaboration processes that work for specific tasks performed during the distributed collaboration sessions. Designers of collaborative systems for distributed work require an understanding of the affordances of different ICTs in order to make informed design choices and to choose a suitable technology.

In this dissertation I sought to present the implementation and study of a collaboration tool for conducting geographically distributed usability inspections in a 3D virtual world environment. The collaboration tool, called INspect-World, allows users to interact in a virtual usability inspection space with virtual avatars in order to conduct a usability inspection session. INspect-Web represents the implementation of a web-based management tool for setting up usability inspection environments automatically and for managing user accounts and usability inspection results. **Figure 1.1** shows the INspect-World virtual world environment and the INspect-Web management interface.

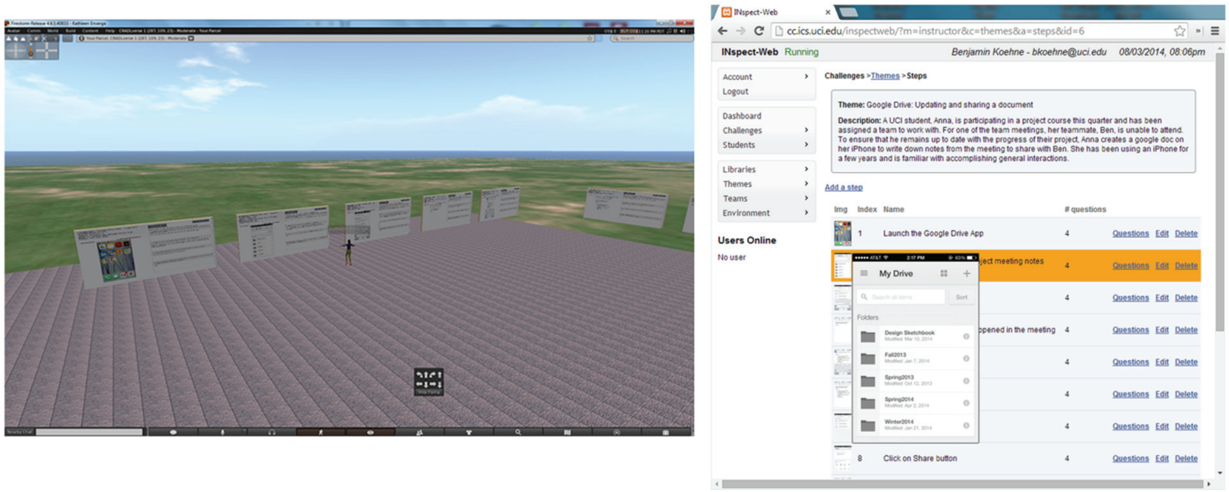

Figure 1.1: The INspect-Web virtual world environment (left) and the INspect-Web management interface (right).

I conducted two empirical studies in INspect-World with 26 distributed teams to observe, analyze, and document collaborative behavior and the development of collaboration strategies in the virtual world. The results show that virtual world technology can be applied to successfully support focused collaborative tasks as done in the INspect-World environment. The documented collaborative behaviors reveal specific types of collaborative strategies that are enabled by the virtual world technology.

In this chapter, I first summarize the past and present of the application of ICT in collaborative tools for supporting distributed collaboration. In the following, I discuss my motivation for applying and studying virtual world technology in distributed collaboration. The increasingly lower barrier to entry of virtual world technology and the current lack of understanding in the CSCW community how virtual world technology affects focused, collaborative behavior are articulated. Finally, I preview how virtual world technology was implemented and evaluated in the INspect-World project and close with an overview of the chapters in this dissertation.

1.1 ICT in CSCW for Supporting Distributed Collaboration

Over the course of more than 20 years, research in the field of Computer-Supported Cooperative Work (CSCW) has looked extensively into distributed work processes, distributed team compositions, and ICT supporting distributed work processes (Powell, Piccoli, & Ives, 2004). Past and ongoing CSCW research on distributed teams has been conducted on the organizational level, e.g. (Hinds & McGrath, 2006), on the team level (Connaughton & Shuffler, 2007), and on the individual team member level (Koehne, Shih, & Olson, 2012; O'Leary & Mortensen, 2010). Research results highlight observed difficulties inherent in distributed work and suggest best practices to mitigate the challenges. Olson and Olson reviewed and synthesized past studies on distributed work and showed that, despite the introduction of more advanced ICT into organizations over the years, distributed work is still inherently difficult (Bos, Buyuktur, Olson, Olson, & Voida, 2010; G. M. Olson & Olson, 2000).

The development and application of ICT for supporting collaborative and distributed work between groups and individuals has advanced rapidly over the years. Research on using ICT to support collaborative activities began with a focus on supporting collaborative activities in shared meeting rooms, resulting in collaborative writing systems, e.g. (Dourish & Bellotti, 1992), and electronic meeting room systems supporting a range of collaborative activities on electronic whiteboards and other tools (Moran et al., 1996; Stefik et al., 1987).

Research on distributed collaboration contexts investigated different technologies for collaboration awareness properties. A qualitative investigation into text chat communication showed that different layers of information transmitted through text can help users to collaborate and coordinate activities (B. A. Nardi, Whittaker, & Bradner, 2000).

Video and audio technology has seen application in video conferencing systems that have constantly been refined to create a sense of tele-presence between distributed collaborators. Moving beyond the aspect of tele-presence, video was not only used to create awareness and presence of collaborators, but enabled the collaboration on non-human objects in the sense of “video-as-data” (B. A. Nardi et al., 1993). Focused efforts have been made to support collaborative activities in video-conferencing systems by maintaining spatial faithfulness for multiple users and by discovering the right balance of audio and video-transmitted cues for collaborative activities (Nguyen & Canny, 2005).

1.2 A Case for Re-Visiting Virtual World Technology for Distributed Collaboration

In recent years, a new class of ICT has gained popularity in industry and in the CSCW community. From their early beginnings in the form of mostly text-based Multi-User Dungeon (MUD) systems (Curtis, 1992; Muramatsu & Ackerman, 1998), 3D virtual world systems today scale to thousands of users interacting in virtual worlds. Popular massively multiplayer online role-playing games (MMORPGs) draw millions of concurrent users to play together in detail-rich, 3D fantasy worlds. Accessing most public virtual world systems does not require high-end computer hardware. Modern laptops today have sufficient processing and graphics power that allow users to experience virtual worlds. The more recent development and broad availability of innovative virtual reality interface hardware, such as *Oculus Rift* (Oculus, 2014) and *Google Glass* (Google, 2014), have the potential to further lower the barrier to entry for virtual world technologies and their application in areas beyond gaming.

While selected industry sectors have successfully adopted virtual world technologies for collaborative industrial and military training (Kincaid, Donovan, & Pettitt, 2003; Lin, Ye, Duffy, & Su, 2002), there are few success cases in CSCW of collaborative systems employing virtual world technologies.

The development of novel online learning experiences can serve as an example for an opportunity to apply novel collaboration technology. In 2012, a new category of online learning systems referred to as massively open online courses (MOOCs) received much attention in the research community and the media (Daniel, 2012). While MOOCs have the potential to lead the way towards a more open and accessible education for interested parties around the world, they have also been criticized for not delivering on the promise of a true collaborative online learning experience (Bates, 2012; Hazelkorn, 2013). Researchers have applied virtual world technologies to entirely replace the physical classroom or provide a virtual campus experience (De Lucia, Francese, Passero, & Tortora, 2009). Many of these approaches have failed to be largely adopted and large MOOCs providers are already transitioning to so called SPOCs that focus small, private online courses (Fox, 2013).

Past research in public MMORPGs and Second Life (LindenLab, 2014) provided valuable insights into collaborative group play and virtual identities in the context of social and gaming activities (Ducheneaut, Yee, Nickell, & Moore, 2006; Bonnie Nardi & Harris, 2006; Wadley & Ducheneaut, 2009). Virtual ethnographies conducted in Second Life and World of Warcraft (Blizzard, 2014) have provided valuable accounts of the general social underpinnings of individual users making sense of virtual spaces (Boellstorff, 2008; B. Nardi, 2010).

Given the ever-increasing availability of affordable virtual world technologies and natural user interfaces and their appeal to large groups of users in the gaming area, virtual world technology should be seriously considered to have the potential to enable focused, distributed teamwork. Virtual world technology combines elements of audio-visual and text communication in a realistic 3D environment. Collaborative activities can take place in a shared and persistent virtual space. The focus of the collaborative efforts is represented in the same virtual space populated with virtual representations of the distributed team members.

CSCW designers require a good understanding of how virtual world technologies can support specific collaborative activities and how users interact in the virtual space to achieve collaborative goals. In a similar fashion to past CSCW research conducted on audio, video, and text-based collaboration systems, researchers need to re-evaluate collaborative behavior in virtual worlds. An understanding of specific types of collaborative strategies achievable by distributed teams in virtual worlds can help designers of collaborative systems in CSCW choose virtual world technology for the right application areas. Given the appeal and success of virtual world technology outside of CSCW, the value of virtual world technology for CSCW needs to be carefully analyzed and grounded in empirical data.

1.3 Evaluation of Virtual World Technology

To evaluate virtual world technology for the application in focused, distributed collaboration, I sought to develop a system called INspect-World that allows small teams to collaboratively perform distributed usability inspections in a virtual world. The system supports the cognitive walkthrough usability inspection method. The cognitive walkthrough method was chosen to offer a structured and well-defined task in the virtual world that requires a small team to collaborate closely in the virtual world. Typically conducted in collocated teams, the cognitive walkthrough method requires distributed teams in the virtual world to develop individual strategies to complete the usability inspection process.

I decided to develop a custom-built virtual world system to study users that focus primarily on a collaborative task instead of users that primarily follow a different goal and engage in collaborative processes as a secondary activity. I planned to collect data that provided insights into the individual perspective of each collaborator in the distributed team in order to conduct a more balanced analysis on the data that incorporates activities that may otherwise be hidden to the observer. Individual viewpoints of collaborators were important in order to understand their motivations to collaborate in a distributed team.

Figure 1.2: Individual study room setup in Hana lab at UC Irvine.

In two empirical studies, a total of 110 users performed 26 distributed usability inspection sessions in INspect-World v.1 and the later updated system INspect-World v.2. The studies differed from previous research conducted on collaborative behavior in virtual worlds as I was able to analyze and document collaboration strategies in a custom-built virtual world system that was specifically designed for conducting a focused collaborative task.

Both INspect-World studies were conducted at the University of California, Irvine in Hana lab at the Department of Informatics. For the initial study participants were recruited from an Undergraduate class taught at the Department of Informatics. For the second study, study participants were recruited from the Donald Bren School of Information and Computer Sciences at large. Participants in both studies were undergraduate students enrolled in the majors Computer Science, Informatics, or Business Information Management. Following an introduction to the INspect-World system, groups of up to five students conducted a cognitive walkthrough session in the virtual world. All participants worked on a laptop computer in an individual study room at Hana lab to simulate the geographical distribution of all team members. **Figure 1.2** shows one of the individual study rooms. Participants were asked to participate in an interview to discuss their experience in the virtual world. I observed collaborative behavior during the usability inspection session in INspect-World, analyzed the recorded video and interview data, and documented specific collaborative strategies observed in the virtual world. The results provided insights into the practicality of using virtual world technology for distributed collaboration. The documented collaborative behavior, discussed in detail in Chapter 4 and Chapter 6, provide a stepping stone towards considering virtual world technology for further application in collaborative tools for distributed usability inspections and in other areas.

1.4 Overview of Dissertation Chapters

This chapter provides the motivation to consider virtual world technology for enabling geographically distributed work on focused tasks conducted in small teams.

Chapter 2 introduces the research that provided the background for the development of the INspect-World system. I discuss how distributed collaboration affects work in the area of software development and highlight common issues faced by geographically distributed software development teams to provide concrete examples for the need to explore novel ICT in collaborative tools. In the following, I discuss usability inspections in the context of distributed collaboration and how researchers have studied collaborative behavior in virtual worlds. Extensive ethnographic investigations have looked into public online virtual worlds to unpack collaborative behavior and aspects of virtual identity. Outside the areas of gaming and public virtual worlds, virtual world technology has been applied in industry, software engineering education, and online learning to enable collaboration in small groups. Finally, I discuss how research in CSCW forms another background element to the INspect-World project. ICT has been applied in many collaborative tools with different objectives and I argue for the use of virtual world technology.

Chapter 3 introduces the implementation of INspect-World and INspect-Web that together form a virtual world system designed to enable small, geographically distributed groups to conduct usability inspections. I discuss the functionality of the system by walking through a typical use case scenario. In the final section of the chapter I introduce the hardware setup that was used to host the INspect-World system. Providing details on the software implementation of INspect-World and INspect-Web, I show how the web application interfaces with the OpenSimulator virtual world platform.

In **Chapter 4**, I discuss the methodology of a large-scale empirical study conducted to evaluate the initial version of the INspect-World system. The goal of the study was to observe, document, and analyze collaboration strategies employed by the teams conducting distributed usability inspections in INspect-World. The findings are presented using four collaboration themes that emerged from an in-depth, grounded theory-based research approach. The collaborative behavior displayed by the teams in INspect-World is documented and contextualized using data collected from interviews with the study participants.

Chapter 5 reviews the implementation of INspect-World v.2 representing an updated version of the initial version of INspect-World based on the observations made in the first study. The system was updated to fix software bugs and to implement interface enhancements and additional elements that were aimed at improving the user experience in the virtual world. The chapter provides the rationale behind the design choices made for the implementation of INspect-World v.2.

In **Chapter 6**, I discuss the methodology of a follow-up study conducted in the updated INspect-World v.2 system. The study design follows the research methodology used in the initial study as closely as possible to allow a comparison of the findings and to evaluate the updates implemented in the virtual environment. An additional goal of the follow-up study was to review the collaborative themes and the related collaborative behavior documented in the initial study in INspect-World v.1. The results are discussed in relation to the themes observed in INspect-World v.1 in order to verify the collaboration themes and to discuss differences observed in INspect-World v.2.

The discussion in **Chapter 7** draws on the results of both studies and synthesizes the findings into concrete collaboration strategies employed by the users in the INspect-World system. I discuss the findings in the context of the application of virtual world technology in collaboration tools. I provide examples from the area of online education to show that the application of any ICT in established collaboration contexts needs to be evaluated carefully.

In **Chapter 8**, I draw concluding thoughts on virtual world technology at large and the work conducted on the INspect-World project specifically. I discuss my thoughts on the future development of virtual world technology and its use in geographically distributed collaboration.

CHAPTER 2: Distributed Collaboration in Virtual Worlds

I developed INspect-World based on research conducted in the fields of software engineering, Human-Computer Interaction (HCI), Computer-Supported Cooperative Work (CSCW), and end-user development (EUD). My own studies in these areas also informed the design approach taken in the INspect-World project. This chapter compiles the work that informed the design of the INspect-World system and the empirical research studies conducted in the INspect-World system.

The challenges faced by geographically distributed teams in the software development industry provided the motivation to build a system that enables focused collaborative work in a shared environment. Geographically distributed work has become common work practice in the software development as software development teams increasingly need to collaborate on various software development activities across geographical distances. Past research has looked into common issues faced by distributed team members in global software development. These issues are not unique to the field of software engineering, but they provide concrete examples of work practices that require collaborative tools to work in geographically distributed settings.

Usability testing represents an important milestone in many software development projects that is particularly difficult to accomplish in distributed teams. Ideally, usability testing occurs at various stages in a software development project and is conducted with a small team of experts. The cognitive walkthrough inspection method, supported in INspect-World, represents a common usability testing method that is used to review software interfaces with a collocated team of experts. The cognitive walkthrough inspection method requires a group of experts, such as programmers and other project members, to collaboratively walk through an action sequence on the software interface under review. Past research has looked into the nature of usability inspection methods in software development, the way inspection methods are applied, and what makes usability inspections difficult to adopt for development teams. Building on these findings, the INspect-World system has been designed to allow distributed teams to conduct the cognitive walkthrough method in the collaboration environment of the virtual world. The cognitive walkthrough usability inspection method defines focused collaborative processes that were implemented in INspect-World to show that virtual world technology can be applied to specific collaborative tasks and to observe focused collaborative behavior.

The field of CSCW has a long history of studying distributed collaboration and the design of collaboration tools. Past research has defined the states of collaboration readiness and technology readiness to identify organizational and individual strategies that enable collaboration at a distance. Reviewing the organizational and technical underpinnings of collaboration readiness serves to unpack the problem space in which collaborative tools are applied. Virtual world technology represents a relatively new type of information and communication technology in the CSCW space that builds on a strong theoretical and technical foundation.

I made the design decision to build the INspect-World system on a virtual world platform to enable distributed usability inspections. Past research in public virtual world systems has analyzed general user behavior in virtual worlds or focused on collaborative behavior as part of other main activities, such as play and other social activities. The characteristics of virtual world technology available today need to be understood as an ongoing development from the very beginnings of text-based multi-user systems and early research and theory on simulations. I draw from the historical perspectives and the documented application of modern virtual world technology in various domains to position virtual world technology in the collaborative tool space.

The virtual space in the INspect-World system was designed to enable self-organization and the development of collaboration strategies in distributed teams. I investigated the right balance of scaffolding to guide the usability inspection process and an open system to provide the (virtual) space for the development of individual collaboration strategies. Previous research conducted in the fields of end-user development (EUD) and human-centered design has looked into systems that empower end-users to be creative and, if applicable, gradually become designers of the collaborative system. Researchers have developed socio-technical systems that focus on the design of convivial tools in domain-oriented systems. My own research on the topic showed that public virtual world systems exhibit scaffolding systems and in some cases sufficient flexibility for groups of users to perform collaborative tasks in relatively open-ended and customizable virtual worlds.

2.1 Distributed Software Development

Researchers in human-computer interaction (HCI), and in the field of computer-supported cooperative work (CSCW), have contributed to a large and growing body of research investigating the challenges of distributed work (G. M. Olson & Olson, 2000). Best practices for distributed team managers have been proposed to mitigate common difficulties encountered by individuals in geographically distributed teams (Koehne et al., 2012; Powell et al., 2004). Researchers refer to the terms “virtual work” and “virtual teams” to discuss team configurations and management practices that define geographically distributed work (Bell & Kozlowski, 2002; Mortensen, 2012).

The nature of virtual teams can vary greatly in terms of their configuration and composition of team members (Martins, Gilson, & Maynard, 2004). The notion builds on the definition of "team" which is defined by Katzenbach and Smith as a "small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they are mutually accountable." (Katzenbach & Smith, 1993) The notion of virtual team expands on this original definition and describes teams that utilize communication technology to work across space, time, and team boundaries (Maznevski & Chudoba, 2000).

Distributed software development has been investigated as a specific work area in which virtual teams find application (Carmel & Agarwal, 2001; J D Herbsleb, 2007). Distributed development practices increasingly expand across countries or even continents with the goal to lower development costs and to tap technical expertise in emerging markets across the world (Heeks, Krishna, Nicholsen, & Sahay, 2001).

While research in distributed teams has identified common issues, such as the lack of common ground and awareness between distributed team members, software development teams face unique challenges (Ramesh & Dennis, 2002). From the team perspective they can be summarized as:

- **Complex work processes**: Software development projects involve complex work processes that range from early design specifications and requirements engineering to software design, implementation, (usability) testing, and final verification processes. Virtual teams in the software development field need to develop strategies to translate the various software development processes to distributed settings (Carmel & Agarwal, 2001; James D Herbsleb, Mockus, Finholt, & Grinter, 2000).

- **Long-term collaborative projects:** Iterative software development takes time and often utilizes resources from previous product development cycles. Large research projects can last for years and require collaborative environments that allow participants to iteratively work on shared resources. Researchers have investigated strategies to successfully manage long-term software development projects in virtual teams (Ebert & De Neve, 2001).
- **Diverse team composition and large team sizes:** Software development teams can be large and composed of team members with different roles and specializations. Team managers need to account for this diversity and offer flexible environments to allow for multi-user collaboration (Hazzan & Dubinsky, 2006). Additionally, team compositions can change often and new team members need to be brought up to speed in the team.
- **Tool support for distributed software development:** Software development teams require tool support to conduct computer-aided software design and to maintain awareness of their collaborators. Extensive research has investigated the development of shared design tools and awareness systems for global software development teams (de Souza, Quirk, Trainer, & Redmiles, 2007; Froehlich & Dourish, 2004; Mangano, Baker, Dempsey, Navarro, & van der Hoek, 2010).

The nature of distributed work in software development has evolved from being short-term and focused on relatively simple tasks in meeting situations to encompass long-term collaborations in distributed team configurations with multiple users working on shared artifacts in real time (Wilson & D’Cruz, 2006).

2.2 Usability Inspections in Software Development

Usability evaluation techniques find broad application in the field of software development. Usability evaluation, also referred to as usability testing, describes an approach that investigates a software product in terms of its property of being usable (Nielsen, 1994). Usability testing aims to investigate the extent to which a product appears usable by the intended user population to achieve the tasks for which the product was designed (Preece, Rogers, & Sharp, 2007).

Usability evaluations are conducted using a variety of empirical techniques. In HCI, techniques range from human performance measures on specific tasks in controlled laboratory settings, such as GOMS (Card, Moran, & Newell, 1983; John, Prevas, Salvucci, & Koedinger, 2004) and user satisfaction surveys, to broader field studies that sample user experiences with the product in actual social and physical real-world contexts of use.

In software development, software inspection techniques are used to review work products throughout the development cycle. They are different from other software inspection techniques, such as code reviews and fault detections, in that they are aimed at user interfaces of the software product. Usability inspections focus on non-functional requirements that are to be judged by usability experts (Rieman, Franzke, & Redmiles, 1995).

Usability inspection techniques represent a specific class of usability evaluation techniques that allow experts to evaluate user-interface elements based on conformity with pre-defined usability principles and usually do not involve actual end-users in the evaluation process. Usability inspection techniques can be conducted without expensive recruitment of external participants and at early stages of the software development project.

The Heuristic Evaluation technique, first developed by Molich and Nielsen (Molich & Nielsen, 1990), represents a commonly used inspection technique in software development and other areas. A group of experts evaluates a user interface based on a set of heuristics and notes discrepancies in an evaluation report.

Walkthrough inspection techniques, e.g. the Cognitive Walkthrough inspection technique (Polson, Lewis, Rieman, & Wharton, 1992), are used to assess usability issues with a group of usability experts or developers of the software development team. The Cognitive Walkthrough enables usability experts to locate usability problems in a user interface based on screen shots, mockups or live systems. Evaluators first describe a typical user, choose tasks to be evaluated and formulate detailed action sequences necessary to complete the tasks. Next, the evaluators walk through the action sequences, asking questions about action effects, availability, associations, and progress towards task completion. The cognitive walkthrough inspection technique was implemented in the INspect-World system. A detailed description of the implementation can be found in Chapter 3 and Chapter 5.

Conducting regular software usability inspection sessions can be challenging for software development teams. Ciolkowski et al. (Ciolkowski, Laitenberger, & Biffl, 2003) summarize common issues encountered by teams conducting usability inspections. Development teams voiced concerns regarding the effort put into usability inspection sessions compared to the perceived payoff in the form of an improved product in the end of the project. Individuals had to invest a considerable amount of time and other resources into inspection processes before they saw the results later in the development project. The delay caused the team members to be more hesitant to commit to inspection sessions. Additionally, development projects within the company often did not fit "of-the-shelf" inspection techniques. This mismatch occurred on the individual team member level (levels of expertise) and with the product that was inspected for example when the product specifics were not covered by the used inspection methodology.

Many usability inspection methods applied in software development suffer from the so called "evaluator effect" which refers to the effect that expert evaluators commonly discover a great variety of different usability problems (Hertzum & Jacobsen, 2001). A large number of evaluators are necessary to achieve convincing and valid results for most methodologies.

The Cognitive Walkthrough inspection technique has also been found to be particularly difficult to master by novice practitioners (John & Packer, 1995). While walkthrough techniques can provide a detailed analysis if conducted correctly, a considerable overhead related to setup work often can makes inspection sessions costly. There have been attempts to automate aspects of the evaluation process (Hudson, John, Knudsen, & Byrne, 1999) to lower the setup costs. Methods have been adjusted to fit specific application areas (Blackmon, Polson, Kitajima, & Lewis, 2002) and processes have been optimized to create more streamlined usability workflows (Spencer, 2000). However, many challenges still persist and the trend towards distributed software development contexts introduces more difficulties.

2.3 Virtual World Systems

Virtual worlds still represent a relatively new class of collaboration technology. To understand how virtual words in particular can be useful in the context of geographically distributed collaboration and what exactly one can learn from its application in scientific contexts, it is useful to discuss the historical development of computer simulations. There have been shifts in the use of simulations over time that highlight its potential and that signal certain pitfalls that should be avoided.

Virtual worlds are multi-user virtual environments (Schroeder, 2011) that represent a specific class of virtual reality technologies. Schroeder (Schroeder, 1996) defines virtual reality as "a computer generated display that allows or compels the user (or users) to have a feeling of being present in an environment other than the one that they are actually in and to interact with that environment". As such, a virtual world is defined as a collaborative virtual reality (VR) technology that creates persistent virtual, i.e. computer-generated, three-dimensional environments in which multiple users interact with the environment and with other users.

The first use of computer simulations for scientific purposes can be traced back to the 1940s when John von Neumann, Nicholas Metropolis and Stanislaw Ulam ran experiments at the Los Alamos National Laboratory under the Manhattan Project (Galison, 1996). Applying the so called Monte Carlo Method, computer simulations were used to simulate physical systems based on theoretical models and to compute large set of random number samples. In these cases "simulation is a trial theory, and the role of machine computation is to render the test of that theory 'unambiguous'' (Keller, 2003), p. 207. Epistemologically, computer simulations in these cases were used to produce knowledge by extending the possibility of computation of large sets of data and of the theoretical behavior of autonomous models.

It has been argued that computer simulations afford novel ways of creating knowledge because they extend our perceptions of the “real” to new dimensions (Keller, 2003). While this view has its critics (Frigg & Reiss, 2009), Peter Galison went as far as to state that computer simulations create a “trading zone” between different fields of science by establishing an almost natural language through which various scientific practices can be performed (Galison, 1996). In discussing how a trading zone is established, Pias emphasizes that the more universal use of computer simulations in a broader set of disciplines would have been “unimaginable without the simultaneous development of CGI computer graphic imaginary …” (Pias, 2011).

The advances of CGI and computer simulations can be observed when reviewing the technological development of virtual worlds and modern computer games. Virtual worlds represent a specific class of virtual reality technologies. A virtual world is defined as a collaborative virtual reality technology that creates persistent virtual, i.e. computer-generated, three-dimensional environments in which multiple users interact with the environment and other users (Schroeder, 1996). There are new qualities to virtual worlds that make them inherently different when compared to early computer simulations. While virtual worlds simulate a 3D environment, its virtual objects and representation of users, they are networked and can function as an environment for social interaction. Another major difference lies in the focus on visual simulations and representations that can be explored together.

Virtual worlds create environments for collaborative knowledge production in the virtual environment. For instance, simulating use contexts of applications in the virtual world allows the users to reflect on usability inspection issues in a different light. The network component allows for discussions in the team which help to verify the discovered usability issues. Embodiment and presence in the virtual world can create virtual extensions to the real world that blend distributed social interaction with simulation of context and environment.

The scientific research potential of virtual worlds has been acknowledged in academia (Bainbridge, 2007). Virtual worlds provide a novel tool and technology for researchers to study distributed collaboration in various application areas. The use of virtual worlds, similar to the idea of “trading zones” formulated by Galison, presents an opportunity to observe different activities of distributed groups on a uniform technical platform. Open virtual world platforms can be adjusted to fit development processes of virtual teams in different contexts.

An important development that made virtual worlds increasingly interesting for application in distributed collaboration was the transition from locally installed CAVE-type VR systems and similar hardware solutions to networked virtual world systems. Networked virtual environments make it possible for users to connect to the virtual environment from geographically distributed locations. Historically, networked virtual environments have their roots in two separate developments. ARPANET first demonstrated networked and interactive computer graphics in 1972 developed by the U.S. Advanced Research Projects Agency (Leiner et al., 1997). One of the motivational factors underlying ARPANET was the sharing of scarce computer resources at the time and the development of military battlefield simulations. This development continues until today (Macedonia, 2002).

Contemporary virtual world systems can be traced back to text-based, real-time virtual worlds, so called Multi-User Dungeons (MUDs) (Rufer-Bach, 2009). MUDs represented one of the first public virtual worlds that have been studied for collaboration and interaction (Curtis, 1992; Turkle, 1995). MUDs have been the focus of a special issue of the CSCW journal publication (Schmidt, 1998). Early MUD systems began adding more social interaction features (e.g. "social MUDs") and slowly developed into more modular and complex systems (Dourish, 1998). Ackerman, Muramatsu, and colleagues have studied how mediated communication in text-based virtual worlds affects social regulation among players and what types of social activities are most prevalent in MUD virtual worlds (Ackerman, Muramatsu, & McDonald, 2010; Muramatsu & Ackerman, 1998).

The online social space "Habitat" represents one of the few developments until the 1990s that used networked and interactive computer graphics in addition to text-based communication (Morningstar & Farmer, 1991). The growing popularity of multiplayer online games has since accelerated the technical development of virtual worlds. The number of supported concurrent users in virtual world systems is growing rapidly and the technology used to render realistic, high-quality network graphics is improving rapidly (Bonnie Nardi & Harris, 2006).

As noted earlier what is available today in the form of commercial virtual world systems has evolved from the long history of computer simulations. The first use of simulations was recorded in connection with so called "war games" that first emerged in the 17th century (Allen, 1987). In the form of board games and with miniature military units and buildings, simulations were used to train army movements and strategic thinking. Later installments in the 1950s expanded the concept of simulation to scenario-based war games used for a range of political situations (Gredler, 2004). Until today, the military has invested heavily in combat simulations and flight simulators (Miller, Hobday, Leroux-Demers, & Olleros, 1995) in military training.

Today, the two most popular and publicly used applications of virtual worlds are:

- **Massively-multiplayer online role-playing games** (MMORPGs), such as World of Warcraft (Blizzard, 2014) and Guild Wars 2 (NCSoft, 2014), offer scripted online gaming virtual world environments. Users purchase a monthly subscription to access the virtual world. Players play in teams or on their own to complete gaming objectives. The player's virtual avatar progresses in terms of its abilities and equipment as the player advances in the game.
- **Open-ended virtual worlds,** such as Second Life (LindenLab, 2014) and OpenSimulator (OpenSimulator, 2014), offer users an open virtual world environment that is not only focused on gaming but a broader range of activities. Users can construct scripted virtual objects in the environment or simply explore the virtual space to socialize with other users.

Virtual worlds themselves have been the focus of usability evaluations and frameworks for analyzing social interactions in shared virtual environments have been defined (Schroeder, Heldal, & Tromp, 2006; Schroeder, 2011). My own analysis of usability inspections in virtual worlds built on these frameworks. The "VIEW of the Future" project that describes detailed methods tailored for the evaluation of interactions in virtual realities and virtual environments that were considered during the study design of the INspect-World system (Karaseitanidis et al., 2006; Wilson & D'Cruz, 2006). From a higher-level perspective, Pausch et al. investigated the usability of virtual realities in terms of the users' immersion compared to desktop applications, and found that users were able to maintain a better frame of reference in the virtual reality (Pausch, Proffitt, & Williams, 1997). Users were able to transfer learning experiences from the virtual reality to the real world. Virtual worlds have been investigated for collaborative user interactions previously. Both qualitative and quantitative studies investigating online games have looked at collaborative play and how players learn from each other during gameplay (Bonnie Nardi & Harris, 2006; Bonnie Nardi, Ly, & Harris, 2007). Boellstorff provided ethnographic accounts of everyday encounters in the virtual world of Second Life based on his own participation (Boellstorff, 2008). Nardi also conducted extensive ethnographic studies of virtual worlds (B. Nardi, 2010). Virtual worlds have since found application in education (Wankel & Hinrichs, 2011), health care (Boulos, Hetherington, & Wheeler, 2007), and scientific collaboratories (Djorgovski et al., 2010).

In my own research I reviewed virtual world technology in terms of its application for distributed collaboration (Koehne & Redmiles, 2012). Virtual world technology offers unique qualities that can help to perform usability inspections in small, distributed teams:

- **Shared points of reference and orientation**: The virtual environment allows users to maintain points of references during the usability inspection process. Switching between inspected interface elements only requires turning the avatar. Other users have an immediate sense of the reference change and can interpret activities accordingly.
- **Persistent 3D environment:** Usability inspections in the virtual world can be paused and resumed at any point of time during a collaborative session. The state of the environment is preserved so that changes made to the environment and the progress in the collaborative activity can be observed and resumed easily.

- **Recording of usability inspections:** Actions in the virtual world can be recorded and archived for later review or replay. This allows for a more in-depth analysis of how usability issues were discovered in the context of discussion or specific action sequences.
- **Data management and planning:** Open-source virtual world platforms, such as OpenSimulator, offer ways for managing and capturing data generated during collaborative activities in the virtual world. The data can be analyzed separately or made available to other applications that interface with the virtual world system.

With colleagues, I have argued for the utility of virtual worlds in conducting collaborative research (Koehne, Redmiles, & Fischer, 2011). Studying collaboration and engagement in popular online virtual world systems provides opportunities to learn about user behavior and the development of collaboration strategies in distributed teams.

Accessing most public virtual world systems does not require high-end computer hardware. Modern laptops today have sufficient processing and graphics power that allow players to experience virtual worlds on broadly available devices. The more recent development and broad availability of innovative virtual reality interface hardware, such as *Oculus Rift* (Oculus, 2014) and *Google Glass* (Google, 2014), have the great potential to further lower the barrier to entry for virtual world technologies and their application in areas beyond gaming.

Given the ever-increasing availability of affordable virtual world technologies and natural interfaces and their appeal to large groups of users in the gaming area, we believe that the time is right to re-examine the use of virtual worlds for supporting targeted collaborative activities in the workplace and in education. CSCW designers require a good understanding of how virtual world technologies can support specific collaborative activities and how users interact in the virtual space to achieve collaborative goals.

2.4 Computer-Supported Cooperative Work and End-User Development

The design focus of INspect-World on distributed usability inspections positions the work in the context of Computer-Supported Cooperative Work (CSCW). Distributed teams have been the focus of extensive research in CSCW for more than two decades (Gibson & Cohen, 2003; Powell et al., 2004). This work recommends enabling remote workers with innovative communication platforms and providing organizational and managerial strategies to bridge geographical distances between teams (G. M. Olson & Olson, 2000). INspect-World can be viewed as an enabling technology to allow distributed teams to conduct usability inspections. At the same time, INspect-World allows researchers to observe collaborative strategies performed by distributed team members. The observations can be used to design novel systems in CSCW that use virtual world technology to enable collaborative activities.

Researchers in CSCW have looked into organizational strategies to address common challenges faced by distributed teams in various collaboration areas. The term 'collaboration readiness' in CSCW describes the ability of organizations and institutions to provide structural and technical support for collaborative activities across geographical distances (J. S. Olson & Olson, 2013). Collaboration readiness can be achieved on different levels of the organization and is concerned with various characteristics of the work conditions. Distributed teams need to establish a common understanding of shared knowledge and vocabulary in the team. Cultural differences in terms of national cultures defining individual work styles and company culture differences in different work locations affect how teams develop collaborative patterns (Connaughton & Shuffler, 2007). Team leaders and company managers need to create a balance between internal competition and a collaborative and sharing company culture (Bos et al., 2010). Time zone differences can make distributed work particularly difficult when collaborative activities need to be handed over to time-shifted teams (Tang, Zhao, Cao, & Inkpen, 2011). Distributed scientific collaboration or so called "collaboratories" have been the focus of CSCW research on collaboration readiness (Farooq, Ganoe, Carroll, & Giles, 2007; G. M. Olson, Zimmerman, & Bos, 2008). Distributed collaboration on scientific projects is becoming a more and more common work practice in research institutions. Similar to distributed software development, scientific research groups need to build common ground of shared knowledge that might be stored in different data formats, manage different work styles and cultures of the collaborating laboratories in distributed locations, and create awareness of individual work conducted on shared research projects.

Besides organization strategies and work styles, distributed teams nowadays increasingly rely on collaboration technology that has become crucial to work on shared data, to communicate efficiently across distances, and to coordinate activities across geographical distances. Collaboration readiness can in most cases only be achieved alongside of a state of technology readiness. While collaboration readiness refers primarily to organizational factors on the individual team member level and on the team level, technology readiness refers to the availability and successful application of collaboration technology that enables distributed teams to work together on shared tasks. Technology readiness for distributed collaboration has been investigated in the context of scientific collaboration

(Farooq et al., 2007) and other areas such as globally distributed software development (James D Herbsleb, Mockus, Finholt, & Grinter, 2000).

Technological tools can enable effective collaboration across distances if they are used appropriately by the collaborators. Many different technologies exist that can enable collaboration across distances. Sarma at al. define three different types of information technologies that are used in distributed work (Sarma, Redmiles, & der Hoek, 2010). **Communication tools** enable collaborators to exchange information. Communication tools can differ greatly in terms of the media richness of the technology used to transmit the messages. For example, video represents a far richer medium than text and can be used to enable face-to-face communication at a distance while maintaining social cues in the conversation that convey important tones and emotions. **Artifact management tools** allow collaborators to share, collaboratively edit, and visualize work objects in the distributed team. Meeting support tools enable the collaborative editing of documents and awareness tools show developers the progress and status of distributed collaborators working on the same source code. **Task management tools** help distributed teams to gather and organize information about a project and to plan activities for distributed team members. The management of tasks and the breakdown into individual activities becomes crucial when many team members need to coordinate activities in the distributed team.

The INspect-World system is uniquely positioned in the space of distributed collaboration technologies because the system lends from different types of tools laid out by Sarma et al. Building on a virtual world technology platform INspect-World represents a rich communication tool in a graphical 3D virtual space in which users communicate through avatars. The system provides objects in the virtual world to allow teams to focus on the distributed task of conducting a usability inspection. The environment visualizes the object of the task, a cell phone application's interface, on a realistic cell phone model in the virtual world. The INspect-Web application, interfacing with the INspect-World virtual world server, allows usability inspection managers to schedule and set up collaboration sessions. The INspect-World system thus cannot be assigned to only one specific collaboration tool type. The system was designed to provide a comprehensive solution for conducting distributed usability inspections.

Technology readiness on the organizational level refers to the provision of the right types of collaboration technology, or a combination thereof, to distributed teams. On the individual team member level, the adoption of the technology needs to be accepted so that the technology can be used by whole the teams. Mark and Poltrock found that collaboration technology slowly diffuses through the distributed team (Mark & Poltrock, 2001). Collaboration readiness and technology readiness are interwoven processes that need to be considered when a novel collaborative system is introduced.

In my own research, I have implemented collaborative tools and studied collaborative technology. The results of this work contributed to the development of the INspect-World system. I developed a system for cooperative sketching in distributed meetings that focused on maintaining eye contact with the collaborator (Thies & Koehne, 2009). A review of CSCW literature with a focus on virtualization technologies and video-conferencing systems was conducted (Koehne & Redmiles, 2009) and found that several systems lack appropriate tool support for mediating awareness and social collaboration contexts. In a more recent study I and colleagues investigated how individuals in distributed teams developed strategies to cope with the daily challenges of working remotely and alone (Koehne et al., 2012).

Individual remote workers establish unique work rhythms, visibility management techniques, and social support infrastructures while using collaborative technology during their daily work.

An additional field of study that influenced the INspect-World project is represented by end-user development (EUD) (Lieberman, Paterno, Klann, & Wulf, 2006). EUD focuses on empowering end-users to become creators in open systems. Research in EUD is looking into concepts such as the transition from novice users to experts, scaffolding processes, and the importance of socio-technical environments for end-user empowerment. The meta-design framework (G. Fischer & Giaccardi, 2006) adopts many EUD concepts and lays out ways to gradually enable end-users to become active contributors in domain-oriented design environments. Meta-design defines activities, processes, and objectives to create new media and environments that allow users to act as designers and be creative. The theoretical concepts underpinning the INspect-World project borrowed theoretical concepts of meta-design and end-user development to ultimately create an open system that incorporated concepts of user empowerment. I wanted to create a system that provides sufficient room for the development of individual collaboration strategies while still providing the necessary scaffolding for maintaining collaboration and teamwork.

