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An Empirical Investigation of Virtual World Projects and Metaverse Technology Capabilities

Abstract

Metaverses are immersive three-dimensional virtual worlds (VWs) where people interact with each other and their environment, using the metaphor of the real world but without its physical limitations. Unique technology capabilities of metaverses have the potential to enhance the conduct of virtual projects, but little is known about virtual worlds in this context. Virtual project teams struggle in meeting stated project outcomes due to challenges related to communication, shared understanding, and coordination. One way to address these challenges is to consider the use of emerging technologies, such as metaverses, to minimize the impact on virtual project teams. Applying a theoretical foundation for virtual teams in metaverses that includes both technology capabilities and the social interaction that takes place in the metaverse environment, we conducted an empirical investigation of project teams in a virtual world setting. The study examined the interplay of communication, representation, interaction, and team process tools with behaviors that led to role clarity, shared understanding, and coordination. While each individual technology capability contributed to project execution and outcomes, much of the power of the environment emerged through the interplay of social behaviors and technology capabilities. The results have intriguing implications for how metaverse technology capabilities might provide new ways to address gaps in the current research and practice of virtual project management and virtual teams.

Keywords: virtual worlds, metaverses, virtual world project management, virtual project management, virtual teams, collaboration.

1. Introduction

Trends in globalization and competition require organizations to consider how they operate and manage projects in an increasingly virtual environment. Virtual project teams must coordinate across geographic, temporal, and cultural boundaries in order to find ways to communicate effectively (Khazanchi & Zigurs, 2005). Advancements in information and communication technologies provide both opportunities and challenges for virtual project teams that can affect virtual project outcomes.

One such new technology is the metaverse. A metaverse is a three-dimensional virtual world (VW) where people interact with each other and their environment, using the metaphor of the real world but without its physical limitations (Davis, Murphy, Owens, Khazanchi, & Zigurs, 2009). These environments are being used for such activities as recreational gaming, social interaction, Internet marketing, e-commerce, and e-learning (Ives & Junglas, 2008; Kahai, Carroll, & Jestice, 2007). Well known examples of metaverses include Second Life[1] and Teleplace.[2] Metaverses provide unique technology capabilities that may provide opportunities for virtual project teams. These distinctive technology capabilities can be broadly classified into the following four areas (Davis, et al., 2009):

1. *Communication* to support immediate feedback, language variety, and multiple cues and channels.
2. *Rendering* that utilizes three-dimensional imagery to provide new ways to represent and communicate ideas.
3. *Interaction* to support real time activities such as interactivity, mobility, and the ability to mimic face-to-face conversation where avatars can invoke non-verbal communication cues.
4. *Team process tools* to support process structure, information processing, socialization, and community building.

The dynamic nature of these capabilities represents an undeveloped potential that can be tapped and changed through interaction in the metaverse to enhance collaboration and team/project outcomes. In addition, the use of technology capabilities affects the social and technical aspect of virtual teams in a way that has the potential to minimize discontinuities impacting virtual project teams (Chudoba, Wynn, Lu, & Watson-Manheim, 2005). Therefore, we approach metaverses through an interactionist, socio-technical view, which means that social interaction affects and is affected by technology capabilities, and the emergent use of those capabilities ultimately affects outcomes.

Virtual projects rely on distributed team members and technology for coordination, communication, and completion of project activities. These teams must closely coordinate projects and find ways to communicate effectively in order to overcome discontinuities relating to geographic, temporal, and cultural diversity. Despite the availability of sophisticated collaboration tools, virtual project teams struggle to meet stated project outcomes due to challenges related to communication, developing a shared understanding, and geographic and cultural dispersion (e.g., Cousins & Robey, 2005; Cramton, 2001; Jin & Robey, 2008; Majchrzak

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[1] www.secondlife.com

[2] www.teleplace.com

& Malhotra, 2003; Pinsonneault & Caya, 2005; Powell, Piccoli, & Ives, 2004; Robey, Schwaig, & Jin, 2003; Sotto, 1997). One way to address some of these challenges is to consider the role of immersive technologies, such as metaverses, in a virtual project. Interesting questions arise about what, if anything, is unique about using metaverse technology capabilities for virtual teams? Are team outcomes different in a VW project team?

Our goal in this study is to explore how virtual project teams interact in a VW, with a particular interest in understanding how the technology capabilities of metaverses affect virtual project team performance and outcomes. How do people use the unique technology capabilities of VWs to complete projects? How do the social and technical interactions of a three-dimensional VW affect role clarity, shared understanding, or project outcomes? Although there are reasons to think that a three-dimensional virtual environment may have the potential to improve communication and coordination and minimize challenges related to dispersion, it is not evident how VW capabilities affect team performance and outcomes. Therefore, our research addresses the following overarching question: *How do metaverse technology capabilities affect virtual project team processes and outcomes?*

In order to address this question and further understand the potential of metaverse technology capabilities, we conducted an empirical investigation of project teams in a VW. We used a conceptual foundation grounded in previous theories and research that we developed in earlier work (Davis, et al., 2009). The present study extends the original conceptual model to include projects conducted in a VW, i.e., virtual world projects, and provides the first examination of specific aspects of the model. In analyzing the results, we consider the interplay between social and technical components and the ensuing effects on virtual project outcomes.

Our study provides several theoretical and applied contributions. First, this study is the first to present empirical support of our conceptual model about the role and impact of metaverse technology capabilities on virtual team behaviors and virtual project outcomes. In particular, the study examines the interplay of metaverse technology capabilities with the social and technical aspects of virtual teams. Second, the study provides insight into how metaverse capabilities are different from other collaboration technologies and how these capabilities affect virtual projects. Third, we use empirical data to support our model and develop propositions for future research. Fourth, the research demonstrates a novel approach to studying metaverse technologies and virtual teams empirically that can be replicated for expanded studies on our model and beyond.

From a practical perspective, our results illustrate the value of immersive technologies to address discontinuities and challenges related to virtual project teams. The study also offers insights into how virtual teams operate and conduct virtual projects in metaverses. Finally, the study provides guidance for using metaverse technology capabilities to enhance team activities such as team building, developing shared understanding, and coordinating work tasks.

The next section provides the theoretical foundation and model that form the basis of this research. We then describe the research method, followed by a discussion of the results and major findings. The paper concludes with a discussion of key limitations, contributions, and implications for further research.

2. Theoretical Foundation and Research Model

The model used in this paper builds on previous work, which developed and articulated a theory for conducting research in metaverses. The model includes both technology capabilities of the metaverse and the social interaction that takes place in the environment (Davis, et al., 2009). We have adapted and extended the existing model to include components that are important to the research question for the current study. Figure 1 presents the research model for this study, consisting of six components: (1) metaverse (2) virtual world project, (3) people/avatars, (4) metaverse technology capabilities, (5) behaviors, and (6) outcomes. The model shows that virtual team members work together within metaverses to conduct projects that produce both *in-world* and *out-world artifacts,* which are objects created by humans for a purpose. The extensions to the original model are the in-world and out-world artifacts and the context of virtual world projects. This model also differs from the original one in that the outcomes included are those that are most relevant to the context of a virtual world project.