I conducted empirical studies in a public game-oriented and an open-ended virtual world (Koehne, Fischer, & Redmiles, 2011) to investigate how virtual worlds support elements of EUD. I found that a central element of the gaming environment was represented by the social context that provided players with a sense of community and a support infrastructure. The virtual world systems provided a various scaffolding mechanisms for supporting novice users to become acquainted with the functionality of the system.

While a virtual world platform can provide the technical elements and communication baseline for the implementation of a collaborative environment, it is essential that designers invest in design elements that make the environment usable for each individual team member. The importance of an understanding of the multiplicity and diversity of users in technological development has been championed in the field of human-centered design (Oudshoorn & Pinch, 2003). Users do not always adopt technology in straightforward processes. In the context of distributed teams designers may need to consider allowing end-users to reconfigure the collaborative system at use-time as requirements can change throughout the work on the task.

On the basis of the core concepts of the meta-design framework (G. Fischer & Scharff, 2000) and my investigations in public virtual worlds (Koehne, Redmiles, et al., 2011), the following human-centered design concepts can serve as a guideline for the design of a collaborative tool for distributed usability inspections using virtual world technology:

- **Domain orientation**: The virtual world environment needs to be focused on the domain of a specific collaborative activity. The goal is to provide a virtual space for collaborative activities in the domain of usability inspections. Thus the environment needs to support activities leading towards the actual inspection processes (such as organization of sessions, gathering inspection resources, etc.), and not solely focus on a fixed inspection task alone.
- **Convivial Tools:** The virtual world environment needs to provide tools that allow each user to make contributions in the best way they see fit. Convivial tools do not restrict users to fixed inputs, but encourage creative activity during the interaction with the system (Illich, 1973). For instance, in the case of usability inspections, the

system should encourage users to discover usability issues by highlighting common problem areas in the interface and by offering different types of input (e.g. voice and text).

- **Open, evolvable systems:** The virtual world system should be open for change to adapt to different types of usability inspections or changes to currently practiced usability inspection techniques. Virtual team configurations can change regularly which in turn often requires changes to how the team handles software processes. Changes to the inspection environment also need to be initiated by the users and not the system administrators alone.
- **Underdesigned systems:** The implementation of the virtual world system should leave room for change. The goal should be to develop a system that provides enough flexibility to allow users to adopt the system to their individual needs.
- **Collaborative work processes:** By encouraging collaboration during the inspection process, users are motivated to not simply use the system, but to become active contributors for changes. Users can evolve from the consumer role to the designer role and eventually change the system and implement their own strategies of technology use (Gerhard Fischer & Ostwald, 2002).

The meta-design framework presents a unique lens to look at the design of collaborative systems as collaborative spaces that promote the empowerment of end-users. The empowerment of end-users does not need to lead all the way to designer role, but a gradual empowerment can lead to a different collaborative atmosphere and provide motivation to think and collaborate with tools that engage the team members.

CHAPTER 3: INspect-World v.1 Implementation

The INspect-World system consists of two linked tools. INspect-World provides the virtual world environment that is used by the distributed teams to conduct usability inspections. INspect-Web represents a web-based management tool to set up usability inspection sessions in INspect-World, to manage users of the system, and to review usability inspection results[1]. This Chapter introduces the functionality of INspect-World and INspect-Web. The implementation discussed in this chapter was later updated with the release of INspect-World v.2 which will be discussed in Chapter 5.

The main goal with the development of INspect-World was to create a system that would allow groups of geographically distributed collaborators to perform usability inspections on a software interface. Another goal was to focus specifically on virtual world technology to explore how users would develop collaboration strategies in the virtual 3D context. The goal was to achieve the right balance between scaffolding provided in the virtual world system and an open environment that would allow the development of individual strategies. The system would have to provide the necessary infrastructure to help users move through the process of a usability inspection session. At the same time the system should not put too many constraints on how collaborators would choose to organize their teamwork and to develop individual approaches to the usability inspection task at hand.

To realize this balance, the system was built on top of the open-source virtual world platform OpenSimulator (OpenSimulator, 2014). The OpenSimulator system provided the foundational open virtual world platform that allowed users to interact and communicate in

[1] Michael Caldera, a visiting researcher to the CRADL research group at UC Irvine, contributed to the implementation of INspect-Web.

a virtual 3D space using virtual avatars. To support the role of managers planning usability inspections for teams of collaborators, the installation of OpenSimulator on the project server was heavily customized to create a framework that allowed for the semi-automatic creation of virtual usability inspection environments. The system uses the user input typically required for conducting usability inspections in co-located settings. A web application INspect-Web was interfaced with the virtual world system provided by INspect-World. Using the web application, usability session organizers could create user accounts for usability evaluators and organize users into teams. The web application was used to automatic generate custom usability inspection environments in INspect-World based on the usability inspection input uploaded to the web application. Automatically generating the virtual usability inspection environment drastically lowers the set up times for planned usability sessions ahead of the action inspection session with evaluators. Manually creating a usability inspection environment in the unaltered OpenSimulator system for each and every planned usability session would result in an unreasonable preparation overhead and the need for expert virtual world designers for each session.

Taken together, INspect-Web and INspect-World make up a system that builds on a reliable virtual world technology platform providing the essential communication tools and a virtual interaction framework to enable collaboration within groups of usability evaluators. At the same time, the modifications made to the OpenSimulator system allow the custom web application INspect-Web to link with the virtual world server and provide the essential tools for managing and creating the usability sessions and user accounts.

3.1 INspect-Web – Usability Inspection Setup and Management

The INspect-Web component represents a web application that connects to the virtual world server installation and provides management functions for usability session managers and regular evaluators. Evaluators can edit their account information and usability session managers can generate virtual world usability session environments based on custom usability inspection input. The following section walks through the functionality of INspect-Web following a typical workflow that a usability session manager would follow to set up a new cognitive walkthrough usability session for two teams in INspect-World.

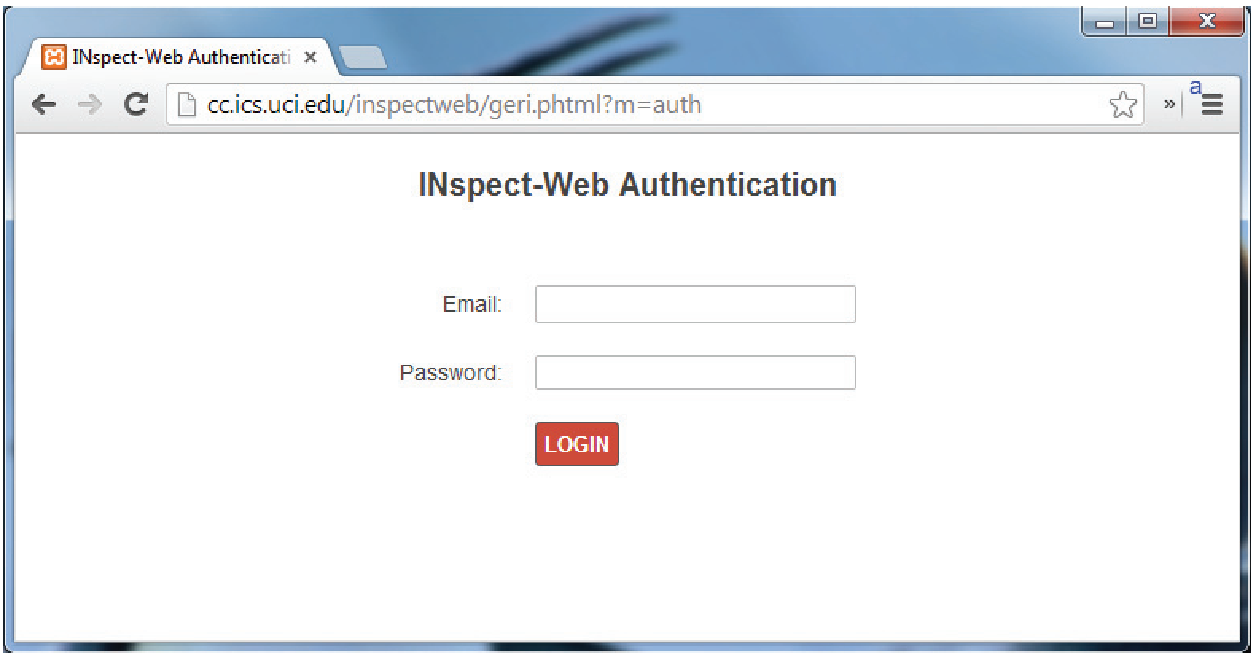

Figure 3.1: INspect-Web login interface.

To set up a virtual usability session in INspect-World, the user (a usability manager in this example) first logs into the INspect-Web application (see: **Figure 3.1**). The system distinguishes between three different types of user accounts. Administrators have full access to all features including server diagnostic views. Managers have access to user management and usability management functionality. Evaluators can edit their own account information, such as password, email and username. Evaluators can also review the results of previously conducted usability inspection sessions that they performed with their team in the virtual world.

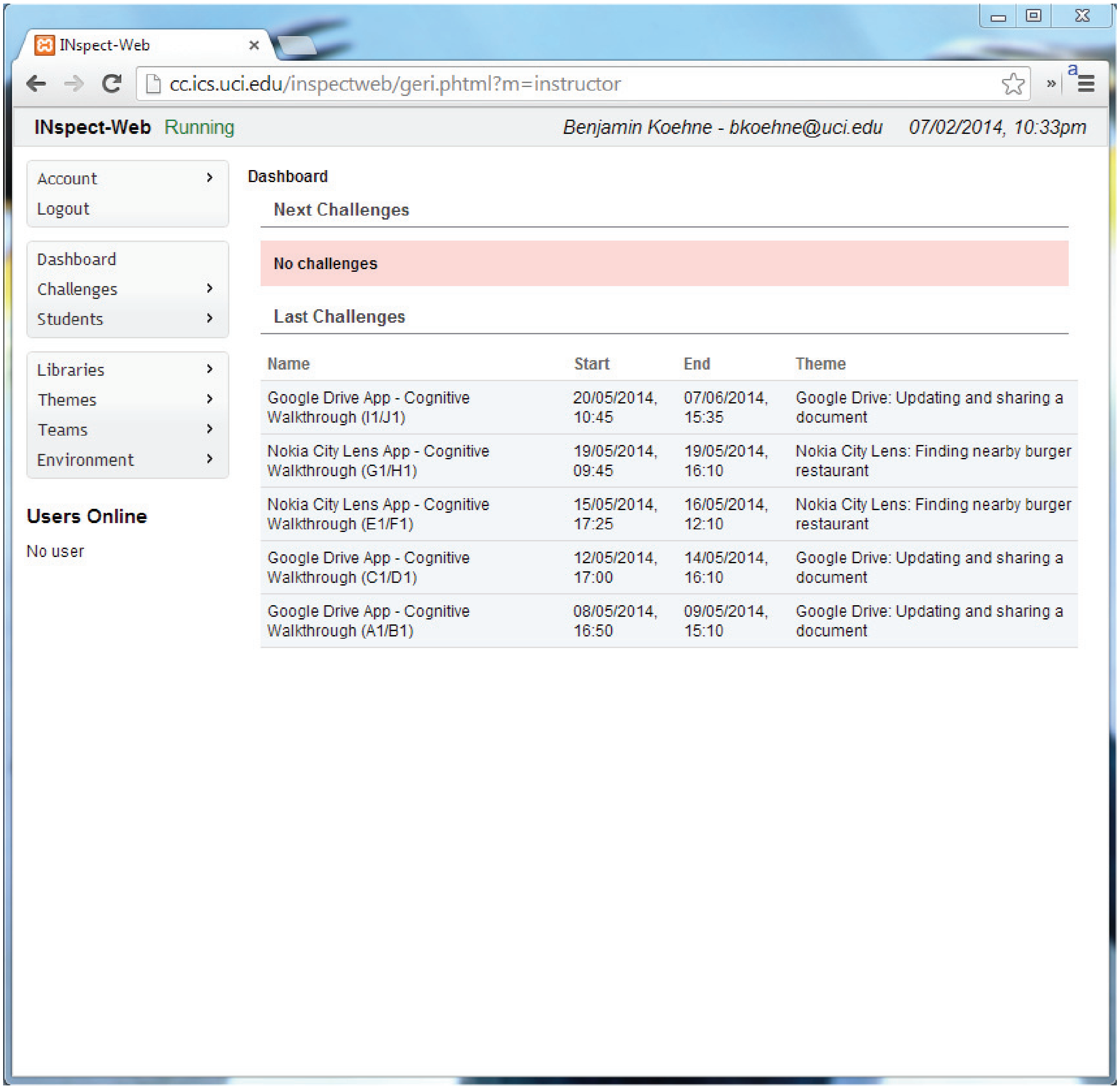

Figure 3.2: INspect-Web Dashboard view.

Figure 3.2 shows the Dashboard view after the manager successfully logged into the INspect-Web application. From here, the manager has access to the full functionality of the system from the menu on left had side. The dashboard shows past and current "*challenges*". Challenges refer to planned and conducted usability inspection sessions in INspect-World.

A challenge is set up between two individual teams that each performs a usability inspection session on the same software interface in the virtual world. Each team performs the usability inspection in a separate inspection space in INspect-World, but will perform in the same virtual environment. Both teams work against the clock, hence each challenge has fields to set the start and end time. As shown in **Figure 3.2**, the manager is presented with an overview of planned and past challenges in INspect-World that she can follow up on.

The overview also shows the "*theme*" that has been selected for each challenge. A theme in INspect-Web represents the defined action sequence performed on a specific software application that is inspected for its usability by a team of evaluators. The action sequence metaphor stems from the cognitive walkthrough inspection method supported in INspect-World. Per default the system follows the methodology and questions defined in the cognitive walkthrough method. The manager has the option to alter the walkthrough inspection questions asked at each action sequence step by editing the themes in INspect-Web.

New challenges can be defined in the "*Add Challenge'*" view in INspect-Web as shown in **Figure 3.3**. The manager provides a unique name for the challenge and selects a specific start and end time from the menus. The theme of the usability inspection is selected from a drop-down list. The list holds all previously defined action sequences. Next, the manager selects the participating teams for the usability inspection session. New action sequences, teams and team members can be added by accessing the corresponding menu items as shown in the following. Once the challenge parameters are all set, the manager confirms the input and the inspection challenge is added to the INspect-World database. The usability inspection session is now scheduled.

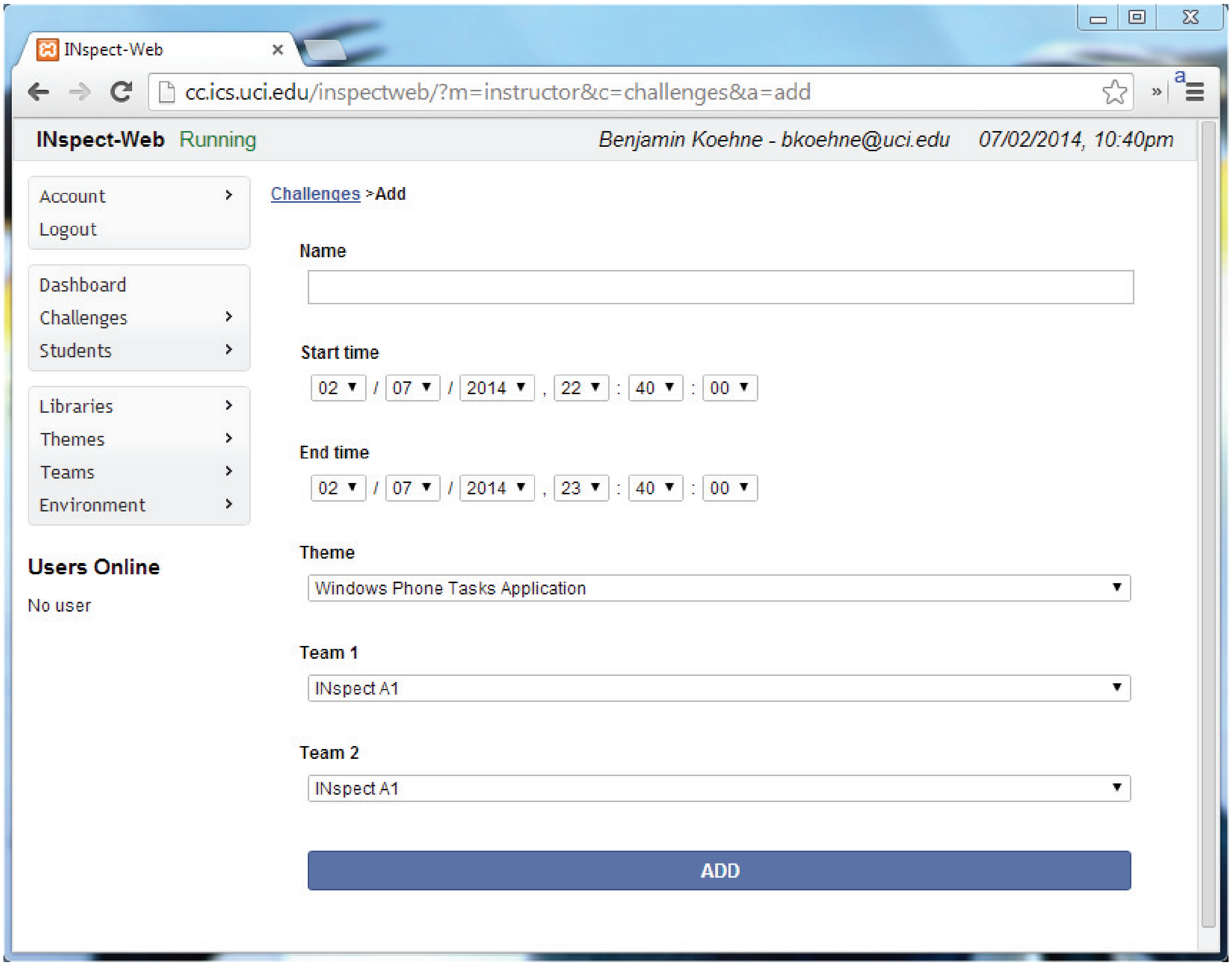

Figure 3.3: INspect-Web – Adding a usability challenge.

The manager can add and edit user accounts by selecting the corresponding menu item. After providing the new user's name and email address, as shown in **Figure 3.4**, the new user is created in INspect-Web and available in the virtual world. The system automatically creates a user account for INspect-Web that the users can use to change their password or email address associated with their account. Users can also review the results of completed usability inspections. Managers can group individual user accounts into teams that will later collaborate in the virtual world. Invisible to the manager, the system also creates a virtual 3D avatar for the newly added user account which is immediately usable in INspect-World. The new user is automatically sent an email with login information for both INspect-World and INspect-Web.

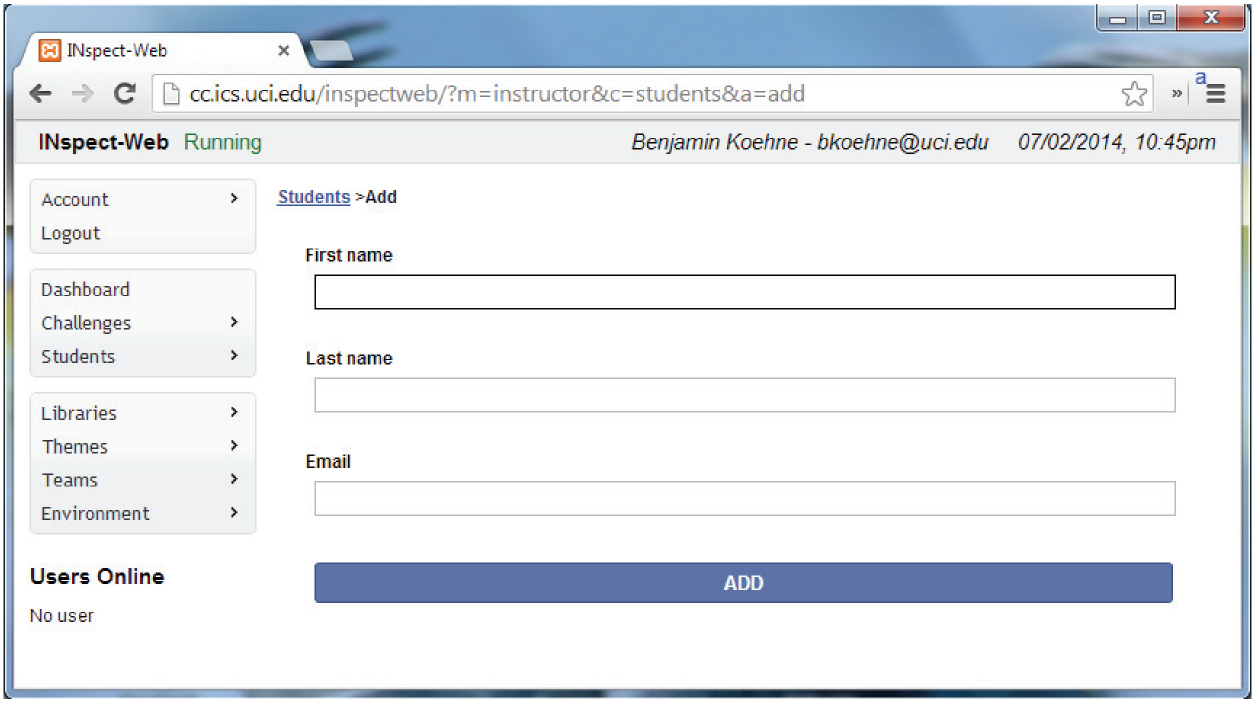

Figure 3.4: INspect-Web – Adding new users.

Using the menu item "Libraries", managers can customize elements of the usability inspection process. By default, usability inspections in INspect-World are conducted on an action sequence of tasks on a given software interface following the cognitive walkthrough usability inspection method. Managers can edit the questions evaluators investigate at each individual action sequence step in the virtual world as shown in **Figure 3.5**. INspect-Web provides the standard set of questions for the cognitive walkthrough inspection method. Libraries can be added, edited, and deleted to manage custom inspection methods.

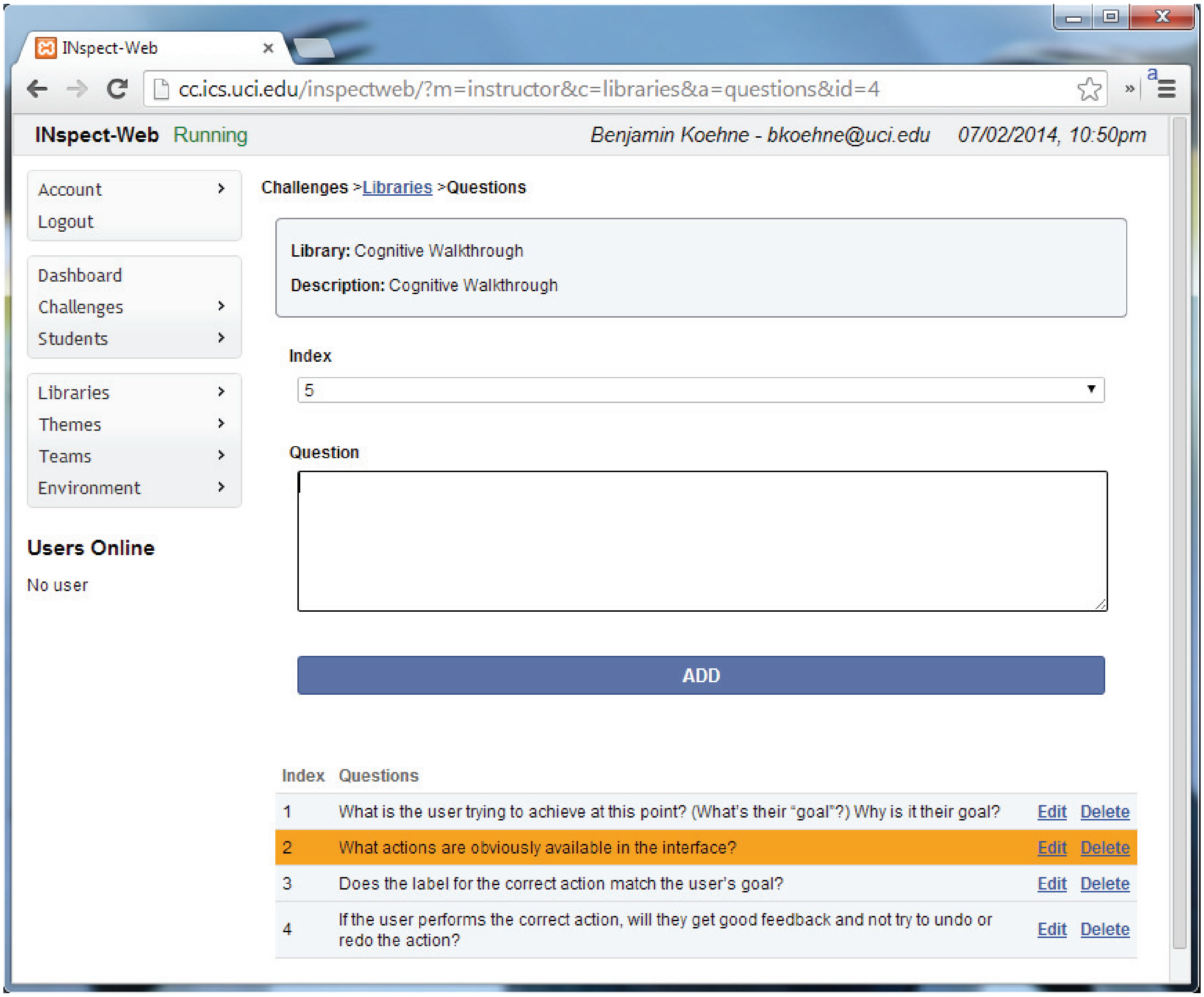

Figure 3.5: INspect-Web – Editing usability inspection libraries.

Before generating the virtual environment for the usability inspection to take place in INspect-World, the manager needs to define an action sequence input for the used usability inspection method. **Figure 3.6** shows the editing process of an action sequence for a planned cognitive walkthrough of a cell phone application. The manager provides a title for the theme, a description, and finally uploads a set of screenshots corresponding to the action steps performed on the software interface under evaluation. An action step is added by providing a screenshot, a short description of the user's action, and the index of the position in the action sequence.

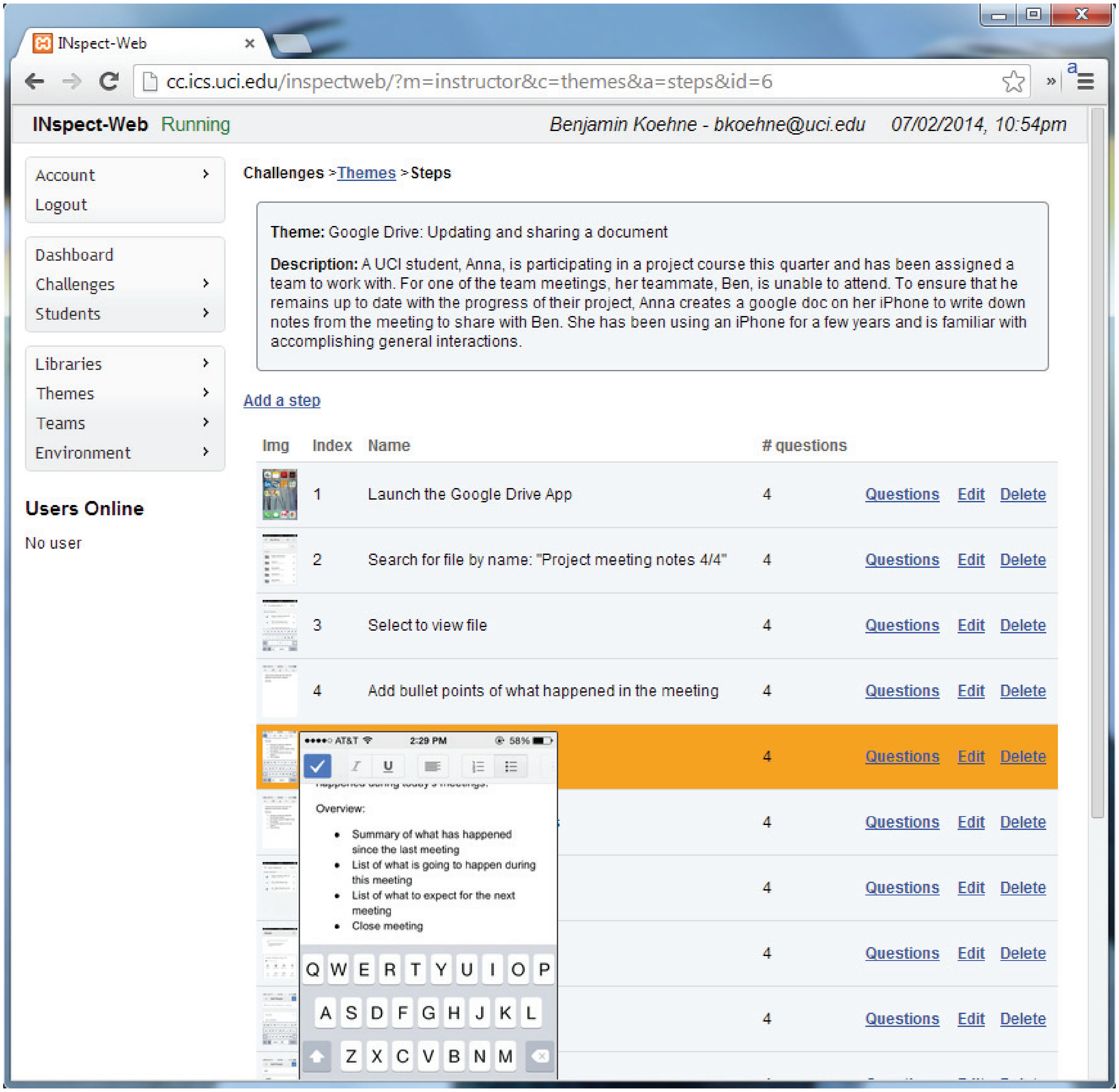

Figure 3.6: INspect-Web – Editing usability inspection action steps.

Once all the information required for the planned usability session in INspect-World is gathered, the manager can proceed to generate the virtual usability inspection environment. Selecting "*Environment*" and "*Build*" from the main menu, as shown in **Figure 3.7**, initiates the automated building process of the INspect-World environment for the provided usability inspection input. INspect-Web uses the information provided by the manager (participating teams, timing of the session, selected inspection method, and action sequence) and populates the information to the INspect-World database. The virtual world server loads the newly added virtual elements and reboots. The INspect-World system is now ready to accept user logins for the scheduled usability inspection session.

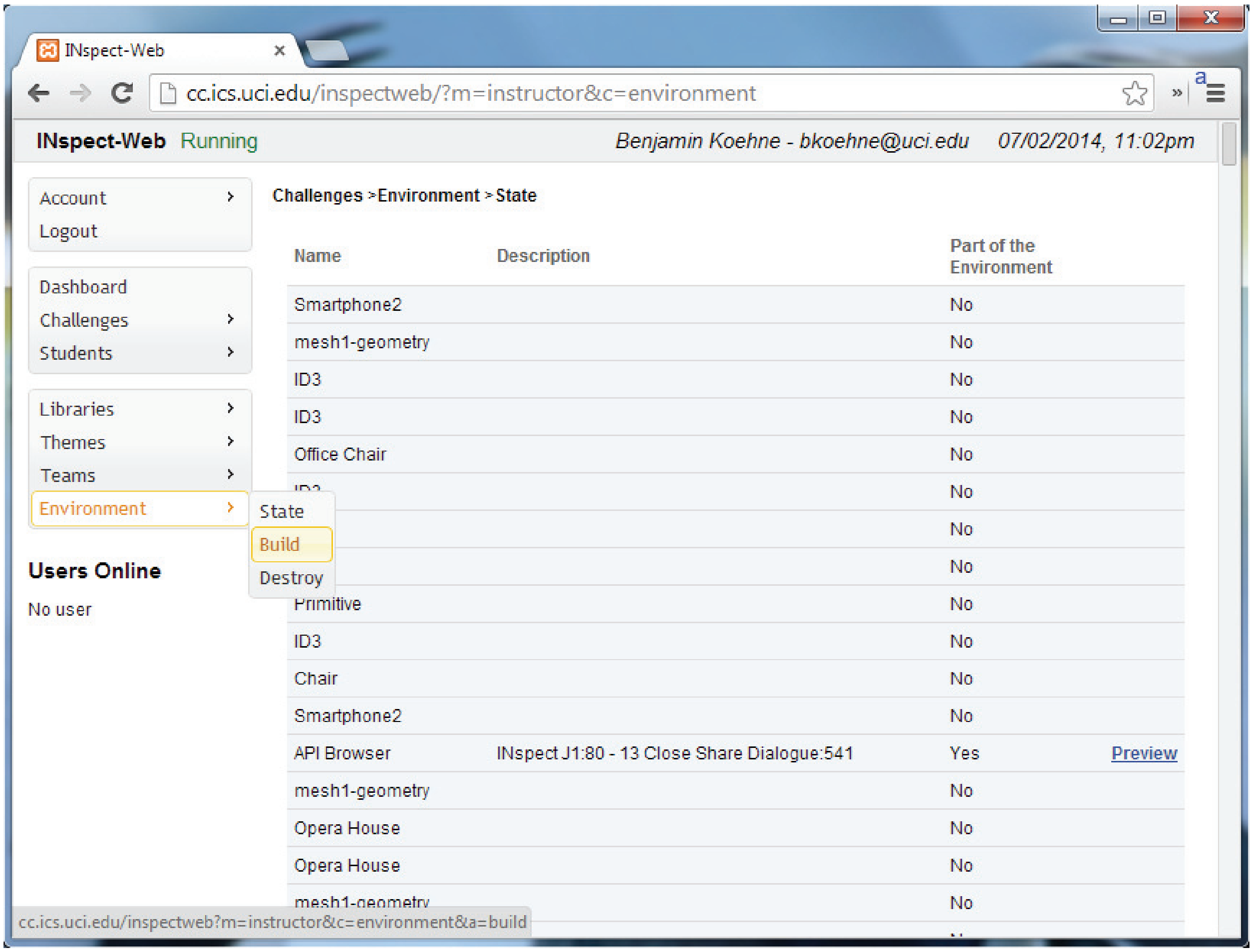

Figure 3.7: INspect-Web – Initiate automated building process.

The INspect-Web system was designed to provide a simple and effective way to set up and manage usability inspections in the INspect-World virtual world setting. Usability managers do not need to bring design or technical expertise with regards to virtual world technology. It would be very costly to manually design unique virtual environments for individual usability sessions and to create virtual avatars manually. The INspect-World system also serves as an interface for regular evaluators to review their inspection reports and to manage their account. Another benefit lies in the accessibility of the web application from the web browser. Evaluators and managers can connect to INspect-Web from geographically distributed locations. The evaluation process and management processes can thus be both conducted without the need for face-to-face meetings.

3.2 INspect-World – Virtual Usability Inspection Environment

The INspect-World system represents the counterpart to the INspect-Web component discussed in the previous section. INspect-World provides the virtual 3D space for conducting usability inspections in small teams. The system builds on a customized installation of the open-source virtual world server platform OpenSimulator. OpenSimulator provides the basic 3D environment, inventory services, avatar services, 3D objects building services, and communication services. The following describe the elements of INspect-World by walking through the typical experience of a user conducting a usability inspection with a small group of evaluators.

To access the virtual world environment, evaluators use a specific client software, also called "viewer software", that is compatible with the underlying OpenSimulator platform's communication protocol. Most available clients are free of cost and provide similar functionality compared to the official Linden Lab client software that is used to connect to the popular virtual world Second Life (LindenLab, 2014). Popular client software solutions for OpenSimulator at the time of writing are *Hippo Viewer* (HippoViewer, 2014), *Imprudence/Kokua* (KokuaViewer, 2014), and *Firestorm* Viewer (FirestormViewer, 2014). Many of the available clients are the result of community development projects. Each project often follows a particular design philosophy with a different focus on selected features supported by the client. INspect-World is compatible with all previously mentioned clients, but the development and usability testing of INspect-World was conducted using the *Firestorm Viewer* client software. *Firestorm Viewer* is available for Windows, MAC OS, and Linux operating systems.

Figure 3.8: INspect-World client software and features (Firestorm Viewer).

Figure 3.8 shows the main interface of the *Firestorm Viewer* after successfully logging into INspect-World in the role of an evaluator who is about to conduct a usability inspection session. The user uses keyboard and mouse to interact with the client. In the center of the screen (**Figure 3.8**: 1) the user sees their virtual avatar. The avatar has a default appearance from the moment the user account is created in INspect-Web. The user can edit the appearance of the avatar at will. Avatar customizations options range from general body physique (height, body shape, hair color, facial features) to custom clothing (shirts, pants, shoes, etc.) and attachments (e.g. hats, glasses, or signs). The system shows the user name on top of the virtual avatar. Users also see the other avatars' name in the same fashion.

Camera controls (**Figure 3.8**: 2) and movement controls (**Figure 3.8**: 3) allow the user to navigate the virtual space with the avatar. Movement controls can be accessed using the mouse or keyboard shortcuts (e.g. arrow keys, or AWSD key bindings.). There is an option to switch between three separate movement speeds: walking, running, and flying. Flying will lift the avatar from the ground and allows fast movement across the virtual space. Camera controls (**Figure 3.8**: 2) allow the user to view the virtual space from different angles and camera locations. The camera can be completely detached from the avatar to the preferred angle and viewpoints. The user can also switch into a first-person view in which the user can virtually look through her avatar's eyes and does not see the virtual avatar's representation when navigating the virtual world.

A mini map of the virtual environment helps with the orientation in the virtual space. Objects are shown as grey areas, whereas users are represented as colorful dots. A larger world map with more details is accessible through the bottom task bar. Communication is available through text chat (**Figure 3.8**: 5) and voice chat (**Figure 3.8**: 6). Text messages are entered in the lower left of the screen (**Figure 3.8**: 5). Once submitted, users in the close vicinity of the avatar can see the message. When entering a text message, the avatar plays a typing animation, indicating to close-by user that the user is currently typing a message. Voice chat uses a push-to-talk system. When the user decides to talk to other team members in the vicinity, the user presses the microphone button (**Figure 3.8**: 6) while talking into the microphone. The audio is submitted to other users in the close vicinity. The white dot above the avatar turns green and flashes while a user is using voice chat.

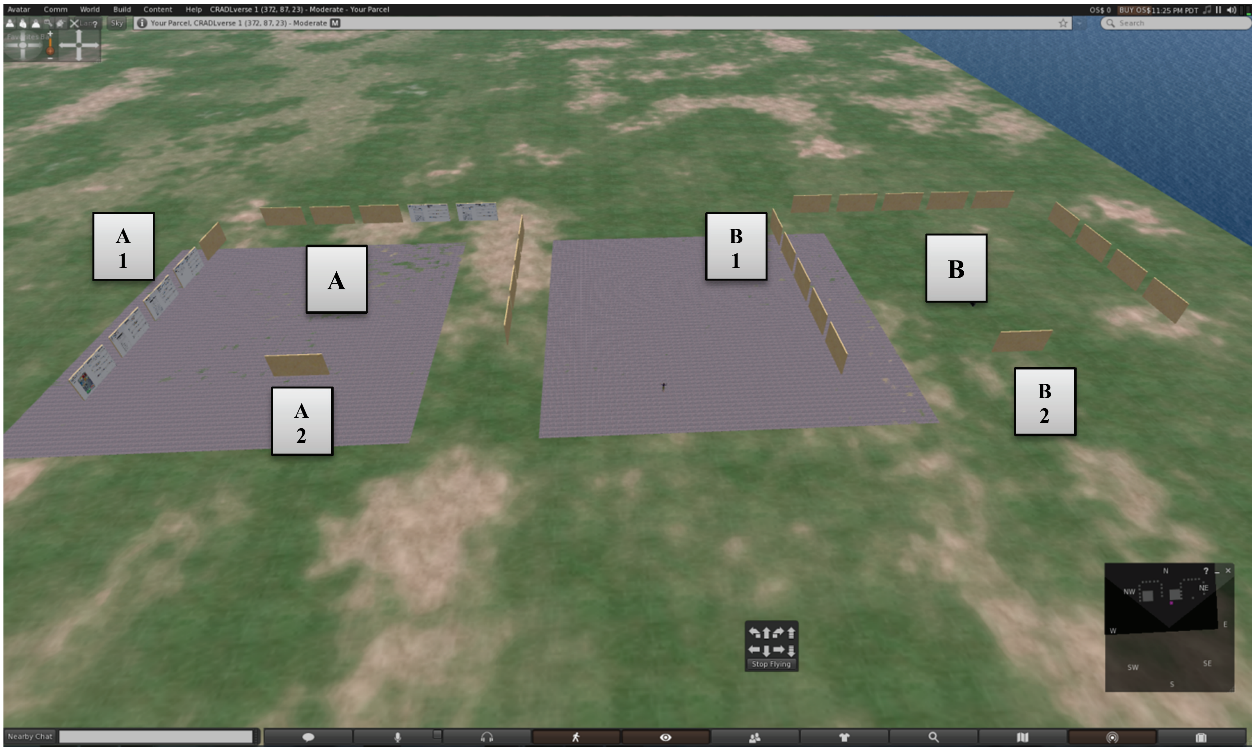

Figure 3.9: INspect-World arena – view from the top.

INspect-Web generates two identical usability inspection spaces in INspect-World that are located adjunct to each other (see: A & B in **Figure 3.9**). **Figure 3.9** shows a bird's eye view of the two usability inspection spaces in INspect-World. Each usability inspection space, in the following called arena, is designated to one of the two teams participating in the usability inspection session. Each arena consists of two main elements: evaluation screens (**Figure 3.9:** A1, B1) and one score screen (**Figure 3.9:** A1, B2). The arenas are generated based on the input provided through INspect-Web. In the example shown in **Figure 3.9**, the usability inspection action sequence consists of 14 action steps. Thus the system generated 14 individual evaluation screens for each action step along the left, top, and right edges of each arena. The lower edge is used to place a score screen in the center. Based on the number of action steps of the given usability inspection input provided in INspect-Web the arenas are extended along the left, right, and upper edges.

As the evaluator logs into INspect-World he is placed into one of the two arenas together with her team. The team begins the usability inspection in the lower left corner of the arena where it finds the initial evaluation screen showing the first action step. The team progresses clock-wise around the arena from screen to screen to complete the evaluation of the given action sequence. There is no particular restriction on how the team moves in the arena. The collaboration strategies are defined by the teams themselves.

Figure 3.10 shows the evaluation screen in detail from the viewpoint of an evaluator who works on a cognitive walkthrough usability inspection. The screen reflects the information that was input in INspect-Web for the planned usability inspection session. The upper left side of the evaluation screen (**Figure 3.10:** 1) shows the team's name and a short description of the current action step. A countdown timer shows the remaining time for the inspection session. The state of the interface, i.e. a screenshot of the screen at the action step, is shown below the countdown of the inspection session (**Figure 3.10:** 2). The screenshot is the main focus of the team as the task is to evaluate the action step based on the interface. The right hand side of the display shows the note taking text fields (**Figure 3.10:** 3). The question for each answer field is defined by the selected usability inspection method in INspect-Web. The team elects a scribe that will take notes during the inspection session. The scribe inputs the notes that the team agrees on into the corresponding text fields. Each inspection screen is shared between all collaborators in the team to enable the collaboration on the shared content and user input.

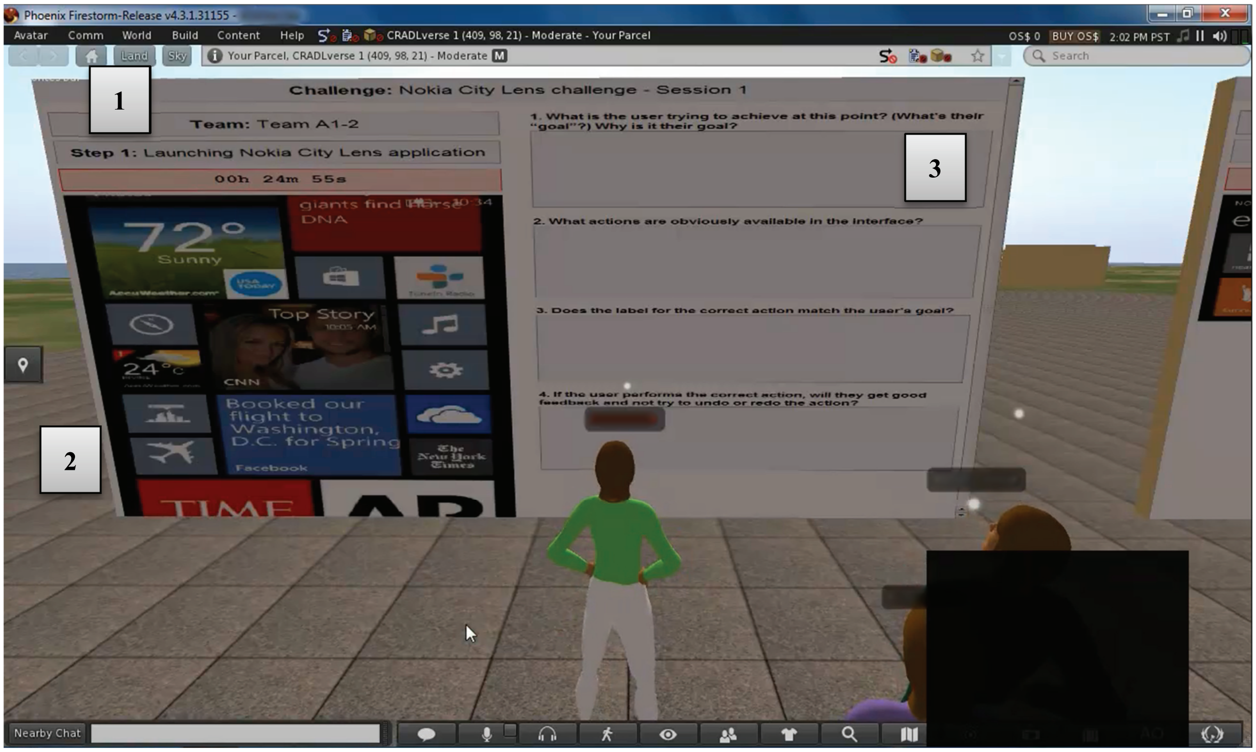

Figure 3.10: INspect-World evaluation screen.

The score screen, shown in **Figure 3.11**, provides the teams with its current standing in the usability inspection competition. Two progress bars juxtapose the total number of answered questions of each team that updates live throughout the inspection session. The screen also shows a description of the context of the usability inspection as defined in INspect-Web. The score screen can be interpreted as showing the state of the competition between both teams. If no competition is intended between the teams, the score screen can serve to inform each team about the completion of the inspection task. The score screen was intentionally placed in the in the lower center of the inspection arena and not in the immediate vicinity of the inspection screens. The design rationale for this decision was to make the competitive aspect of INspect-World optional. A competition mode is not appropriate in some industry settings, but the mode can potentially help to generate user engagement in educational contexts.

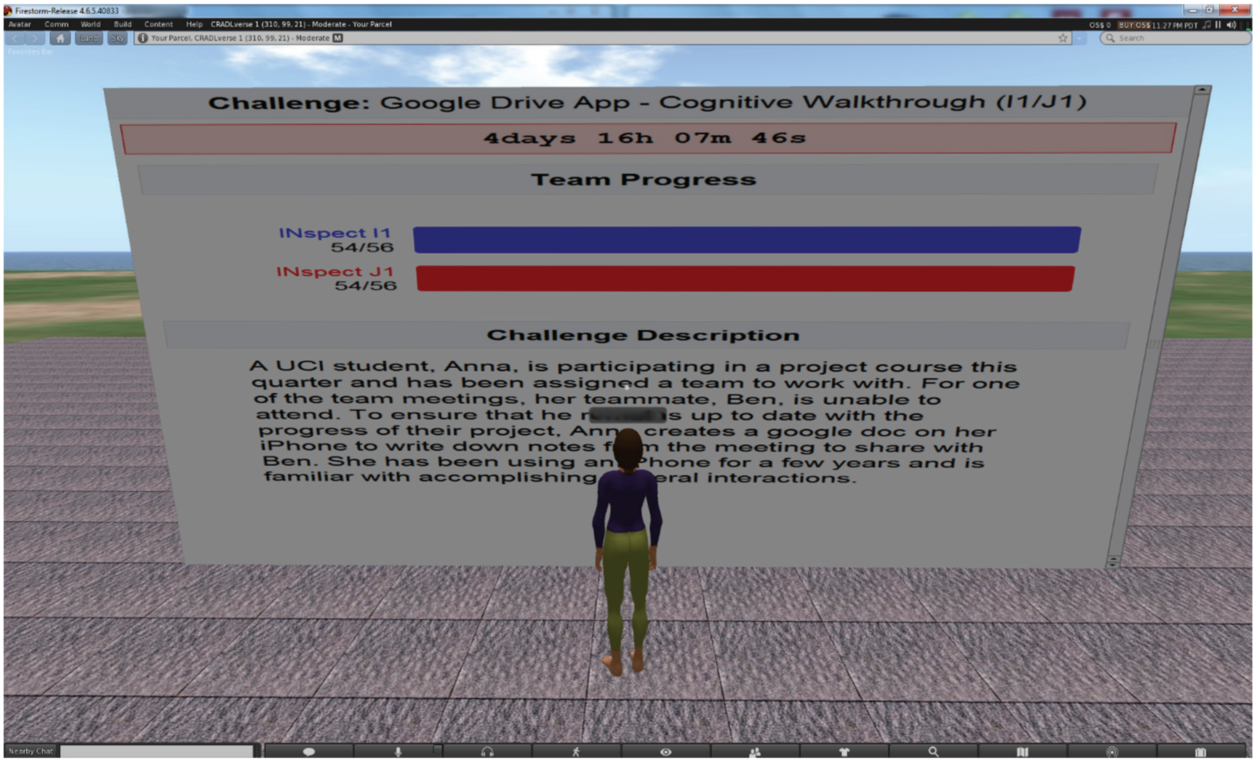

Figure 3.11: INspect-World score screen.

As the team of evaluators gathers in their arena in INspect-World, the team members can immediately begin with the usability inspection by moving to the first inspection screen. The team needs to develop a strategy to complete the session within the given time. INspect-World does not impose certain strategies on the team. The open virtual space leaves (virtual) room to develop strategies involving team movement, task delegation, communication, and organizational structures. Once the timer for the session has run out, the all inspection screen input boxes are disabled automatically. Evaluators can log into INspect-Web following their session in the virtual world to review the result of the walkthrough inspection.

3.3 INspect-World and INspect-Web – Technical Implementation

The INspect-World system was implemented using the open-source virtual world platform OpenSimulator. The web application INspect-Web was built to manage usability inspection sessions in INspect-World. Both INspect-Web and INspect-World were installed on a server machine that was set up to provide the virtual world services and the management services to the users. This section describes the software implementation of INspect-World and INspect-Web and the project server setup is introduced. A particular focus is put on how the web application interfaces directly with the virtual world database system to automate the generation of usability inspection arenas based on the user input in INspect-Web.

3.3.1 INspect-World Project Server Setup

A server machine was set up in the laboratory to host the INspect-World system. The server machine ran the operating system Microsoft Windows 7 Professional (SP1). The server was equipped with an Intel Core Quad 2 (Q660) processor clocked at 2.4 GHz and 4 GB of RAM. The server was connected to the UC Irvine intranet allowing users with a UC Irvine network account to access its services directly on campus or from the open internet using a VPN connection to the campus network.

In preparation for the installation of the virtual world system and the development of INspect-Web, the Apache webserver software was installed as a Windows service in addition to the database software MySQL v.5.1.52. The file server software FileZilla was installed to allow the developers to remotely update configuration and system files on the server system.

The INspect-World system consisted of two the main components INspect-World and INspect-Web. INspect-World offered the virtual world services that allowed users to access the virtual world environment by using the Firestorm Viewer client software. INspect-Web represented a custom-built web application that interfaced with INspect-World and could be accessed using any modern web browser software.

The INspect-World system was implemented by building on the open source virtual world platform OpenSimulator (OpenSimulator, 2014). Out of the box, OpenSimulator represents a multi-user 3D application server that is used to create virtual world environments that are similar to the look and feel of Second Life (LindenLab, 2014). The binaries of OpenSimulator v.0.74 were installed on the project server.

OpenSimulator could be configured to run one or more *regions*. A *region* is defined as a virtual space of a certain size in the virtual word in which assets and users are managed. Users in the virtual world could seamlessly move between neighboring regions in the virtual world or switch over to more distant regions provided by distributed OpenSimulator installation instances run on other servers.

The data services provided by OpenSimulator included the login service, asset service and user account service. OpenSimulator supported two main operational modes: *"Standalone"* and *"Grid mode"*. In "*Standalone mode",* the main executable of OpenSimulator runs all data services and manages the configured regions in a single process on the same server machine. The alternative *"Grid mode"* allows for running individual data services on different machines on the network. Regions on distributed OpenSimulator instances could be connected to the local grid mode installation.

The INspect-World project server's installation of OpenSimulator was configured to work in *"Standalone mode"*. The goal was to centralize all services on one machine because there were no immediate plans to establish a grid of distributed regions across distributed servers. OpenSimulator was configured to run a set of four adjunct regions that together formed one large quadrant. One region was reserved for the inspection arenas and the interaction of evaluators in INspect-World. The remaining regions were used for system testing and the design of the inspection arena elements. The MySQL database system was configured to host the database of the OpenSimulator installation. Direct access to the OpenSimulator database was essential for the development of INspect-Web which will be discussed in the following sections.

Out of the box, the OpenSimulator system does not provide a built-in voice chat solution but the system can be configured to use a number of external voice chat services (e.g. Mumble, Asteriks PBX, and Vivox voice). Vivox voice (Vivox, 2014) provides a cost-free service for no-profit projects. The INspect-World system was configured to connect to the Vivox voice service at the time the system loaded INspect-World.

3.3.2 INspect-World Inspection Arena Implementation

The inspection arena in INspect-World was implemented in two stages. First, the individual inspection arena elements, such as the inspection screen and the phone model, were designed and created directly in the OpenSimulator virtual world environment using the Firestorm Viewer client's design tools (see: **Figure 3.12**). A special texture was applied to the inspection screen's front facing panel. Instead of choosing a static texture, the "*media-on-prim*" texture was used that allowed displaying a dynamic website that can be controlled by avatars in the virtual world. *Media-on-prim* renders a pre-set website on the front-facing panel side. When an avatar approaches the virtual screen the default set website is loaded automatically and the user can interact with the website by clicking and typing on the virtual screen.

The website displayed on each inspection screen in the arena had to be unique and had to reflect a particular action step of the usability inspection sequence. Instead of manually building a series of inspection screen models and applying a unique website to each inspection screen model, the goal of the implementation realized in INspect-World was to automatically generate both the inspection screen models and the corresponding inspection screen websites displayed on each inspection screen. Manually creating each inspection screen and manually applying a custom website would create an unfeasible preparation overhead before a usability inspection could be performed in the virtual world.

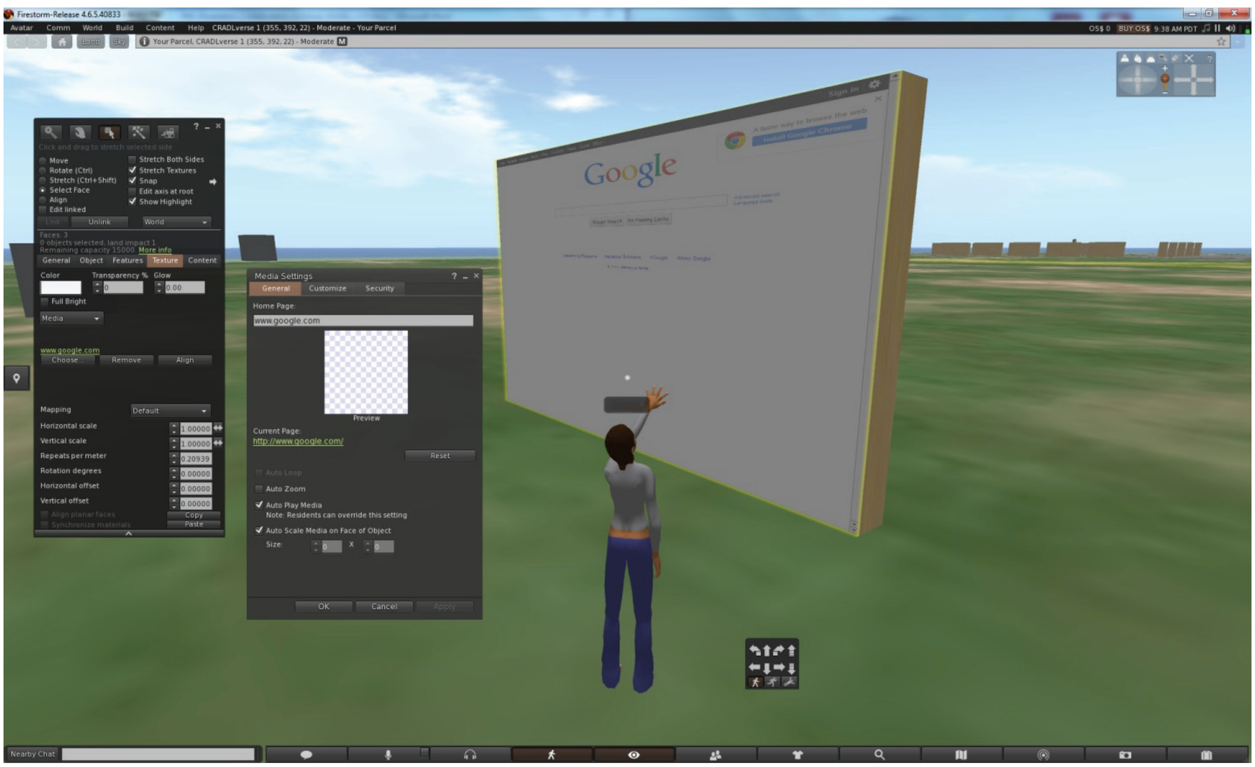

Figure 3.12: Inspection arena design in INspect-World.

In the second stage of the development, the INspect-Web web application was developed. The web application was implemented mainly using the scripting language PHP and JavaScript to provide dynamic inspection screen front ends that could be accessed using a custom HTTP address. INspect-Web was hosted on the project server using the Apache HTTP server software. Calling a specific HTTP address with unique URL parameters returned the inspection screen front ends for a specific action sequence step of the defined usability inspection project.

In order to automatically create a series of inspections screens in INspect-World and to automatically apply the correct action step URL to each screen using the web application, the database structure of OpenSimulator had to be analyzed carefully to understand how the OpenSimulator system stores virtual world server objects in the database. The INspect-Web application had to be programmed to directly insert records into the OpenSimulator database and to read from the database. Any modifications directly on the database level had to be performed with caution to avoid corrupted data records.

An analysis the OpenSimulator database hosted on the project server machine showed that each object in the virtual world was stored in the database with a universally unique identifier (UUID) represented by a 128 bit number and could be directly identified. A set of the OpenSimulator data tables could be attributed to system services that provided the persistent elements of the virtual world system (e.g. the tables *auth, Avatars, Friends, GridUser, Presense, assets,* and *inventoryitems*). Another set of data tables were used by the virtual world simulator that constructs the virtual world environment (e.g. the tables *prims, primshapes, estate_users,* and *estate_settings*). Prims represent the basic building element in OpenSimulator from which almost all virtual objects are constructed. A prim can be shaped into more complex models by defining its spatial properties and by combining individual prims with other prims of different shapes in order to create elaborate virtual structures.

By observing changes of database entries after performing specific actions in the virtual world or on the OpenSimulator console, a thorough understanding of OpenSimulator's data structure was developed and individual data tables were identified that had to be accessed in order to directly insert virtual objects into the virtual world environment without using the design and scripting tools of the Firestorm viewer client software. The following provides an overview of the data tables that needed to be accessed from INspect-Web to create new user accounts and to generate the inspection arenas.

Creating a new user account affects a number of tables in the database from user authentication to inventory management. The authentication table *auth* holds the UUID of the new user and a password hash together with a salt value. The password hash is calculated using the *md5* algorithm. The table *useraccounts* holds additional information about the user account such as the first and last name of the user, the email address, and a time stamp value, among other information. Additionally, when a new user was created in OpenSimulator a new inventory entry was created for the new user's avatar and published with a set of default clothing.

To automatically insert new objects into the virtual world environment, i.e. in order to create the individual inspection screens and to publish the screens in the inspection arena, the INspect-Web application needed to perform transactions on two specific tables in the OpenSimulator database. The *prims* table of OpenSimulator contained 80 fields that defined a prim's exact position in the virtual region based on three dimensional axes, its orientation in the virtual space which was defined by different degrees of rotations, its UUID, its creator's UUID, and a number of other parameters that defined how avatars could interact with the object. The *primshape* table stored the shape parameters for an object. The 28 fields of *primshape* defined the dimensions (thickness, height, width) of the object, the texture (including the media-on-prim texture option), and how avatars in the virtual world could interact with the object.

INspect-Web uses a newly developed, custom API to access the OpenSimulator database on the project server. The developed *OpenSimulator API* builds on the Representational State Transfer (REST) architectural style and uses the PHP scripting language to provide abstracted interfaces to an OpenSimulator database. The system has been made available as open-source on Google Code (Caldera, 2014). INspect-Web implements the *OpenSimulator API* to directly write to and read from the OpenSimulator database. INspect-Web automates the management and creation of usability inspections in the virtual world and provides an easy-to-use user interface for evaluators.

CHAPTER 4: INspect-World v.1 Evaluation

The evaluation of INspect-World v.1 was designed to observe, analyze, and document collaboration strategies performed in the virtual world. The second goal was to investigate the usability of the INspect-World system itself. The study design focused on observations conducted in the virtual world and interviews conducted with the participants following their experience in INspect-World. Observations were recorded from each team member's individual perspective. The obtained interview data was used to contextualize the observations from the video recordings and to investigate individual views on collaboration practices. The data was analyzed using a grounded theory-based approach that allowed me to focus on collaborative behavior in the context of the virtual collaboration environment.[2] The results of the study in INspect-World v.1 indicated directions for the development of INspect-World v.2 and the design of a follow-up study discussed in **Chapter 5** and **Chapter 6**.

4.1 INspect-World Study Methodology and Setup

INspect-World was developed as a proof of concept environment supporting distributed usability inspections in a virtual world environment. In unison with INspect-Web, INspect-World allows managers to set up custom usability inspection spaces in a virtual world without a large preparation overhead and the requirement of special design or technical skills. To evaluate the usability and practicality of the INspect-World system, a large-scale study with 76 participants was conducted. While the general usability of INspect-World in the context of realistic usability inspection tasks was the underlying theme of the

[2] The author was assisted during the data analysis by Grace Pai and Gerardine Montebon who were undergraduate research assistants in the CRADL lab at UC Irvine.

investigation, another goal was to specifically investigate collaboration strategies that teams of evaluators in INspect-World would develop during the inspection process. Observing the remediation of collaborative activities into the virtual world could reveal unique behavior and collaboration strategies with implications for the development of novel collaborative tools and practices in the field of Computer-Supported Cooperative Work (CSCW).

The evaluation of INspect-World v.1 was conducted at the University of California, Irvine. The participants of the study were recruited from an undergraduate class on the topic of Human-Computer Interaction (HCI). Students enrolled in the HCI class majored in information and computer science fields. The class syllabus covered a variety of introductory topics in HCI. A series of three lectures focused on usability and usability evaluation in HCI. As part of the lecture on usability evaluation methods, the students were introduced to the cognitive walkthrough usability inspection method. The instructor presented the theory of the method and typical use cases in industry. The students were also walked through a complete example of conducting a cognitive walkthrough on an action sequence. An open discussion in the classroom allowed for clarification questions on the inspection method.

The HCI class offered a discussion section held in conjunction with the lecture to allow for discussions and feedback sessions with the teaching assistant and to give students time to work on group projects. In connection with the lectures on usability evaluations, the students received an assignment to complete a cognitive walkthrough inspection in a group of 3 to 5 students. Students were offered to conduct the cognitive walkthrough using pen and paper with a group of students in the classroom. As an alternative assignment students were offered to complete a cognitive walkthrough session in INspect-World. For the INspect-World option, students would perform the cognitive walkthrough exercise in INspect-World during the official class discussion times in a research laboratory on campus. We stressed that the participation in our study was completely optional. Students were not graded for the quality of the assignment. Participation in the paper option or the virtual world option both yielded the same amount of credits that were awarded for completing the assignment. Out of 93 enrolled students in the HCI class, 76 students voluntarily signed up to participate in our study. Out of the 76 participants, 49 participants agreed to participate in 30 minute long interview sessions with me after their experience in the virtual world. Participation in the interviews was also completely voluntary and an alternative assignment was offered that awarded the same amount of credits for participation.

4.1.1 Virtual World Study Sessions

I created 16 teams of up to 5 students that would collaborate on the usability inspection task in INspect-World v.1. **Table 4.1** shows the resulting team compositions of all participants in the study. Per session in the virtual world, two teams competed against each other in INspect-World v.1 (see: shaded rows in **Table 4.1**). Both teams were logged into INspect-World and worked in their team's own inspection arena which was placed adjunct to the competing team's inspection arena.

All participants completed two separate study sessions at the Hana usability laboratory at Donald Bren Hall on the campus of UC Irvine. The first session lasted 45 minutes and was used to introduce groups of up to 10 students to the INspect-World system. I met with the participant groups in a large meeting room before their usability inspection session for which they would work alone from individual rooms. During the orientation sessions in the meeting room, I showed the participants how to login to the INspect-World system with their standard avatars for the first time. I provided guidance on how to navigate the virtual world and how to edit their avatars' appearances. The participants were also introduced to the general concept of how the usability inspection session would be conducted in INspect-World. During the orientation session, all participants could follow along the instructions on their individual laptop computers and try out the system immediately.

Team #	Team size	Male/female	Interviewees
A-1-1	5	2/3	P1, P2, P3, P4
A-1-2	5	2/3	P6, P8, P9
A-1-3	5	3/2	P11, P12
A-1-4	5	3/2	P16, P17, P18
B-1-1	5	3/2	P21, P22, P23, P24, P25
B-1-2	5	3/2	P27, P29, P30
B-2-1	5	4/1	P31, P32, P34
B-2-2	4	4/0	P36, P38, P39
F-1	5	4/1	P40, P42, P43, P44
F-2	5	4/1	P45, P46, P47
F-3	4	3/1	P50, P51, P52, P53
F-4	3	3/0	P55
T-1	5	3/2	P58, P59, P60
T-2	5	3/2	P62, P64
T-3	5	3/2	P68, P70, P71
T-4	5	4/1	P73, P75, P76
Total	**76**	**51/25**	**49**

Table 4.1: INspect-World v.1 study participants, male/female distribution, and interview participants from each team.

One week following the orientation sessions, pairs of teams were invited to the laboratory at a time to conduct the virtual cognitive walkthrough. All teams performed the cognitive walkthrough on the same cell phone application action sequence in INspect-World. To simulate geographical distribution, each team member was provided with an individual laptop computer and was asked to work from an isolated study room at Hana lab.

Each participant was handed out a printed document that summarized the context of the action sequence that was to be analyzed during the inspection session. The document listed the names of all team members and suggested evaluator and scribe roles for each team member. The suggested roles were not binding. By suggesting a scribe in the team, my hope was to provide teams with initial scaffolding to organize the team's collaboration.

The action sequence to be analyzed by all teams in the virtual world was described in the following way on the document:

Virtual Cognitive Walkthrough: Finding a Burger Restaurant Nearby Using Nokia City Lens on Windows Phone

Figure 4.1: Lumia 920 Windows Phone (cognitive walkthrough example).

Walkthrough context*: An exchange student new to UCI exits Donald Bren Hall and wants to try a famous American burger for lunch. The student is experienced using her Windows Phone* *device (model Lumia 920). She knows how to navigate to applications. She is also familiar with the three main functional hardware keys on the device: Back, Home, and Search (see illustration above).*

Once outside Donald Bren Hall, the student uses her Windows Phone to access the application Nokia City Lens (with the small city skyline icon, left to the Facebook application). Nokia City Lens allows the user to discover nearby points of interest by overlaying restaurants, shops, and points of interest directly on the live image of phone's camera.

The application implements an innovative use concept: Holding up the phone like a camera shows the camera's live view and holding the phone down to input text switches to a class map and text input style.

Each participant was asked to read the handed out document carefully before logging into INspect-World v.1 to perform the cognitive walkthrough with their team members. The action sequence and context of the cognitive walkthrough was not revealed to the participants before the virtual world study session, but all participants were familiar with the INspect-World environment because they had participated in the orientation session one week earlier. I did not provide specific instructions in terms of team management or collaboration in the team. The teams were familiar with the essential components needed in INspect-World to complete the walkthrough, but they had to develop their individual approach to complete the inspection task in the virtual world.

Figure 4.2: Hana lab, individual study room.

For the second study session in the virtual world, each participant was asked to take a seat in an individual study room. Each individual study room (see: **Figure 4.2**) was equipped with a work desk and a chair. The study room also featured an overhead, remote-controlled camera that was used to observe the participants during the inspection session from a remote study control room (see: **Figure 4.3**). The video from the overhead camera was not used during the analysis of the usability inspection sessions. However, the participants were observed during the inspection sessions to help with technical issues only if necessary. The participants were usually not interrupted during the usability inspection session.

Figure 4.3: Hana lab, study control room.

The video from the inspection sessions was captured directly on the laptop computers using the *Morae* screen recording software (Techsmith, 2014). The participants' facial expressions were captured using the web camera that was integrated in the screen. The laptop computer provided to the participants ran the virtual world client software *Firestorm Viewer* (FirestormViewer, 2014) and was placed on the work desk in the individual study room. Except for an external mouse, a plugged in power adapter, and the walkthrough information document, no additional hardware was provided to the participants. The study setup in the individual study room from the participant's viewpoint is shown in **Figure 4.4**.

Figure 4.4: Laptop setup used in the INspect-World v.1 study.

In total, the second study session lasted 45 minutes of which the students spent about 15 minutes for arrival and setup and 30 minutes in the individual study room working on the usability inspection task in INspect-World v.1.

4.1.2 Interviews

I asked all 76 students to participate in an optional 30 minute long, semi-structured interview. Participation in the interview was offered as a bonus assignment in class for which the students were offered 5 credits towards their final grade. Similarly to the INspect-World study session, an alternative bonus assignment was offered in the HCI class that rewarded students with the same amount of credits towards their final grade. Because of this arrangement, participation in the interviews with me was completely optional. Students that had chosen to conduct the cognitive walkthrough assignment using pen and paper were similarly offered an alternative bonus assignment.

49 students opted to participate in the interview sessions (see: **Table 4.1**). The interviews were semi-structured, lasted 30 minutes, and were conducted in-person with me in the meeting room at Hana lab. I began by asking the participants about their background and previous experience with virtual worlds. The interview then focused on the participant's experience in INspect-World, the team's collaboration strategies, and the participant's identification with the avatar figure in relation to other collaborators in INspect-World. I provided sufficient time for each interviewee to elaborate on their accounts and asked open-ended questions that allowed the participants to express their honest opinion about their experiences.

4.1.3 Data Collection

During the course of the study, that lasted about 5 weeks in total, 16 teams conducted a virtual cognitive walkthrough session in INspect-World (see: **Table 4.1**). 49 interviews were conducted in the laboratory. The laptop computers used by the participants during the study sessions were identical models with the same hardware configuration and screen sizes. Each laptop was equipped with an external mouse connected to a USB port. No other external peripherals were used. Each laptop ran the Windows 7 operating system and was equipped with the same software packages. For this study I installed *Firestorm Viewer* v.4.3.1 that was run in full-screen mode during the study sessions. Each laptop was also equipped with the screen recording and qualitative analysis software *Morae Recorder* by Techsmith

(Techsmith, 2014). The recording on each laptop was started when the participant logged into INspect-World and stopped when the usability inspection session had ended. During the recording *Morae Recorder* was minimized to the system tray resulting in a full screen recording of the *Firestorm Viewer* client software. The integrated video camera in the screen of each laptop computer was used to capture the portrait video of the participants which was embedded in final video recording (see: **Figure 4.5**). Audio was recorded using the laptop's integrated microphone. This allowed me to capture both voice and text chat during the inspection session. Using the described setup and recording the screen of all individual team members I was able to examine individual viewpoints during the teamwork and analyze activities from different perspectives.

Figure 4.5: Screen recording (face and names anonymized).

Using the previously described laptop setup, 76 videos of individuals interacting in INspect-World were recorded. In total, I collected 36:40 hours of usable video data. A small number of recordings failed or had to be paused due to the recording software crashing intermittently. In four cases, the video recording had to be stopped on some laptops because the system was overheating. All laptops operated under full system resource load running the virtual world client software and recording the session in the background task.

The 49 conducted interviews were audio-recorded using a mobile dictation voice recorder in the usability laboratory's meeting room.

Since no external microphone or cameras were used to record the screens and the participants during the inspection sessions in the virtual world, data collection was relatively unobtrusive and did not noticeably distract the participants from concentrating on the task in INspect-World.

4.1.4 Data Analysis: Qualitative Analysis with a Grounded-Theory-based Approach

A systematic, qualitative approach was developed to analyze the data collected in the course of the INspect-World evaluation. Confronted with a large data set, 36:40 h video recordings and 24:30 h interview audio recordings in total, I applied a grounded theory-based approach to work as close to the data as possible. Following the grounded theory method provided me with a structured and focused way to explore the qualitative data within the boundaries of my domain of interest. The general goal of a grounded theory-based approach is to make sense of diverse observations by systematically extracting and connecting phenomena in the data. The gathered insights are rigorously and repeatedly tested against the data. Findings are strongly based, i.e. "grounded", in the data and iteratively derived from a single or a growing data set (Muller, 2014).

Following the initial formulation of grounded theory by Glaser and Strauss (Glaser & Strauss, 1967), the method, or rather the family of methods combined under the grounded theory umbrella, has taken differing directions and was extended by researchers in different ways. The continuous evolution and differing adaptions of grounded theory make it difficult to point to a single, concentrated definition that is largely applied in the majority of research projects (Bryant & Charmaz, 2007; Clarke, 2005). The grounded theory method has been applied in HCI and CSCW to study information infrastructures (Bowker, Baker, Millerand, & Ribes, 2010), boundary objects (Star & Griesemer, 1989), and many other areas in which researchers were challenged to make sense of phenomena without having an a-priori theory or a specific point of entry to the analysis. The Grounded theory method does not provide a way to test existing theories or preconceptions about phenomena in a data set, but rather represents a collection of research methods to create a theory through careful exploration of the collected data. The focus of the grounded theory method lies on the data and builds on a concept referred to as "*abductive inference*" (Haig, 2005; Muller, 2014). The concept of *abductive inference* at its core can be described as the discovery of "surprises" in the data which are rigorously tested and explained using the same data. The grounded theory method suggests a number of ways (methods) to organize and systematically test surprises found in the data. This structured and iterative process can eventually enable the researcher to formulate coherent and robust theories that are meaningful to an intended target audience of a specific domain.

The grounded theory method suggests structured research procedures to make sense of the data and to let surprises guide the *abductive inference* process of the researcher. A careful and organized process is important in order to maintain scientific rigor and to achieve the construction of a coherent theory. Grounded theory specifically encourages researchers to revisit data when interesting phenomena have been discovered during the initial analysis. Instead of formulating a theory ahead of the initial data analysis, i.e. through *"deductive inference"*, the researcher looks specifically for a deeper understanding of a phenomena discovered in the data. This iterative process can occur using a single dataset, but researchers can also collect more data to confirm theories and to be able to explain details of the findings. The family of methods defined in the grounded theory framework provides researchers with well-organized approaches to work as close to the data as possible and to strategically discover interesting insights.

The approach taken to analyze the INspect-World study data is based on the core ideas of the grounded theory method. My goal was to formulate, document, and analyze collaboration strategies employed in distributed teams when conducting distributed usability inspections in the virtual world. Beginning with the analysis, I did not look for specific strategies that one would expect in the data based on previous studies on distributed collaboration in software engineering or other areas. I rather analyzed the data without any preconceptions to explore the behavior exhibited by the team members. In case interesting phenomena emerged from the data analysis, the discovered phenomena would be iteratively evaluated using the same data set.

While the core underpinning from the grounded theory method and many of its differing approaches were used, the goal of the study was not to develop a single, unifying theory. If grounded theory was applied in its entirety the outcome should indeed be a grand theory. Rather, I adopted the research methods of grounded theory to follow a well-structured, qualitative research process with the goal to report findings that are closely based on the collected data and that can provide a stepping stone towards a better understanding of collaborative behavior in virtual worlds. My hope is that future research can build on the findings presented in this dissertation and eventually develop comprehensive theories on collaborative behavior in virtual worlds.

4.1.5 Video Data Analysis

The video data was analyzed by myself with the help of two research assistants using the qualitative analysis software *Transana* (Transana, 2014). To prepare for the first stage of analysis all videos were grouped by the teams participating in the study sessions in order to later cross-reference findings and to be able to review behaviors from the perspectives of different team members in the same virtual inspection arena.

During the first stage of the analysis three researchers open-coded all videos, proceeding from team to team while following the concepts of discovering surprises in the data as described in the grounded theory method that was discussed in the previous section. During open coding the researches watched the videos for the first time and placed descriptive labels (open codes) on phenomena in the video that signaled interesting collaborative or general behavior to them (see: **Figure 4.6**). The researchers concentrated on an open-minded coding process that was, as far as possible, not defined by previous conceptions or expectations of the researchers. Whenever an open code was assigned in *Transana*, the observed behavior segment was also time-coded and fully transcribed for further analysis in later stages of the analysis.

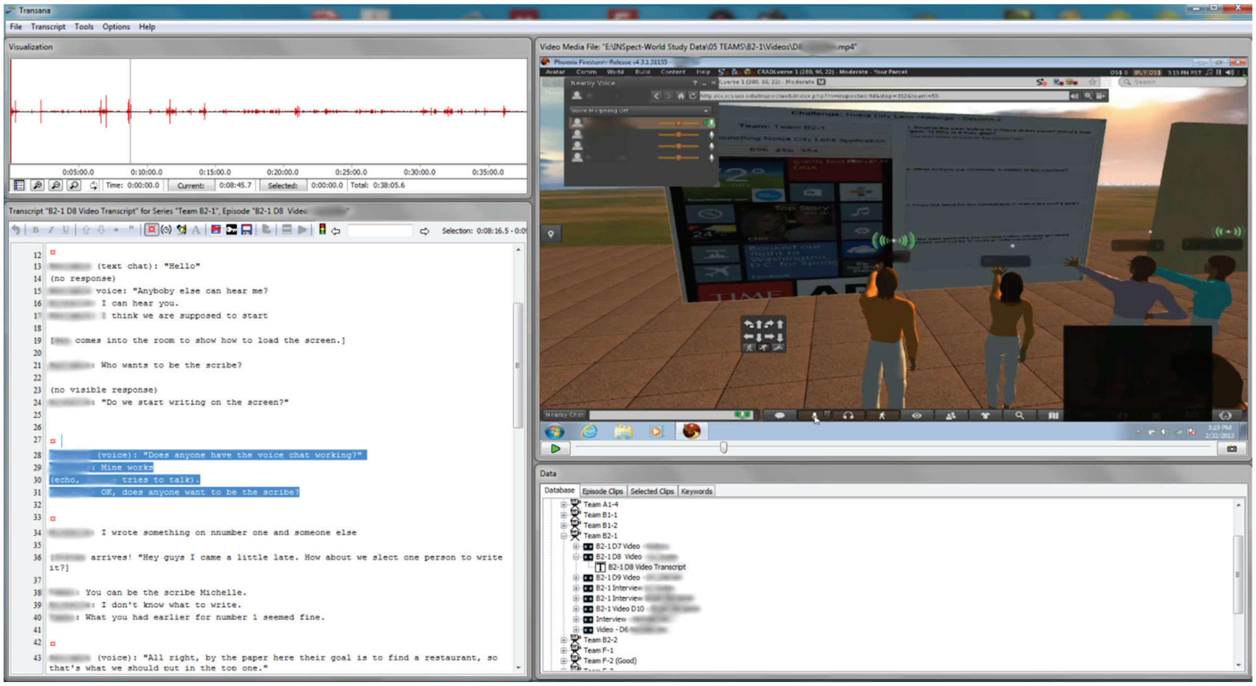

Figure 4.6: Open Coding in Transana.

Once all videos were open-coded by all three researchers individually, the findings were discussed in the group. The discussion was facilitated by extracting video clips from the full-length study videos based on the open coding process. **Figure 4.7** shows an affinity diagram that was used to make sense of data following the open coding process. Each yellow post-it note represented a video clip of interest extracted from the video data. In total, 75 video clips of varying lengths were created in the initial session and subsequently grouped into topic clusters.