Virtual world projects, in the middle of Figure 1, represent the context in which metaverse technology capabilities and behaviors interact. The model is grounded in a socio-technical system view of work systems, which takes as its underlying premise the interdependencies between people and technology (Bostrom & Heinen, 1977; Adman & Warren, 2000; Lamb & Kling, 2003). This view enables us to study the impact of metaverse technology capabilities on both social and technical aspects of VWPs, with particular emphasis on their interactions.

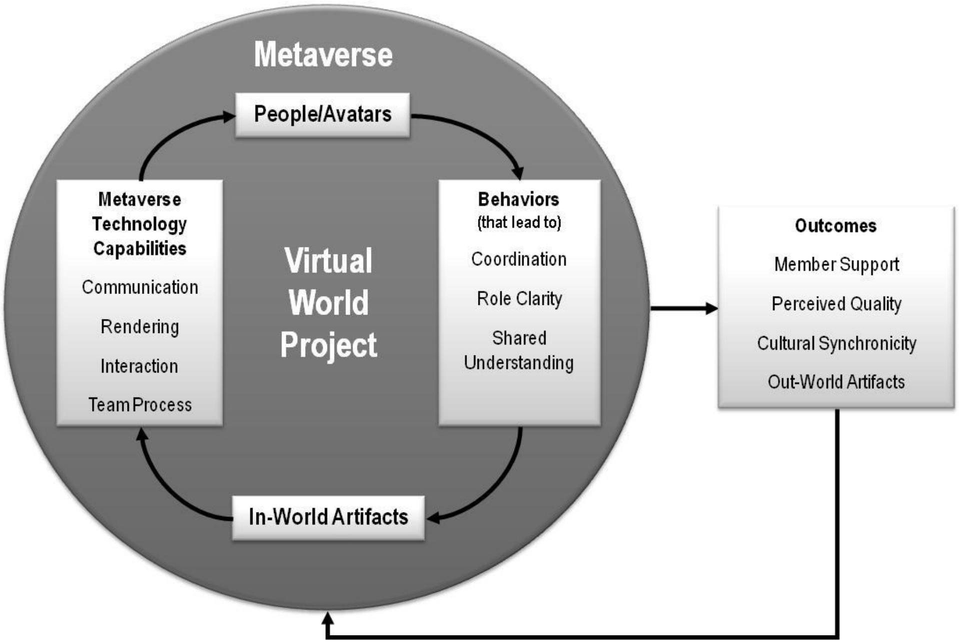

Figure 1: Model for Virtual World Projects and Metaverse Technology Capabilities (adapted from Davis, et al., 2009)

Metaverses provide a unique context for studying virtual projects because of their three-dimensional immersive nature. They offer technology capabilities that support relationships among people, which in turn affect task processes. The socio-technical aspect of the model helps map some of the key dependencies between people and behaviors, people and technology capabilities, technology capabilities and behaviors, and technology capabilities and outcomes. In our model, metaverse technology capabilities represent the technical component, which provides support for communication, rendering, interaction, and team processes. Behaviors represent the social component. The arrows and circular relationships represent the interplay among components. In order to identify those components that work together to achieve effective results, the socio-technical perspective guides our analysis to observe the emergent behaviors that occur through the use of the metaverse technology and impact that each component has on the other. Table 1 presents a definition of the six components of the model, each of which is elaborated briefly in the section that follows.

Component	Definition
Metaverse	An immersive three-dimensional virtual world where people interact with each other as avatars, using the metaphor of the real world but without its physical limitations (Davis, et al., 2009).
Virtual World Project	A project conducted partially or wholly in a metaverse through a collaborative team of people/avatars.
People/Avatars	User-created digital representations of people that symbolize a user's presence in a VW (Bailenson, Swinth, Hoyt, Persky, Dimov, & Blascovich, 2005). People control avatars.
Metaverse Technology Capabilities	The capabilities for communication, rendering, interaction, and team process that allow participants to act and interact inside the metaverse.
Behaviors	Actions controlled by people outside the metaverse and manifested inside the metaverse through the interaction and communication of avatars.
Outcomes	In-world and/or out-world artifacts that represent the result of team activities.

Table 1: Definition of Key Components of the Research Model

The ***metaverse*** attempts to eliminate the perception of physical separation so that participants can interact as though they are in the same space (Schroeder, Heldal, & Tromp, 2006). The technological capabilities embedded in a metaverse are often configurable to allow team members to select different ways to interact. This configurable, dynamic nature of the metaverse environment provides a shared space wherein a virtual team can interact to perform assigned project tasks in a wide range of ways to suit their particular needs.

A ***virtual world project (VWP)*** is carried out by avatars who work together in ways similar to traditional face-to-face interaction. VW technology capabilities are leveraged to produce in-world artifacts that can remain available to project teams throughout the project life cycle. Examples of in-world VWP artifacts include an object used to brainstorm ideas or a note card containing detailed project requirements. Out-world activities can also produce VWP artifacts, such as e-mails sent to team members or project schedules created in face-to-face meetings.

The ***people/avatars*** component represents the link between the human and virtual actor. People can modify their avatar appearance to create dramatically different representations. The more realistic the avatar's representation and behavior, the greater is the participant's sense of engagement (Blascovich, 2002; Lombard & Ditton, 1997; Steuer, 1992). As such, variations in how people select and customize in-world representations affect avatar interactions. Particularly important in VWPs is the extent of presence and realism of people's representation of avatars. Formally, presence is the sense of being in an environment, including the sense of being with and interacting in symphony with others in a virtual space (Slater, Sadagic, Usoh, & Schroeder, 2000; Steuer, 1992). As technology has improved, people have experienced higher levels of presence and sense of being "immersed" in virtual environments (Guadagno, Blascovich, Bailenson, & McCall, 2007). Behavioral realism is the degree to which participants behave in a manner they believe they are expected to behave, similar to face-to-face interactions (Blascovich, 2002). A key contributor to realistic behavior is the avatar's ability to interpret verbal and nonverbal cues from the representation of others and to react with appropriate responses

(Blascovich, 2002). The ability to interpret these verbal and nonverbal cues is essential in the context of VWP teams.

The component of ***metaverse technology capabilities*** can change dynamically through interaction in the metaverse (Davis, et al., 2009), as people/avatars use communication, rendering, interaction, and team process capabilities during a project. The foundation for these capabilities draws from various theories, including media richness theory. The need for immediate feedback, multiplicity of cues and channels, language variety, and personalization are basic to media richness theory (Daft & Lengel, 1986) but variations of these and related capabilities also appear in later conceptualizations of communication technologies (e.g., DeSanctis & Poole, 1994; Nunamaker, Dennis, Valacich, Vogel, & George, 1991; Powell et al., 2004). Virtual team members use and adapt these capabilities to support different aspects of communication and team processes. The use and adaptation of these capabilities influence how teams complete project activities.

Metaverse technologies typically offer a variety of unique communication channels including the use of head-to-toe visual communication among avatars, video and audio chat, and the communication of deliberate body language, gestures, and other nonverbal cues. Metaverse technologies allow participants to create and modify objects, providing new ways to convey complex ideas through the capabilities of personalization and vividness. Avatars can also use graphics capabilities to build new artifacts individually or collaboratively in real time, creating an effect referred to as "immediacy of artifacts." These capabilities provide an opportunity for immediate feedback regarding project tasks. Interaction in a metaverse presents a shift from traditional environments and, when combined with communication and rendering capabilities, interaction offers more than current non-metaverse collaboration technologies (Davis, et al., 2009). Metaverse technologies also provide support for team processes through custom objects and tools such as three-dimensional brainstorming and recording tools. The potential for custom tools to support team processes represents an untapped potentiality for technology capabilities to enhance team performance. Table 2 defines and provides specific examples for each of the four categories of metaverse technology capabilities.