Affinity diagramming helped the researchers to identify topics of interest in the video data. Following the sharing of open coding results, the researchers individually wrote memos about concepts they saw in the data based on their own analysis and the discussion in the group. Following the grounded theory method, the researchers iteratively went back to the data to question existing groupings of open codes. Memos at first included coding labels and pointers to examples in the video data and were gradually extended with short text paragraphs interpreting the findings and linking the memos to other concepts that might be related. Open coding transitioned into axial coding and memo writing.

Figure 4.7: Affinity diagramming technique.

The iterative process of individual memo writing, that forced the researchers to continuously return to the data, and discussing the findings in the group generated about seven core concepts that reflected unique thematic classes of collaboration strategies employed in the virtual world. At this stage, the interview data was incorporated into the analysis. The interview data was an important piece in the data collection because it provided the researchers with the valuable point of views of the participants interacting in the virtual world. While the analysis of the video data was based on observations of the researchers and their interpretation of the observed behaviors, the interviews provided an important perspective that was initially hidden from the researchers. 32 interviews were fully transcribed in *Transana*. The remaining 17 interviews were scanned for relevant passages and partially transcribed. Using the developed core concepts based on the video data, the researchers now linked quotes from the interview transcripts to the memos. For instance, the concept of scaffolding in the virtual world was supported by interview segments in which the interviewee commented on how the evaluation screen in INspect-World guided the team's progression during the cognitive walkthrough session.

In grounded theory there is a fine line to walk between the concept of letting theory emerge from the data and the role of an active researcher constructing theory analyzing the data. There is still debate amongst grounded theory practitioners on the issue (Bryant & Charmaz, 2007). When analyzing the data collected from the INspect-World study open coding was conducted with an open mindset, and only keeping the basic framing of collaborative activities in mind. Yet, all researchers had a background in HCI and CSCW and it was close to impossible to become a completely neutral observer during the analysis. However, the researchers did their best to let the data speak for itself throughout the data analysis.

The analysis of the complete data set from the INspect-World v.1 study took three months in total. Open coding on the video data was completed in about one month, followed by the clustering of open codes, affinity diagramming of video clips, and the development of concepts in the second month. The final month of analysis was characterized by group discussions, memo writing, and the incorporation of the interview transcript data.

4.2 INspect-World Study v.1 Results

The discussion of the findings is presented using four themes that emerged from the grounded theory-based data analysis. The themes are the result of the coding and memo writing process performed by the researchers in the group and individually. The themes and collaboration practices discussed in this section do not present a completely holistic picture of all activities that the users performed in INspect-World v.1. The results rather represent a subset of activities that show particular behaviors that speak to collaboration practices in the virtual world. The virtual world technology platform used in INspect-World represented the foundation for the observed collaborative behavior and created a unique context for the teams to work on the distributed usability inspection task. Each collaborative theme in this section is presented alongside concrete examples from the collected data that show how the participants collaborated in INspect-World v.1 to complete the cognitive walkthrough task. The data points are derived from the video data transcripts and interview transcripts. The discussed findings are significant because the described collaborative behavior was observed in multiple teams in similar ways.

The themes presented in this section are validated and expanded in **Chapter 6** using the data collected from a follow-up study. Concrete collaboration strategies are derived from the observed behavior in the collaborative themes in **Chapter 7** where I draw the results together and discuss their implications for CSCW and other fields.

4.2.1 Self-Organization in an Open Virtual Space

Each team in INspect-World v.1 was provided with basic instructions how to navigate the virtual environment and how to use the main components of the system. The instructions were provided during an orientation session with the researchers. Additionally each team member was handed a printed document to take to their individual study rooms that specified the cognitive walkthrough action sequence and listed their team members. The printout did suggest a scribe role, but the teams were told that they were allowed to switch roles in the team as they saw fit. The researchers purposefully did not provide the teams with specific guidelines how to collaborate on the virtual cognitive walkthrough task in the team or how to delegate the work. Teams were formed randomly from the participant pool. The orientation session did not allow time for the teams to coordinate face-to-face before the virtual walkthrough session began.

The INspect-World v.1 system provided a virtual world space with the essential components to convene the usability inspection. The virtual environment imposed only basic constraints on the users' actions. The users were not able to move or alter the inspection arena screens. The construction of new virtual elements was disabled in the system and environmental settings, such as the topography of the land and the scripting of custom events, were disabled for the participants. On the other hand, movement in the open space was not restricted. The players were able to edit their avatar's appearance in any way they liked. I did not prescribe either voice chat or text chat as the primary form of communication. Upon entering INspect-World v.1, a team member's avatar was automatically sent to the team's usability inspection arena but there was no prescribed process that defined how the team had to complete one step in order to advance to the next step in the usability inspection. The INspect-World system was "open" not only in the sense of the virtual space and the free movement, but also in the way that the teams were able to approach the collaborative usability inspection task.

On average, each team spent 29:30 minutes in total logged into INspect-World v.1 to work on the distributed cognitive walkthrough task. The cognitive walkthrough action sequence analyzed by the teams in INspect-World v.1 consisted of 15 action steps. On average, the participating teams were able to complete 7.2 steps (median = 5, SD = 3.64). This relatively low completion rate was expected because of the limited time that I was able to provide for the inspection session. Despite the time limitation two teams (*B-1-1, B-2-2*) were able to complete all 15 action steps. Teams *B-1-1* and B-2-2 succeeded in completing the inspection task because they quickly agreed an efficient team strategy. Strong team leaders also played an important role as will be shown in the following discussion.

On average, all teams spent 11:45 minutes (median = 12, SD = 2.95) on the first inspection screen. The time spent on the subsequent inspection screens varied based on the nature of the individual action step and on how controversial each step was discussed in the team. However, the time spent on the following inspection steps was generally significantly less because most teams used the initial inspection screen to agree on an overall strategy and to come to terms with the team's organization or a lack thereof. **Figure 4.8** shows how team *F-1* gathers around an inspection team and discusses the inspection questions using text chat.

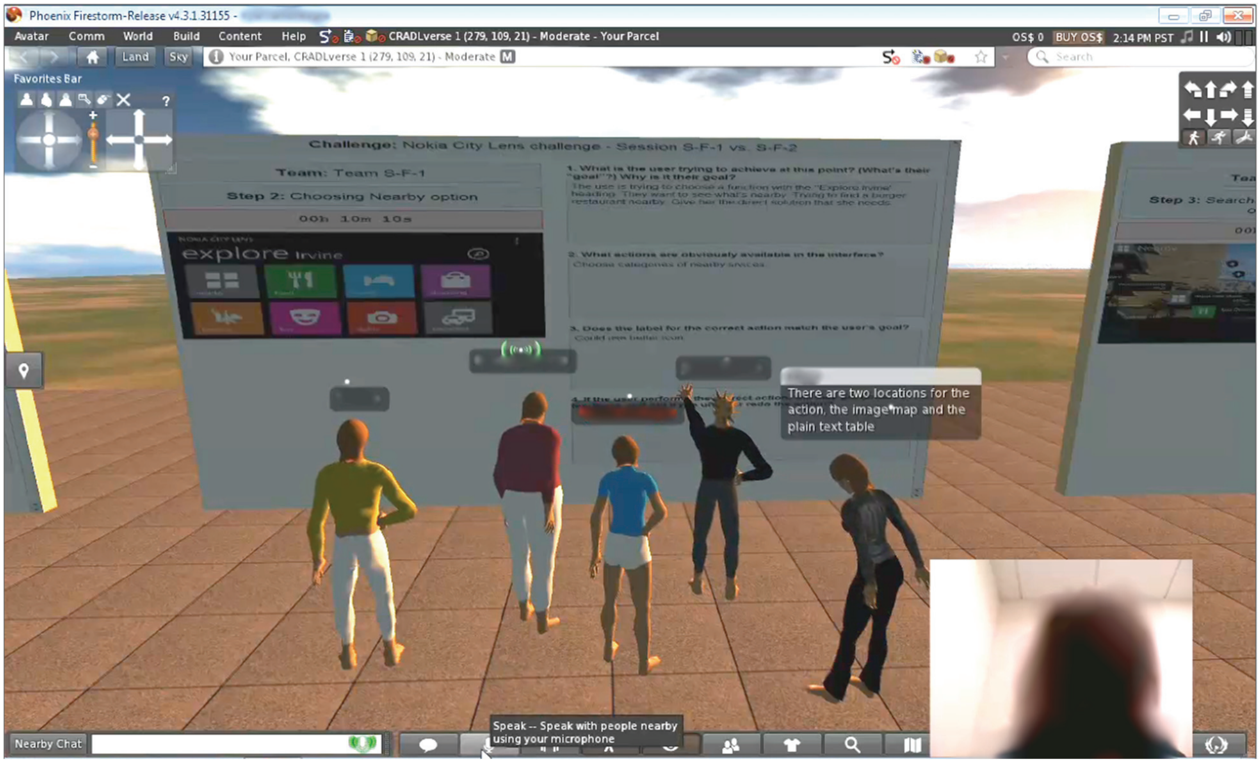

Figure 4.8: Team *F-1* discussing walkthrough step in INspect-World.

The initial process of building the team's organizational structure, of building a shared understanding of the task, and of collectively deciding on an initial strategy how to perform the inspection process together, was facilitated by the nature of the open environment and the affordances that the INspect-World environment offered to the individual users.

The build-up time for a team to transition into an efficient collaborative rhythm was quite high and many teams spent significantly more time to complete the initial inspection screen compared to the following action steps. From an outside observer's perspective, the initial process of the team gathering and standing together with their avatars in front of the initial inspection screen might at first glance appear like a display of general confusion and disorganization. However, studying the individual team members' perspectives particularly in the beginning of the session, but also throughout the inspection session, revealed a more differentiated process. The open, virtual space created an atmosphere in which users took a pragmatic and explorative approach to try out the available features and the functionality of the system. I observed a number of users experimenting with their avatars' appearance (see: **Figure 4.9**), testing the inspection screens for responsiveness, and exploring the inspection arena by flying across the virtual space with their avatar. These individual exploratory activities in the virtual space were not immediately visible to other users in the team, yet all team members shared a sense of presence in the same unfamiliar usability inspection environment. INspect-World allowed the team members to individually and privately explore the range of activities afforded by the system before engaging with other team members. The explorative activities were not as expressive as direct communication and they did not interrupt other conversations or collaborative activities that other team members were engaged in at the same time.

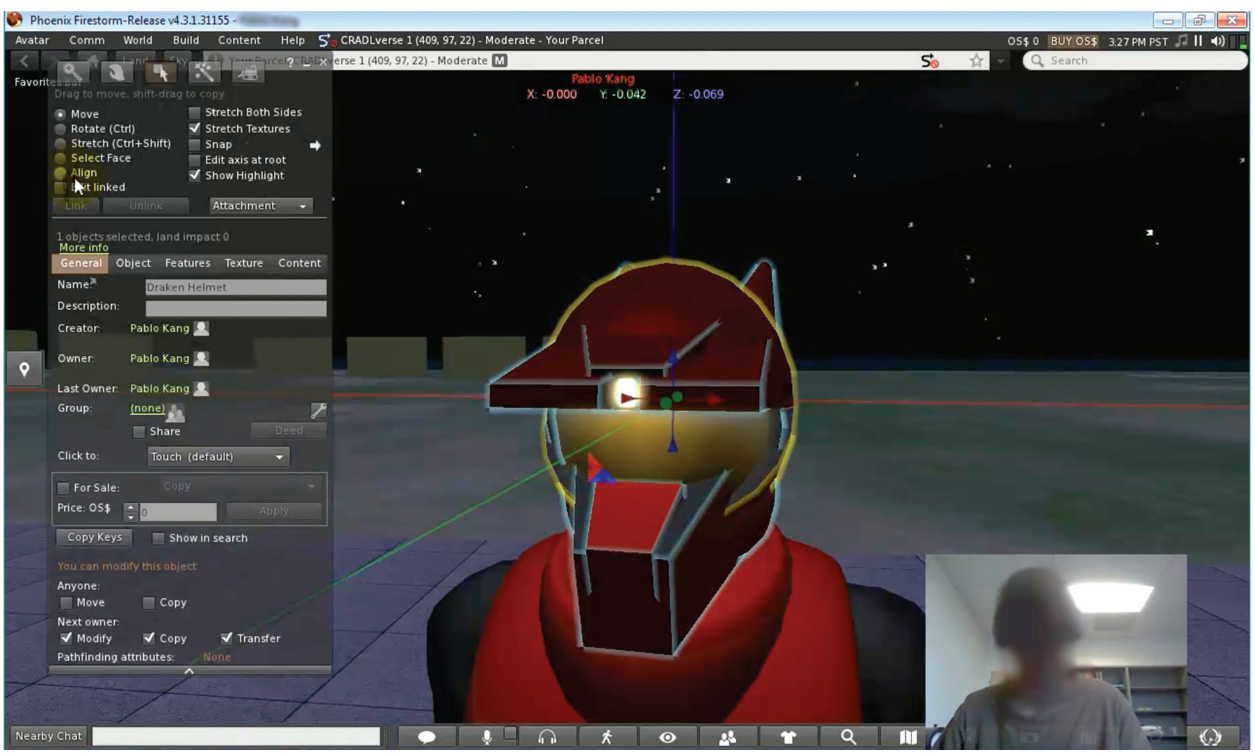

Figure 4.9: User editing helmet.

During the interviews, 40 out of the 49 interviewees stated that they had previous experiences with virtual world technology enabled environments. Most of the 40 interviewees with previous experience had played online multiplayer games that involved virtual avatars. During the interviews 38 participants stated that they did take a long time to get accustomed to INspect-World's navigation controls and communications systems.

While the nature of the unstructured virtual space initially helped individual team members to approach the task at hand, the next step in the collaboration process involved working in the team. An important role during the orientation phase was played by an emerging team leader or a team leader duos that would suggest the next steps for the team and help the team to get started in the beginning of the collaboration. The unregulated organizational environment allowed the team leaders to establish themselves without being officially appointed in advance. I found that by establishing themselves as resourceful team members, many individuals transitioned into team leadership roles that they kept for the whole inspection session.

For instance, *P69* of team *T-3* breaks the initial silence in the team by announcing via voice chat:

"Hey guys this is [P69]. I see [P68] you have already typed some stuff [text in the action step screen] in. And though it seems like it doesn't always want to safe what you have typed … If you want to talk about some of these answers that would be excellent." (P69)

To which *P68* replied in voice chat:

"Let's see... The label says 'Does this match the right action?' Which is kind of to launch the application... So I would assume... 'Yes' for [question] number 3." (P68)

From this point on an extensive discussion unfolds which also draws in other team members. *P69* overcame the initial silence by gently commenting on *P68*'s input. From this point on, *P68* and *P69* began to collaborate throughout the task, controlling the flow of the usability inspection session.

Another way team members established themselves as team leaders was by providing the team with short summaries of the inspection task to get every team member on the same page and to stimulate discussions. *P29* of team *B-1-2* realized that the initial discussion in his team was not very focused. He then communicated the following using voice chat to change the direction of the discussion:

P29: "You know I'm realizing we didn't ever really talk about what the task is. So I thought I just summarize that again for all of us so that we know what is going on. So we have an exchange student (...)."

P30: "So now I guess they are looking at this screen and trying to find out which one is corresponding to burger. Which logically would be that green food icon or something similar to it."

P29: "Agreed."

By reiterating the topic of the cognitive walkthrough, *P29* helps to focus the discussion in the team on the right topic. *P29* continued to provide leadership by suggesting to move between inspection screens, coordinating the scribe, and facilitating the discussion in the team.

The virtual avatars provided only limited ways of signaling leadership or competency to other team members. However, I was able to observe different methods of establishing competency and leadership qualities in INspect-World v.1: the provision of technical support and the display of mastery of the controls in the virtual world.

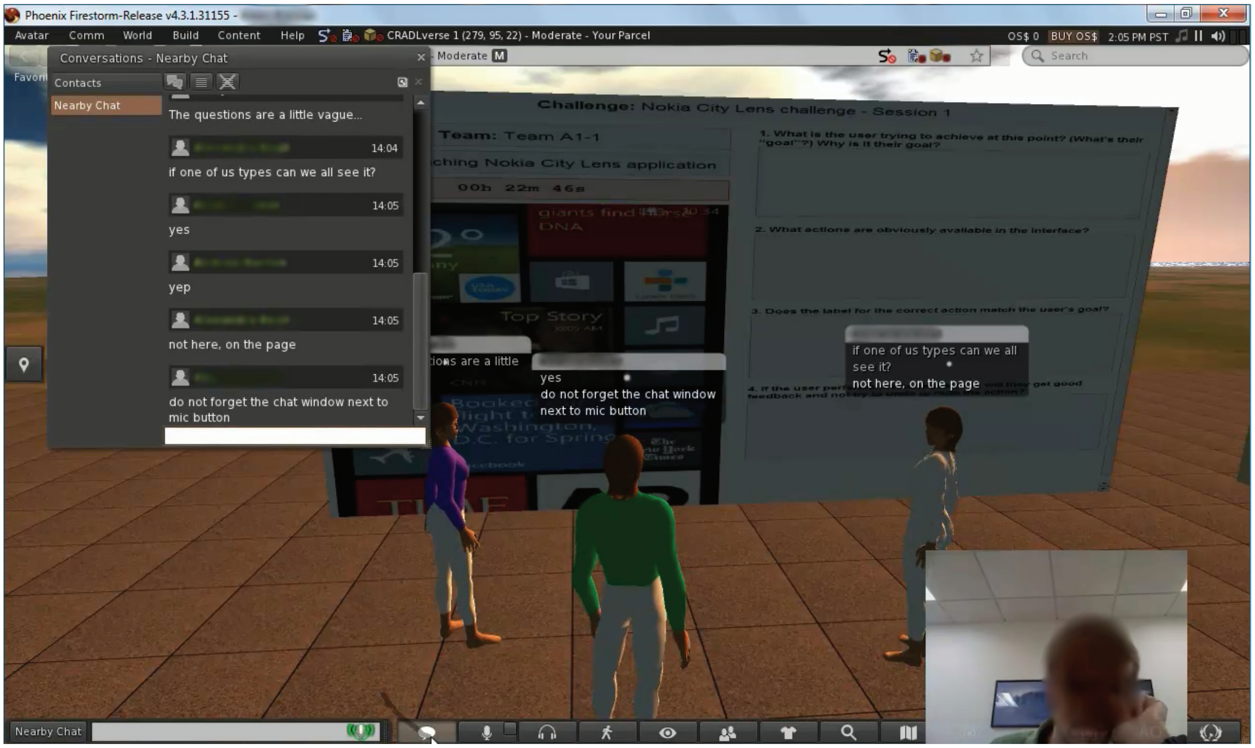

Figure 4.10: *P4* instructing his team to use 'nearby chat' window.

Individual team members provided technical support to help their team members use the INspect-World system. This occurred particularly in early stages of the inspection sessions. *P28* in team *B-1-2* helped his team members to use voice chat when he noticed that he was the only person talking. *P4* from team *A1-1* instructed another team member to use the arrow keys to move her avatar and suggested to use the nearby chat window (see: **Figure 4.10**). Providing technical supports raised awareness and visibility in the team. Both *P28* and *P4* stayed active team leaders during the session. Users that customized their avatars or helped other to do the same were generally seen as competent collaborators. The interview data showed that when individual team members showed off their design skills in the virtual world they were generally seen as capable of leading the team better than individuals that kept using the standard avatar provided by the system.

The open virtual space of INspect-World v.1 afforded a unique context for the teams to initiate the development of collaboration strategies and to build a working collaboration structure. The open space afforded a positive atmosphere to explore the possibilities of the minimalistic environment. Team leaders established themselves through supportive performances. The initial disorientation and confusion mostly transitioned into a concentrated walkthrough performance. Out of the 16 teams, I observed 10 teams that established an organizational structure with one or two team members leading the cognitive walkthrough efforts in the team.

4.2.2 A Level Playing Field as an Opportunity for Participation and Engagement

One might expect that individual team members with outgoing personalities and a tendency to be outspoken during teamwork activities in face-to-face collaborations would act similarly in a virtual world environment. The previous section discussed behavior displayed by individual team members to establish their leadership in the team. However, I also noticed a number of team members across all teams that did not initially appear to be involved in the teamwork. While some of the passive team members did not contribute throughout the usability inspection session, most did eventually get involved at some point of the session and continued to participate to the end of the session.

I observed five separate cases across different teams in which individual team members would gradually become engaged in the discussions and activities. *P35, P51, P53, P70*, and *P72* of teams *B-2-2, F-3,* and *T3* were observed following their team members along throughout the inspection session from the beginning, but they did not communicate with the team via voice or text chat.

For instance, *P35* followed her team as they progressed from the first up to the forth inspection screen. The video recording clearly showed *P35* thinking aloud, mouthing the questions on the inspection screens, and at times nodding in agreement as her team members discussed the inspection questions. At certain points during the discussion, *P35* hovered over the push-to-talk voice button in the *Firestorm Viewer* client interface with her mouse as if she was just about to engage in the discussion. 20 minutes into the task, she eventually did activate voice chat and seemingly out of the blue suggested to work on the next inspection screen with a team member while the other team members were still busy on the current inspection screen. The team did have no objections and *P35* followed through with her plan.

Figure 4.11: *P72* hovering over the push-to-talk voice chat button.

The researchers observed similar behavior displayed by *P51, P53, P70, and P72* who, after being hesitant to participate but still attentive to the task, eventually actively engaged in their team's collaborative efforts. *P72* of team *T-3* followed the team's discussion closely for 25 minutes into the inspection session (see: **Figure 4.11**). Then she makes a suggestion to avoid a bug with the text input. Following the comment that gets acknowledged by the team, she makes other comments in text chat concerning the task all the way to end of the inspection session. *P72* was able to think by herself about the task on her own pace until she decided to actively participate.

Having made the observations of users gradually becoming active collaborators late into the inspection sessions, I turned to the interview data to look for the users' own perspectives on the observed behavior.

In her interview following the virtual world session, *P11* expressed the following:

"I think just the fact that you have an avatar that is not your real person … I think it gives you... if you're someone that's shier then you have more confidence because people with stronger personalities usually take hold of the group. They cannot certainly do that because we are all limited by the character, right? Everyone has the opportunity to chat. You can have multiple people chatting at the same time. So having the virtual aspect allows that people with shier personalities are more involved in the group." (P11)

From *P11*'s perspective, the virtual environment in INspect-World v.1, in combination with the virtual avatar, shielded shier team members from possibly overbearing team members. The option to contribute via text chat while other team members were talking or text chatting allowed the participants to contribute at their own pace because the environment did not transmit direct peer pressure that could be experienced in face-to-face situations. The virtual world environment became a level playing field that created an egalitarian context for collaboration for all participants because all avatars were limited in terms of the communication options, the availability of the same interaction options, and even the same virtual body editing features. The level playing field concept, as it is discussed in this section, only applies to the technology applied in INspect-World v.1 and does not refer to general social or societal concepts. Before the concept can be translated into a general theory more research is necessary to explore the social factors of this phenomenon.

P62 reflected on the differences between team collaboration in a classroom setting and in the virtual world:

"In the classroom setting when you meet person-to-person, you can almost sense who is going to lead the project right of the bet - just by their personality. And then the quieter ones tend to just follow right of the bet. Whereas in the virtual world, you may not ever have met the person and the quieter people could be leaders as well: Just because you don't know anything about their personality even though you can see their avatar. A quite person could make the avatar seem like a charismatic person. I think everyone has the chance and the opportunity to lead whereas when you are meeting face-to-face, the people who are outgoing are automatically the leaders." (P62)

In *P62*'s opinion, the virtual world environment added a layer of anonymity that prevented unquestioned role assignments. Other team members were perceived in the way their avatars represented them and not directly through their real world personalities.

I observed that most of the teams were able to successfully engage all their team members in the collaboration by the end of the inspection session. The engagement process mostly occurred voluntarily and was not forced on the user. In the following example, a user gently asked another team member who had been quiet for 15 minutes into the inspection session to provide input for a specific question on the inspection screen:

P26 (voice): "OK, [P27], do you want to help with moderating question 3?"
[P27 does not answer for about 20 seconds.]
P28 (text): "Press the middle mouse button to talk."
P26 (text): "Some of the laptops don't have mice."
P29: "You can click the button on the bottom of the interface, of the game interface - it looks like a microphone. If you just click and hold it, it will allow you to talk."
P27 (text): "Oh, okay thanks."
P27 (voice): "Can you guys hear me?"
P29 (voice): "Yup, I can hear you."
P29 (voice): "So which would be the correct one? Food or nearby [options on the usability inspection screen]?"
P27 (voice): "I think probably food. Since she is looking for a burger joint."
P28 (text): "I agree."
P29 (voice): "Yeah, nearby sounds like it could be anything nearby." [The discussion continues…]

Team member *P27* had not communicated with the team until the she was gently asked to contribute. From the moment of the gentle request, *P27* contributed regularly to the discussion. In contrast to the cases of gradual engagement described in this section, I also counted 6 team members in total that remained passive throughout their team's inspection session. The anonymity provided by virtual space can also lead to unintended isolation of individual team members.

4.2.3 Scaffolding: Direct and Indirect Influences

In essence, the INspect-World v.1 environment provided a relatively minimalistic environment to enable distributed usability inspections. The core and most obvious elements of the virtual environment were represented by the inspection screens that showed the action steps of the cognitive walkthrough action sequence. The screens both functioned as information sources and information input panels.

While the system purposefully only provided a basic scaffolding structure to enable the cognitive walkthrough mechanics, the system at the same time allowed for sufficient (virtual) space to let users develop their own collaboration strategies with their team members.

The evaluation screens were arranged in a quadrant so that teams could move along the edges to eventually complete the usability inspection task. I observed that five of the sixteen teams strictly moved from one screen to the next and always stayed together as a group throughout the task. Eleven teams developed a more flexible use of the virtual space. Individual team members, such as *P46* of team *F-2*, moved systematically back to previously completed action steps to verify answers or to re-evaluate the flow of the action sequence. Individual team members reported back to the scribe so that she would edit the input accordingly.

Movement in the virtual space, embodied through the avatars' virtual presence, created a unique awareness of activities. The position of the avatar signaled a team member's general status in the collaborative process. The avatars' body shape animations, while not showing specific activities in high fidelity, signaled important activities to the team members. The position of an avatar helped to signal the focus on a specific action step in the inspection arena. A typing animation signaled that a user was currently typing a text message. Hand gestures pointing to an inspection screen when a user clicked on a screen signaled active interaction with the screen which was usually displayed by the scribe. The teams used the signals, movement, and positioning in the virtual space to develop a working collaborative flow.

P47 of team *F-2,* shown in **Figure 4.12**, reported during the interviews:

"I think that if there were no avatars and there were just people typing on screens that would be really disorienting. And it would really help to have an avatar there with animations playing so you could tell what they were working on. Because when I see the avatar typing, I know there is a person in the next room and he is typing on the keyboard. So it gives me a sense of what is going on." (P47)

In the opinion of *P47*, the presence of the avatars made an important difference. The avatars represented collaborators in a humanly relatable way. He was able to relate the observed activities to a human, yet distributed, collaborator.

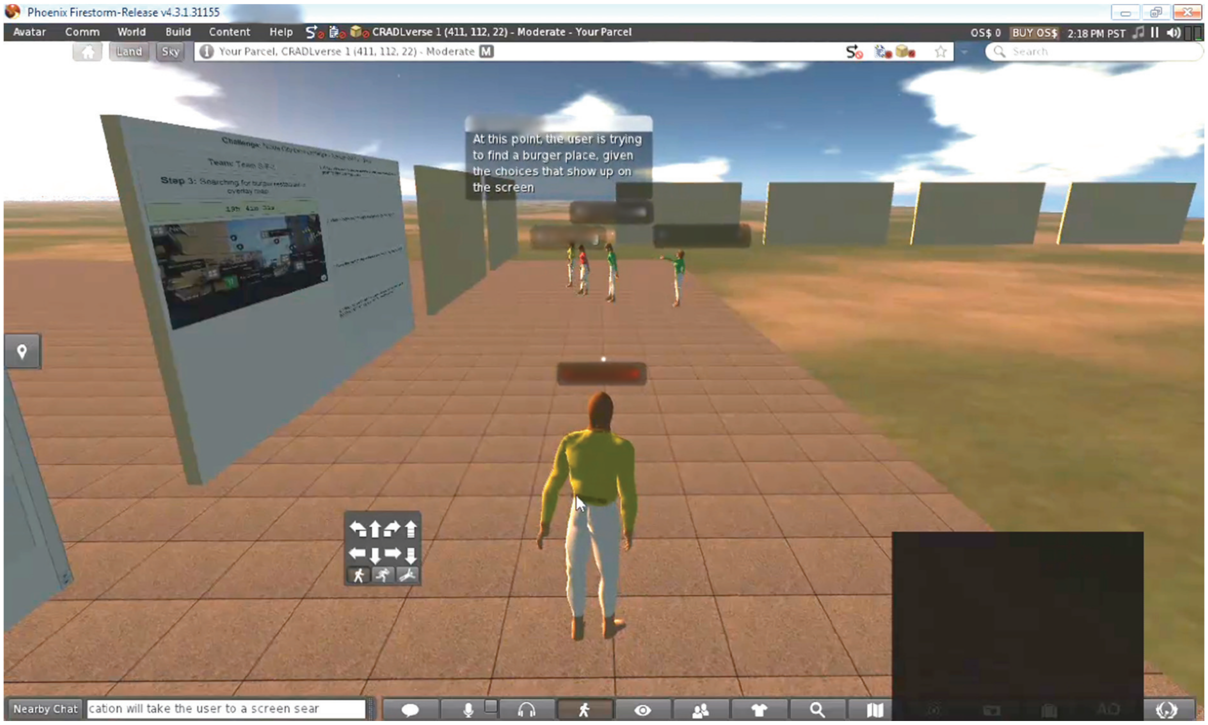

Figure 4.12: ***P47*** **of team** ***F-1*** **looking back at his team.**

The video recordings showed that most users quickly became used to the navigation controls in the INspect-World system. Following a brief moment of unfamiliarity and surprise, most users quickly focused on the task and the communication tools available to them. The virtual world quickly became the accepted and normal collaboration space for the task at hand. The behavior observed in team *T-1* can serve as a good example of the outcome of this process. Team *T-1* had moved from the initial orientation phase on the first inspection screen to work on the second action step. At this point *P58* had trouble seeing the text input on the screen:

P58: "Is there any way to zoom off the text. I can't really see..."
P59: "I don't know how, sorry."
P60: "Just walk closer!"

P60's suggestion to "just walk closer" to the inspection screen at first glance might seem obvious to the observer. However, the statement is significant as it shows that *P60* had accepted the 3D virtual environment as the de facto collaboration space that the team could use like any other collaboration technology to achieve the task. During a conversation in the same team at a later point of time during the inspection session, *P58* unintentionally blocked the line of sight of *P59* who at that moment worked on an inspection screen:

P59 (voice chat): "Sorry, [P58]? Can you move a bit?"
[P58 moves his avatar to the side.]

P59 and *P58* incorporate the virtual space into their interaction and treat the virtual collaboration space similar to any other physical work environment. In a similar situation in team *A-1-2*, *P5* let a discussion about the current action step the team was working on. During the discussion he says:

P5 (voice chat): "Yeah, I see that now [the interface element he was pointed to previously]. Alright - I will take a step back. [P6], you can finish typing..."

P5 moved his virtual avatar to the back of the group to create an unobstructed line of sight for *P6*. The scribe then continued to input the text on the inspection screen. Moving about the virtual space helped the teams to coordinate collaborative activities. Most teams used the open virtual space as scaffolding to organize their activities in similar ways compared to the examples discussed in the previous examples.

Communication represented another crucial component in terms of scaffolding for the collaborative process. I observed individual team members who skillfully used voice and text chat simultaneously to organize the team and to communicate for different purposes.

Figure 4.13 shows *P2* of team *A1-1* using voice chat and text chat to coordinate the discussion on action step four in the inspection arena.

Figure 4.13: Team A-1-1 using voice and text chat in concert.

P2 managed multiple communication channels. For instance, he directed the team using voice chat to suggest moving on to the next action step. At the same time he used text chat to comment on answers to specific inspection questions. *P2* and 15 other participants activated the chat history function in the client's interface to keep track of all txt messages of the team. The chat history window was not introduced during the orientation session. The team members discovered the chat history feature on their own in the *Firestorm Viewer* client software. The feature allowed the team members to evaluate conversations in the team more carefully and to look back at previous statements.

P31 told me the following about the nature of communication in INspect-World v.1:

“(…) it felt to me like the communication between us was a little bit sparser, but when we actually said something it mattered more. So it was less chit-chat, but more business. (…) And we sort of naturally set up a relationship pretty quickly. Certain people were talking more - certain people were typing more. And when somebody was saying something we would all be quiet and let him say it, and then we would say our response. It was interesting how there was a pretty big build-up of a relationship between [the team members]." (P31)

In *P31*’s view, being exposed to the communication resources in INspect-World resulted in a more precise and efficient communication process in the team and in quick relationship building of team members. I was able to observe a similar effect during the initial orientation phase of *P31’s* team, but also in most other participating teams. I generally observed very little personal introductions taking place. Most teams almost immediately discussed the usability inspection task at hand and did not spend much time on social pleasantries. Examples for direct and efficient group communication and collaboration were also observed during onboarding processes and when teams had to cope with technical difficulties.

Teams *T-4*, *B2-1*, and *B1-2* had to cope with the situation that one of their team members arrived late to the inspection session. In all three cases, the late team members were quickly brought up to speed by their co-workers. Moreover, the arrival of the team members did not cause a long-lasting distraction from the task. *P74*, for instance, was initially working in team *T-3*, but eventually realized that he should have been working in team *T-4*. Upon arrival in team *T-4*, the following conversation occurred:

P74: “Well, I was on the wrong team for half of the walkthrough.”
P75: “<laughing> No problem. We’re texting our comments.”
P76: “Lmao.”
P74: “So the label clearly matches the goal because (…)”

The walkthrough session continues relatively seamlessly without much interruption and direct focus on the ongoing task at hand. Late onboarding processes in team *B2-1* and *B1-2* also did not cause the teams to lose focus on the task. The new users were also able to review the work of the team quickly by exploring the inspection arena.

A different type of disruption in INspect-World v.1 was caused by technical issues. Teams encountering technical issues had to cope with the problem in the midst of their collaborative activities. A software bug in INspect-World v.1 in rare cases caused the text input on the inspection screens to flicker when multiple users typed into the text input fields simultaneously. Team *A-1-2* encountered this issue on the first inspection screen. The team quickly acknowledged that the same problem existed for all its team members. However, the team was not stopped by the technical difficulty for very long and quickly focused on the task. *P9* commented on the situation:

P9: "Let's not dwell on it."

Teams in INspect-World v.1 used the inspection arena's elements, but also the general virtual environment as scaffolding to structure and support their collaborative activities. The nature of the open space and the communication between avatars in the 3D world created an indirect scaffolding that quickly became the normal context for collaboration in the virtual world.

4.2.4 Rules: Jumpstarting Collaboration

Users in INspect-World v.1 were told to follow only a few number of rules. The cognitive walkthrough inspection had to be performed in the inspection arena that the team was assigned to. Only tools directly provided in the INspect-World v.1 inspection environment and by the *Firestorm Viewer* client software were to be used to complete the inspection session. Communication with the team had to be performed using the text messaging and voice chat functionalities provided in the system.

Each team member was assigned a specific role for the inspection session but the roles were not binding and team members were allowed to change them. A moderator was assigned to each of the four questions of the cognitive walkthrough method to lead the discussion for the question. Additionally, the scribe role was assigned to one team member. The role assignment was flexible so that the teams were allowed to switch roles at will. However, only the scribe was allowed to input the team's answers into the appropriate text input fields on the inspection screens, ensuring that only one team member at a time was taking notes. Following the cognitive walkthrough inspection method, the teams were told to collaborate as a team to investigate the interface at each action step of the sequence. The teams were supposed to agree on inspection results collaboratively.

The video data revealed that only 2 of the 16 teams in the INspect-World v.1 study followed the given instructions strictly from the beginning and throughout the inspection session.

14 teams in INspect-World v.1 did interpret the instructions more loosely and diverted from the rules either from the very beginning or as the team progressed into the inspection task. The most common alterations were related to role changes of team members. The assignment of moderators for individual questions initially helped the teams to start the conversation on the first inspection screen. The assigned scribe role further reduced uncertainty about the note taking process in the beginning of the inspection session. *P25* of team *B-1-1* stated during her interview:

“The main thing that I want you to know about our group is that we didn't follow directions. But it's interesting because we still collaborated by not following directions. Because we had a common purpose and that common purpose bound us to realize that we wouldn't beat the clock unless.... so the constraints on us having these different roles - it was also like another clock. (…)We wanted to win. And that's why we changed... we broke rules - to win! Yeah." (P25)

From *P25*’s perspective, the time pressure and competition caused the team to not strictly follow instructions. The willingness to win the competition caused the role changes in the team, but also created a common drive in the team to complete the task.

Based on the video recordings, team *B-1-1* did not only change roles. 15 minutes into the task and with little time remaining, the team decided to distribute all team members across the arena to work simultaneously on multiple screens. With only two minutes remaining in the inspection session, the team grouped up and reviewed the completed inspection screens together.

Three other teams (*B1-2, B-2-2*, and *T-1*) diverted from the instructions to optimize their inspection progress. The teams did not intentionally seek to break the rules. The rules lost importance as the collaboration had passed the initial orientation phase and the teams focused on optimizing their collaboration efficiency. While team *T-1* stayed together as a group and used one team member as a scribe, some of the team members took on a scouting role and explored the inspection arena. The scout proofed to be a useful addition not only for team *T-1*. The nature of the walkthrough task often required teams to re-evaluate a previous actin step or to look for feedback in an action step further ahead in the action sequence.

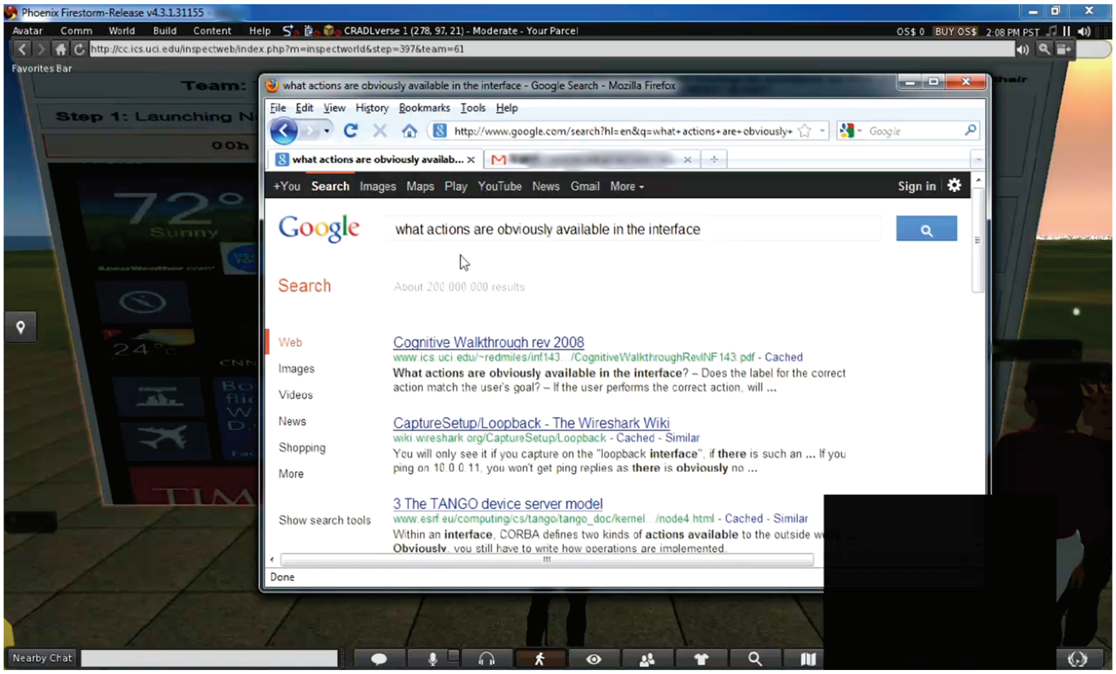

Figure 4.14: P43 using the external browser to look up cognitive walkthrough information.

Two users used external resources to research information that could help them to answer the cognitive walkthrough questions on the inspection screens. Both *P40* and *P43* of team *F-1* used the web browser installed on the study laptop computer. *P40* viewed the website displayed on the inspection screen in a browser window. The web browser provided an unobstructed view outside the virtual world. *P40* never told his team members of his method. User *P43* used the web browser to research the cognitive walkthrough inspection technique by using the Google search engine (see: **Figure 4.14**). *P43* eventually discovered the same slides that were presented during the HCI class on the cognitive walkthrough method in the classroom. Although some of the discussed cases represent extreme examples, they show that some users actively sought for help even outside the context of the virtual world.

CHAPTER 5: INspect-World v.2 Implementation

The INspect-World v.1 research study conducted with 76 undergraduate students provided valuable insights into how the teams collaborated in the virtual world and used the system. Many of the observed teams were surprisingly resourceful and adapt to the control of their avatar. Despite the limited time available for the INspect-World study session, the teams largely managed to develop successful strategies to plan and conduct usability inspections in the virtual world. As the study participants worked on the task given to them, the awkwardness of mediating their activities through their virtual avatars gradually faded into the background.

The scaffolding provided in INspect-World v.1 to help the teams perform the virtual cognitive walkthrough was intentionally minimalistic. The goal of the INspect-World v.1 design was to provide a virtual environment that would provide the essential components needed for performing usability inspections. At the same time, I aimed to maintain an open environment that would not distract users from the task and from the development of collaboration strategies. The goals was to maintain the right balance between sufficient scaffolding, necessary rules, and an open (virtual) space. In most cases the INspect-World system provide the right balance, but I also made note of issues that held some teams back and could be improved. The goal with the implementation of INspect-World v.2 was to improve the system to allow users to more efficiently conduct usability inspections. A second goal was to review and validate the findings from the study conducted in INspect-World v.1. The updated INspect-World v.2 system would not change the underlying inspection process in order to compare user behavior in both versions.

5.1 Design Considerations Following the INspect-World v.1 Study

The observations made in the INspect-World v.1 study showed that users faced a few issues related to the usability of the inspection arena. The goal of the development of INspect-World v.2 was to fix the issues encountered by the teams and to improve the features of INspect-World to create an improved scaffolding system for the users. At the same time, the essential mechanics of the inspection process in INspect-World (inspection screens, arena arrangement, etc.) were not to be changed. No issues were found with the INspect-Web application user interface and it remained unchanged. Updating the look and feel of the inspection screens in INspect-World required altering the underlying systems of INspect-Web that generated the inspection arena based on the user input.

5.1.1 Usability Issues Related to the Inspection Screen and Text Input

The inspection screens in INspect-World v.1 had a minimalistic layout that at all times during the usability inspection session showed the text input areas for all cognitive walkthrough questions. **Figure 5.1** shows the first action step for a cognitive walkthrough inspection session on a Windows Phone application. The focus of the usability inspection efforts is on the screenshot of the action sequence. All questions to be answered by the team are to the right of the screen paired with the text input areas. Teams were asked to elect a scribe to input the answer text as the team had come to a consensus for a particular question. However, each team member was able to input text into any field on the screen. The original intention for this setup was to allow the teams to easily switch scribes roles during the inspection session and to allow every team member to grow into the scribe role. Changing scribes and team roles was an important component of changing strategies and employing dynamic strategies. The text input fields were programmed to display any text entered into the field automatically to all team members looking at the screen in real time. The update mechanic to refresh the text input was an essential feature of the inspection screen in order for the team to collaborate on the answers.

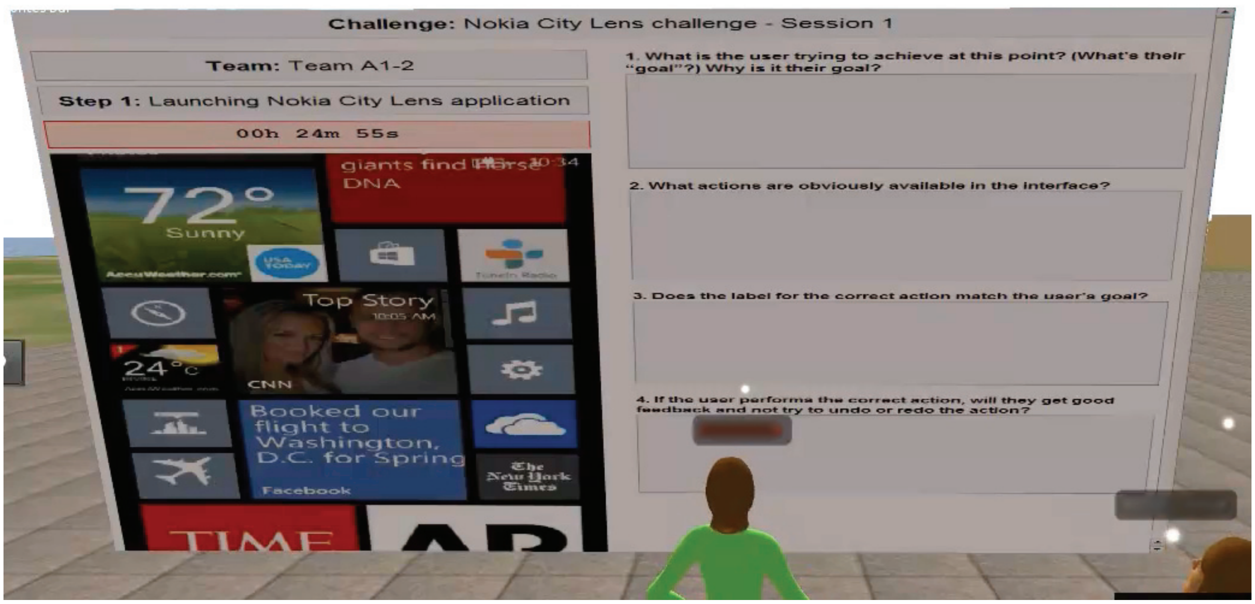

Figure 5.1: INspect-World v.1 inspection screen.

There was however a problem with the described design approach taken on the inspection screens. Although most teams did indeed elect a scribe who would fill in the answers, many team regular members who did not have the scribe role still clicked into the text fields, for instance to mark text or to focus on a segment, and thereby unintentionally triggered the update mechanism. In instances when multiple users interacted directly with the text input areas, the update mechanism became unreliable and text input began to visually flicker in the text areas for individual users. Simultaneous text input also led to general confusion concerning which team member contributed to which text segment.

Having all questions always visible required coordinative efforts from the team to direct the scribe and the discussion in the team to the current task item.

5.1.2 Lacking a Sense of Task Context During the Inspection Process

Every participant in the INspect-World study was given a printed document that did not only list all team members, but that also held information about the context of the action sequence that the team analyzed during the session. The document explained context in the form of a story of a user trying to find a restaurant in the close vicinity and using the application to be analyzed during the usability inspection. The provided context on the printout was important to consider before conducting the cognitive walkthrough as it represented an important input to the analysis. For example, the printout stated that the user was familiar with the general layout of the Windows Phone operating system. Considering this piece of information during the usability inspection would change how the team considers the individual action steps. If the team can assume that the user has previous experience with the phone, finding the application icon on the home screen is an easy task while it might take an unexperienced Windows Phone user considerably more time. The cognitive walkthrough method also prescribes the careful consideration of the imagined user's abilities. The goal was to keep the experience in INspect-World as close as possible to the cognitive walkthrough method's specifications.

The video data and the interview transcripts showed that the context provided on the document was not always fully considered when the teams conducted the sessions. The information was not readily present in the virtual world when the teams focused on the inspection screens. Although the context was provided on the score screen most teams were focused on the collaboration and did not move to the score screen to review the task information.

5.1.3 Action Step Interactivity on the Inspection Screens

I counted 38 individual team members who expected the screenshot shown for each action step on the inspection screen to be interactive. The users clicked on the screenshots multiple times expecting the static image to represent the state of a live phone application. It appeared as if the virtual environment created an expectation to bring interactive functionality to the display. During the implementation of INspect-World more interactive functionality was considered to be implemented on the inspection screens, but the idea was eventually discarded.

To replicate usability inspections in the virtual world, more specifically the cognitive walkthrough method, my goal was to stay as close to the process prescribed by the usability inspection method as possible. Creating an inspection screen with a fully interactive phone emulator would not be true to the cognitive walkthrough method in terms of the way it is typically conducted in practice. A team that evaluates an early software prototype in a software development project usually does not have a fully working software system available for usability testing. Even if a working prototype was available, the input used for the cognitive walkthrough inspection session would be a series of screenshots. Additionally, spending time on an interactive interface would considerably lengthen the inspection process and introduce more variables into the inspection process. A lengthy inspection process with a lot of variability would stand in contrast to the premise of fast, well-structured, reliable, and cost-effective usability inspection sessions.

I considered to allow users to navigate between action steps on a single evaluation screen in the virtual world. However, the idea was discarded due to the availability of the virtual open space. If the complete inspection process could have been performed on a single screen, there would be nearly no benefit to perform the usability inspection process in the virtual 3D world compared to a traditional video conferencing setting. Transferring the process of a proven usability inspection method from a face-to-face collaboration context to a virtual world context requires designers to think carefully about maintaining the balance of newly added functionality and the original principles of a proven method in well-established collaboration contexts. Designers are faced with the dilemma of introducing novel and often anticipated functionality while still maintaining core concepts of an established and tested process.

5.1.4 Competition in INspect-World

INspect-World v.1 was designed to allow two teams to simultaneously conduct usability inspections on the same action sequence in adjunct inspection arenas. The design choice to introduce a competitive aspect into the environment was made to foster the engagement and excitement of the evaluators. Inspired by popular online games in virtual worlds and a number of studies conducted on collaborative aspects of competitive play in virtual worlds, the goal was to offer selected gaming aspects that would motivate teams to perform well in the collaborative usability inspection process. The competition model was not implemented as a mandatory component of the usability inspection process. Rather, the goal was to give teams the choice to pick up on the competition if it would help their own collaborative strategies. The progress of both teams was shown on a score screen in the lower center of the arena, but the information was not directly integrated into the inspection screens. Two teams in the INspect-World v.1 study directed their attention and strategies fully to the competition. These two teams regularly consulted the score screen and compared their efforts to the competing team. Four teams used the score screen solely to review the status of the team's progress in the arena. The majority of the teams however did not focus on the competition and rather focused solely on their own teamwork. Ten team members stated in their interviews that they were not at all aware of another team being present in the virtual world at the same time.

Teams that did not pick up on the competition were not necessarily less engaged in the task, but instead more focused on completing their own evaluation screens. The varying team compositions resulted in different collaboration characteristics. While certain teams made use of the competitive elements in INspect-World, other teams worked better on their own.

Providing the competitive elements in INspect-World was partially also motivated by the initial target audience. If used for student assignments, a competition might help to with engagement and provide more motivation to complete the assignment. When used in professional work contexts, the competitive elements could rather be used to validate usability inspection findings of a large number of evaluators that collaborate in the virtual world. If two teams of professional collaborators perform a cognitive walkthrough inspection on the same application, the results from both inspection session could be compared to validate findings and to identify x usability issues that have been discovered by both teams.

5.2 Design Changes: INspect-World v.2

INspect-World v.2 represents an incremental update that addresses a number of usability issues and adds new features to the system. The update did not change the basic framework of INspect-World or INspect-Web. The web interface of INspect-Web remained unchanged, but changes were made to the underlying INspect-Web system that generates the evaluation screens displayed in INspect-World's usability inspection arenas.

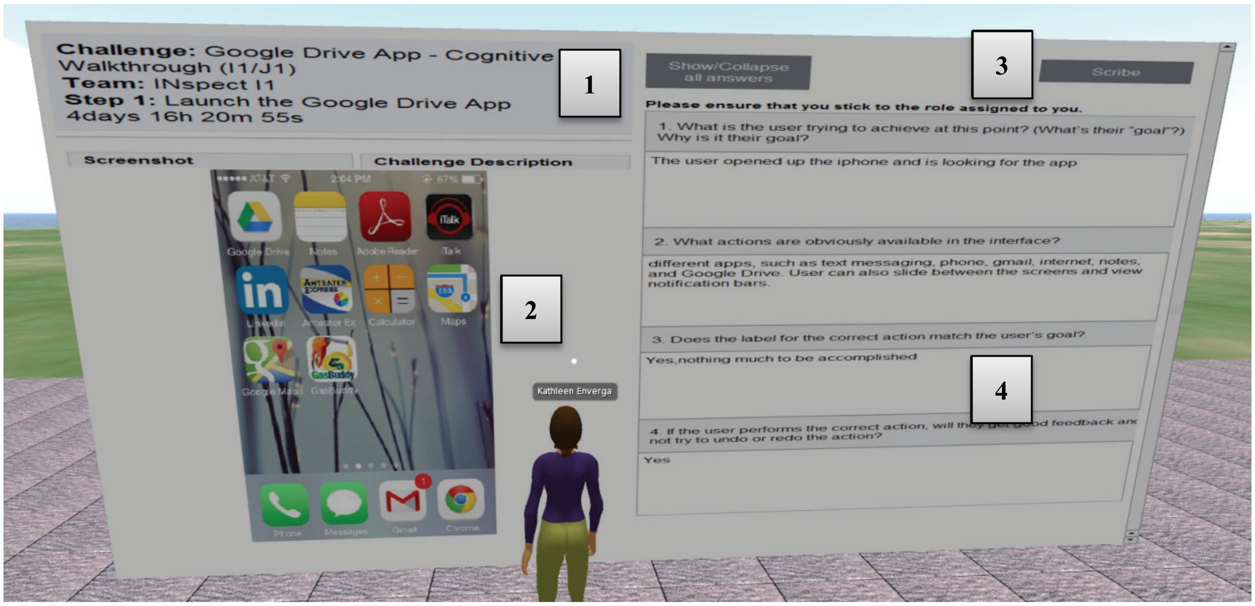

Figure 5.2: INspect-World v.2 inspection screen.

Figure 5.2 shows the updated inspection screen in INspect-World v.2. Compared to the evaluation screen in INspect-World v.1 (see **Figure 5.1**), the new version incorporated a more modern and cleaner design. Information about the current usability inspection session, the inspecting team, the time remaining and the title of the action step were consolidated into a single information pane (see **Figure 5.2:** 1). The change created more screen space for the action step screen shot (see **Figure 5.2:** 2). User could switch between the screenshot and a summary of the cognitive walkthrough context description by using the tabs above the screenshot. Significant layout changes were implemented to improve the text input fields and the scribe user experience. A scribe button (see **Figure 5.2:** 3) was added that served to unlock the text input fields for the user who presses the button (see **Figure 5.2:** 4). Once the team had chosen a scribe, the scribe would press the button to enable scribe mode. Only the user that clicked the scribe button would then be able to edit the text fields to make edits.

Non-scribe users saw the locked input fields by default. Locked input fields updated automatically when the input was edited by the scribe. Clicking into locked text input fields had no effect for non-scribes and did not interrupt the scribe who was making edits. Adding mainly served to prevent unintentional and simultaneous text input on inspection screens.

The update still allowed collaborators to rotate the scribe role or to change scribe roles ad-hoc in the middle of discussions. The scribe mode added important scaffolding to the INspect-World system by providing a more reliable data input method.

While the system synchronized text input across all views for all users, individual users had the option to customize the right panel view (see **Figure 5.2:** 4). The questions and answer fields were arranged in an accordion-style display. Clicking on a question would show or collapse the associated answer field. A click on the button on the top of questions pane collapses or showed all questions and answer fields. By collapsing individual questions a user could customize the right panel view to focus on only on specific questions. The individual customizations were hidden from the other collaborators as they represented individual customization options. The action step screenshot in the left panel was not modified to be more interactive. Instead, an interactive phone model was added to the center of the usability inspection arena space.

Figure 5.3 shows an avatar interacting with the newly added virtual phone model in INspect-World v.2. The virtual phone model was placed in the center of the arena and served as an interactive representation of the complete action sequence of the usability inspection. The phone's shape resembled a typical smart phone shape. The virtual phone's proportions were intentionally much larger compared to a physical phone so that the users could explore the interface display together when gathering as a team in front of the virtual device.

Figure 5.3: INspect-World v.2 interactive smart phone model.

The virtual phone's home screen showed the screenshot of the first action step under review in the inspection session. The users could navigate to the following action step on the phone by performing the correct action on the display to reach the next actions step. In the example shown in **Figure 5.3**, the user would click on the Google Drive icon on the virtual phone's display to get to the home screen of the Google Drive application. From there, the user would perform the next correct action to get to the third action step and to continue to navigate all action sequence steps. A home screen button on the low center of the phone returned the user to the first action step.

In contrast to the static screenshot shown on the evaluation screens, the screen on the phone model was interactive and encouraged the users to explore the phone model. The virtual phone was designed to provide an interactive way to experience the flow of the action sequence. The phone model was also added to remind the users of the device context of the inspected application. I chose to limit the virtual phone's interactivity strictly to the correct action sequence path. The user could not divert from the path and, for instance, launch another application from the home screen on the virtual phone display.

INspect-World v.2 introduced subtle changes to the virtual environment that did not drastically change the major design concepts of the original INspect-World system. The changes to the evaluation screen kept its basic functionality unchanged but added important scaffolding to support unhindered text input. The updated inspection screens also provided additional features that could be activated on a case by case basis if the user chose to do so. Additional context of the usability inspection was provided by a tab directly on the inspection screens. The virtual phone model provided an interactive way to experience the action sequence flow. Using the phone model was not required to complete the usability inspection task. Rather, the model provided optional scaffolding for individuals or the whole team to review the transitions between the action steps. The essential process of walking through the actions steps along the arena remained as close as possible to the definition of the cognitive walkthrough method.

When transferring an established process model from the real world context to a previously untested virtual world context, a designer is faced with striking a balance between trying to translate the process as exact as possible and adding sensible features that build on the advantages provided by the new context (e.g. unlimited virtual space, 3D modelling, automation, animations, etc.). With the implementation of INspect-World v.2 I decided to add optional features to offer new functionality while carefully improving the original design concepts.

CHAPTER 6: INspect-World v.2 Evaluation

The evaluation of INspect-World v.1 with 76 undergraduate student participants resulted in a large dataset that was thoroughly analyzed. The study provided valuable insights into the usability of INspect-World v.1 itself and revealed a number of collaboration strategies in the virtual world. Based on the feedback gathered from this first study, several improvements were made to the system resulting in INspect-World v.2. Following the same grounded theory-based method applied in the initial study, the next step was to verify discovered collaboration strategy using the updated INspect-World system and to review the user experience given the added and updated functionality. A second study was designed that replicated the design of the first study as closely as possible to produce a comparable dataset. The goal was to focus on the same audience and experimental setup while incorporating the new INspect-World v.2 system into the evaluation process.

The goals for the INspect-World v.2 study are summarized in the following:

- **Providing more time for the usability session in INspect-World**

  The initial study's timing of study session was limited by the class syllabus. The given class discussion time allowed an average 20-25 minutes time for the usability inspection session in the virtual world. The analysis of the video data showed that most teams needed at least 5-10 minutes to become oriented in the inspection arena before they could begin with the inspection process. The remaining time was then often too short for the teams to advance far in the action sequence. Providing a more generous timing had the potential to give the teams more room and flexibility to develop collaboration strategies and to work more carefully on the task. The goal was not to extend the session time indefinitely. Being able to conclude usability inspections in a relatively short amount of time represents one of the core benefits of the approach that I did not want to lose. Usability inspection approaches stand in contrast to long-term evaluation approaches that are applicable in different contexts. Based on the recorded progress of the teams performing in the initial INspect-World study, it was determined that 40 minutes time in the virtual world would allow teams sufficient time to implement collaboration strategies while still being able to ideally complete the inspected action sequence.

- **Evaluating two different action sequences in INspect-World v.2**

  In the initial study in INspect-World v.1 all teams conducted the virtual walkthrough inspection on the same action sequence. INspect-Web was built to conveniently set up virtual inspection environments for any input provided by the usability managers. In the follow-up study the goal was to compare the performances of teams working on two different action sequences.

- **Evaluating system updates: evaluation screen changes**

  The most significant design change in INspect-World v.2 was reflected by the updated evaluation screen. The screens added an important text input field used to unlock text editing. An accordion view of the questions allowed users to collapse and show individual questions in their individual view of the evaluation screen. Finally, users were able to view the action sequence context description using a tab control on the left hand side of the updated evaluation screen. The goal was to evaluate the changes in terms of their usability, functionality and use. I wanted to evaluate whether the changes positively impacted the collaborative activities and how individual users reacted to and made use of the updated evaluation screens. The observed behavior will be reviewed in comparison to how the original version of the evaluation screens were used in INspect-World v.1.

- **Evaluating system updates: voice chat client adjustments**

  Users in INspect-World v.1 experienced occasional issues with the voice over IP system used in OpenSimulator. Users transmitted voice messages by pressing a push-to-talk button in the *Firestorm Viewer* client software interface. During the orientation sessions, users were instructed to release the button when they were finished talking, thereby turning off the microphone on the laptop. Because headphones were not an option due to the recording setup used during the study sessions, the laptop's speakers were used to play back the sound during the inspection sessions. The *Firestorm Viewer* client interface showed a control checkbox that allowed the user to permanently activate the microphone which in some cases resulted in audio feedback when teams used voice chat. As a result, two teams stopped using voice chat completely when faced with the audio feedback issue. While it wasn't possible to modify the *Firestorm Viewer* interface directly, I added a key combination that allowed the activation of voice chat during the inspections sessions. The push-to-talk feature was further detailed during the orientation session with more emphasis on the added hotkey. The goal for the follow-up study was to observe how teams would use voice chat differently given a more clear instruction on its use.

- **Evaluating new system component: virtual cell phone model**

  An interactive cell phone model was added to the INspect-World v.2 inspection arenas. The phone model allowed users to explore the action sequence of the usability inspection on an interactive phone screen. The evaluation screen arrangement remained unchanged and the phone model was added to provide optional scaffolding for the teams. The goal for the follow-up study was to evaluate the usability and usefulness of the virtual phone to build a better understanding of the action sequence. Added as an optional tool and not as a mandatory element of the usability inspection process, I planned to evaluate when and under which circumstances the virtual phone would be incorporated into the usability inspection process, and if the placement of the phone model in the center of the arena would allow the teams to effectively interact with the virtual device. On the individual user level, I planned to evaluate how users would position their avatar towards the phone and interact with the interactive screen and what kind of functionality the individual user would expect from the model.

- **Validation of collaboration strategy themes found in INspect-World v.1**

  The data analysis of the initial INspect-World study with 76 undergraduate students revealed four distinct collaboration strategy themes. Following the grounded theory-based approach used in the initial study, I planned to develop a more thorough understanding of the collaboration categories discovered previously. A follow-up study provided an opportunity to re-evaluate the findings using a new dataset that was gathered targeting the same audience and maintaining the same study setup. While improvements and bug fixes were implemented in INspect-World v.2, the core system and virtual usability inspection process remained the same so that the collaboration categories discovered in INspect-World v.1 could be validated and possibly extended using data from a follow-up study. I was interested in how the teams would self-organized in the open virtual space. In light of the added phone model, the extended usability inspection time, and the updated evaluation screens, a re-evaluation of the collaboration strategies surrounding team organization, but also the concept of the level playing field establish during the initial study was warranted. Reviewing different types of scaffolding in INspect-World v.2 promised to contextualize and extend the findings reported in the initial study.

The following sections of this chapter I introduce the study methodology applied during the follow-up study and I discuss the results of the study in contrast to the collaborative themes established in **Chapter 4**.

6.1 INspect-World v.2 Study Methodology and Setup

A second study was designed to evaluate the updated INspect-World v.2 system in the light of the findings of the first study conducted in INspect-World v.1. My first goal was to evaluate the changes that were implemented in the system to improve the overall usability of the virtual environment and to address specific issues encountered by the users in INspect-World v1. Second, I aimed to validate and possibly extend the collaboration strategies observed in INspect-World v.1. In order to build on the data collected during the initial study, the design of the follow-up study had to be comparable in terms of its target population and its study session processes. The INspect-World v.2 environment itself had not changed fundamentally in terms of the how the teams would be able to approach the usability inspection task in the virtual world. Some optional features had been added, but the basic concept of conducting the usability inspection had remained unchanged.

I did not have access to the same target population, i.e. the students from the undergraduate HCI class in the School of Information & Computer Sciences at UC Irvine, to recruit participants from for the follow-up study. In an effort to keep the target population as similar as possible, I instead recruited undergraduate students with information & computer science majors at the same school at UC Irvine. The study session were set up in the same laboratory spaces and the same equipment was used. The following describes the recruitment and study procedures in more detail.

6.1.1 INspect-World v.2 Study Recruitment

The participants of the follow-up study were undergraduate students (female & male) with ICS majors of the Donald Bren School of Information & Computer Sciences at UC Irvine. I did not recruit student participants that were under 18 years old and I did not require potential participants to have any previous experience with virtual world systems or usability inspections methods. Recruitment began in the last week of March 2014 and lasted for two weeks.

Without access to the same undergraduate class that I recruited from for the initial study, I first advertised for the follow-up study by posting flyers in the Donald Bren Hall building on UC Irvine campus which was occupied by the Donald Bren School of Information & Computer Sciences.

The flyer specifically spoke to ICS undergraduate students and introduced the basic study procedures. On the flyer, I asked students for 75 minutes of their time and highlighted that participants would be compensated with $15 (see: **Figure 6.1**).

Invitation to Participate in Research Study

Distributed Usability Testing in Virtual Worlds

Are you …

- An **Undergraduate student in ICS** at UC Irvine and **18 years or older**?
- Able to participate in a 75 minute virtual world usability session and an optional 30 minute interview about your experience?
- Generally available in Spring Quarter 2014 and willing to earn **$15**?

Study information

You will experience performing a team-based usability evaluation in a 3D virtual world with your avatar. You will learn how to use the system in an orientation and you will be asked to complete a short survey in the end. Your total time spent in the lab will be approximately 75 minutes. Your privacy will always be protected carefully. In an optional 30 minute interview we will ask you about your experiences in the virtual world.

No previous experience with usability testing or specific virtual world systems is required to participate. **You will be paid $15 for participating in this research study.**

If interested, please contact the lead researcher, Benjamin Koehne, who can be reached via email at bkoehne@uci.edu or via phone: (xxx) xxx-6683.

Lead Researcher
Benjamin Koehne
Ph.D. Candidate
Department: Informatics
bkoehne@uci.edu

www.cradl.ics.uci.edu
CRADL Collaboration Research in Action, Design, & Learning

Faculty Sponsor
David Redmiles
Professor
Department: Informatics
redmiles@ics.uci.edu

Figure 6.1: INspect-World v.2 study invitation flyer.

In addition to posting flyers, I also advertised for the study by emailing local student club and organization leaders that were affiliated with the school of ICS. The study flyer was attached to the email and the nature of the study was explained in more detail in the email's body text. I asked the student club and organization leaders to hand out the flyer to their members if they felt that the study was interesting for their organization's members.

Additionally, I contacted current undergraduate-level course instructors at the school of ICS directly with information about the study. Five instructors kindly granted me to use a few minutes in the beginning of their lectures to announce the study in front of the assembled classes.

Once interested students contacted me, I answered their questions about the study over email, phone, or in-person. Contact information from the potential subjects was obtained via email between me, the lead researcher, and the potential subjects. Once all questions were answered and students decided to become study participants, they were added to the participant pool.

Posting flyers, contacting club leaders, and presenting in undergraduate classes, I recruited a total of 34 participants that matched the target population requirements. The recruitment phase was completed within 2 weeks. **Table 6.1** shows an overview of the participants in the INspect-World v.2 study. The 34 (23 male, 11 female) undergraduate student participants were gradually scheduled for study sessions in the Hana laboratory. Scheduling was an ongoing activity throughout the study because many individual schedules had to be considered. Once a group of at least 4 participants was successfully scheduled for a specific time slot, the session was set up and confirmed. A minimum of two participants had to form one of two teams for each usability inspection session in INspect-World v.2. Two teams performed in INspect-World v.2 on the same action sequence in the adjunct inspection arenas.

Team #	Team size	Male/female	Action sequence	Participants
A-1	5	4/1	Google Drive	P1, P2, P3, P4, P5
B-1	4	2/2	Google Drive	P6, P7, P8, P9
C-1	3	2/1	Google Drive	P10, P11, P12
D-1	2	2/0	Google Drive	P13, P14
E-1	4	2/2	City Lens	P15, P16, P17, P18
F-1	4	2/2	City Lens	P19, P20, P21, P22
G-1	3	2/1	City Lens	P23, P24, P25
H-1	3	3/0	City Lens	P26, P27, P28
I-1	3	2/1	Google Drive	P29, P30, P31
J-1	3	2/1	Google Drive	P32, P33, P34
Total	**34**	**23/11**	**20/14**	

Table 6.1: INspect-World v.2 study participants.

The study teams were assigned to one of two action sequences (see: Table 6.1). "Google Drive" stands for an action sequence performed on the Google Drive application for Android phones. "City Lens" refers to an action sequence performed on the Nokia City Lens application for Windows Phone. The City Lens action sequence was used in the initial study in INspect-World v.1.

Instead of scheduling additional interview sessions, all participants were asked to fill out a short experience survey in the end of the virtual world inspection session.

6.1.2 INspect-World v.2 Study Sessions

Two participating teams met with me and my research assistants in the laboratory at the time scheduled for the study session. Each study session lasted a total of 75 minutes and consisted of two separate phases. For the first 20 minutes of the study session, both scheduled teams met with me in a meeting room located at Hana lab at UC Irvine for an orientation session. During the orientation session, I first presented an introduction to the cognitive walkthrough usability inspection method. The presentation covered the same introduction to the inspection method that students participating in the INspect-World v.1 study had seen in a classroom lecture. I also provided room for clarification questions. Following the presentation, all participants logged into the INspect-World system using their own laptops in front of them arranged on the conference table. I helped the participants to become familiar with the virtual world environment and the functionality of INspect-World.

Following the orientation session, the participants were handed the same printed document given to participants of the initial study. The document summarized the context of the usability inspection task and listed all team members. The participants were then asked to take their laptops, mice, and instructions document to an individual study rooms that was assigned to them in the laboratory. The laboratory space used for the INspect-World v.2 study was the same that was used for the initial study (see: **Chapter 4**).

Each INspect-World team conducted a 50 minute usability inspection session in INspect-World v.2. The participants logged into the virtual world system on their own laptop computers and met their team members in their inspection arena to begin the inspection session. Two teams competed in INspect-World v.2 per study session.

The timer for the usability inspections was set to 50 minutes. During the final 5 minutes of the study session, the participants were asked to complete a short Likert scale survey. The survey was handed to the participants in their individual study rooms. The survey questions covered the participants' experiences navigating in the virtual world and collaborating with their team members on a scale from 1 (*strongly agree*) to 5 (*strongly disagree*).

The users rated the following 16 statements in the Likert scale survey:

- Navigating INspect-World
    - I quickly got used to how navigation and camera controls worked in the virtual environment.
    - I was able to get a good sense of what my team members were doing.
    - Interaction with the walkthrough screens generally worked well.
- I felt like I was able to contribute a fair amount to the team's walkthrough effort.
- I felt comfortable to contribute to my team's discussions using my avatar.
- I prefer using text chat over voice chat in the virtual environment.
- The roles in my team were stable throughout the cognitive walkthrough session.
- The Cognitive Walkthrough Method
    - Performing the usability inspection was overall enjoyable.
    - I feel like I now have a good understanding of the cognitive walkthrough method after performing the session with my team.
    - The virtual space allowed us to see each step of the walkthrough in context of the whole task.
- Our team found the 3D model of the phone helpful to get a better sense of how the app worked.
- My team was always aware of the remaining time.
- I felt like the coordination in my team gradually improved during the walkthrough session.
- I was aware of the other team's progress.

- I would use INspect-World again to conduct distributed usability inspections.

The completed surveys were collected after five minutes in the end of the study session. The study session lasted 75 minutes in total. Finally, the participants were compensation with $15 in cash for their participation in the study.

6.1.3 INspect-World v.2 Study Data Collection and Analysis

The participants used the same laptops that were provided to the students in the INspect-World v.1 study. Some software components were updated on the laptop computer. The operating system Windows 7 was updated to the latest version and all security patches were applied. The *Firestorm Viewer* client software used to access the virtual world was updated to its latest version and the graphics driver was updated to work with the new *Firestorm Viewer* version. The screen recording setup did not change compared to the INspect-World v.1 study. Each laptop was equipped with the screen recording and analysis software *Morae Recorder* by *Techsmith* (Techsmith, 2014). The recording on each laptop was started when the participant logged into INspect-World v.2. During the recording, *Morae Recorder* was minimized to the system tray. The integrated video camera in the screen of the laptop computers was used to capture the portrait video of the participants which was embedded in the final video recording. Audio was recorded with the video from the laptop microphones.

34 individual screen recordings of the participants interacting in INspect-World v.2 were recorded. The videos had an average runtime of 42:30 minutes. In total, I collected 23:28 hours of usable video data and 34 completed Likert scale surveys.

To analyze the video data, I built on the methodology used for the initial INspect-World v.1 study. The videos were imported into *Transana* (Transana, 2014)and analyzed in the context of the already coded videos and interview transcripts from the initial study. I used the same grounded theory-based approach to look specifically for the collaboration strategy themes observed in the initial study. One video recording of each team was fully transcribed in *Transana*. The videos of all remaining team members of each team were time-coded, following the themes described in the full transcript. Having completed the procedure for all teams, I conducted open coding rounds, but also incorporated the codes already created during the INspect-World v.1 data analysis process.

Video clips were extracted from the video recordings using *Transana*. Affinity diagrams were created to discover novel aspects related to the new and updated elements in INspect-World v.2. Previously created affinity diagrams were extended with data from the follow-up study to review the findings and to extend and update topic clusters.

I wrote memos on new concepts related to updated or added components in INspect-World v.2 such as the added virtual phone model and the updated inspection screens. Memos based on the video and interview data from the initial study were extended or rewritten using the added data from the follow-up study.

6.2 INspect-World v.2 Study Results

The results of the second study are discussed in the context of the findings from the initial INspect-World v.1 study. The follow-up study was conducted to evaluate changes made to the environment and to validate collaboration strategies employed by participants in INspect-World v.1.

The analysis focused on the following topics:

- **INspect-World environment additions and changes**
    - Added interactive cell phone model

- Updated inspection screens
- Extended usability inspection time and voice chat adjustments

- **Validation of collaboration strategy themes**
  - Self-Organization in an Open Virtual Space
  - A Level Playing Field as an Opportunity for Participation and Engagement
  - Scaffolding: Direct and Indirect Influences
  - Rules: Jumpstarting Collaboration

In the following sections I first discuss findings related to the INspect-World v.2 changes and additions. Next, I review the collaboration themes in the light of the collaborative behavior observed in the updated system.

6.2.1 INspect-World v.2 Environment Changes

INspect-World v.2 implemented the following changes compared to the INspect-World v.2 environment:

- **Added interactive cell phone model**: A virtual phone model allows the teams to explore the action sequence of the usability inspection on an interactive interface. Users can click through the task to understand the transitions between individual action steps. The virtual phone's screen is shared and updates for all users when interacted with.
- **Updated inspection screens**: The usability inspection screens were updated to prevent accidental text editing and text input by multiple users simultaneously. Users can customize the view of the text input areas in the updated version.

- **Extended usability inspection time and voice chat adjustments**: The usability inspection time available to the evaluators in the study was increased. The mapping for of the commands to activate voice chat was changed to prevent open mic issues that caused audio echo in the INspect-World v.1 study.

In this section, I present findings that focus specifically on how the participants reacted to the implemented changes in INspect-World v.2. It is not possible to completely isolate interactions observed in the virtual world with specific system components from the broader activities performed to complete the usability inspection task. Yet, I found a number of common patterns when individuals and teams encountered the updated system features.

6.2.1.1 Virtual Phone Model

The most obvious change in the INspect-World v.2 environment was the added virtual cell phone model. The interactive display of the phone allowed the team members to navigate the action sequence by clicking through the correct actions on the display. The phone model did not provide any other functionality. The model was stationary and could not be picked up or moved by the users. The interactive screen would only allow users to navigate between the action steps of the usability inspection task.

The phone model was introduced to the study participants during the orientation session before the beginning of the study session in INspect-World v.2. I explained the purpose of the phone model, i.e. only to explore the correct action sequence, and emphasized that using the phone model was optional and not required to complete the usability inspection task.

P7 of team *B-2* discovered the virtual phone late in the inspection process at the second-to-last inspection screen. Two team members followed her to look at the virtual phone, but soon return to the inspection screens to continue the task without taking the virtual phone into further account. Teams *A-1, C-1, H-1, I-1*, and *J1* did not consult the virtual phone during the session.

5 out of 10 teams made use of the virtual phone model (*B-2, D-1, E-1, F-1, and G-1*). The way the teams incorporated the virtual phone into the inspection task varied. Teams that did consult the virtual phone at an early stage in the inspection process all continued to use the virtual phone throughout the task and in most cases heavily relied the virtual phone to guide their answers to the cognitive walkthrough questions.

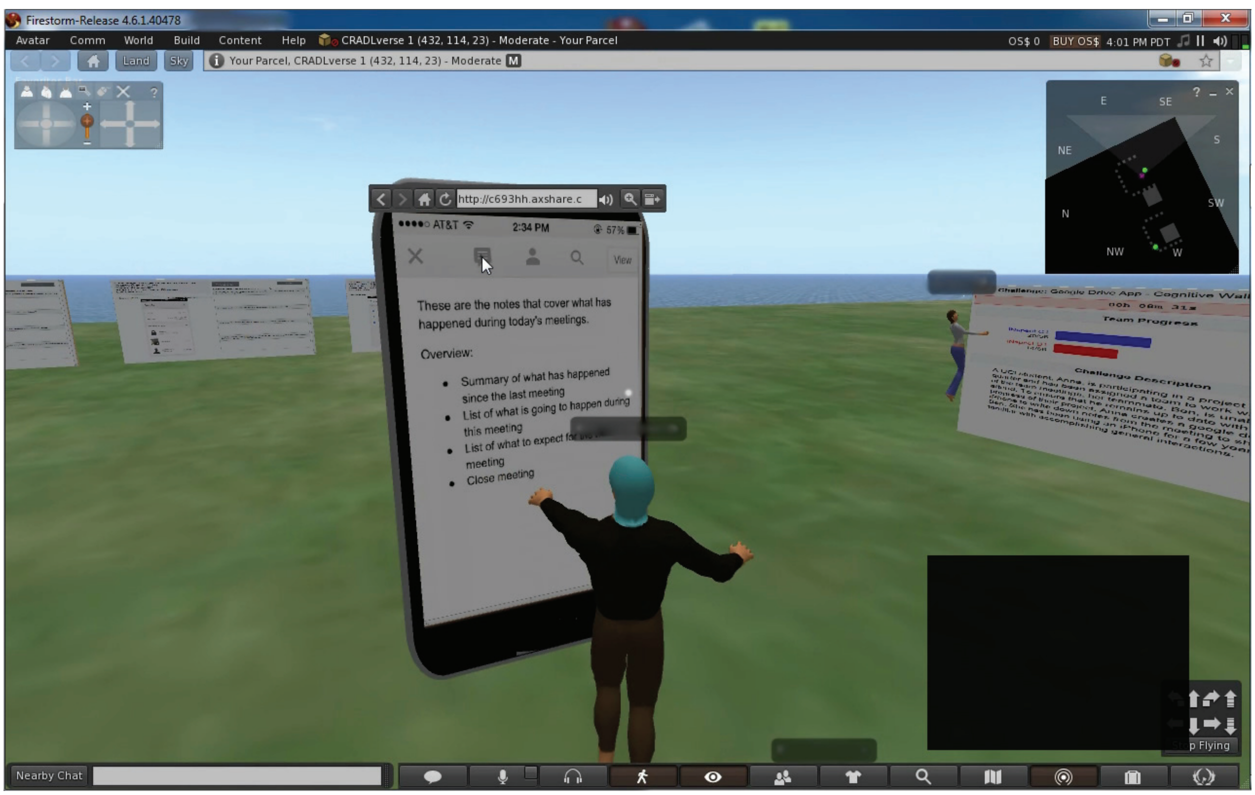

Figure 6.2: Team *D-1* uses the virtual phone model.