Category	**Definition**	**Capabilities**
Communication	Capabilities that support communication and collaboration.	Channel expansion Communication support Feedback Multiplicity of cues and channels Language variety
Rendering	Capabilities that support the process of creating life-like images, e.g., avatars and objects, in the VW environment.	Personalization – allows for personal focus among people (Daft & Lengel, 1986) Vividness – the richness of the environment (Steuer, 1992)
Interaction	Capabilities that support the process of people/avatars working together with others and engaging with the VW environment.	Mobility Immediacy of artifacts
Team Process	Capabilities for supporting the team's process that are provided through custom objects and tools.	Process structuring Information processing Appropriation support Socialization and community building

Table 2: Metaverse Technology Capabilities (adapted from Davis, et al., 2009)

The ***behavior*** component is manifested through the interaction and communication of avatars. Although there are many behavioral dimensions that have been shown to be important within the context of virtual team collaboration (e.g., Jarvenpaa, Knoll, & Leidner, 1998; Jarvenpaa & Leidner, 1999; Peters & Manz, 2007), we chose to focus on those behavioral dimensions that have the highest likelihood of being uniquely impacted by metaverse technology capabilities. We are interested in specific behaviors that lead to role clarity, shared understanding, and coordination. Because teams in a VW typically meet in the virtual space at the same time and the same place, we are not directly interested in aspects of temporal or geographic coordination. We focus instead on task and role coordination. We classify these components under behaviors rather than outcomes because we are interested in the behaviors that lead to these emergent states. An emergent state in this context is defined as "constructs that characterize properties of the team that are typically dynamic in nature and vary as a function of team context, inputs, processes, and outcomes" (Marks, Mathieu, & Zaccaro, 2001, p. 357). The dynamic nature of the model, with a direct feedback loop from outcomes, supports the notion that these behaviors are an emergent state. They influence the execution of work processes and teamwork, and in doing so they impact team outcomes. Table 3 defines the three behaviors.

Behaviors leading to:	**Definition**
Coordination	The mechanism through which people and technology resources work together to carry out specified activities in order to accomplish stated goals (Grant, 1996; Khazanchi & Zigurs, 2005; Malone & Crowston, 1994).
Role Clarity	A state of understanding individual roles including feeling certain about one's authority on the team, knowing one's responsibilities and knowing what is expected (Kayworth & Leidner, 2001/2002).
Shared Understanding	Mutual knowledge, mutual beliefs, and mutual assumptions that team members develop during the ongoing process of communication (Clark & Brennan, 1991; Khazanchi & Zigurs, 2005; Stahl, 2005).

Table 3: Behaviors of Interest

The ***outcomes*** component reflects significant prior research on outcomes as a function of both work products and psycho-social results that impact longer-term performance (Hackman & Morris, 1978; Hackman, 1993; McGrath, 1984; McGrath, 1991). Therefore, we assess VWP outcomes in this multi-dimensional way. We also include outcomes that may be unique to a metaverse environment, namely cultural synchronicity and out-world artifacts. By observing the interaction between technology capabilities and virtual team behaviors, we hope to gain a better understanding of how the interplay of these components affects VWP outcomes. A brief definition of relevant outcomes studied is provided in Table 4.

Outcomes	**Definition**
Member Support	Relation between individual members and the group (McGrath, 1991).
Perceived Quality	Perception of the quality of group outcomes (Gouran, Brown, & Henry, 1978).
Cultural Synchronicity	Extent to which people are aligned in their perceptions of others' cultural characteristics.
In-World Artifacts	Objects produced inside the VW.
Out-World Artifacts	Objects produced outside the VW.

Table 4: Outcomes of Interest

3. Research Method and Measurement

This study is a first step in providing empirical evidence of how virtual teams conduct projects in a metaverse and utilize its unique technology capabilities. Therefore, we used an exploratory study approach with multiple cases to compare and contrast findings and to develop ideas for further study (Yin, 2003). In our study, each virtual project team was considered a case, or an experiment, thus resulting in multiple cases. Our goal was to identify patterns that emerge based on our model. Because the research design is exploratory, the goal is also to develop ideas for further study (Yin, 2003). Yin (2003) has argued that each case can be considered as an experiment and follow a replication logic. A replication logic is analogous to that used in multiple experiments (Hersen & Barlow, 1976). The result of the multiple case approach is the support and enrichment of a rich theoretical framework, that is, our conceptual model. This approach is in line with Yin’s (2003) reasoning for using cases to generate knowledge. The cases in our study served to help generate knowledge regarding team interactions in a metaverse environment.

Five VWP teams composed of individuals with varying skills and backgrounds conducted a virtual project in Second Life that required them to interact and create an artifact within a constrained amount of time. The five teams completed the task at different times. The task was the same for all five teams, but the instructions varied slightly from team to team, based on feedback from previous teams. For example, feedback from the first two teams suggested that they were not aware that team process tools were available to them for use. In addition, team members were unsure of how much time remained to complete the project task. As a result, we modified the instructions to emphasize the availability of the team process tools, and we placed a countdown timer in the project work area. We collected data on team member interaction and perceptions of the process and outcomes via questionnaires, video, text chat log transcripts, and screen captures. Table 5 shows our tests of validity for the research.

Tests	Case Study Tactic	Phase of Research
External Validity	• Use replication logic in multiple-case studies	Research design
Construct Validity	• Use multiple sources of evidence • Establish chain of evidence	Data collection
Reliability	• Use case study protocol	Data collection
Internal Validity	• Perform pattern-matching • Perform explanation-building	Data analysis

Table 5: Tactics for Empirical Case Study Research (based on Yin, 2003, p. 34)

Yin (2003) argues that external validity can be achieved through replication and comparison of cases. In our research, evidence was sought from both individual cases and across multiple cases. These results are the focus of our discussion and findings. The following sections provide further detail about the setting, participants, task, data collection, and data analysis process.

3.1. Setting

Second Life served as our instantiation of a metaverse for the study, chosen for its stability and maturity as a three-dimensional VW environment. In Second Life, avatars interact in workspaces called islands. The island used in this study contained an isolated area in which project teams could meet and collaborate on their assigned task.

For the purpose of our study, we developed two team process tools within Second Life: (1) a three-dimensional brainstorming and voting tool to share ideas, and (2) a countdown timer. An avatar that represented a technology support person (i.e., our metaverse lab assistant) was unobtrusively present during each virtual team session to answer questions concerning the project.

3.2. Participants

Prior to soliciting participants for the study, we obtained human subjects approval from our Institutional Review Board. We then recruited participants from around the world, through personal contacts and established educator and developer interest groups within Second Life. For example, we received feedback from interested individuals located in the Netherlands, Hong Kong, India, and the United Kingdom. Due to the synchronous nature of the task, participants were required to meet at the same time, even though they were distributed across various time zones. Twenty-one participants were chosen for the study based on their ability to participate in one of the sessions of the virtual project at the same time. These participants were divided into five project teams, with each team meeting at a separate time and day. Participants had no prior history working with one another. They were motivated to participate in the project because they were interested in studies of Second Life and they received monetary compensation for their time (5000 Linden dollars, which is the equivalent of $20).