Team *D-1* had just completed the first inspection screen, when *P14* said to *P13*:

"Actually if you check out the IPhone emulator. I think it's pretty cool. It just takes you through the flow. It kind of just like progresses with every screen we work on. It's like this one." (P14)

The team used the virtual phone in concert with the inspection screens. Working on the inspection screens together, the team moved to the virtual phone to answer the fourth inspection question whether the interface provided good feedback to the user (see: **Figure 6.2**). One way to answer the fourth question would have been to walk to the next inspection screen and to review the next action step in the sequence for the feedback provided in the interface. For team *D-1* however, the virtual phone provided a better view of the transition between actions.

Team *E-1* took a different approach to using the virtual phone (see: **Figure 6.3**). The team discussed the virtual phone from the very beginning of the inspection session. *P18*, the most vocal team member, from the beginning held the strong opinion that all steps of the action sequence had to be performed directly on the virtual phone and he tried to push the team to focus most activities on the phone model. Not all team members were convinced and some wanted to focus on the inspection screens instead.

Figure 6.3: Team *E-1* interacts with the virtual phone model.

The virtual phone in team *E-1*'s case caused a lot of confusion during the crucial team orientation phase as this excerpt of their conversation shows:

P18: "So I think we have to walk all the way to that thing over there that looks like a phone and try to launch that app."

P17: "How do we answer the questions?"

P18: "Well, we have to like do the task before we answer the question."

P17: "Oh okay."

P18: "So we have to walk over there and actually like use the virtual phone and try to find the local event thing."

P16: "I don't think we need to use the phone..."

P18: "How else would we launch the Nokia City lens app?"

P18 was convinced that the team needs to perform the actions on the phone. Instead of following the cognitive walkthrough method and cycling through the pre-defined action steps, the virtual phone created the wrong expectation and impression of interactivity and task integration. Eventually team *E-1* did get back on track and completed four inspection screens. The team did use the virtual phone to navigate the flow of the action sequence and moved between inspection screens and the phone model.

In contrast to team *E-1*'s strategy, teams *F-1* and *G-1* integrated the virtual phone fully into their collaboration workflow. Team *F-2* used the virtual phone to better understand the transitions between the action steps and to quickly advance forward and backward in the action sequence. While the scribe stayed with the inspection screens the other team members moved between the virtual phone, the score screen, and the inspection screens. At one point, *P20* asked another team member to read an inspection question to him while he is reviewing the action sequence on the virtual phone model:

P20: "OK, can somebody read the second question for step 2?"

P22 (voice): "What actions are obviously available in the interface?"

P20: "OK, I see. The words are very blurry right now. I cannot see anything."

P21: "lol"

P20: "I see some places. A restaurant..."

P20: "Is that good enough for question 2?"

P1 (text): "Looking through different categories of nearby places."

Figure 6.4: Team *F-1* uses the virtual phone model.

Figure 6.4 shows an exchange between *P19* and *P20* of team *F-1*. Two team members at the virtual phone were directed by the other team members at the inspection screens to explore the current action step that read that the user was "holding down the phone" to perform an action on the interface. The team subsequently tried to apply this action to the virtual phone which was unsuccessful because the phone model could not be moved or picked up in the arena. The observed behavior provided another example of how some teams tended to expect more form the virtual phone than it was designed for. The virtual phone's functionality to show the flow of the action sequence did help the team to work on the cognitive walkthrough, but the team gradually expected the phone model to do much more.

Team *G-1* provided another example for using the phone model to discuss an action step. *P23* of team *G-1* was working on the inspection screen and saw *P24* standing nearby the virtual phone model. First *P23* made sure that *P24* could understand him to then ask her to try out the functionality displayed for the action step that he was working on. *P24* could eventually confirm the flow and the collaboration continued:

P23: "Hillary, can you hear me?"

P24: "Yes."

P23: "Ok, awesome, just testing."

P23: "Pretty much for this question: Let me know if it actually turns into something and is it actually taking you there"?

P24: "It's actually not taking me to anywhere."

P24: "At first it wasn't working, and now it works for some reason. It brought me to a search reason."

P25: "Like, what did you press, what button?"

P24: "I just pressed the magnify glass."

The five teams that used the virtual phone integrated the model into their overall collaboration strategy. Other than originally intended by the designer to serve as occasional scaffolding to review the flow of the action sequence during the usability inspection, the phone model became an essential feature of the INspect-World environment. The phone model was not only a simple helpful tool, but often became the center of collaborative efforts, causing teams to split up to consult the virtual phone while working on the usability inspection screens. In some cases, the reliance on the phone model distracted from the task at hand and the teams expected the phone model to provide advanced features that were not supported in INspect-World v.2. Four of the five teams using the phone model expected the model to provide similar functionality compared to a physical phone and thought the model to be an essential tool to complete the cognitive walkthrough. On the other hand, five teams did not use the model and focused only on the inspection screens.

6.2.1.2 Updated Usability Inspection Screens

INspect-World v.2 introduced changes to the inspection screen. The inspection screens were the main focal point for the evaluators in the virtual inspection arena. The screens showed the essential information necessary to evaluate the action sequence at each step and they provided the essential scaffolding to input the results of the usability discussion in the team. The goal in updating the inspection screens was not to completely overhaul the inspection process, but to improve the usability of the screen itself and to prevent problems encountered with the inspection screen by evaluators in INspect-World v.1.

The most significant change to the screen was the addition of a “scribe mode”. The team’s scribe could unlock scribe mode by clicking the button on the top right of the screen. The button made the text fields editable and the scribe was able to input text. The text fields remained locked for all other team members, but the text input was still shown to all evaluators in real time (see: **Figure 6.5**).

To begin to understand the difference of use of the updated inspection screen compared to the initial design, it is useful to first look at how the teams performed in INspect-World v.2. On average, all ten participating teams were able to complete 9.8 action screens (median = 10, SD = 4.66) in INspect-World v.2. Four teams (*A-1, B-1, H-1,* and *I-1*) were able to complete the entire action sequence. On average, all teams spent 10:02 minutes (median = 9:25, SD = 3:57) on the first inspection screen. Compared to the teams working in INspect-

World v.1, the teams in INspect-World v.2 on average spent 1:43 min less on the initial inspection screen and were able to complete 2.6 more action screens.

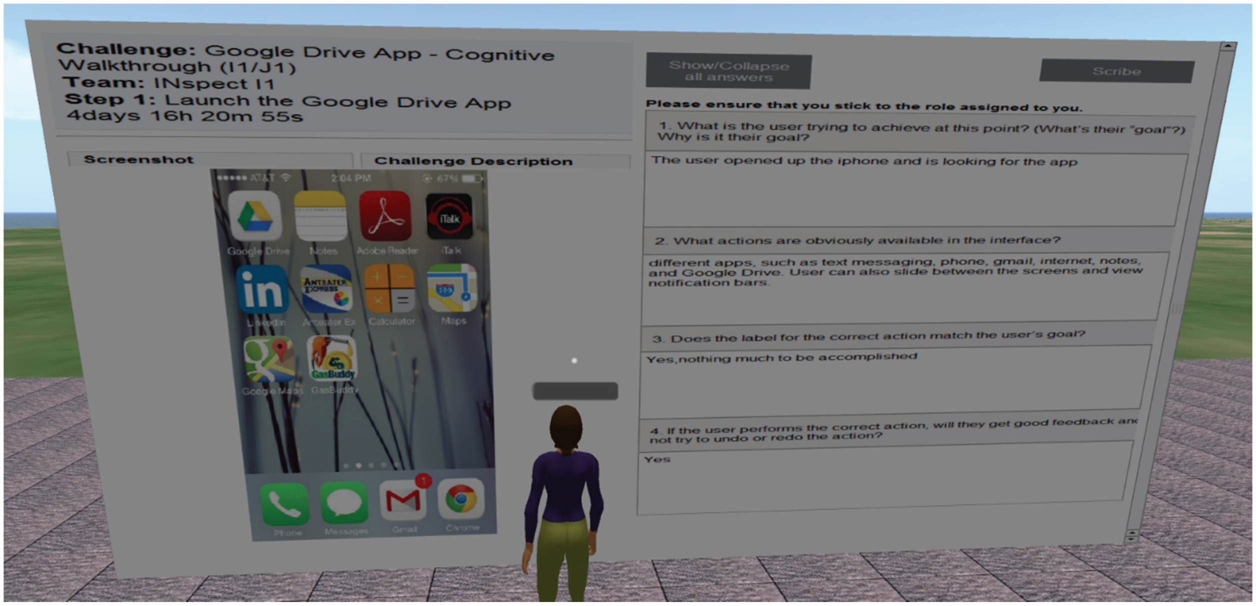

Figure 6.5: Updated usability inspection screen.

The higher count of completed action screens does not only directly correlate to the updated screens. The data is not conclusive enough to attribute higher completion rate to the inspection screen design alone because teams in INspect-World v.2 had significantly more time available for the usability inspection compared to the teams in INspect-World v.1. The virtual phone in the center of the inspection arena (discussed in the previous section) added an additional tool for teams to drive their discussions. Teams that heavily included the phone model into their discussions (teams *D-1, E-1, F-1, G-1*) did not complete all action screens, but they spent a longer time discussing each question and conducted a more in-depth and elaborate analysis on each action step.

The fact that, on average, teams in INspect-World v.2 spent 1:43 minutes less on the first inspection screens deserves further discussion. As discussed in **section 4.2.3**, the teams in INspect-World v.1 used significantly more time on the first action step compared to the following inspection screens in order to come to terms with the inspection task, the inspection screen's interface, and the team's initial strategy how to organize the collaboration. An important aspect of the initial discussion was the clarification of roles in the team that served as a catalyst for developing initial strategies, how to answer the questions on the screen, and how to delegate the work. The scribe button functionality on the updated inspection screens helped the teams to more quickly jumpstart the discussion and to delegate the work based on the more obvious scribe role assignment. However, the initial inspection screens still served as the first major milestone to coordinate the team's collaboration.

Aside from helping the teams to clarify the scribe's role in the team, the added scribe mode drastically limited the number of cases in which multiple users would unintentionally edit text input fields at the same time. In INspect-World v.1 the issue resulted in flickering text output in the text areas that were visible to all collaborators. Only team *E-1* encountered the problem again in INspect-World v.2 due to a particularly overbearing team member who for some time ignored the team's efforts to focus on one scribe.

The updated inspection screens featured an accordion control that allowed participants to control the view of the text input fields in their own view of the inspection screen. By default all questions were shown on the right panel. Each question could be collapsed or shown based as the user preference how to view the questions. The goal was to create a custom view for each participant to focus on individual questions as the team cycled through the questions collaboratively. This combination of individual control and shared views of the input text areas caused confusion in three teams (*H-1, D-1*, and *F-1*). *P28* of team

H-1 had used the accordion view to highlight the question the team was working on. Since customizing the right panel, *P28* was convinced that every user was responsible for filling out their own forms and asked *P27* to provide the answers the team had decided on so that he could input the text in his view:

P28: "Wait a minute, did you guys finish No 2?"
P27: "Yeah, I think we just put in every title that's available on this screen. Is there something that's missing?"
[…]
P28: "Can you copy what you have in your chat?"

P28 eventually received the input from *P27* and copied the text into the inspection screen's input fields. In *P28's* understanding at this moment in the collaboration process, the inspection screens provided individual views for each team member. Users in team *D-1* and *F-1* had similar impressions of the virtual phone model and wondered if their team members could see their progression on the virtual phone when they cycled through the action sequence on the screen. Interacting with collaborative objects in the virtual world, most users assumed that their individual view would be shared with the collaborators. When there was no actively and collaboratively created content, such as the text input in the text areas on the inspection screen, the distribution of shared views on virtual objects was not obvious to many participants.

The design decision to provide users with individual customization options brings into question how a balance between individual customization and shared views in the virtual world environment can be achieved. In its current design in INspect-World v.2 the customization options were not heavily used. When used, the individual customization options tended to confuse users about the shared view of artifacts in the virtual world.

Team members used the newly implemented tab control to switch between the screenshot of the action step and the description of the task on the inspection screen. The general inspection process originally observed in INspect-World v.1 did not change in INspect-World v.2 that featured the updated screens.

6.2.1.3 Extended Usability Inspection Time and Voice Chat Fixes

The study in INspect-World v.2 allowed the teams 20 minutes more time for the inspection sessions compared to the time allotted in INspect-World v.1. The added time was valuable as all participating teams still spent a significant amount of time on the first inspection screen to coordinate and to decide on a strategy to work on the screens.

The added amount of time worked in favor of efficient teams (such as *A-1, B-1*, and *H-1*) that completed the usability inspection task relatively quickly. Team *A-1* completed the final inspection screen with 8 minutes to spare in the inspection session. The team however did not waste the time in the end and began to double-check the text input made across the whole inspection arena. Individual team members went over the text input on selected screens and extended or edited answers. The inspection results provided by team *A-1* were brief and not very detailed upon completion of the inspection arena. The added time allowed the team to work backwards and improve the input. Similarly, teams *B-1* and *H-1* used the additional time to review their input.

The added time also gave the teams more opportunities to engage in off-topic conversations and chit chat. Instead of racing through the task to beat the clock at all costs, there was time for complementing other team members on their outfit or for celebrating the team's progress when compared to the competing team. Team *B-1* stopped at inspection screen 9 when *P30* pointed out the view across the virtual ocean with the sun beginning to set:

P6: "Check out the nice ocean view."
P7: "Is it sunset?"
[P8 opens the configurations panel in her virtual world client and sets the daytime to evening time to see the sunset view]
P6: "Hmmm I don't think so."

Moments like this helped to build an enjoyable atmosphere and a good team spirit. Individual team members also edited their avatars during the inspection session while waiting for the scribe to fill in the answers or while waiting for other team members.

The added inspection time did not negatively impact the teams' effort to complete the usability inspections. Teams were still driven by the time limited time provided to complete the inspection task:

[P21 is exploring the arena, looking ahead at all coming steps. He then returns to the team.]
P21: "Think we need to hurry up. Not much time left."
P20: "Yeah, 17 min."

Mapping the activation of the voice chat functionality to the [CTRL] on the laptop computer helped to prevent most voice echo issue that occurred in INspect-World v.1. Only one team encountered voice echo issues when multiple team members activated their microphone simultaneously. The team learned from the experience and took turns in speaking following the incident.

6.2.1.4 Two Different Usability Inspection Themes

Six teams (20 participants) performed the usability inspection session in INspect-World v.2 on a *Google Drive* action sequence. Four teams (14 participants) performed the usability inspection on the same *City Lens* action sequence that was used in the INspect-World v.1 study.

While all teams in the INspect-World v.2 study developed differing strategies to approach the inspection screens and to incorporate the virtual phone model into their collaboration, a specific set of strategies or behavioral patterns could not be attributed to one of the two action sequences. I did not notice significant differences related to the cognitive walkthrough theme used in the team's general behavior. It could be said that the *Google Drive* action sequence included less potential usability issues than the *City Lens* action sequence. The *Google Drive* app overall had a more coherent interface. The discussions and general process the teams engaged in however did not differ significantly.

6.2.2 Review of Collaboration Themes Found in INspect-World v.1

The analysis of the data collected during the initial study conducted in INspect-World v.1 revealed four collaboration themes that were used as a framework to discuss collaborative behavior and the development of collaboration strategies employed by the users in the virtual world. The data collected from the INspect-World v.2 study was analyzed using the same methodology with the goal to review and to extend the collaboration themes. In the following, the results of the video data analysis are discussed with the goal to re-visit the collaboration themes originally defined in **Chapter 4**.

6.2.2.1 Self-Organization in an Open Virtual Space

On average, each team spent 43:20 minutes in total logged into INspect-World v.2 to work on the distributed cognitive walkthrough task. The action sequences analyzed by the teams in INspect-World v.2 consisted of 14 action steps in the *Google Drive* action sequence and 15 action steps in the *City Lens* action sequence. On average, the participating teams were able to complete 9.8 steps (median = 10, SD = 4.66). Four teams (INspect A-1, B-1, H-1, and I-1) were able to complete the entire action sequence. On average, all teams spent 10:02 minutes (median = 9:25, SD = 3:57) on the first inspection screen.

Compared to teams working in INspect-World v.1, the teams using INspect-World v.2 on average had 13:50 minutes more time available and they completed 2.6 more inspection steps. The number of teams that were able to complete the inspection task went up from 2 to 4 teams. The average time spent on the first inspection screen was 1:43 minutes less on average compared to the teams working in INspect-World v.1.

Teams in INspect-World v.2 also spent a significant amount of time on the initial inspection screen. I observed similar behavior compared to the INspect-World v.1 study. The time on the initial inspection screen was used to clarify the nature of the task and to agree on a strategy best suited to go about the inspection task. In INspect-World v.2 team leaders emerged more quickly compared to the teams observed in INspect-World v.1. The process of becoming a team leader was different compared to INspect-World v.1. Two major factors drove the initial orientation phase across all teams: the clarity of the scribe role and the competition between both teams in INspect-World.

The video recordings showed that when the teams gathered around the first inspection screen, most individual team members explored the screen by hovering over its components with their mouse pointers. Most of the users soon discovered the scribe button which signaled the scribe mode. While the scribe role was introduced during the orientation session in the same way that it was introduced to the teams working in INspect-World v.1, having the scribe role attached to a specific action in the virtual world brought the issue to the team's attention immediately. One of the first discussion points brought up by most teams concerned the scribe role in the team. Having found the scribe or having assigned a new scribe in case the pre-assigned scribe wanted to give up the role, served as a lead-in to break the ice and begin the discussion of the usability inspection task.

Team *A-1*'s discussion at the first inspection screen reflected the importance of the scribe role:

P1: "Are we supposed to start?"
P2: "Don't know…"
P3: "I think so."
P4: "We have to answer how to launch the app."
P1: "Who's scribe?"
P4: "So in top bar we write 'user tires to open app'"
P5: "I'm scribe."
P4: "Anthony is."
P4: "1: Open up the app so they can use it."
P4: "2: Pre-existing user interface lets user know they can open by tapping."
P4: "3: Label matches because it says Google Drive."
P4: "4: App open so yes."
P4: "Anthony do you see this?"
[P5 is typing the answers into text areas on the inspection screen.]
P5: "Yes. All right, next one..." [The team moves to inspection screen #2.]
[…]
P4: "Let's do shorter answers - handout says it's ok."
P5: "kk."

By focusing on the scribe role immediately, team *A-1* was drawn directly into the task and began to answer questions without much delay. *P4* who initially addressed the scribe *P5* began to lead the team by suggesting answers. *P4* and *P5* continued on to lead the team throughout the task.

A similar observation was made in in team *B-1*:

P7: "OK, so I've been assigned the scribe role. So it's ok with everyone? Or do you guys want to change roles?"
P8: "I'm fine."
P6: "Yeah, I think we're good. We got to win!"

P7 of team *B-1* started the discussion with asking about the scribe role assignment. The team went on to discuss the questions while *P7* remained a diligent scribe who filled in the text input areas on the inspection screens based on the voice chat discussion. Both team *A-1* and *B-1* strictly stuck to their elected scribes and had one additional vocal team leader who directed the team. Both teams completed the inspection task with some time to spare. In team *C-1* the initial conversation went as follows:

P1 (text chat): "Hello!"
P2 (voice chat): "Hi [P1], do you hear me ok?"
P1 (voice chat): "Loud and clear."
P1: "[P1], you and I are the evaluator and [P3] you are the scribe. Is that ok?"
[Team goes on to discuss the answer to the first question.]
P2: Sounds good. Ahm, [P3] - do you want to go ahead and type that down?
[The team waits for [P3] to type the answer and continues the inspection.]

Team *C-1* also began to organize its collaboration around the scribe's role in the team. Team *A-1, B-1*, and *C-1* were amongst the teams that did not use the virtual phone model for their usability analysis. Teams that did use the virtual phone model focused their attention on the phone model from the beginning and reasoned about how to integrate the model effectively into the inspection task. Team *D-1* began the conversation by referencing the virtual phone model and by suggesting to build the collaboration on the interaction with the phone model:

P13: "OK, so apparently we are supposed to interact with the giant cell phone in the middle of the arena and one of us writes down basically what the evaluator says."
P14: "Yeah, so I guess so whoever has something to say says it and then the other person can write."
P13: "OK, that sounds good."
P14: "All right."

Compared to teams in INspect-World v.1, teams working in INspect-World v.2 had access to features in the virtual world environment that allowed them to initiate their team building and strategy development. Although teams in INspect-World v.1 were aware of the scribe role, the significance of the role was not always immediately apparent in the virtual world. The scribe button on the inspection screens and the added virtual phone acted as visible anchors for strategy and team building. Users in INspect-World v.1 mostly used individual performances of support to establish organizational structures (see: **Section 4.2.1**) in the open environment. The availability of obvious anchors in INspect-World v.2 allowed team members to more quickly establish a discussion about the team's strategy.

6.2.2.2 A Level Playing Field as an Opportunity for Participation and Engagement

Section 4.2.2 introduced the concept of a level playing field in INspect-World that allowed team members to engage in the team's collaboration at their own pace. In the interviews, participants in the INspect-World v.1 study stated that the virtual environment created a collaborative atmosphere in which users generally felt comfortable to interact due to the same mediated interactive context for every user. Users felt that they had the same abilities and the same capabilities to represent themselves through their avatars.

In the INspect-World v.2 study, I observed fewer examples of gradual engagement of individual team members. Team *A-1, H-1*, and *I-4* all had individual team members that became involved in communicating with the team more than 15 minutes into the task. Similar to the observations made in INspect-World v.2, the team members did pay attention to the task and the team's input on the inspection screens from the beginning.

There were instances in the teams' collaboration that led me to extend the level playing field model under consideration of the strong leadership of individual team members displayed in several teams. Team *A-1* developed a strategy that allowed them to quickly advance between inspection screens and to eventually complete the inspection task with time to spare. At first glance, the team's scribe, *P2,* formed an effective leadership duo with *P3* who directed the team, suggested answers to the questions and was generally very vocal on voice chat. Team members *P4* and *P5* are initially not active on any chat channel, but they follow the team's progression. At minute 12 into the inspection session, *P4* manages to contribute briefly to the discussion on text chat, but the scribe and *P3* had already established a rapid collaboration style that was difficult to follow for the other team members. An unspoken bond between *P2* and *P3* had developed who controlled the inspection session in a way that did not allow room for discussions. At minute 26:48 into the inspection session the team had reached action step eight that involved different sharing options in the *Google Drive* action sequence. *P4* decided to make a suggestion in text chat after having been unable so far to contribute because of the fast moving leadership duo:

[The team has reached step 8 of the action sequence.]

P4 (talking to herself): "Damn Steven, you're answering them all..."

P4 (text chat): "How about the + button..."

P3: "Yeah, add that." [Referring not to P4's input but a previous suggestion by P2]

P4 (talking to herself): "You guys got this. You don't need me... I'm out."

P4 was clearly frustrated with the way *P3* and *P2* have taken control of the inspection process. However, the other team members are unaware of her frustration. *P4* chooses to not participate for the remainder of the inspection session. The example shows some of the drawbacks of the level playing field concept. There is a possibility that individuals use the open system to take control of the collaboration process while losing sight of passive collaborators. *P3* and *P4* did not shut out *P4* on purpose – they were rather too immersed in their concentrated collaboration to notice the problem.

Similar effects of a strong leadership duo were observed in team *I-1*. The team consisted of three team members of whom two collaborated closely from the beginning of the usability inspection. Like team *A-1*, team *I-1* was able to complete the inspection task with time to spare. Initially all three team members communicate with each other. Eventually however, *P29* could not follow the inspection process as *P30* and *P31* progressively answer inspection questions at an increasing speed.

Team *E-1* experienced difficulties coming to terms with the usability inspection task in INspect-World v.2 from the beginning. *P16* suggested to begin answering the questions on the initial inspection screen based on the screenshot provided. The suggestion would have brought the team onto the right track. However at that moment *P15* insisted on a different strategy. *P15* was convinced that the team had to perform the actions on the provided virtual phone first in order to be able to answer the questions:

P15: "So I think we have to walk all the way to that thing over there that looks like a phone and try to launch that app."
P16: "Only Karen can answer so..."
P17: "How do we answer the questions?"
P15: "Well, we have to do the task before we answer the question."
P17: "Oh, okay."
P15: "So we have to walk over there and actually use the virtual phone and try to find the local event thing."
P18: "I don't think we need to use the phone..."
P15: "How else would we launch the Nokia City lens app?"
P16: "[P18], click the Scribe button at up the right corner and then you can type."

P15 misinterpreted the action step description of the cognitive walkthrough as an instruction for the team to perform the action on the virtual phone. *P16* and *P18* tried to correct *P15*, but he insisted on his position. *P16* became visibly frustrated with *P15*'s interruptions and mouthed himself: *"Oh my god..."* during the session. It took the team close to 25 minutes to establish a working rhythm that followed the action sequences on the inspection screens. Although multiple team members disagreed, it took the team a long time to overcome the confusion caused by a very opinionated team member. *P15* eventually worked with the team and tried to integrate *P16* into the discussion who had not participated in the discussion for a while:

P18: "OK. I don't think the icons match. Except for the UCI dining one."
P15: "So, Andrew! Do you think the icons match the text?"
P16: "For this one? Yeah. Cuz hm… We are trying to look for a place to eat. Right?"

P15 managed to bring *P16* back into the conversation after their disagreements about the task. At this point the team had lost 25 minutes of the total inspection time to the conflict resolution efforts (see: **Figure 6.6**).

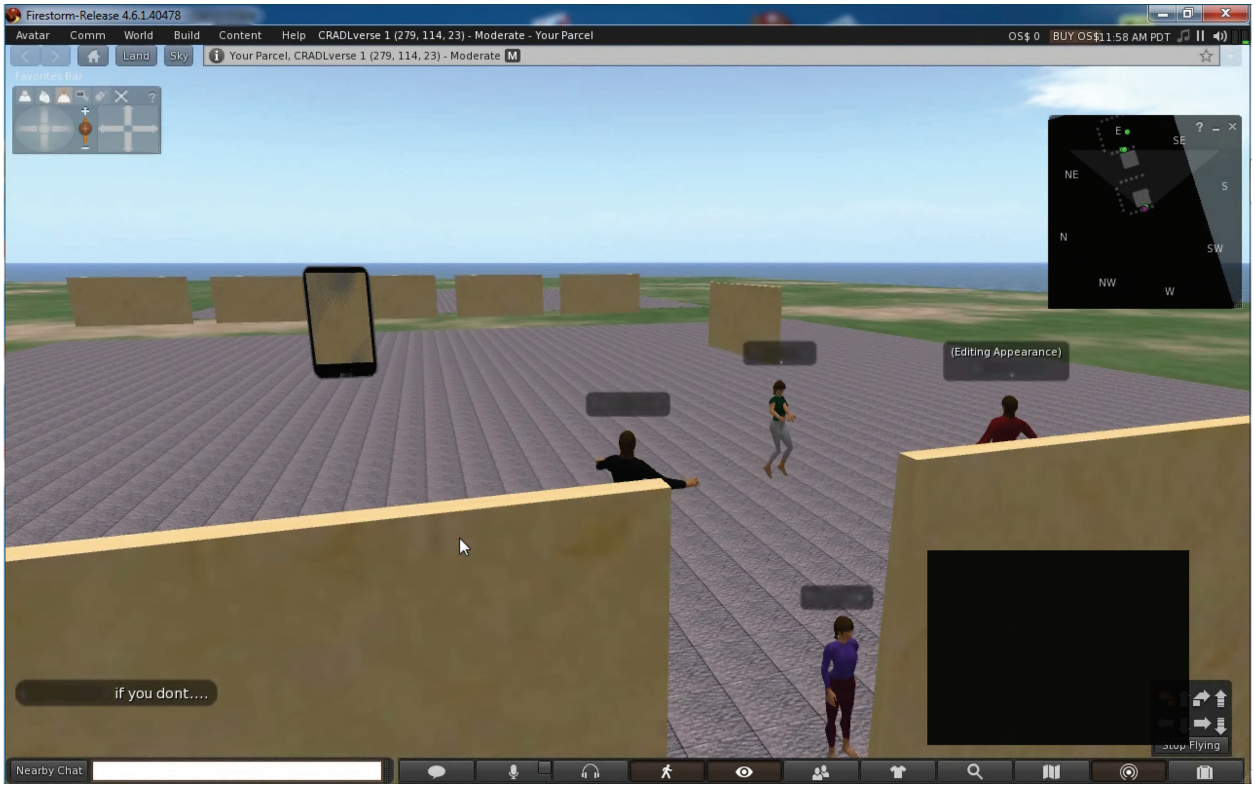

Figure 6.6: Team *E-1* in a disagreement, *P16* is editing appearance.

Overall, I found that the level playing field experienced by users in INspect-World provided individual team members with the opportunity to collaborate at their own pace. Most teams were able to develop organizational structures that fit their team member's diverse personalities. The model however needs to be counter-balanced to keep individual team member's signs of frustration and disagreements visible to the other team members. The anonymous layer provided by virtual world and the virtual avatars needs to be balanced with a system that allows team members to voice visible critique.

6.2.2.3 Scaffolding: Direct and Indirect Influences

Direct and indirect scaffolding elements in INspect-World v.2 played an important role for the teams to organize and conduct their usability inspection sessions. The scaffolding elements in INspect-World v.1, discussed previously in **Section 4.2.3**, were also mostly present in INspect-World v.2. The updated inspection screens, the added virtual phone, and the extended inspection session time however impacted how the teams incorporated the scaffolding into their collaboration efforts.

Most teams used the arrangement of the virtual screens and the position of the avatars during the usability inspection sessions to infer the current work focus of fellow team members. Movement in the space, for instance from one inspection screen to the next screen, signaled a transition to the next action step that was usually initiated by the team leader. Team *B-1* regularly used the chronological arrangement of the screens to look ahead or to go back to the previous step to verify reports of the team.

Similar to the observations made in INspect-World v.1, the users in INspect-World v.2 quickly got used to interacting in the virtual space. The virtual environment soon became the normal collaboration context and was treated similar to a physical collaboration space. *P6* of team *B-1* for example blocked the vision of one of her team members in the following exchange:

P7: "That cloud blocking my vision. LOL" [P6 moves to the side]
P8: "Yeah, P6 go sit down!"
P6: "Whooops sorrrryyyy!"
P8: "lol"

Further observations in the data showed users apologizing for walking into other avatars or for pushing other avatars by accident.

The virtual phone served as direct scaffolding to answer the cognitive walkthrough inspection questions. The phone allowed the users to click through the complete flow of the action sequence. Teams that used the phone as part of their usability inspection analysis, particularly used the phone to answer question four of the cognitive walkthrough on the inspection screen. Question four was concerned with the user feedback of the action step. By exploring the action sequence on the virtual phone, users were able to investigate the transitions between the action steps more rapidly compared to moving to adjunct usability inspection screen.

The virtual phone was also used to organize the teamwork. Team *D-1* and *F-1* split up the team into two groups. One group stayed with the inspection screen (scribe and one more team member), while the second group was delegated to operate the virtual phone and reported back to the team at the inspection screen. The groups were separated in the virtual space which allowed for a quick delegation of tasks for each team member.

INspect-World v.1 and INspect-World v.2 were designed to host a usability inspection challenge between two teams. Both teams perform the usability inspection in adjunct arenas simultaneously. The score screen in the lower center of each arena displayed the progress of both teams in real time. While both teams worked against the clock, they also competed against each other. The competitive aspect of the usability inspection was equally introduced to the study participants in INspect-World v.1 and INspect-World v.2. I found that the competition did not play a significant role for 13 of the 16 teams in INspect-World v.1. The majority of teams focused solely on the inspection task and never consulted the score screen to compare their performance to the other team. When shown a screenshot of the score screen during the interviews only 7 of 49 interviewees confirmed to have looked at the score board in INspect-World v.1. Teams that did recognize the competition mode consulted the score screen in the end of the session to review the team's result, but the competition was not referred to during the collaboration on the inspection task.

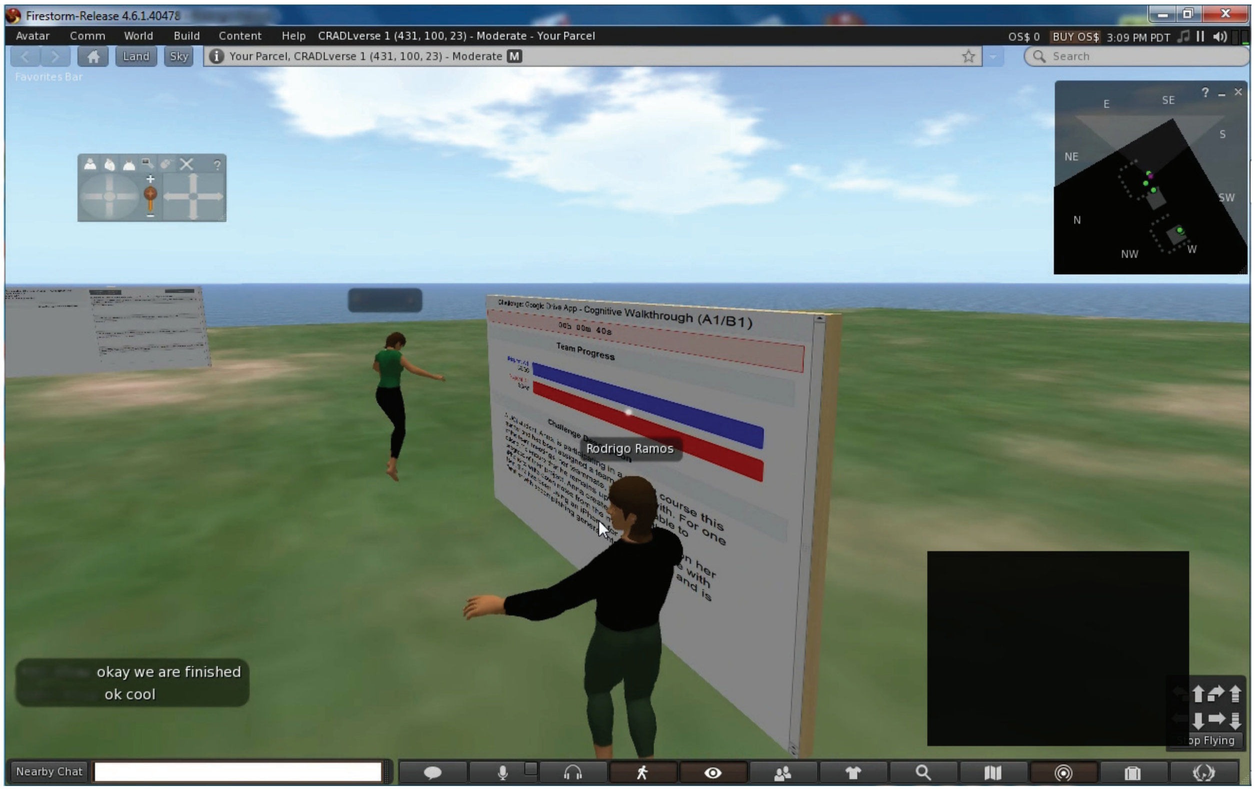

Figure 6.7: Team B-1 reviewing the score in the end of the inspection session.

In contrast, 5 out of the 10 teams in INspect-World v.2 integrated the competition actively into their collaborative activities. In team *A-1,* that completed all action steps of the usability inspection, two team members (*P1, P4*) regularly moved to the scoreboard and reported the status of the competition back to the team:

P1: "The other team answered the same amount of questions."

P1: "We are tied."

Team *A-1* finished the usability inspection with some time to spare. The competition and the countdown motivated the team members to proceed fast from screen to screen. The reports of the status of the competition in between the inspection activities helped the team to stay focused.

Team *B-1* competed with team *A-1* in INspect-World v.2 and was also always aware of the competition. Once team *B-1* (see: **Figure 6.7**) reached the second-to-last inspection screen, *P8* returned to the team working on the inspection screen. The following conversation took place at that moment:

P8: "I think A1 cheated."
P9: "LOL"
P9: "By having multiple scribes?"
P9: "How many questions did they finish?"
P7: "I think they're done. But we can still finish!"
P8: "idk looks like they are done."
P8: "That's the spirit Katie!"
P7: ":)"

The teams that did engage in the competition were able to use the competition as indirect scaffolding that motivated the team to put in their best effort. Teams in INspect-World v.2 had generally more time available to work through the initial orientation phase to orient the teamwork towards the competition.

Team *H-1* used the score board in the end of the inspection session to find out that one inspection screen was missing an answer:

P26: "For some reason it's [the score screen] showing 59 out of 60, I don't remember if we missed one."
P27: "I think we should go around and look for the last one."

P26: "Yeah. Let me know if you spot any blank ones."

[The team scouts the inspection arena for the blank answer.]

P27: "Oh, it's the third one... We got to put yes on the third one."

P26: "Ok... Thank you very much...." [P26 fills in the answer.]

P26: "Her we go."

P28: "We're winning! We're a good team."

P26: "Let's refresh, because I filled in the last one."

[The screen shows that all steps were completed.]

P26: "YEAH! Awesome. 60/60 :) Good job everyone."

The team was excited about winning the competition and congratulated each other for a job well done. The competition provided the main motivation for the team to perform well in the usability inspection task and provided the scaffolding to motivate the team.

6.2.2.4 Rules: Jumpstarting Collaboration

The instructions and handouts provided to the INspect-World v.2 study participants did not differ from the INspect-World v.1 study material. A set of roles were suggested to the team (evaluator, moderator, and scribe) but the teams were allowed to switch these roles if they chose to do so. Only one scribe was allowed to type per inspection screen which was made more obvious in INspect-World v.2 due to the updated interface of the inspection screen. The teams were asked to follow the cognitive walkthrough inspection principles: the group had to evaluate the action steps together, come to a consensus and have the scribe input the agreed upon answer to each inspection question on the screen. The actions steps had to be analyzed in sequential order to evaluate the task flow completely.

I was surprised to find that none of the teams observed in INspect-World v.2 broke the cognitive walkthrough principles. All 10 teams stayed together as group to analyze the action steps. Movement between screens and the virtual phone was more frequent and individual team members did roam the inspection arena more frequently to review the score screen. But the roaming team members eventually returned to the team to help with the inspection or to deliver the information gathered.

Similarly to the teams in INspect-World v.1, the teams in INspect-World v.2 used the initial role assignments to begin the discussion about the inspection task and the team's general approach.

Team *G-1* discussed the scribe role at the outset of the inspection session:

P24 (voice chat): "Let's figure out who is going to write out the answers... So on the paper I'm the scribe, but I don't think I'm good at writing. So anyone else who wants to write the answers?"
P23: "I'm ok..."
P24: "Wait, who else is in our team? There are three people in each team, right? Oh, [P25], ok."
[P25 joins the team]
P25:" I can be the scribe!"
P24: "Sounds good, thank you Allan!"
P23: "OK, thanks!"
P35: "No problem."
P23: "OK, what is the user trying to achieve at this point? What's their goal? Why is it their goal?"

P24 was the pre-assigned scribe, but was not comfortable with the role. *P24* took over the scribe role and the team immediately started working on the first question on the inspection screen. A very similar conversation occurred in team *J-1* in the very beginning of the inspection session:

P34: "OK, Sara you want to be the scribe? I don't really want to be the scribe, but I can."
P33: "Do I just type everything then?"

P34: "Yeah, I think so."
P34: "Yeah, if you come over here, behind me I'm guessing. Click the scribe button and then you kind of like scroll down. And once you scroll down a little bit you should see like the scribe it's like on the right hand side."

P33 became the new scribe of team *J-1* and remained in that role throughout the inspection session. Similar role discussions took place in all teams when they began to work on the initial inspection screen. The role assignment helped to initiate the discussion and focused the team immediately on the task.

The scribe role was taken quite seriously by most teams. Team *B-1*'s scribe had just moved to the virtual phone model to review an action step, when *P8* called him back to the team waiting in front of the inspection screen:

P7: "Come back and scribe for us!"
P8: "We got 3 mins."
P7: "What are you doing?"
[P6 returns from the virtual phone]
P8: "Wow it looks weird. Can you type?"
P6: "Yeah."

The team waiting at the inspection screen did not activate the scribe mode by themselves but waited for the scribe to return.

Team *G-1*'s inspection session can serve as an additional example. Four action steps into the session, the scribe *P24* noticed that his team member *P25* edited the input on the previous inspection screen. *P25* reminded *P24* that there should only be one scribe screen (see: **Figure 6.8**).

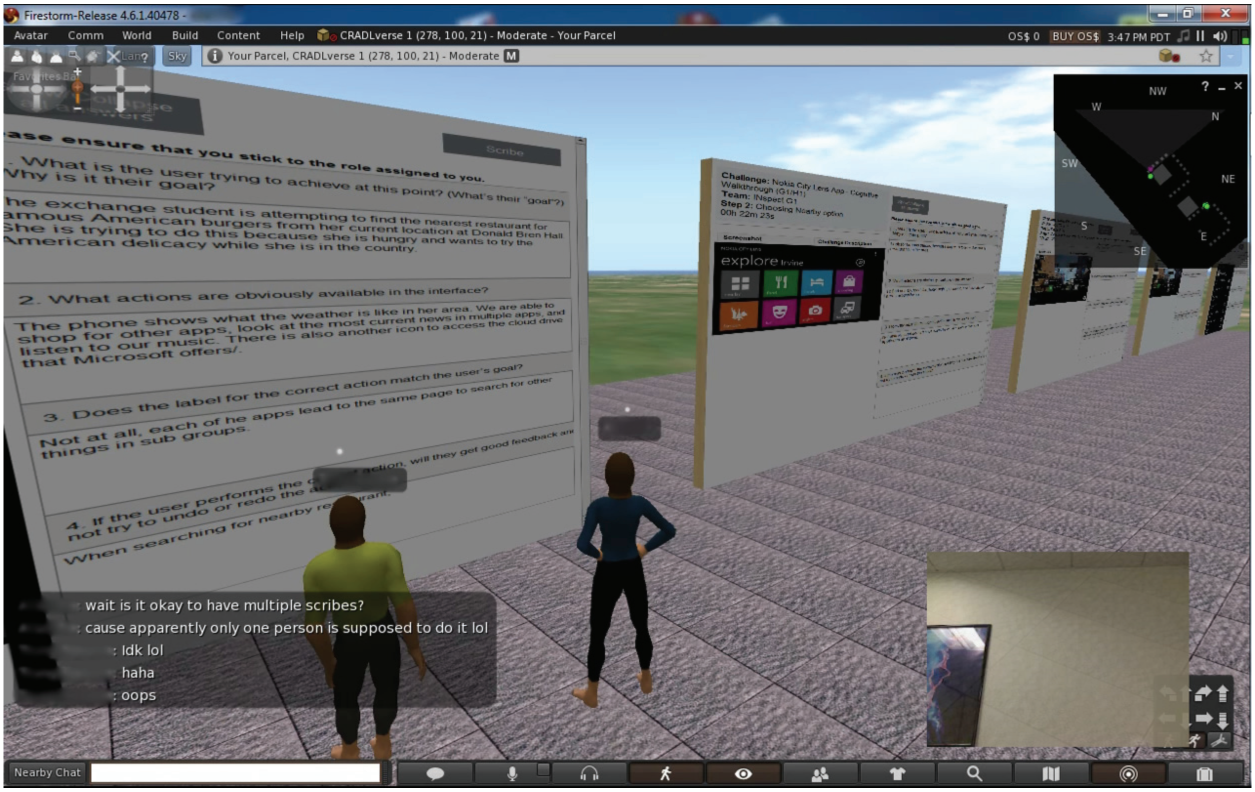

Figure 6.8: Team *G-1*'s scribe reminds his team member of the rules.

There were a few exceptions when rules were broken in INspect-World v.2. The exceptions however occurred because some teams encountered a technical issue in INspect-World v.2 that in rare cases cause an inspection screen not to load. The inspection screen remained blank and only manually refreshing the browser layer on the inspection screen fixed the issue. The technical details of the inspection screen's implementation were unknown to the users and the solution to the problem was not obvious.

Three teams (*B-1*, *H-1*, and *G-1*) encountered the described technical issue. All three teams reacted to the problem in the same way. Team *B-1* encountered the issue on the third inspection team:

P8: "Uhhh I can't see anything."

P7: "me neither"

P6: "ditto?"
P9 (voice): "Same here, I can't see anything. Move on to the next one and come back later?"
P8: "Yeah."

The team very quickly decided to not dwell on the issue too long, skipped the inspection screen, and continued to work on the next action step. In the end of the session, team *B-1* returned to the blank screen, successfully recovered it, and completed the inspection task.

Team *H-1* experienced the same technical issue on a different inspection screen in the middle of their inspection session:

P26: "Ahm, the screen just went grey."
P27: "Yeah, I have no idea. Do you know how to go back?"
P28: "Just click outside the window and you will be back."
P26: "It's still showing grey for me."
P28: "Yeah, it doesn't work."
P26: "Yeah, same here."
P28: "Let's move on to the next one."

The technical issue did not stop team *H-1*'s collaboration flow for a long time. The team quickly decided to continue with the inspection on the next screen.

6.2.3 Survey Results

In the end of the inspection session in INspect-World v.2, each participating team member was asked to fill out a brief exit survey. The paper survey asked the participants about their experience in INspect-World v.2. The participants were asked to evaluate 15 statements on a Likert scale from 1 (strongly agree) to 5 (strongly disagree). The statements were based on the following themes:

- Navigation & Controls in INspect-World
- Contributing to the teamwork in INspect-World
- The Cognitive Walkthrough process in INspect-World
- Awareness during the usability inspection process in INspect-World
- Overall assessment of INspect-World

The first set of statements was concerned with navigating the INspect-World environment using the provided *Firestorm Viewer* client software on the laptop computers. Users indicated that they were able to quickly understand the navigation and camera controls in the *Firestorm Viewer* (see: **Figure 6.9**, *Controls*, 'I quickly got used to how navigation and camera controls worked in the virtual environment.', mean: 1.70). Upon joining their team members, users agreed with the statement that they had a good understanding of their team members' activities in the virtual world (see: **Figure 6.9**, *Awareness*, 'I was able to get a good sense of what my team members were doing.', mean: 2.18). Controlling the interaction with the inspection screens was rated slightly worse, but users still reported that the interaction with the inspection screens generally worked well (see: **Figure 6.9**, *Screens*, 'Interaction with the walkthrough screens generally worked well.', mean: 2.32).

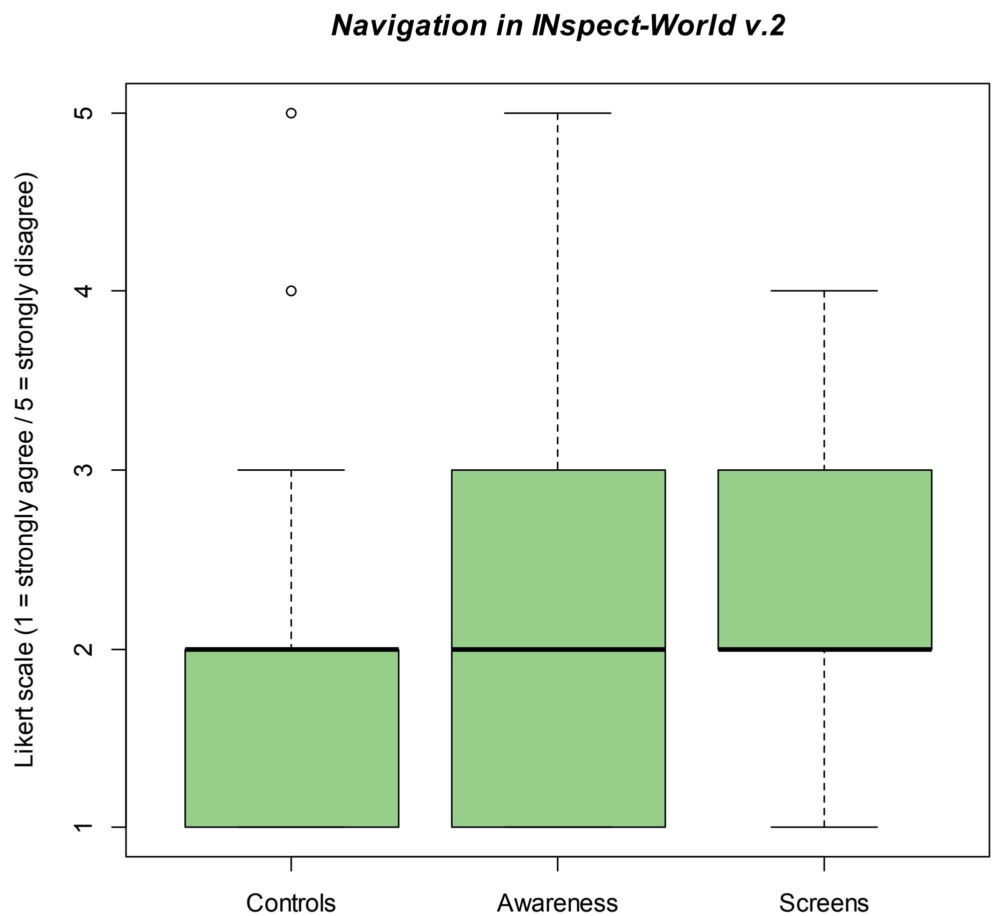

Figure 6.9: Survey results – Navigation in INspect-World v.2.

When asked to self-evaluate their contribution to their team's efforts in INspect-World v.2, most users indicated that they contributed a fair amount to the collaborative task (see: Figure 6.10, *Contribution*, 'I felt like I was able to contribute a fair amount to the team's walkthrough effort.', mean: 1.97). Most users strongly agreed with the statement that contributing to the team's effort using an virtual avatar was comfortable (see: **Figure 6.10**, *Avatar*, 'I felt comfortable to contribute to my team's discussions using my avatar.', mean: 1.76). Using an avatar to interact in the virtual world did not represent an issue for most users which is an interesting result considering the avatar representation acted as the main proxy for any interaction in the virtual world. When contributing to the team's discussions users were undecided on preferring text chat over voice chat in the virtual world (see: **Figure 6.10**, *TextPreferred*, 'I prefer using text chat over voice chat in the virtual environment.', mean: 2.65). This result is also reflected in the video data. Voice and text chat was used interchangeably depending on the context of the collaborative activity.

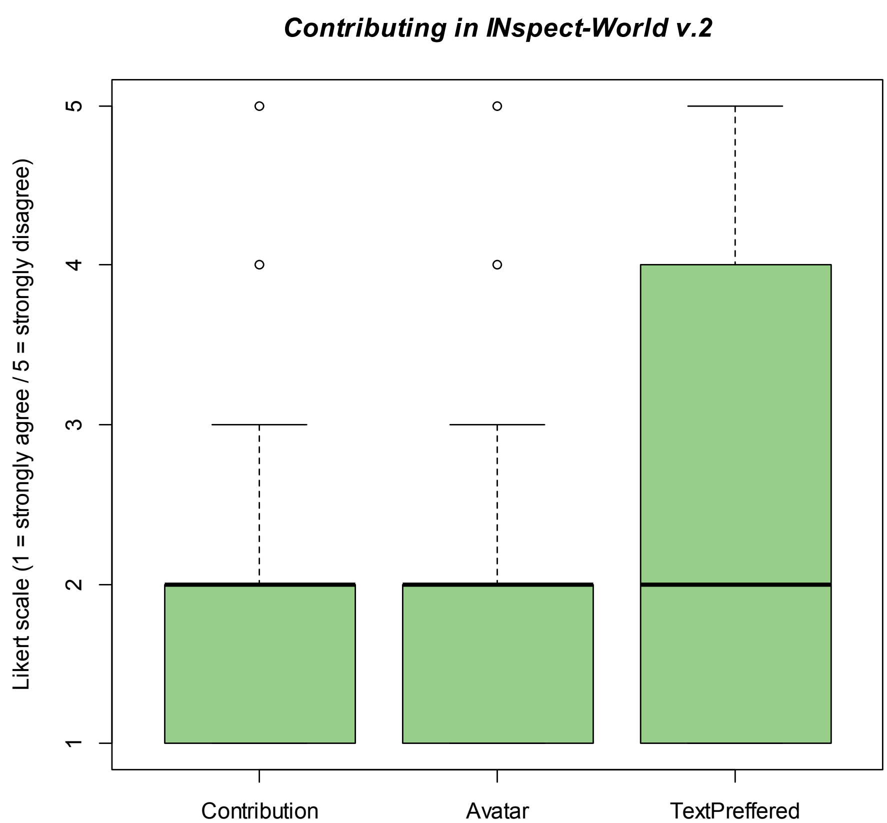

Figure 6.10: Survey results – Contributing in INspect-World v.2.

When asked to provide their opinion about statements related to the cognitive walkthrough inspection process in INspect-World v.2, the results did show that many participants were unsure whether the roles in their team had remained stable throughout the inspection process (see: **Figure 6.11**, *StableRoles*, 'The roles in my team were stable throughout the cognitive walkthrough session.', mean: 2.29). However, participants strongly sided with the statement that the coordination in their team gradually improved over the course of the usability inspection (see: **Figure 6.11**, *Coordination*, 'I felt like the coordination in my team gradually improved during the walkthrough session.', mean: 1.82).

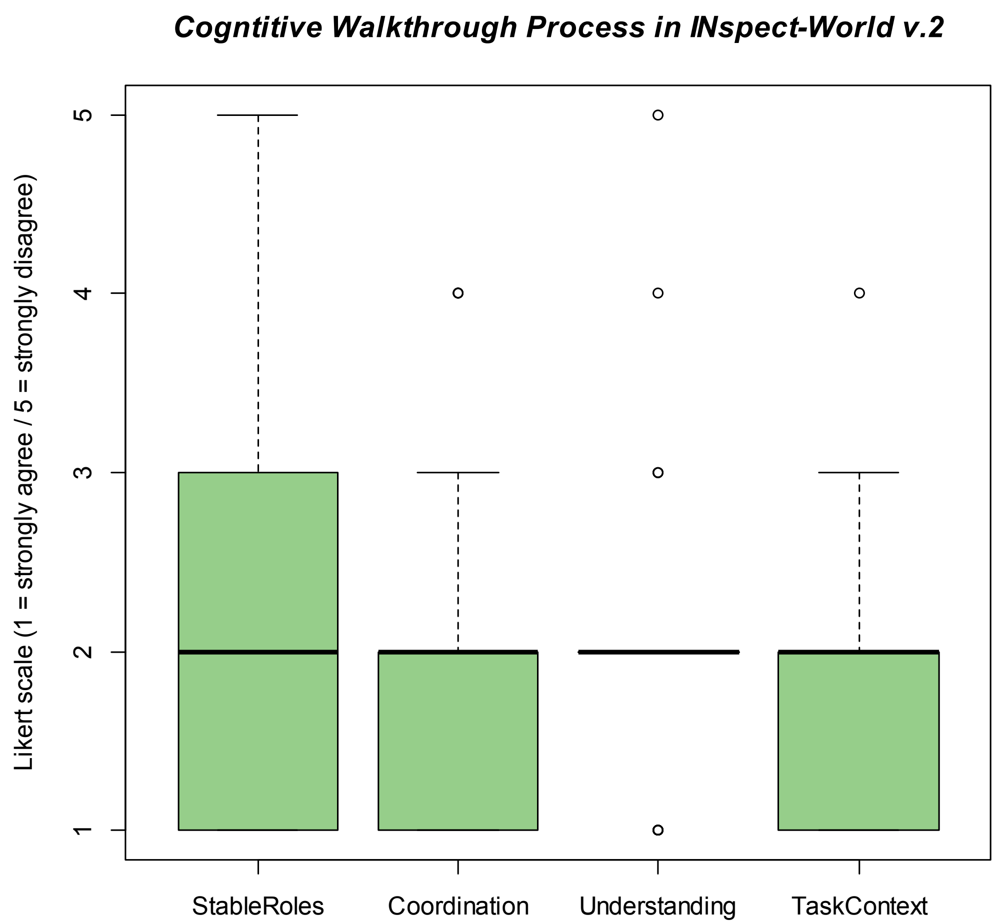

Figure 6.11: Survey results – Walkthrough process in INspect-World v.2.

The finding reflected the experiences described by the users during the interviews conducted in the INspect-World v.1 study. Initial confusion in the teams usually transitioned into a productive collaborative rhythm. Users developed a good understanding of the cognitive walkthrough inspection method (see: **Figure 6.11**, *Understanding*, 'I feel like I now have a good understanding of the cognitive walkthrough method after performing the session with my team.', mean: 2.0).

Additionally, users strongly agreed with the statement that the virtual world setup helped the team to see the individual action steps in relation to the complete action sequence of the inspection task (see: **Figure 6.11**, *TaskContext*, 'The virtual space allowed us to see each step of the walkthrough in context of the whole task.', mean: 1.76). This is an important result, as it supports the design goal to provide a context-rich environment in the virtual world.

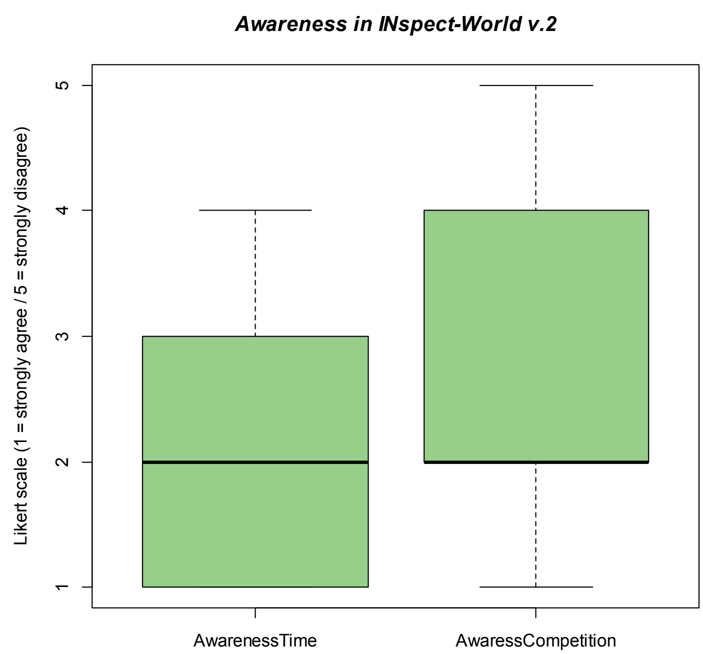

Figure 6.12: Survey results – Awareness in INspect-World v.2.

The results of the survey suggest that most users of INspect-World v.2 had a good awareness of the remaining time available to complete the usability inspection (see: **Figure**

6.12, *AwarenessTime*, 'My team was always aware of the remaining time.', mean: 2.14). On the other hand, users were less aware of the competing team's status (see: **Figure 6.12**, *AwarenessCompetition*, 'I was aware of the other team's progress.', mean: 2.76). The video recordings showed that three teams did not engage in the competition and only focused on their own task. The results are inconclusive whether the teams made a conscious choice to not consider the other team or whether the focus on the own task simply took all the team members' attention.

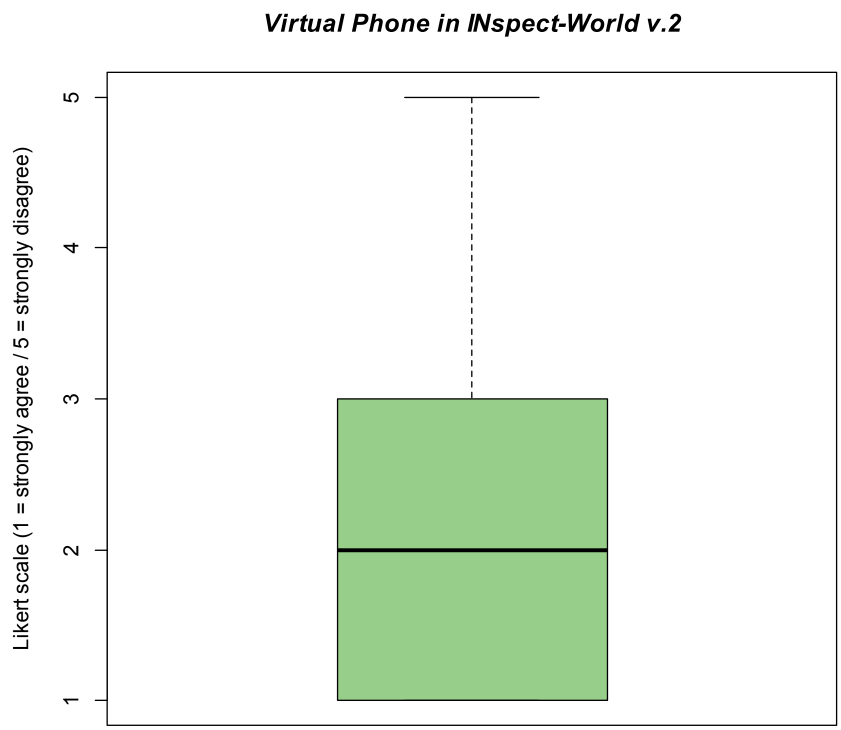

Figure 6.13: Survey results - Virtual phone model.

The virtual phone model received a mixed rating (see: **Figure 6.13**, 'Our team found the 3D model of the phone was helpful to get a better sense of how the app worked.', mean:

2.31). Some teams included the phone model to a large degree into the inspection process. Other teams had higher expectations in the virtual phone's functionality.

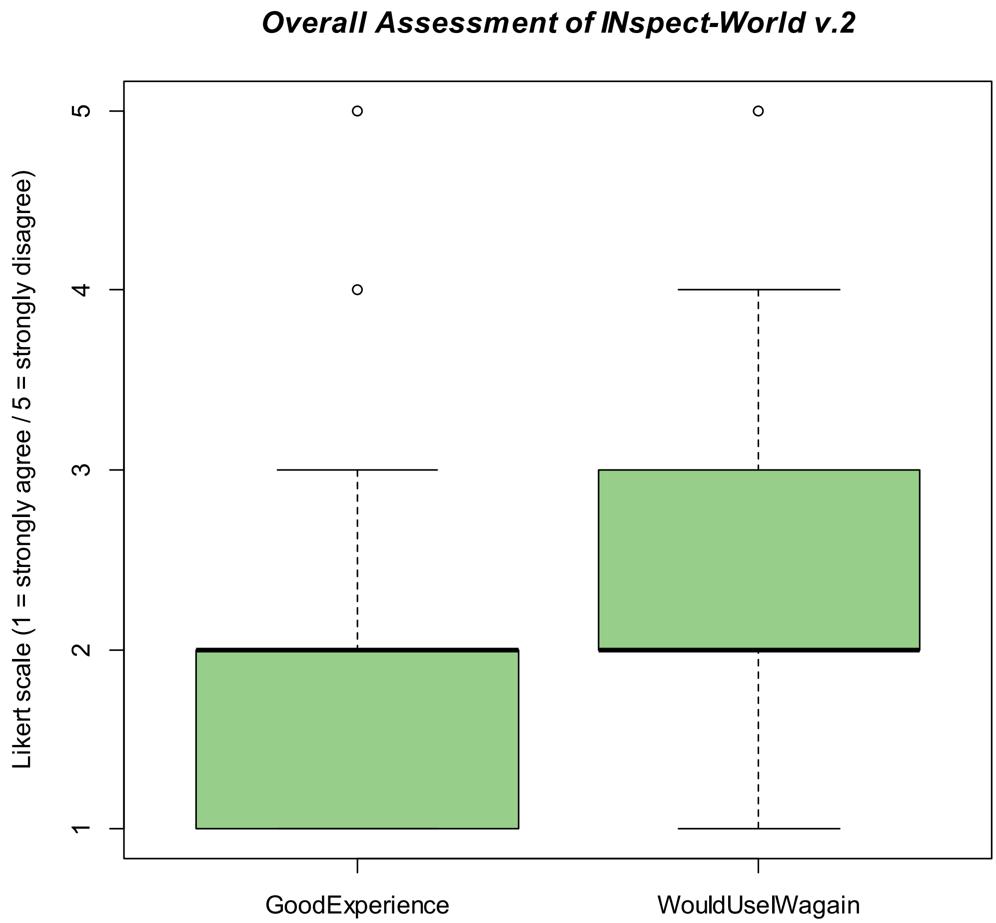

Figure 6.14: Survey results - Overall assessment of INspect-World v.2.

Users strongly agreed that the experience in INspect-World was enjoyable overall (see: **Figure 6.14**, *GoodExperience*, 'Performing the usability inspection was overall enjoyable.', mean: 1.85). A good number of users indicated that they would use INspect-World v.2 again to conduct distributed usability inspections or were undecided on the subject (see: **Figure 6.14**, *WouldUseIWagain*, 'Performing the usability inspection was overall enjoyable.', mean: 2.20).

CHAPTER 7: Discussion

From its outset, the INspect-World project was motivated by potential I and colleagues saw in virtual world technology to support distributed collaborative work. Virtual world technology had advanced to a state in which its application made technological and economic sense.

From a technological point of view, the technology has reached a high level of sophistication that allows designers to create realistic 3D virtual worlds based on stable virtual world technology platforms. The growing popularity of massively-multiplayer online role playing games (MMORPGs) is constantly pushing the development of powerful graphics engines and networking systems to support large online virtual world systems. Modern MMORPGs showcase complex interactive 3D simulations with scripted events and gameplay elements, allowing millions of concurrent users to immerse themselves in realistic 3D gaming environments. The players share social experiences and collaboratively work towards shared objectives in the competitive gaming environments. While MMORPGs often represent the high-end of the technological spectrum, virtual world technology has also found application in employee training for high risk industries, military simulations, and medicine.

Form an economic point of view, the application of virtual world technology has become a reasonable alternative or addition to audio and video-based collaboration tools. Accessing most public virtual world systems does not any longer require high-end computer hardware. Modern laptops today have sufficient processing and graphics power to support modern virtual world client software. The more recent development and broad availability of innovative virtual reality interface hardware, such as Oculus Rift (Oculus, 2014) and

Google Glass (Google, 2014), have the potential to further lower the barrier to entry for virtual world technologies and their application in areas beyond gaming. Open source virtual world platforms, such as the OpenSimulator project, and open-source virtual world graphics engines, such as the Unreal Engine 3, have become available for free or at low licensing fees for commercial use. The application of virtual reality and virtual world technology on mobile devices is becoming increasingly practical. Mobile devices are increasingly equipped with powerful graphics processors and advanced sensor systems that can be used for the application of virtual world technology.

Virtual world technology did not become available in the form of a sudden technological innovation. Instead, the technology developed from early text-based multi-user communication systems, building on increasingly advanced computer networking infrastructures, into the advanced virtual world and virtual reality systems available today. Virtual world systems have developed into more than communication tools. Interactions in 3D virtual worlds have become more meaningful because of the persistence of actions in modern virtual world platforms. Activities performed in the virtual world have a permanent impact on the virtual environment which allows users to pick up on activities upon re-entering the virtual space. Users can transfer their social experiences and work products of activities in the virtual world to the physical world. Activities in virtual worlds are not isolated to a temporary space, but can be effectively integrated into activities performed in the physical world.

So far, there are only few success cases in CSCW of collaborative systems employing virtual world technology. Yet there is a great need for effective collaborative tools to support collaboration across geographical distances that CSCW research is traditionally engaged with. Past research in CSCW on collaborative systems however has shown that the community first needs to build an understanding of the technological platforms used to build collaborative tools. For instance, video technology was only gradually used in collaborative tools to enable group work in specific scenarios and team constellations. Audio and video technology was eventually used in collaborative tools to enable awareness, an important aspect of distributed collaborative work, and rich media communication. Maintaining eye contact and preserving social cues through video communication was discovered as a worthy goal to peruse in collaborative tools that built on communication platforms using video technology. At the same time, the integration of collaborative tools in organizational structures and work processes needs to be studied more. CSCW research can provide contextualized observations of novel technology in use that help practitioners and designers to evaluate the technology for its application.

The INspect-World project incorporates virtual world technology to provide a novel tool for conducting geographically distributed usability inspections. The developed virtual environment for distributed usability inspections and the empirical evaluations presented in this dissertation contribute to advancing the CSCW research community's understanding of collaborative behavior employed during focused geographically distributed teamwork in virtual worlds. Past research has found that usability testing, an integral part of the daily work of software development teams and various other industry and research areas, represents a challenge for practitioners on two dimensions. First, usability inspection methods are still often difficult to learn, costly to conduct and suffer require a number of usability experts to conduct inspection sessions together. Second, the growing number of distributed teamwork settings in industry and academia, makes it increasingly difficult to evaluate design products as a team in a shared and collocated physical space. The INspect-World system directly addresses these concerns by contributing a valuable alternative to commonly used rich media conferencing systems.

The empirical evaluations described in the previous chapters directly contribute to a better theoretical understanding of how users relate to virtual collaborative environments enabled through virtual world technology. The discussed observations from two empirical studies show that virtual world technology can provide a context-rich environment in which users perform collaborative task using particular collaboration strategies and represent themselves in novel ways to other collaborators using the affordances of the virtual world technology. The virtual world technology platform used in INspect-World does more than provide a communication tool. The design of the virtual inspection arena, the focus on the cognitive walkthrough usability inspection method, and the nature of the open virtual space created a unique collaboration context in which users employ novel collaboration strategies.

The findings reported based on the analysis of data gathered from two empirical studies in INspect-World v.1 and INspect-World v.2 provide concrete observations of collaborative behavior structured into four collaborative themes that emerged from the grounded theory-based analysis. The following section describes concrete collaboration strategies that were applied by individual or groups of participants. Designers can learn from the presented strategies to decide whether virtual world technology can form the basis for a collaborative tool for a specific project or target group of users. Practitioners can learn from the collaboration strategies employed in the virtual world to apply them in their own work or to train other users in the use of collaboration tools based that are built using virtual world technology. Organizational research fields can work with the findings to advance research in technology adoption in organizational structures and management.

7.1 Collaboration Strategies Employed in INspect-World v.1 and INspect-World v.2

The interplay of a level playing field, scaffolding mechanisms, and flexible rules creates a unique collaborative context in INspect-World. At first glance, applying virtual world technology appears to add a layer of complexity to the collaborative process that might inhibit fragile collaboration elements such as team building or work coordination. I found in my studies that adapting to the virtual world environment was not problematic for most participants. When technical problems occurred for individual users, a support infrastructure developed within the team to cope with the issues.

The INspect-World system provided the right amount of structure and rules to jump-start collaboration in the usability inspection process in the virtual world. The collaborative activities were defined by a surprising climate of self-organization and coordination. Team leaders had an opportunity to naturally transition into leadership positions. Interaction in the virtual 3D space through avatars also afforded new ways of working together that blended individual work with group work at a geographical distance. Individual team members had a chance to think through and sometimes research their contributions on their own pace before contributing to the team.

The users' representation through virtual avatars and the availability of both video and audio chat created a practical and experienced level playing field. Individual team members that were initially hesitant to participate in the discussion were shielded from peer-pressure to participate immediately. Team leaders on the other hand found ways to gently encourage participation of individuals indirectly through their avatars which was perceived as less threatening.

INspect-World afforded opportunities for creative and focused teamwork at a geographical distance that differed from typical conferencing settings. Collaborators in the virtual world continuously interpreted the virtual presence and the mediated actions of their team members. What appeared to be a considerable overhead at first, quickly transitioned into a natural component of the teamwork.

Based on the structured discussion of the findings, I am able to formulate specific collaboration strategies employed by the users in INspect-World v.1 and INspect-World v.2. The presented collaboration strategies can help designers and practitioners who consider using virtual world technology in geographically distributed work contexts to make design decisions. Virtual worlds afford collaboration contexts that enable users to work together in novel ways. My goal is not to present a comprehensive list of all possible collaboration strategies in INspect-World v.1 & INspect-World v.2. Rather, the collection of collaboration strategies discussed in this chapter have emerged as significant, re-occurring behavior across multiple teams and are strongly grounded on the collected data.

The collaboration strategies are discussed with added markers to show the relation to previously discussed collaboration themes in **Chapter 4** and **Chapter 5**:

- Self-Organization in an Open Virtual Space *[Strategy_Building]*
- A Level Playing Field as an Opportunity for Participation and Engagement *[Level_Playing_Field]*
- Scaffolding: Direct and Indirect Influences *[Scaffolding]*
- Rules: Jumpstarting Collaboration *[Rules]*

Using individual work and exploration to advance teamwork without interrupting team collaboration *[Strategy_Building]*

Team members worked on selected tasks individually, in some cases using external tools, to eventually share their results with the team. The virtual world shielded their detailed activities from their team members allowing them to work in parallel. The collaborative process of the team did not get interrupted. In the beginning of the session, team members individually explored the inspection arena and other elements of the virtual environment to build an understanding of the environment. The other collaborators in the team are not aware of the individual's detailed activities to build an understanding of the task and the environment. Collaborators see an abstracted view of their team members in the form of moving avatars. The team's collaborative process is thus rarely interrupted and individual work can take place in parallel to the group's discussions and advancement in the inspection arena.

Establishing group leadership and team building through supportive performances and initiative actions in the team *[Strategy_Building]*

The leadership structure in the team was not fixed in the beginning of the inspection sessions. Instead, individual team members grew into leadership roles by performing helpful acts and by providing the initiative for their team members to begin the inspection process. Individual team members helped others with the controls of the virtual world client. The performances raised awareness and visibility of individuals in the team that became the leading figure for the remainder of the session.

Gradually engaging in collaborative activities after building an individual understanding *[Level_Playing_Field]*

INspect-World's virtual collaboration space allowed users to build an understanding of the usability inspection task at their own pace. Individual users were able to follow the team's progression without being pressured to participate in early stages of the collaboration. The lack of observable participation in early stages in most cases did not mean that the users were not engaged or unwilling to collaborate with the team. Instead, the users were able to follow the progress of the team and eventually contribute when they felt comfortable enough to contribute meaningful input.

The virtual world context added a filter to the collaborative context that put all collaborators on the same collaboration level. The virtual avatars contributed to the sense of a level playing field that meant that all users used the same proxy to interact in the inspection arena that offered the same minimalistic scaffolding to its users.

Working around interruptions and technical issues in the virtual world *[Strategy_Building, Scaffolding]*

Team members developed an attitude to accept technical issues as a matter of fact and did not get deterred from the task at hand. The immersion in the virtual world created an undistracted focus that was unlikely to get interrupted for long by unexpected technical or team-related events. Teams in INspect-World were faced technical issues. In some cases an inspection screen would not load successfully or the text input would flicker due to multiple users typing simultaneously. Following a short surprise, most teams quickly suggested to move on to the next inspection step and to not dwell on the issue too long.

Flickering text input was also seen as irritating, but the issue was quickly dismissed as minor ‘bug’ that the team should not be too concerned about. Most users did not expect the system to work flawlessly and developed a high tolerance for situations in which the system didn’t function exactly according to their expectations.

The same strategy was observed in relation to the usage of the virtual phone model that provided the teams with a way to explore the action sequence. Some users expected much more functionality from the model and tried to perform actions on the phone’s screen that were not available in INspect-World v.2. Once the users had discovered that the phone model did not support the desired functionality, they quickly accepted the fact and continued the work on the inspection task.

Allowing for efficient onboarding of collaborators *[Scaffolding, Strategy_Building]*

Team members provided new arrivals with a quick overview of the task that enabled quick onboarding. By observing the team’s location and progress in INspect-World, onboarding team member were able to quickly make sense of the team’s collaboration status. Three teams had to integrate late arriving team members. The process was very quick and didn’t interrupt the team’s progression in the usability inspection task.

Using chat and voice channels in unison to advance collaborative processes *[Scaffolding]*

Teams in INspect-World used voice and text chat interchangeably. While text chat allowed for the clarification of precise inspection input, voice chat was often used to signal activities in the virtual world and to provide directions to other team members. For instance, users skillfully used both voice and text chat to provide feedback to the scribe while directing team members to look at the inspection screens.

Using the 3D space and the avatars to infer and signal collaborative activities and living in the virtual space *[Scaffolding]*

Avatar positioning in the virtual space was used to direct attention to specific elements of the collaboration. Positioning of avatars was used to coordinate tasks and to infer the attention and activities of fellow team members.

The 3D virtual environment quickly became the normal interaction space for the team members. Users called on team members to join them on specific inspection screens and to move their avatars so that the scribe could work without obstruction. Users observed the virtual space to look for other team members. For instance, if a team member was standing by the virtual phone model, the scribe would ask this team member to look for a specific action step transition on the model.

Jumpstarting collaboration building on rules *[Rules]*

Rules and regulations primarily provided important scaffolding in early stages of the collaboration to initiate the work on the inspection task. Rules helped to jump-start the development of individual strategies and team coordination tactics. The rules, such as allowing only one scribe for each inspection screen, provided an early structure that supported the development of other strategies.

Using the open virtual world context to develop custom-tailored strategies for the team *[Scaffolding, Strategy_Building]*

Faced with a virtual environment that provided little direct guidance and scaffolding, teams had to develop custom strategies to approach the task. These strategies evolved based on the team's status in the competition and the internal organization of the team. The unregulated and minimalistic virtual space created an atmosphere in which the teams could develop creative strategies and approaches without being forced into regulated collaboration processes.

Building on anchors and rules in the environment to launch collaboration efforts initially and modify strategies as the team has found a rhythm *[Scaffolding, Rules]*

Movement in the virtual inspection arena was an important way to coordinate the team and to collaboratively work on the inspection task. Users initially grouped around the inspection screens that represented the main focus. Further into the task, the work was delegated based on the users' own initiatives or based on a team leader's suggestion. Individual team members scouted the inspection arena to inform the team about upcoming inspection steps. Visual anchors, such as the virtual phone model, and the scribe mode on the inspection screens helped the teams to build awareness in the team and to construct dynamic collaborative processes as the team progressed along the inspection task.

Motivating the team using information about the competing team and time pressure *[Rules, Strategy_Building]*

Team members used the competitive aspects of INspect-World to encourage teamwork. The willingness to beat the team in the adjunct arena provided the motivation to complete the usability inspection process within the given time constraints. The fact that the information of the live progress of the competing team was always available to each team in the competition created a situation in which the team's progress could always be put in relation to the competitors.

Building a positive collaborative team atmosphere by poking fun and showing playfulness *[Level_Playing_Field, Strategy_Building]*

Teams managed to create a positive atmosphere in the team by inserting lighthearted jokes or off-topic activities into the collaboration process. Unexpectedly changing the avatar's experience, playfully pushing other avatars, or simply pointing out the nice view of the sunset in the inspection arena provided welcome breaks from the serious collaboration on the usability inspection task.

7.2 Implications for Design and Application Areas in Distributed Collaboration

The collaboration strategies discussed in the previous section provide tool designers and practitioners in areas of distributed collaborative work with a set of collaborative behaviors that are likely to occur when a focused, collaborative task is performed in a collaborative tools supported by virtual world technology. The strategies can help designers to decide whether virtual world technology can contribute to their envisioned collaboration tool for a specific application area and work context. The rich description of the context in which the strategies occurred in INspect-World provides important insights into collaborative behavior that arises in small distributed teams. The design of the inspection arena in INspect-World followed a minimalistic approach that provided the essential scaffolding to perform usability inspections, but that did not completely pre-determine the collaborative processes of the distributed teams. For instance, movement in the virtual world could have been restricted to a narrow corridor between the inspection screens by the designers. Viewing angles and virtual avatar controls could have been restricted to limit the collaborative activities and off-topic activities strictly to the interaction with the inspection screens. Instead, users in INspect-World were able to explore the arena freely and embed the provided scaffolding into their team and strategy building activities. Users in INspect-World were able to experience virtual world technology in a relatively pure form while focusing on a collaborative task. I followed this approach inspired by the principles of the meta-design frame work that has been applied in the field of end-user development (G. Fischer & Giaccardi, 2006). The conducted studies in INspect-World differ from previous accounts in public virtual worlds in which researchers observed collaborative behavior in the context of either highly scripted activities, i.e. in multiplayer online games, or general social activities.

INspect-World supports collaboration on an arguably technical task. Usability inspections are applied in software engineering to review software interfaces at different stages of a software development process. When the cognitive walkthrough usability inspection technique is performed in INspect-World, teams go through collaborative phases and activities that are similar to other collaborative scenarios. Geographically distributed teams often need to find ways to collaborate with team members they have not met in real life. Distributed teams need to coordinate the team's organizational structure and team member roles using communication tools. Finding common ground and establishing both collaboration readiness and technology readiness is a challenging task that distributed teams are faced with from the outset of planned collaborative activities. Collaborative tools are used to establish and negotiate collaborative readiness at early stages. Teams in INspect-World v.1 and v.2 had to negotiate similar processes and the observed behavior and the derived collaboration strategies can inform the design of collaborative tools that support processes to establish collaborative readiness. To achieve technology readiness in distributed teams, designers need to make informed decisions about choosing the right technology for specific collaborative processes that they want a tool to support. The results obtained from the INspect-World project can serve as an initial information resource to evaluate virtual world technology for its application in collaborative tools.