Nearly 86% of the participants had six months to two years of experience working in Second Life. Two participants had less than six months experience in Second Life, and one participant had three or more years of experience. All but one of the participants reported that they had experience building objects in Second Life before this project – a skill crucial to their assigned task. (Appendix A shows detailed demographic data of the participants.)

3.3. Task

Participants were assigned the task of working together in Second Life to construct a three-dimensional “Rube Goldberg” machine within one hour. Rube Goldberg machines are complex, highly over-engineered contraptions that perform a simple activity (Merriam Webster, 2010). We chose this task for several reasons. First, the task was contained and executable within one hour, which was the maximum time that we expected participants to be available to engage in the project activity. Second, the task was complex enough to mimic a real-world project that included initiation, planning, and execution activities. Third, the task’s complexity was expected to require team members to work together and interact extensively. Finally, designing and building a Rube Goldberg machine requires creativity and provides an opportunity to observe how participants use the features and capabilities of the metaverse.

At the beginning of the project, the lab assistant provided a project overview to all participants and an individual instruction card to each team member that contained a unique project requirement. The intent of the individualized instruction cards was to compel participant interaction and information sharing. (Appendix B provides complete instructions for the task.)

3.4. Data Collection and Coding Procedures

Quantitative and qualitative data were gathered for each team session. To establish construct validity (Table 5), the case study used multiple sources of data, consisting of video, still images, text chat logs, and an exit survey. To enhance construct validity of the data collected, we carefully maintained a chain of evidence supported by sufficient citations referring to specific data sources – images, video, text chat logs and/or survey data. This allowed us to trace from conclusions back to the initial research questions and from questions to conclusions (Yin, 2003).

To increase reliability, we used a case study protocol during data collection to guide us in carrying out the data collection process. The protocol included an overview of the case study project, field procedures, and case study questions (Yin, 2003). The overview included the background information about the virtual project(s), the questions under investigation, and relevant literature about the issues at hand. The field procedures consisted of information pertaining to procedures for collecting data, a schedule of data collection activities, and other operational details for collecting the data. Finally, the protocol included substantive case study questions reflecting our line of inquiry, e.g., *how and to what extent do team members take advantage of the unique characteristics of VWs; how do people represent themselves in these interactions?* These questions helped to ensure valid and reliable data collection and analysis relative to the original research question. Table 6 describes each of the data sources followed by a brief discussion of each source.

Data Source	**Description**
Video	Full-motion continuous images of individual performance and team interactions while working in the VW. Captured by metaverse lab assistant via systems video recorder. Total of 5 one-hour videos and 41 images.
Still Images	Screen captures of individuals and teams at various points during the execution of their VWP.
Text Chat Logs	Text capture of dialogue among subjects using instant messages or notes. Recorded in text chat log file and transcribed to Excel spreadsheet for coding.
Exit Survey	Post-project survey with open-ended questions and measured items to capture participant demographics and perceptions of key components.

Table 6: Data Collected

The chat session data was coded following well-accepted procedures. Each group had varying amounts of text from chat, ranging from 280 to 651 lines of text. Each line of text represented a communication act and was evaluated in terms of our specific areas of interest to determine the type of communication exchange. A single line of text could have multiple codes, indicating multiple communication acts. Table 7 shows the coding categories for chat text.

Communication Type	Guidelines
Team Process Tools	Any reference to the supplemental team process tools that had been provided within Second Life.
Representation	Communication relating to avatar appearance.
Role Clarity	Communication assigning responsibility, questions regarding roles and tasks, and questions regarding time remaining for the task (e.g., What am I supposed to do?).
Shared Understanding	Comments establishing shared understanding (e.g., I agree, I get it), or questions indicating lack of understanding (e.g., What are you doing? How does that fit?).
Coordination	Statements regarding process or allocation of tasks (e.g., You take that part, I'll do this).
Gestures	Use of gestures[3] within Second Life chat channels, or Internet lingo such as abbreviations or emoticons.

Table 7: Coding Categories and Guidelines

Two people coded the text chat log using Cohen's Kappa technique (Brennan & Prediger, 1981). They followed the process of coding one text chat log together in order to formalize the coding procedure. The coders then coded another text chat log individually. Cohen's Kappa for the comparison of the individually coded sheet was calculated as 0.6249, indicating full agreement.[4] The coders divided the remaining three text chat logs between themselves and coded them individually. Appendix C provides a sample of one of the coded text chat logs and details of Cohen's kappa calculation.

The exit survey was completed at the end of the one-hour session. Participants were asked a few background questions relating to their experience in Second Life, followed by questions about their project. The survey included both closed and open-ended questions on a variety of components related to our research model. We consulted relevant literature to compose the survey questions and used validated measures from previous research for each component of interest in the study. Table 8 provides details regarding the measures for the exit survey.

Component	Area of Interest	Source	# of Items
People/Avatars	Presence	(Barfield & Weghorst, 1993)	2
Behaviors	Coordination	(Green & Taber, 1980)	8
Behaviors	Role Clarity	(Rizzo, House, & Lirtzman, 1970)	6
Behaviors	Shared Understanding	(Mulder, Swaak, & Kessels, 2002)	3
Outcomes	Perceived Quality	(Green & Taber, 1980)	6

Table 8: Measures for Exit Survey

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[3] Gestures are unique combinations of sound, animation, and chat that can be preconfigured to initiate with a command or a specific phrase. For example, an avatar can clap his or her hands and play the sound of applause when a person types: /clap.

[4] K (Kappa) interpretations: < 0 indicates no agreement, 0.0-0.20 very low agreement, 0.21-0.40 low agreement, 0.41-0.60 moderate agreement, 0.61-0.80 full agreement, and 0.81-1.00 almost perfect agreement (Landis & Koch, p. 159).

3.5. Data Analysis

We used a triangulation approach for data analysis by examining the content of participant text chat logs while simultaneously considering individual actions and team interactions as portrayed in video and still images. We evaluated these synthesized observations in light of participants' comments and perceptions from the exit survey and developed holistic assessments of the findings. Blending of multiple data sources supported the examination of the components from a variety of perspectives and enhanced the reliability of the results. Our analysis involved careful review of the combined data sources to identify patterns and offer explanations. True triangulation of data is supported by more than a single source of evidence (e.g., Sieber, 1973; Yin, 1982). Our overarching research question served as the basis of the analysis. We identified patterns that were based on our research question and supported by more than a single source of evidence (i.e., data source). Table 9 describes how we triangulated the data sources to support analysis of each aspect of the model.

Further analysis continued by reviewing multiple data sources both individually and collectively. For example, participants had been provided with a three-dimensional brainstorming tool to share ideas. On the exit survey, only four of all twenty-one participants (19%) reported that they attempted to use the supplemental tools. After analyzing the video images and text logs, it was apparent that at no time was an entire team focused on the tool for a group activity, as initially envisioned and designed. To better understand why the tools were not used, questions regarding the tools were added to the exit survey after the first team had completed its project. When participants indicated that they did not clearly understand that the tools were available for their use, we changed task and lab assistant instructions to address that issue for subsequent groups. In spite of these efforts, subsequent data showed that the tools were still not utilized.