Introducing novel information and communication technology (ICT) into established fields can be difficult and requires careful scrutiny by designers tasked with the evaluation of suitable technology. The field of *online learning* can serve as an example of the introduction of ICT into established processes with the goal to enhance the user experience and to enable collaboration processes online and across geographical distances.

7.2.1 Massive Open Online Courses and the Application of ICT

Using information and communication technology (ICT) to teach students in higher education has many advocates, such as Ito et al. (Ito et al., 2008), but it also has its share of critics. Arum and Roksa warn against a lack of rigor at large universities (Arum & Roksa, 2011). Based on surveys of 2,300 students enrolled across four large colleges and universities the authors show that a large number of students (45%) did not show a significant improvement in learning during the first 2 years of their undergraduate education. The number only slightly improves to 36% for the last 2 years that the students spent at the university. In many cases, students learned better individually than in group projects in class. Joel Spring describes how networks of highly influential ICT companies and individuals in public administration can have a great influence on investments into ICT systems for educational purposes (Spring, 2012). These accounts highlight the need to be aware of the external forces that influence the usage of ICT for learning in public education. Additionally, ICT should be applied with care and consideration for individual learning styles and learning contexts. In industry, managers need to be aware of similar influences. ICT might be necessary in many distributed team settings, but using virtual world technology might not be the best solution for all kinds if (informal) collaboration and communication in the team.

Massive Open Online Courses (MOOCs) have received significant attention and excitement in recent years, particularly in 2012, promising to massively broaden access to online education for internet connected users (Daniel, 2012). A MOOC can be described as an online course often with the option of free registration and a publically shared curriculum (McAuley, Stewart, Siemens, & Cormier, 2010). Daniel points out that there are indeed two major MOOC types: cMOOCs and xMOOCs. Early versions of MOOCs (cMOOCS) originated in Canada and were based on a philosophy of connectivism, networking, and open access (Illich, 1971, 1973). The main goal then was to provide a system that would allow interested students to access to all available resources at any time and empower them to share these resources with others. Participation in these processes would be accomplished with the students' tools of choice, such as Moodle, Second Life and other types of conferencing systems.

Recently popular xMOOCs promoted by Ivy League universities in the US follow a more behaviorist approach and aim to provide a more constrained set of bundled tools that students can use to participate in online courses. The mainstream movement of xMOOCs began in late 2011 when Sebastian Thrun, then a professor at the University of Stanford, began to offer his class on Artificial Intelligence for free to internet users around the world. Thrun went on to found Udacity, a for-profit MOOCs platform. Others followed suit, such as Coursera, also a for-profit organization, and edX, a non-profit MOOCs platform backed by influential university on the east coast of the US.

MOOCs became a popular and much talked about phenomenon in 2012 backed by influential universities in the United States and on the international level. Yet, scientific evaluations of MOOC systems are still not widely available. There are however accounts that point to the problematic aspects of current MOOCs systems:

- According to the New York Times, classes offered by edX , Udacity, and other platforms still show dropout rates exceeding 90 percent (Lewin, 2013).
- When offering MOOC classes online with the goal to provide access to large populations worldwide, it is easy to forget about local context and cultures of learners and online access is not always guaranteed to students behind the digital frontier (Hazelkorn, 2013).
- Teachers state that the preparation work for teaching a MOOC class can be high (Kolowich, 2013b).
- MOOCs are often seen as a method to save money by university officials, and not necessarily as a means to provide better teaching methods or to broaden access to education in general. Financial interests of outside technology provides can harm the put the academic aspirations of some programs into question. (Kolowich, 2013a).
- MOOCs work relatively well for teaching well-scoped and defined topics that have problems with clear solutions and less room for interpretation. Examples are

programming classes or math. Teaching social or political sciences in MOOCs is more difficult since there are no right or wrong answers that can be easily graded or discussion in MOOCs online forums.

- Reliable grading and evaluations in large MOOC classes is problematic. Automated grading or peer-based grading cannot replace meaningful and individual feedback provided by educators to their students (Sherman, Bassil, Lipman, Tuck, & Martin, 2013).
- Message boards in MOOCs do not have the potential to replace interactive in-class discussions. However, some class content, including software process-related project work, requires more in-depth discussions which are very hard to accomplish using online message boards.
- Computers alone cannot personalize education – they rather offer a different channel to access educational resources (Bates, 2012). MOOCs course offered through Coursera or Udacity do not essentially offer a personalized education, but rather another channel to access a moderated set of materials presented in video chunks and downloadable documents.

Udacity founder Sebastian Thrun in a recent interview spoke critically about the educational model of his own company's MOOC system (Chafkin, 2013). Thrun, like others, is troubled by the still high drop-out rates of up to 90% in currently offered MOOC courses on Udacity.

Recently educators, higher education institutions, and private corporations have suggested new directions for MOOC-like systems to address some of the issues (Scott, 2013). Coursera has moved to shorter courses to address high drop-out rates. Harvard has begun to offer SPOCS (small, private, online courses) that revert the massive scaling towards smaller online classes for small teams (Hashmi, 2013). Other platforms begin to include live video chats to foster more live interactions between participants or to offer hybrid approaches that "flip the classroom" and combine online courses with in person meetings in smaller groups. All of these approaches are still young, but show that there is a force to change current MOOC approaches.

The development of ICT solutions for online education shows that many factors need to be considered that might not be initially obvious. Virtual world technology has the potential to support individual online education scenarios that focus on specific exercises, such as usability inspections in INspect-World, but the technology choice to support an activity needs to be evaluated individually for each case.

7.2.2 Simulation Games in Software Engineering Education

To transform traditional teaching methods and to better link teaching programs to industry requirements, education professionals have actively looked for new approaches to teaching software engineering principles. Publications in the three major conferences on computer science education (ITiCSE, ICER, and CSEE&T) show an increasing interest in using computer simulations and games for teaching software engineering concepts. Most commonly referred to as "simulation games", these approaches have been categorized as a new movement in active and experientially based learning with a focus on real world problems (Garris, Ahlers, & Driskell, 2002; Kolb & Kolb, 2005).

The term "simulation games" is part of a complete ecosystem of definitions and classifications of educational concepts concerned with games (Breuer & Bente, 2010). In the field of learning and education, the term "serious games" was first used for games that teach, learn and educate (Michael & Chen, 2005). Another popular classification called "game-based learning" expresses "any learning on a computer or game" (Breuer & Bente, 2010; Prensky, 2003) and subsumes serious games and simulation games.

Previously developed simulation games for software engineering education have shown that the concept has potential. *SimSE* (Baker, Oh Navarro, & Van Der Hoek, 2005; Navarro, Baker, & Van Der Hoek, 2004) implements a role playing game for software developers. SESAM represents a single player simulation game (Ludewig, Bassler, Deininger, Schneider, & Schwille, 1992) in which players plan a software project. *MOSEProcess* builds on *SimSE* to implement a 3D virtual environment in which students take on different roles during a simulated software development project (Ye, Liu, & Polack-Wahl, 2007).

Simulation games have not found much traction in software engineering education. Often times, the available systems are not flexible enough to cope with dynamic changes of teaching practices and changing class schedules. In some cases, simulations games aim too high and attempt to support complicated processes instead of focusing on a single aspect. The future for simulation games could lie in an integration with MOOC systems, discussed in the previous section, to allow distrusted learners to work on a problem together. If and how such an integration can be accomplished however is unclear. It is possible that virtual world technology can provide a link between the two fields. The INspect-World project has shown that a web application can be integrated with a virtual world server.

CHAPTER 8: Conclusion

Geographically distributed collaboration is becoming the new norm to work in many business areas, research institutions, and even online education. Achieving collaboration readiness is a complicated process that touches on many levels of the organization itself, the distributed teams, and the individual worker. For most distributed collaboration scenarios, there is no silver bullet to create the right mindset in the team, the individual, and the organization to enable the perfect collaboration context. Team compositions change, individual team members' roles evolve, and the organization's goals are in constant flux due to fast moving global markets.

Technology readiness that goes hand in hand with collaboration readiness is equally difficult to achieve. Distributed collaboration in most application areas is not possible without technical tools that in their fundamental role enable a reliable way for the distributed team to communicate the information necessary to accomplish the goals of a shared task and goal. For certain collaborative efforts, asynchronous messaging exchange systems, such as E-Mail, are sufficient to work across distance and complete tasks together. Other types of collaborative tasks require more immediate and richer types of communication that go beyond what even richer media types, such as video and voice chat, can provide. A CSCW designer is then tasked with not only deciding on a suitable communication platform, but with building a collaboration tool that combines the right media type with additional functionality to satisfy the specific requirements of the collaborative context. Choosing the right communication media, or combination of media is essential to build effective collaboration tools for dynamic collaboration contexts. Both video and audio communication has been tested and applied in CSCW. Video has found its way into universally useful low-cost video conferencing solutions that are applied in numerous distributed collaboration scenarios today.

Researchers have looked into the capabilities of video communication for collaborative activities. Like any other communication media, video works very well in specific collaboration scenarios, but lacks in other areas. It took time to build an understanding of how users would find video useful, how they would behave when using video in collaborative settings, and how video technology could be integrated into organizations. Researchers have experimented with different video conferencing systems. Over time, the CSCW community built an understanding of what kind of collaborative behaviors could be supported using video communication and what kind of tools could be built using video as the main communication platform. The process to explore existing communication technologies for their application in distributed collaboration is ongoing and keeps responding to changes in industries and advancements in technology.

Using ICT in established areas needs to be carefully investigated before ICT is imposed on an infrastructure in rushed decisions that causes unintended consequences. Using ICT in (online) education for instance did not always lead to desirable results. Before CSCW designers can make informed design decisions on novel collaboration tools for established or emerging collaborative contexts, they require a good understanding of what kinds of collaborative activities are possible to support using different communication media, what kind of user behaviors they can expect and whether this behavior is suitable for the target group, and finally how a flexible a chosen communication platform is to implement custom functionality on top of the communication medium.

Novel information and communication technology can provide opportunities for the development of collaboration tools for particularly challenging work contexts. Virtual world technology represents a unique class of communication technology that is particularly flexible in the way it can be applied in distributed collaboration. Virtual world platforms afford a new form of audio-visual real-time communication in a shared 3D space. The representation of users in the virtual world in the form of virtual avatars and the interaction in a realistic and persistent virtual space put virtual world technology in a different communication technology class than other technologies previously used in CSCW systems. Findings from studies conducted on video conferencing systems and other collaborative tools that do not use virtual world technology can only begin to inform the design of collaborative tools building on virtual world technology. While it is quite possible that users show similar collaborative behavior in virtual worlds compared to when they interact using video communication or other systems, virtual world technology could support unique or altered collaborative behavior are more or less favorable for certain types of collaborative work.

The results of the INspect-World project provide a stepping stone between the past and the future of the application of virtual world technology. The project showed that virtual world technology represents a feasible option for the implementation of a collaborative tool designed to support a specific collaborative process. At the same time, the observations made in two empirical studies conducted with the initial and a follow-up version of the INspect-World system are the starting point for further research on how virtual world technology shapes collaborative behavior in distributed teams.

The implementation details of INspect-World v.1 and v.2 in **Chapter 3** and **Chapter 5** showed that virtual world technology can provide a flexible foundation for the development of a fully functional collaborative tool. Taken together, INspect-World and INspect-Web support both the management and the conduct of a well-defined collaborative task in distributed teams. OpenSimulator, the open-source virtual world technology platform used for the implementation of INspect-World, offered the flexibility needed for the integration with a web application built using the PHP scripting language. 26 distributed teams, 110 participants in total, conducted a usability inspection sessions using the cognitive walkthrough inspection method in INspect-World. The INspect-World system remained stable throughout all conducted usability inspection sessions. Issues found with the inspection screen interfaces were fixed in INspect-World v.2. Individual components of the INspect-World system can be worked on without affecting other critical components. All 110 users were managed in the INspect-Web web application. The results of the usability inspections could easily be collected and reviewed from the web interface.

The collected video and interview data from the empirical studies conducted in INspect-World v.1 and INspect-World v.2 provide an important starting point to a better understanding of collaborative behavior in distributed teams that are enabled by virtual world technology. The studies conducted in INspect-World differ from previous studies in public virtual worlds on collaborative behavior because the INspect-World system was specifically built for the focused work on a collaborative task that is typically difficult to perform in distributed teams.

The analysis of the data focused on collaborative behavior from a technological lens. The collaboration themes developed as a result of the study in INspect-World v.1 are understood as categories of collaborative behavior and strategies enabled by virtual world technology. The documented collaboration strategies are not necessarily exclusive to collaborative virtual world environments, but they provide CSCW designers with an understanding of the types of collaboration strategies possible in virtual worlds. The observations from the initial study in INspect-World v.1 were re-visited in a follow-up study to verify the findings and to develop a more in-depth description of the collaborative behavior. Concrete collaboration strategies based on the whole data set provide a useful summary for practitioners and designers who evaluate virtual world technology for supporting distributed team work.

It makes sense for CSCW designers and practitioners to look into virtual world technology to support distributed collaboration. Open source virtual world platforms like OpenSimulator can serve as effective testbeds for the implementation of prototypical collaborative tools. Interface hardware is becoming technically more sophisticated, more user-friendly, and more affordable. However, more research is needed to fully understand the usefulness of virtual world technology to support distributed collaboration in different application areas. The INspect-World project provides an important step towards the more widespread use of virtual world technology in CSCW tools for distributed collaboration. The rich dataset collected during both INspect-World studies potentially holds much more insights when analyzed from different angles and using different methods of analysis. Another avenue for the continued work on the INspect-World project lies in the implementation of support for advanced user interfaces such as Oculus Rift. Novel user interfaces could dramatically change the user experience and lead to exciting new application areas for virtual world technology in the future.

References

Ackerman, M. S., Muramatsu, J., & McDonald, D. W. (2010). Social Regulation in an Online Game: Uncovering the Problematics of Code. In *Proceedings of the 16th ACM International Conference on Supporting Group Work* (pp. 173–182). New York, NY, USA: ACM. doi:10.1145/1880071.1880101

Allen, T. B. (1987). *War games*. New York: McGraw–Hill.

Arum, R., & Roksa, J. (2011). *Academically adrift: Limited learning on college campuses*. University of Chicago Press.

Bainbridge, W. S. (2007). The Scientific Research Potential of Virtual Worlds. *Science*, *317*(5837), 472–476. doi:10.1126/science.1146930

Baker, A., Oh Navarro, E., & Van Der Hoek, A. (2005). An experimental card game for teaching software engineering processes. *Journal of Systems and Software*, *75*(1), 3–16.

Bates, T. (2012). *What's right and what's wrong about Coursera-style MOOCs*. Retrieved August 22, 2014, from http://www.tonybates.ca/2012/08/05/whats-right-and-whats-wrong-about-coursera-style-moocs/

Bell, B. S., & Kozlowski, S. W. J. (2002). A Typology of Virtual Teams . *Group & Organization Management* , *27* (1), 14–49. doi:10.1177/1059601102027001003

Blackmon, M. H., Polson, P. G., Kitajima, M., & Lewis, C. (2002). Cognitive walkthrough for the web. In *Proceedings of the SIGCHI conference on Human factors in computing systems Changing our world, changing ourselves - CHI '02* (p. 463). New York, New York, USA: ACM Press. doi:10.1145/503376.503459

Blizzard. (2014). *World of Warcraft*. Retrieved August 22, 2014, from http://www.us.battle.net/wow/

Boellstorff, T. (2008). *Coming of age in Second Life : an anthropologist explores the virtually human* (p. xiii, 316 p.). Princeton: Princeton University Press.

Bos, N. D., Buyuktur, A., Olson, J. S., Olson, G. M., & Voida, A. (2010). Shared Identity Helps Partially Distributed Teams, but Distance Still Matters. In *Proceedings of the 16th ACM International Conference on Supporting Group Work* (pp. 89–96). New York, NY, USA: ACM. doi:10.1145/1880071.1880086

Boulos, M. N. K., Hetherington, L., & Wheeler, S. (2007). Second Life: an overview of the potential of 3-D virtual worlds in medical and health education. *Health Information & Libraries Journal*, *24*(4), 233–245.

Bowker, G. C., Baker, K., Millerand, F., & Ribes, D. (2010). Toward information infrastructure studies: Ways of knowing in a networked environment. In *International Handbook of Internet Research* (pp. 97–117). Berlin: Springer.

Breuer, J., & Bente, G. (2010). Why so serious? On the relation of serious games and learning. *Eludamos. Journal for Computer Game Culture*, *4*(1).

Bryant, A., & Charmaz, K. (2007). *The Sage handbook of grounded theory*. London: Sage.

Caldera, M. (2014). *OpenSimulator API*. *Google Code*. Retrieved August 22, 2014, from https://code.google.com/p/open-simulator-api/

Card, S. K., Moran, T. P., & Newell, A. (1983). *The Psychology of HumanComputer Interaction*. Hillsdale, New Jersey: Lawerence Erlbaum Associates, Inc.

Carmel, E., & Agarwal, R. (2001). Tactical approaches for alleviating distance in global software development. *Software, IEEE*. doi:10.1109/52.914734

Chafkin, M. (2013). *Udacity's Sebastian Thrun, Godfather of Free Online Education, Changes Course*. Retrieved August 22, 2014, from http://www.fastcompany.com/3021473/udacity-sebastian-thrun-uphill-climb

Ciolkowski, M., Laitenberger, O., & Biffl, S. (2003). Software reviews, the state of the practice. *Software, IEEE*, *20*(6), 46–51.

Clarke, A. E. (2005). *Situational analysis : grounded theory after the postmodern turn*. Thousand Oaks, CA: SAGE Publications.

Connaughton, S. L., & Shuffler, M. (2007). Multinational and Multicultural Distributed Teams. *Small Group Research*, *38*(3), 387–412.

Curtis, P. (1992). Mudding: Social phenomena in text-based virtual realities. *High Noon on the Electronic Frontier: Conceptual Issues in Cyberspace*, 347–374.

Daniel, J. (2012). Making sense of MOOCs: Musings in a maze of myth, paradox and possibility. *Journal of Interactive Media in Education*, *3*.

De Lucia, A., Francese, R., Passero, I., & Tortora, G. (2009). Development and evaluation of a virtual campus on Second Life: The case of SecondDMI. *Computers & Education*, *52*(1), 220–233.

De Souza, C. R., Quirk, S., Trainer, E., & Redmiles, D. F. (2007). Supporting collaborative software development through the visualization of socio-technical dependencies. In *Proceedings of the 2007 international ACM conference on Supporting group work* (pp. 147–156). New York, NY, USA: ACM. doi:10.1145/1316624.1316646

Djorgovski, S. G., Hut, P., McMillan, S., Vesperini, E., Knop, R., Farr, W., & Graham, M. J. (2010). Exploring the Use of Virtual Worlds as a Scientific Research Platform: The Meta-Institute for Computational Astrophysics (MICA). In F. Lehmann-Grube, J. Sablatnig, O. Akan, P. Bellavista, J. Cao, F. Dressler, … G. Coulson (Eds.), *Facets of Virtual Environments* (Vol. 33, pp. 29–43). Springer Berlin Heidelberg.

Dourish, P. (1998). Introduction: The State of Play. *Computer Supported Cooperative Work (CSCW)*, *7*(1-2).

Dourish, P., & Bellotti, V. (1992). Awareness and coordination in shared workspaces. Toronto, Ontario, Canada: ACM. doi:http://doi.acm.org/10.1145/143457.143468

Ducheneaut, N., Yee, N., Nickell, E., & Moore, R. J. (2006). "Alone together?": exploring the social dynamics of massively multiplayer online games. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '06)*. Montreal, Canada: ACM. doi:http://doi.acm.org/10.1145/1124772.1124834

Ebert, C., & De Neve, P. (2001). Surviving global software development. *Software, IEEE*. doi:10.1109/52.914748

Farooq, U., Ganoe, C. H., Carroll, J. M., & Giles, C. L. (2007). Supporting distributed scientific collaboration: Implications for designing the CiteSeer collaboratory. In *System Sciences, 2007. HICSS 2007. 40th Annual Hawaii International Conference on* (p. 26). doi:10.1109/HICSS.2007.506

FirestormViewer. (2014). *Fire Storm Viewer Project*. Retrieved August 22, 2014, from http://www.firestormviewer.org

Fischer, G., & Giaccardi, E. (2006). Meta-design: A Framework for the Future of End-User Development (pp. 427–457).

Fischer, G., & Ostwald, J. (2002). Seeding, Evolutionary Growth, and Reseeding: Enriching Participatory Design with Informed Participation. Malmö University, Sweden.

Fischer, G., & Scharff, E. (2000). Meta-design: design for designers. New York City, New York, United States: ACM. doi:http://doi.acm.org/10.1145/347642.347798

Fox, A. (2013). From MOOCs to SPOCs. *Communications of the ACM*, *56*(12), 38–40.

Frigg, R., & Reiss, J. (2009). The philosophy of simulation: hot new issues or same old stew? *SYNTHESE*, *169*(3).

Froehlich, J., & Dourish, P. (2004). Unifying Artifacts and Activities in a Visual Tool for Distributed Software Development Teams. In *Proceedings of the 26th International Conference on Software Engineering* (pp. 387–396). Washington, DC, USA: IEEE Computer Society.

Galison, P. (1996). Computer Simulations and the Trading Zone. In P. Galison & D. Stump (Eds.), *The Disunity of Science: Boundaries, Contexts, and Power*. Stanford: Stanford University Press.

Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation, and learning: A research and practice model. *Simulation & Gaming*, *33*(4), 441–467.

Gibson, C. B., & Cohen, S. G. (2003). *Virtual teams that work: Creating conditions for virtual team effectiveness*. San Francisco: Jossey-Bass.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory*. Chicago, Illinois, USA: Aldine.

Google (2014). *Google Glass*. Retrieved August 22, 2014, from http://www.google.com/glass/

Gredler, M. E. (2004). Games and simulations and their relationships to learning. In D. H. Jonassen (Ed.), *Handbook of research on educational communications and technology* (pp. 571–582). Mahwah, NJ: Erlbaum.

Haig, B. D. (2005). An Abductive Theory of Scientific Method. *Psychological Methods*. Haig, Brian D.: Department of Psychology, University of Canterbury, Private Bag 4800, Christchurch, New Zealand, American Psychological Association. doi:10.1037/1082-989X.10.4.371

Hashmi, A. H. (2013). *HarvardX Set To Launch Second SPOC*. Retrieved August 22, 2014, from http://www.thecrimson.com/article/2013/9/17/kennedy-school-spoc-edx

Hazelkorn, E. (2013). *A MOOC Delusion: Why Visions to Educate the World Are Absurd*. *The Chronicle of Higher Education*. Retrieved August 22, 2014, from http://chronicle.com/blogs/worldwise/a-mooc-delusion-why-visions-to-educate-the-world-are-absurd/32599

Hazzan, O., & Dubinsky, Y. (2006). Can diversity in global software development be enhanced by agile software development? In *Proceedings of the 2006 international workshop on Global software development for the practitioner* (pp. 58–61). New York, NY, USA: ACM. doi:10.1145/1138506.1138520

Heeks, R., Krishna, S., Nicholsen, B., & Sahay, S. (2001). Synching or sinking: global software outsourcing relationships. *Software, IEEE*. doi:10.1109/52.914744

Herbsleb, J. D. (2007). Global software engineering: The future of socio-technical coordination. In *2007 Future of Software Engineering* (pp. 188–198).

Herbsleb, J. D., Mockus, A., Finholt, T. A., & Grinter, R. E. (2000). Distance, dependencies, and delay in a global collaboration. Philadelphia, Pennsylvania, United States: ACM. doi:http://doi.acm.org/10.1145/358916.359003

Hertzum, M., & Jacobsen, N. E. (2001). The evaluator effect: A chilling fact about usability evaluation methods. *International Journal of Human-Computer Interaction*, *13*(4), 421–443.

Hinds, P., & McGrath, C. (2006). Structures that work: social structure, work structure and coordination ease in geographically distributed teams. Banff, Alberta, Canada: ACM. doi:http://doi.acm.org/10.1145/1180875.1180928

HippoViewer. (2014). *Hippo Viewer Project*. Retrieved August 22, 2014, from http://www.sourceforge.net/projects/opensim-viewer/

Hudson, S. E., John, B. E., Knudsen, K., & Byrne, M. D. (1999). A tool for creating predictive performance models from user interface demonstrations. In *Proceedings of the 12th annual ACM symposium on User interface software and technology* (pp. 93–102).

Illich, I. (1971). *Deschooling society* ([1st ed., p. xx, 116 p.). New York: Harper & Row.

Illich, I. (1973). *Tools for conviviality* (p. xv, 110 p.). London: Calder and Boyars.

Ito, M., Horst, H., Bittanti, M., Boyd, D., Herr-Stephenson, B., Lange, P. G., … Robinson, L. (2008). Living and learning with new media: Summary of findings from the Digital Youth Project. *The John D. and Catherine T. MacArthur Foundation Reports on Digital Media and Learning*.

John, B. E., & Packer, H. (1995). Learning and using the cognitive walkthrough method: a case study approach. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 429–436).

John, B. E., Prevas, K., Salvucci, D. D., & Koedinger, K. (2004). Predictive human performance modeling made easy. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 455–462).

Karaseitanidis, I., Amditis, A., Patel, H., Sharples, S., Bekiaris, E., Bullinger, A., & Tromp, J. (2006). Evaluation of virtual reality products and applications from individual, organizational and societal perspectives—The "VIEW" case study. *International Journal of Human-Computer Studies*, *64*(3), 251–266.

Katzenbach, J. R., & Smith, D. K. (1993). *The wisdom of teams: Creating the high-performance organization*. Boston, MA: Harvard Business Press.

Keller, F. E. (2003). Models, simulation, and computer experiments. In H. Radder (Ed.), *The philosophy of scientific experimentation* (pp. 198–216). Pittsburgh: University of Pittsburgh Press.

Kincaid, J. P., Donovan, J., & Pettitt, B. (2003). Simulation techniques for training emergency response. *International Journal of Emergency Management*, *1*(3), 238–246.

Koehne, B., Fischer, G., & Redmiles, D. F. (2011). *Details on Extending the Meta-Design Theory: Results from Participant Observation of Active Contributors in Virtual Worlds*. ISR Technical Report, UC Irvine.

Koehne, B., & Redmiles, D. F. (2009). *Gaze Awareness for Distributed Work Environments*.

Koehne, B., & Redmiles, D. F. (2012). Envisioning Distributed Usability Evaluation through a Virtual World Platform. In *The 2012 ICSE Workshop on Cooperative and Human Aspects of Software Engineering (CHASE '10)*. New York, NY, USA: ACM.

Koehne, B., Redmiles, D., & Fischer, G. (2011). Extending the Meta-design Theory: Engaging Participants as Active Contributors in Virtual Worlds. In M. F. Costabile, Y. Dittrich, G. Fischer, & A. Piccinno (Eds.), (Vol. 6654, pp. 264–269). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-642-21530-8

Koehne, B., Shih, P. C., & Olson, J. S. (2012). Remote and Alone: Coping with Being the Remote Member on the Team. In *Proceedings of the Conference on Computer Supported Cooperative Work. CSCW 2012.* Seattle, Washington. USA.

KokuaViewer. (2014). *Kokua Viewer Project*. Retrieved August 22, 2014, from http://www.kokuaviewer.org

Kolb, A. Y., & Kolb, D. A. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education. *Academy of Management Learning & Education*, 193–212.

Kolowich, S. (2013a). *Angered by MOOC Deals, San Jose State Faculty Senate Considers Rebuff*. *The Chronicle of Higher Education*. Retrieved August 22, 2014, from http://chronicle.com/article/Angered-by-MOOC-Deals-San/143137/

Kolowich, S. (2013b). *The Professors Who Make the MOOCs*. *Chronicle of Higher Education*. Retrieved August 22, 2014, from http://chronicle.com/article/The-Professors-Behind-the-MOOC/137905/

Leiner, B. M., Cerf, V. G., Clark, D. D., Kahn, R. E., Kleinrock, L., Lynch, D. C., … Wolff, S. S. (1997). The past and future history of the Internet. *Communications of the ACM*, *40*(2), 102–108.

Lewin, T. (2013). *Universities Abroad Join Partnerships on the Web*. *New York Times*. Retrieved August 22, 2014, from http://www.nytimes.com/2013/02/21/education/universities-abroad-join-mooc-course-projects.html

Lieberman, H., Paterno, F., Klann, M., & Wulf, V. (2006). *End-user development: An emerging paradigm*. Dodrecht, The Netherlands: Kluwer Publishers.

Lin, F., Ye, L., Duffy, V. G., & Su, C. J. (2002). Developing virtual environments for industrial training. *Information Sciences*, *140*(1), 153–170.

LindenLab. (2014). Second Life. Retrieved August 22, 2014, from http://www.secondlife.com

Ludewig, J., Bassler, T., Deininger, M., Schneider, K., & Schwille, J. (1992). SESAM-simulating software projects. In *Software Engineering and Knowledge Engineering, 1992. Proceedings., Fourth International Conference on* (pp. 608–615).

Macedonia, M. (2002). Games soldiers play. *Spectrum, IEEE*, *39*(3), 32–37.

Mangano, N., Baker, A., Dempsey, M., Navarro, E., & van der Hoek, A. (2010). Software design sketching with calico. In *Proceedings of the IEEE/ACM international conference on Automated software engineering* (pp. 23–32). New York, NY, USA: ACM. doi:10.1145/1858996.1859003

Mark, G., & Poltrock, S. (2001). Diffusion of a Collaborative Technology Cross Distance. In *Proceedings of the 2001 International ACM SIGGROUP Conference on Supporting Group Work* (pp. 232–241). New York, NY, USA: ACM. doi:10.1145/500286.500321

Martins, L. L., Gilson, L. L., & Maynard, M. T. (2004). Virtual Teams: What Do We Know and Where Do We Go From Here? *Journal of Management*, *30*(6), 805–835.

Maznevski, M. L., & Chudoba, K. M. (2000). Bridging Space over Time: Global Virtual Team Dynamics and Effectiveness. *Organization Science*, *11*(5), 473–492.

McAuley, A., Stewart, B., Siemens, G., & Cormier, D. (2010). The MOOC model for digital practice.

Michael, D. R., & Chen, S. L. (2005). Serious games: Games that educate, train, and inform. Muska & Lipman/Premier-Trade.

Miller, R., Hobday, M., Leroux-Demers, T., & Olleros, X. (1995). Innovation in complex systems industries: the case of flight simulation. *Industrial and Corporate Change*, *4*(2), 363–400.

Molich, R., & Nielsen, J. (1990). Improving a human-computer dialogue. *Communications of the ACM*, *33*(3), 338–348.

Moran, T. P., Chiu, P., Harrison, S., Kurtenbach, G., Minneman, S., & van Melle, W. (1996). Evolutionary Engagement in an Ongoing Collaborative Work Process: A Case Study. In *Proceedings of the 1996 ACM Conference on Computer Supported Cooperative Work* (pp. 150–159). New York, NY, USA: ACM. doi:10.1145/240080.240243

Morningstar, C., & Farmer, F. R. (1991). Cyberspace. In M. Benedikt (Ed.), (pp. 273–302). Cambridge, MA, USA: MIT Press.

Mortensen, M. (2012). From teams to recombinant collaboration: Understanding the evolution of organizational work. *Working Paper, Sloan School of Management, Cambridge, MA*.

Muller, M. (2014). Curiosity, Creativity, and Surprise as Analytic Tools: Grounded Theory Method. In W. A. Olson, J.S.; Kellog (Ed.), *Ways of Knowing in HCO* (pp. 25–48). Berlin, Heidelberg: Springer.

Muramatsu, J., & Ackerman, M. (1998). Computing, Social Activity, and Entertainment: A Field Study of a Game MUD. *Computer Supported Cooperative Work (CSCW)*, *7*(1-2), 87–122. doi:10.1023/A:1008636204963

Nardi, B. (2010). *My life as a night elf priest : an anthropological account of world of warcraft*. Ann Arbor: The University of Michigan Press.

Nardi, B. A., Schwarz, H., Kuchinsky, A., Leichner, R., Whittaker, S., & Sclabassi, R. (1993). Turning away from talking heads: the use of video-as-data in neurosurgery. In *Proceedings of the INTERACT '93 and CHI '93 conference on Human factors in computing systems* (pp. 327–334). New York, NY, USA: ACM. doi:10.1145/169059.169261

Nardi, B. A., Whittaker, S., & Bradner, E. (2000). Interaction and Outeraction: Instant Messaging in Action. In *Proceedings of the 2000 ACM Conference on Computer Supported Cooperative Work* (pp. 79–88). New York, NY, USA: ACM. doi:10.1145/358916.358975

Nardi, B., & Harris, J. (2006). Strangers and friends: collaborative play in world of warcraft. Banff, Alberta, Canada: ACM. doi:http://doi.acm.org/10.1145/1180875.1180898

Nardi, B., Ly, S., & Harris, J. (2007). Learning Conversations in World of Warcraft. IEEE Computer Society. doi:http://dx.doi.org/10.1109/HICSS.2007.321

Navarro, E., Baker, A., & Van Der Hoek, A. (2004). Teaching software engineering using simulation games. In *ICSIE'04: Proceedings of the 2004 International Conference on Simulation in Education*.

NCSoft (2014). *Guild Wars 2*. Retrieved August 22, 2014, from http://www.guildwars2.com/en/

Nguyen, D., & Canny, J. (2005). MultiView: spatially faithful group video conferencing. Portland, Oregon, USA: ACM. doi:http://doi.acm.org/10.1145/1054972.1055084

Nielsen, J. (1994). Using Discount Usability Engineering to Penetrate the Intimidation Barrier. Orlando, FL: Academic Press, Inc.

O'Leary, M. B., & Mortensen, M. (2010). Go (Con)figure: Subgroups, Imbalance, and Isolates in Geographically Dispersed Teams. *Organization Science*, *21*(1), 115–131. doi:10.1287/orsc.1090.0434

Oculus (2014). *Oculus Rift*. Retrieved August 22, 2014, from http://www.oculusvr.com

Olson, G. M., & Olson, J. S. (2000). Distance Matters. *Human Computer Interaction*, *15*(2), 139–178.

Olson, G. M., Zimmerman, A., & Bos, N. (2008). *Scientific collaboration on the Internet*. Cambridge, Mass.: The MIT Press.

Olson, J. S., & Olson, G. M. (2013). *Working together apart: Collaboration over the internet*. (J. M. Carroll, Ed.)*Synthesis Lectures on Human-Centered Informatics* (Vol. 6, p. 152). Morgan & Claypool Publishers.

OpenSimulator (2014). *OpenSimulator Virtual World Platform*. Retrieved August 22, 2014, from http://opensimulator.org/

Oudshoorn, N., & Pinch, T. J. (2003). *How users matter : the co-construction of users and technologies* (p. vii, 340 p.). Cambridge, Mass.: MIT Press.

Pausch, R., Proffitt, D., & Williams, G. (1997). Quantifying immersion in virtual reality. In *Proceedings of the 24th annual conference on Computer graphics and interactive techniques* (pp. 13–18).

Pias, C. (2011). On the Epistemology of Computer Simulation. *Zeitschrift Für Medien- Und Kulturforschung*, *2011*(1).

Polson, P., Lewis, C., Rieman, J., & Wharton, C. (1992). Cognitive walkthroughs: a method for theory-based evaluation of user interfaces. *International Journal of Man-Machine Studies*, *36*(5), 741–773.

Powell, A., Piccoli, G., & Ives, B. (2004). Virtual teams: a review of current literature and directions for future research. *SIGMIS Database*, *35*(1), 6–36. doi:http://doi.acm.org/10.1145/968464.968467

Preece, J., Rogers, Y., & Sharp, H. (2007). *Interaction Design: Beyond Human-Computer Interaction* (p. 800). Wesyt Sussex, England: Wiley; 2 edition.

Prensky, M. (2003). Digital game-based learning. *Computers in Entertainment (CIE)*, *1*(1), 21.

Ramesh, V., & Dennis, A. R. (2002). The object-oriented team: Lessons for virtual teams from global software development. *System Sciences, 2002. HICSS. Proceedings of the 35th Annual Hawaii International Conference on*. doi:10.1109/HICSS.2002.993876

Rieman, J., Franzke, M., & Redmiles, D. (1995). Usability evaluation with the cognitive walkthrough. In *Conference companion on Human factors in computing systems - CHI '95* (pp. 387–388). New York, New York, USA: ACM Press. doi:10.1145/223355.223735

Rufer-Bach, K. (2009). *The Second Life grid : the official guide to communication, collaboration, and community engagement* (1st ed.). Indianapolis, Ind.: Wiley.

Sarma, A., Redmiles, D., & der Hoek, A. (2010). Categorizing the Spectrum of Coordination Technology. *IEEE Computer*, *43*(6), 61–67. doi:10.1109/MC.2010.163

Schmidt, K. (1998). Special issue on interaction and collaboration in MUDs. *Comput. Supported Coop. Work*, *7*(1-2).

Schroeder, R. (1996). *Possible worlds: the social dynamic of virtual reality technology*. Westview Press, Inc.

Schroeder, R. (2011). *Being There Together: Social Interaction in Shared Virtual Environments* (p. 336). New York: Oxford University Press, USA; 1 edition.

Schroeder, R., Heldal, I., & Tromp, J. (2006). The Usability of Collaborative Virtual Environments and Methods for the Analysis of Interaction. *Presence: Teleoperators and Virtual Environments*, *15*(6), 655–667. doi:10.1162/pres.15.6.655

Scott, C. (2013). *Much-hyped, MOOCs maneuver toward Version 2.0*. Retrieved August 22, 2014, from http://singularityhub.com/2013/10/30/much-hyped-moocs-maneuver-toward-version-2-0/

Sherman, M., Bassil, S., Lipman, D., Tuck, N., & Martin, F. (2013). Impact of Auto-grading on an Introductory Computing Course. *J. Comput. Sci. Coll.*, *28*(6), 69–75.

Spencer, R. (2000). The streamlined cognitive walkthrough method, working around social constraints encountered in a software development company. In *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '00* (pp. 353–359). New York, New York, USA: ACM Press. doi:10.1145/332040.332456

Spring, J. (2012). Education Networks: Power, Wealth, Cyberspace, and the Digital Mind. Sociocultural, Political, and Historical Studies in Education. *Routledge, Taylor & Francis Group*.

Star, S. L., & Griesemer, J. R. (1989). Institutional Ecology, "Translations" and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science*, *19*(3), 387–420.

Stefik, M., Foster, G., Bobrow, D. G., Kahn, K., Lanning, S., & Suchman, L. (1987). Beyond the Chalkboard: Computer Support for Collaboration and Problem Solving in Meetings. *Commun. ACM*, *30*(1), 32–47. doi:10.1145/7885.7887

Tang, J. C., Zhao, C., Cao, X., & Inkpen, K. (2011). Your time zone or mine?: a study of globally time zone-shifted collaboration. In *Proceedings of the ACM 2011 conference on Computer supported cooperative work* (pp. 235–244). New York, NY, USA: ACM. doi:http://doi.acm.org/10.1145/1958824.1958860

Techsmith. (2014). *Morae*. Retrieved August 22, 2014, from http://www.techsmith.com

Thies, P., & Koehne, B. (2009). Electronic Glassboard - Conception and Implementation of an Interactive Tele-presence Application. In *HCI International 2009*. San Diego, CA: Springer. doi:http://dx.doi.org/10.1007/978-3-642-02583-9_69

Transana. (2014). *Transana*. Retrieved August 22, 2014, from http://www.transana.org

Turkle, S. (1995). *Life on the Screen: Identity in the Age of the Internet*. New York: Simon and Schuster.

Vivox. (2014). *Vivox Voice*. Retrieved August 22, 2014, from http://vivox.com/

Wadley, G., & Ducheneaut, N. (2009). The "out-of-avatar experience": object-focused collaboration in Second Life (pp. 323–342).

Wankel, C., & Hinrichs, R. (2011). *Transforming Virtual World Learning* (Vol. 4). Bingley, UK: Emerald Group Publishing.

Wilson, J. R., & D'Cruz, M. (2006). Virtual and interactive environments for work of the future. *International Journal of Human-Computer Studies*, *64*(3), 158–169.

Ye, E., Liu, C., & Polack-Wahl, J. A. (2007). Enhancing software engineering education using teaching aids in 3-D online virtual worlds. *Frontiers In Education Conference - Global Engineering: Knowledge Without Borders, Opportunities Without Passports, 2007. FIE '07. 37th Annual*. doi:10.1109/FIE.2007.4417884