Aspect of Model	**Measures**
Communication	Still Images and Video • Number of actions in response to team/individual actions • Number of instances of deliberate gestures Text Chat Log • Number of gestures flagged in text
Interaction	Still Images and Video • Instances of 1-on-1 interaction • Instances of 1-to-many interaction • Instances of avatars introducing new objects into the environment • Instances of anyone wandering away from group • Instances of building object/script during task Text Chat Log • Instances of phrases such as “watch this” or “take this object”
Representation	Still Images and Video • Instances of using graphics or objects to convey point Text Chat Log • Comments regarding appearance • Comments indicating use of objects to represent ideas
Team Process Tools	Still Images and Video • Instances of using tools provided Text Chat Log • References to a process or tools • Asking lab assistant for help
Role Clarity	Still Images and Video • Instances of avatars assuming a power position relative to other team members • Instances of avatars instructing others Text Chat Log • Comments explicitly assigning responsibilities for specific components • Comments establishing schedule/time commitments • Votes/polling for concurrence on project design • Instances of avatars taking a leadership role • Instances of an avatar questioning progress on tasks Exit Survey Items
Shared Understanding	Still Images and Video • Instances of head nods & other OK-type gestures Text Chat Log • Instances of comments like “I understand” • Comments on other’s appearances (cultural) Exit Survey Items
Coordination	Still Images and Video • Instances of face-to-face avatar chatting • Instances of avatars working on an object Text Chat Log • Comments such as you take that part, I’ll do this Exit Survey Items
Outcomes	Exit Survey Items

Table 9: Data Analysis Measures for Specific Components of the Model

We used still images and video to review how team members interacted with each other during the virtual project and within the VW. The goal was to obtain specific information regarding where avatars stood in relation to each other, how they dressed, and how they used technology to interact, communicate, manage the virtual project, and behave. For example, still images revealed that avatars typically created several different objects and those objects were strewn about the work area. We examined the images to understand how the groups used VW technology capabilities to build objects and demonstrate their ideas. We also looked for any relationship between avatar appearance and team member roles. Overall, we were considering the following questions while analyzing the images and video: 1) how do people represent themselves in interactions in a VW? and 2) how do people interact with others in a VW?

The text chat log was analyzed to determine in which type of communication activities participants spent the most time. For example, almost every group spent time at the beginning of their session trying to determine who could perform which tasks based on their skills and experience. Teams used the chat feature for those discussions and assignments. Participants spent 60% of their time developing a shared understanding. The Second Life metaverse is specifically built as a three-dimensional visual environment that is augmented with textual and audio communication capabilities. The chat logs were replete with instances of avatars using the ability to build three-dimensional visuals to construct examples of the ideas they were discussing. This process of discussing and visually representing ideas exemplifies the mutually-reinforcing use of media capabilities inherent to metaverse technologies.

Our analysis is also based on statistical analysis of the survey data. We calculated the mean and standard deviation across all project teams for closed questions (Table 10), and reviewed open-ended questions to identify patterns.

Row	Construct	Mean / St. Dev	Type of Measure
1	People/Avatars – Presence	4.25 / 0.78	5-point Likert scale
2	Behaviors – Coordination and Presence	3.14 / 0.78	5-point Likert scale
3	Behaviors – Coordination (Personal Task Participation)	3.57 / 0.78	5-point Likert scale
4	Behaviors – Role Clarity	4.40 / 1.74	7-point Likert scale
5	Behaviors – Shared Understanding (Content)	4.14 / 1.24	7-point Likert scale
6	Behaviors – Shared Understanding (Social Relations)	3.33 / 1.31	7-point Likert scale
7	Behaviors – Shared Understanding (Process)	3.52 / 1.37	7-point Likert scale
8	Outcomes – Perceived Quality	3.00 / 1.12	5-point Likert scale
9	Outcomes – Solution Satisfaction	3.15 / 0.97	5-point Likert scale

Table 10: Survey Results

We used pattern matching and explanation building to increase internal validity of our conclusions (Table 5). Pattern matching helped us to identify specific outcomes in each case that related to our research model. We used explanation building to analyze the case data to build an explanation about the actions of a virtual project team (Yin, 2003). We incorporate the results of our analysis into the discussion of findings. In the section that follows, we end the discussion of each finding with a proposition that can be developed into specific hypotheses in future research.

4. Findings and Discussion

We begin with an overview of how the teams typically worked together to complete their assigned project. We describe the context for the subsequent discussion of the findings, which is grouped into three major themes that illustrate the interplay between specific technical and social components of our research model.

At the start of each session, participants typically gathered in the assigned Second Life workspace, arranged their avatars in a loose circle, introduced themselves, and shared their Second Life experiences. Participants then received a Second Life note card with an individualized project requirement. Participants typically "read" these cards to each other by exchanging chat messages that conveyed the essence of the requirement. The teams approached the task by assessing who could do which tasks based on their skills and experience. This activity involved a rapid exchange of text messages summarizing each person's Second Life expertise, followed by visual demonstrations of skills and abilities. The following excerpt from the chat log reflects a typical exchange.

> Avatar 1: *"What skills are we bringing to the mix? And what do we want the machine to do?"*
> Avatar 2: *"I ccan [sic] build and conceive, scripting is difficult"*
> Avatar 1: *"Ok"*
> Avatar 3: *"I'm mainly build but i am familiar with scripting that I have taken apart, etc"*
> Avatar 4: *"I'm not a skilled modeler, not at all very good at scripting, but I like trying things out"*
> Avatar 1: *"Lol"*
> Avatar 1: "*Guess that makes me the scripter by default"*

Second Life offers multiple communication channels such as text chat, voice chat, instant messages, live video, and note cards. However, the primary communication channel used by study participants was text chat, as evidenced by more than 1,500 lines of text in the text chat logs for the five teams. The majority of each team's chat related to clarifying roles, coordinating team activities, and building a shared understanding. In fact, nearly 60% of the text messages were specific to shared understanding.

Within the text chat, teams used *Internet language* (also known as Internet lingo), an abbreviated form of written electronic communication. Teams used Internet language to communicate in a compact, succinct manner, which seemed to replace nonverbal cues that typically provide feedback in traditional face-to-face communication. For example, "LOL" (laughing out loud) and the smiley emoticon "☺" served as a quick replacement for a smile and seemed to indicate agreement or positive reinforcement in response to a thought or comment.

As the team members sorted out skills, some participants built sample artifacts to demonstrate their abilities. Building sample artifacts paved the way for teams to transition into brainstorming potential solutions for their task. Custom-developed brainstorming tools were available to all teams; however, none of the teams chose to use these tools, even when encouraged to do so. Instead, team members typically stayed in a loose circle arrangement, exchanged text messages, and built prototype objects to illustrate ideas.

As the project progressed, team members began building components of what would become their solution. The loose circle arrangement disappeared as participants began to work individually or in smaller groups of two to three people. Individuals would periodically "check back" with their team members by physically repositioning their avatars so that they could "see" what their team members were doing and by exchanging status messages via text chat. Team members then re-formed in a loose circle to assemble their components into a final working model. The assembly process often initiated a lively exchange of text messages. Participants displayed a strong sense of urgency as they tried to assemble their machine within the allotted time. Near the end of the project, messages were exchanged which said "*hurry, we have [x] minutes left*" and "*we can't do that because we only have [x] minutes left*."

Once the task was completed, participants completed the exit survey. Analysis of responses to open-ended questions indicates that many participants focused on communication as the key to team success. Participants generally indicated a clear understanding of roles within the team. Participants also typically felt that their team did a good job of blending ideas and contributions; however, some commented that there was not a fair division of labor. Throughout the dynamic group exchange and execution of a complex task within a tight timeframe, participants used many of the technology capabilities afforded by the metaverse environment. Although there were variations in behaviors and use of capabilities among the teams, we observed some consistent patterns that appeared across all teams. The following sections provide a detailed discussion of each of the three specific themes that we observed, highlighting the social and technical interplays that affected team processes and project outcomes.

4.1. Interplay of Communication, Rendering, and Interaction Capabilities in Building Shared Understanding

Our first set of findings focuses on the interplay of metaverse technology capabilities with the behaviors leading to shared understanding. Figure 2 shows the specific portion of our model that describes the interaction between the social and technical systems affecting behaviors that lead to shared understanding.

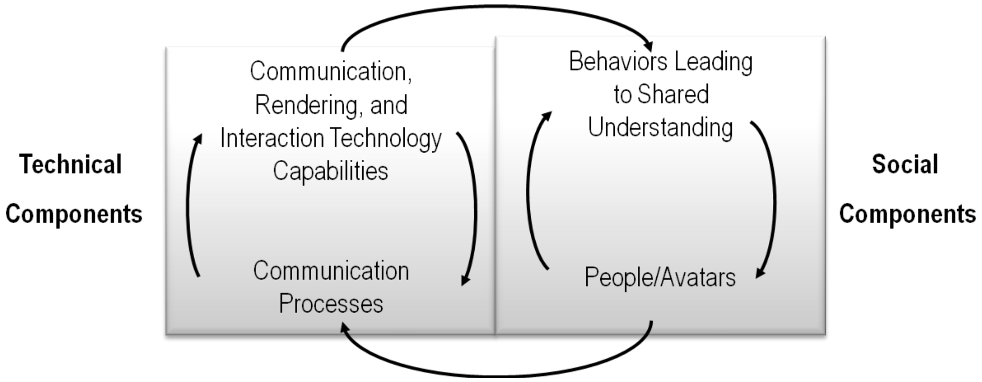

Figure 2: Interplay of Components Affecting Behaviors Leading to Shared Understanding

Shared understanding is a special challenge for virtual teams due to different disciplines, functions, geographies, and cultures (Alvi & Tiwana, 2002; Arnold, Faisst, Harding, & Sieber, 1995; Cramton, 1997). However, our results suggest that these teams were not only able to establish shared understanding, but were able to do so quickly. We identified communication relating to shared understanding within the first ten communication exchanges for all groups, and building of objects followed shortly after. Shared understanding appeared to happen quickly because participants were able to use metaverse technology capabilities to represent their ideas visually and to display emotion and nonverbal cues to provide feedback. This observation is in line with previous research on the importance of nonverbal cues for updating understanding and giving meaning to content, other group members, and group process, resulting in more efficient and effective interaction (Mulder, 1999; Mulder & Smeele, 2000). It appears that shared knowledge of the task is less important in virtual teams than in collocated teams (e.g., Espinosa, Slaughter, Kraut, & Herbsleb, 2007; Malhotra, Majchrzak, Carman, & Lott, 2001). Previous research suggests that participants are more concerned about knowing the skills, expertise and abilities of other participants (Espinosa, et al., 2007; Malhotra, et al., 2001). In our study, participants established a shared understanding of the task and demonstrated their skills, expertise, and abilities before assigning specific project tasks. Team members were required to complete the project in a one-hour period and were encouraged to collaborate in order to gather all requirements for the project - requirements that had been distributed separately via individual note cards. The teams predominantly used text chat for communication to accomplish the project task. The following dialogue exemplifies the question-and-response process of building shared understanding.

> Avatar 1: *"And what do we want the machine to do?"*
> Avatar 2: *"I was thinking more along the lines of a Human Mousetrap lol"*
> Avatar 1: *"You sit on the chair trigger it...or just say something…and it all swings into action to drop a cage on you?"*
> Avatar 3: *"… I'll start on the small space that will enclose our machine? Not enclose...showcase."*

Individuals relied heavily on text chat even though Second Life provides support for voice chat. One potential explanation for this interesting choice is that team members did not know voice chat was available for the project (which a couple of participants mentioned in the exit survey). Another explanation is that individuals did not need other communication channels because the unique technology capabilities of rendering and interaction enhanced communication in a visual way. Rendering allowed individuals to modify the appearance of their avatars as well as create and modify objects within the environment. Individuals used the *immediacy of artifacts* capability to render three-dimensional objects quickly and vividly as tangible examples of the ideas they were expressing via text chat. Immediacy of artifacts had a positive impact on shared understanding by allowing individuals to visualize the ideas communicated in the text. Team members frequently leveraged this capability, building prototype components in an ad hoc way to demonstrate how a new component could work in their team's Rube Goldberg machine. Once someone had built an artifact, these prototype objects frequently became the center of attention. People would move their avatars toward these items to inspect and comment on the object. Teams often had a collection of objects strewn about their work areas, some of which they incorporated into their solutions (see Figure 3).

Figure 3: Participants Examining Prototype Objects

The fact that participants integrated some of those objects into their final machines supports the notion that building objects to demonstrate ideas may improve shared understanding. One way to account for the unused objects is that teams were able to understand why other artifacts would not work once they saw them. This demonstrated an even deeper level of shared understanding of the task. Project participants specifically highlighted the importance of this interaction between communication, rendering and interaction capabilities in comments on the exit survey about practices that contributed to the effectiveness of their project. Participants did not use the custom-built brainstorming tools to share ideas or create objects, even though the lab assistant suggested they do so. Instead, the teams relied on the interplay of communication and immediacy of artifacts. The custom-built brainstorming tools were modeled after face-to-face brainstorming activities, and the fact that they went unused suggests that traditional execution of team processes like brainstorming may be different in a VW because of the capabilities offered by these environments.

Attitudes and skills may affect the tool that participants choose to represent an idea, which in turn may affect their communication processes. Every team augmented their text communication with rendering and interaction capabilities. Avatars worked individually and together to build objects within the environment that illustrated ideas. Regardless of the success or failure of an individual team, this process of discussing and visually rendering ideas exemplifies the mutually reinforcing use of technology capabilities inherent to metaverse technologies to build shared understanding. Our analysis suggests that the interplay of these components helped build a shared understanding through the three-dimensional visual representation of ideas. Further exploration of these components may suggest new tools to represent and brainstorm ideas.

This conclusion is further reinforced from our analysis of presence measures in the exit survey which showed that participants seemed to have a strong sense of presence. When asked "*How strong is your sense of presence, 'being there', in Second Life?"* respondents reported a high level of presence (Table 10, Row 1). Witmer and Singer (1998) suggest that responses to this question are correlated with comfort and presentation quality. In addition, 90% of participants reported a strong sense of presence, with scores ranging between 70 and 100 on a 100-point scale. The responses are associated with enjoyment, orientation, and presentation quality (Witmer & Singer, 1998). Presence is a multifaceted concept that includes how involved an individual is in an environment as well as how affected the person is by the naturalness of the interactions with the environment and how closely these interactions mimic real-world experiences (Witmer & Singer, 1998). The survey results also indicate that participants had a high level of shared understanding of the requirements for the task. As users focus more attention on environmental stimuli, they become more involved in the experience, which leads to an increased sense of presence (Witmer & Singer, 1998).

Our survey results support the interplay between the social and technical interactions of work processes. Participants were involved in the task, felt a strong sense of presence, and used the visual nature of the environment to support their tasks and understanding. We were not able to correlate individual survey results; however, it would be interesting to determine the sense of presence rating provided by a participant in one team who did not engage in the group activities and whose avatar stood away from the others during the length of the project. This interplay between rendering, interaction, and shared understanding is unique to metaverse environments and our results suggest that multiple factors affect one's sense of presence.

These findings provide support for adaptive structuration theory (AST) which argues that advanced information technologies trigger adaptive structurational processes that can lead to changes in the rules and resources that the technology and/or group provide (DeSanctis &

Poole, 1994). AST supports the interplay between technology and social process, illustrating how different outcomes can develop from the same starting point, which is consistent with our model. Group members appropriated the potentiality of the technology and used each of the capabilities in a way that supported their needs. For example, although voice chat was available to all, participants chose text chat as the primary communication medium.

In sum, the communication, rendering, and interaction capabilities unique to metaverse technologies allowed participants to blend communication techniques while dynamically producing three-dimensional visual artifacts in real-time to build shared understanding – a powerful communication synergy that could lead to new patterns of communication. Based upon these findings, we propose:

> *Proposition 1: Metaverse technologies provide capabilities for communication, rendering, and interaction, and the interplay and on-going use of these capabilities facilitate the building of shared understanding in virtual project teams.*

4.2. Interplay of Interaction Capabilities on Role Clarity and Coordination

Our second set of findings focuses on the behaviors leading to role clarity and coordination. Figure 4 depicts the interaction between the social and technical systems affecting role clarity and coordination. Overall, the synergy among these components has an effect on coordination of project activities.

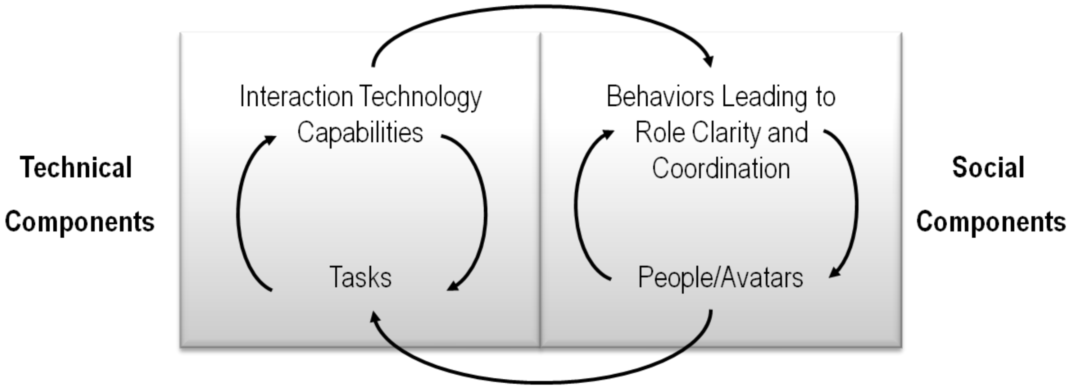

Figure 4: Interplay of Components Affecting Behaviors that Lead to Role Clarity and Coordination

Difficulties with task coordination and communication can prevent teams from sharing and managing knowledge that is critical to team performance (Katzy, Evaristo, & Zigurs, 2000). Prior research on global teams found that it is more difficult to coordinate tasks across sites than within a single site (Espinosa, et al., 2007; Herbsleb & Grinter, 1999). Espinosa et al. (2007) highlighted problems with the lack of presence awareness in geographically-distributed teams. Because of the synchronous nature of the task, our participants were required to be present in the environment for the length of the project. While each participant was present, each was not always active or immersed in the project. The nature of metaverse environments extends the notion of awareness by providing visual cues as to who is active and immersed in the three-dimensional world. Those participants who wandered away from the group and were visually distant from the others were not active participants in the project.

We assessed coordination by observing how team members assigned and distributed work and by analyzing survey data related to coordination. The findings show that participants were neutral in terms of task and role coordination; however, their understanding of skills and roles made coordination easier to accomplish. These results support prior research on virtual teams (Espinosa, et al., 2007; Malhotra, et al., 2001). Survey scores for coordination were neutral, however, scores for role clarity were very high indicating that participants also had a good understanding of problem requirements (Table 10, Rows 3-7). Based on these results, one can conclude that effective coordination was dependent upon several interacting factors – shared understanding, role clarity, and communication.

The teams spent considerable effort trying to determine who could do what based on their skills and experience. Many of the teams struggled with having the right skills to perform needed tasks. The following excerpts show comments from the exit survey relating to the challenges of skills and role clarity.

> *“there was a varying degree of scripting knowledge”*
> *“having only one or two scripters in the team [was a challenge]”*
> *“I felt useless, my skills were not needed”*
> *“We didn’t get a summary of skills at the beginning in order to assign appropriate tasks.”*
> *“delegating tasks to the most skilled person for the job [was a challenge]”*

The text chat log seemed like a logical place to assign responsibility, however, the discussion of roles and role clarity in the text chat was minimal compared to other discussion categories. Only 7% of the text messages were specific to role clarity. Instead, roles emerged organically through an individual’s ability to demonstrate skills. This observation is intriguing when combined with the survey results that indicate participants reported a strong sense of role clarity. The absence of specific role assignments and strong sense of role clarity suggest that verbal role assignments were not necessary in this environment. Participants were able to achieve role clarity by demonstrating their skills and abilities through metaverse interaction capabilities. In particular, interaction capabilities such as mobility, interactivity, and immediacy of artifacts appeared to enhance role clarity and coordination by allowing participants to maneuver quickly and build artifacts visually to show that they had the skills to perform the task.

In a virtual team, it can be difficult to ensure coordination without the immediacy of feedback and the ability to view everyone’s work. We found that VWP teams worked together in a visual manner, moving their avatars to an area where other team members were working. During this process, participants would provide immediate feedback on a task and offer ideas and suggestions. Participants offered feedback via text but also through hands-on demonstration. It was interesting to watch avatars move to an area to look at an object, discuss that object, and then change it. This is worthy of note because avatar placement is not a constraint in a metaverse environment; people can view the environment without having to place the avatar directly next to an object. This finding shows that individuals were mimicking a traditional face-to-face interaction style when working in the VW.

Nonverbal cues also indicated who had a clear role or responsibility within the team. Individuals who did not have a clear role or responsibility were more isolated from the group, standing on the outside and interacting less frequently than others, while those who had clear roles and responsibilities stood closer to the others. These visual nonverbal cues demonstrated which individuals were more engaged in the task. Team members commented on this behavior in the exit survey. For example, one comment stated, “*Avatar A was not engaged and also physically wandered away from the grou*p.”

Role clarity proved to be important to the team’s ability to delegate work effectively. Coordinating temporal dispersion continued to be an enormous challenge that the metaverse technology could not overcome and may even have exacerbated. Trying to coordinate participants across time zones was difficult when team members had to work synchronously, a statement supported by participant comments in the exit survey on VWPs in general.

Multiple factors seem to affect the successful coordination of tasks and delegation of work. Coordination and role clarity in these environments may take on an entirely different process. In order to coordinate work, teams had to understand the skills that each member had, which individuals visually demonstrated to one another. While the project did require participants to create a visual component as the deliverable, it was not necessary for them to demonstrate their abilities. We also found that as teams coordinated activities in a visual way, their understanding of a task changed. Figure 5 shows the evolution of objects throughout a team's project.

Figure 5: Evolution of One Team's Rube Goldberg Machine

The synchronous nature of metaverse technology affected coordination; teams functioned as integrated units rather than as loosely connected asynchronous individuals. Because of the visual nature of the task and the environment, teams were able to collaborate on a task, share ideas, and complete the project in a timely manner.

The collaborative nature of the environment supports the collaborative influence that leaders can bring to a team. In our study, leaders emerged based on their ability to lead the group and delegate work. Leadership roles often rotated based on the task and one's ability to lead the group to completion of the task. However, there were instances where there was an apparent lack of leadership. In addition, members of a team seemed to base their opinions of leadership on their perception of leaders in a traditional face-to-face environment, expecting a leader to rise in the group. Team members commented on leadership, but did not explicitly identify a leader for the project; instead, leadership seemed to rotate among individuals based on activities. The following comments from the exit survey provide insight into leadership within the teams, suggesting that leadership was important, leaders emerged based on the task, and the periods where a leader was not present created a vacuum that led to some ineffectiveness.

> *"No clear leader, poor choice of team members, consensus management style [led to ineffectiveness]"*
> *"Going over the same idea over and over again, without a decision [led to ineffectiveness]"*
> *"When no leader was designated, one team member stood forward to take the lead."*
> *"No leader, confusion of goals, too much brainstorming [led to ineffectiveness]"*

In face-to-face teams, leaders make their presence known by nonverbal cues such as seating location, body language, voice inflections, and style of dress. However, many of these cues are lost in two-dimensional virtual environments (Zigurs, 2003). VWs offer an environment where people can express both verbal and nonverbal cues deliberately. We expected technology capabilities such as visual nonverbal cues, placement of avatars, and an avatar's style of dress to influence emergence of leaders within a team. However, we found that these visual nonverbal cues were not as important in this environment; rather, verbal cues in the text chat were more indicative of leadership roles. Avatars assumed leadership roles based on their ability to perform the job, frequency of communication, and environmental factors, rather than based on their appearance.

As discussed in traditional virtual team research (e.g., Zigurs, 2003), the dynamic nature of task leadership found in these VWPs, where skills guided the roles of individuals on a situational basis, seemed to support emergence of self-directed teams. The study of players in online games supports the finding that leaders shift roles and that leaders who do emerge are sometimes the least expected ones (IBM, 2007) These studies suggest that leadership is not based on one's appearance and is not influenced by the political climate. Rather, leaders emerge based on environmental factors such as the need for a leader or having the right tools or right circumstance in addition to their skills and ability to lead the team. The right environmental factors could facilitate leadership in otherwise reluctant employees. In addition, research evidence supports a relationship among frequency of communication, initiation of task process communication, and being perceived as a leader (Misiolek & Heckman, 2005). Our findings regarding leadership reflect the above conclusions and suggest that effective leadership in VWPs is different from traditional project teams. The fluid leadership model of VWP teams suggests new patterns of control in the management of virtual projects, but we are only at the beginning of our understanding of what those patterns should be.

To summarize, our findings suggest that metaverse technologies provide a unique way to enhance role clarity and coordination through the visualization of ideas and objects. Metaverse technology capabilities enhanced role clarity by allowing roles to emerge based on one's demonstration of skills and abilities. Visual nonverbal cues offered a way to identify quickly those virtual team members who were not engaged in the project due to their distance from the rest of the group. The ability to identify disengaged team members early can have important implications for delegating work and completing project activities. Finally, leadership was important and leaders emerged organically based on skills, environmental factors, frequency of communication, and the direction that individuals provided to other team members. Even so, at times there was an apparent lack of a leader, resulting in ineffective work practices. Overall, the findings suggest the following proposition:

> *Proposition 2: Metaverse technologies provide capabilities for communication, interaction, and rendering, and the interplay and on-going use of these capabilities affect role clarity and coordination in virtual project teams.*

4.3. Interplay of Nonverbal Capabilities and Outcomes

The third and final set of findings highlights the use of nonverbal capabilities. Figure 6 represents the interplay of technical and social components and the impact on team outcomes such as member support, perceived quality, self-image, and cultural synchronicity.

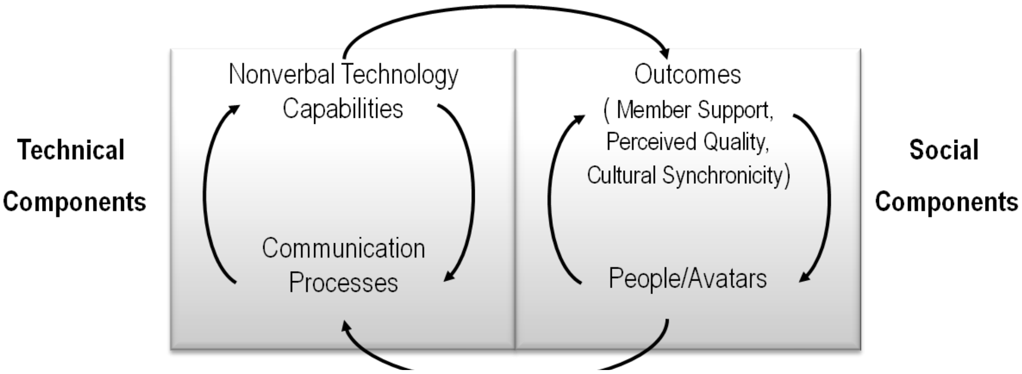

Figure 6: Interacting Metaverse Technical and Social Components Affecting Outcomes

Our findings suggest that avatar interaction in VWs is based on the metaphor of face-to-face situations, relying on the knowledge of how to interact face-to-face, but at the same time departing from the mechanics of face-to-face in interesting ways. Past studies in virtual environments show that people position their avatars near and facing each other when interacting in much the same way they do in face-to-face encounters (Becker & Mark, 2002; Yee, Bailenson, Urbanek, Chang, & Merget, 2007). However, avatars use hand and body gestures less frequently than in face-to-face situations (Smith, Farnham, & Drucker, 2002). Our study confirmed these conclusions. Participants in our study used metaverse technology capabilities to maneuver their avatars in a way that mimics face-to-face encounters, including the use of gestures, Internet lingo and avatar positioning (i.e., turning an avatar away from a group when performing individual tasks). Participants consistently adjusted their avatars as circumstances changed in ways that clearly demonstrated an awareness of how their position affected team interaction. Avatars turned toward each other when "speaking" even though the active communication channel was the text window, which was visible to all participants regardless of what direction they faced.

Still images provide numerous examples of team members positioning their avatars to face each other during team discussion (Figure 7), effectively simulating eye contact. None of the images, however, revealed instances of avatars touching each other.

Figure 7: Avatar Positioning

This use of positioning allowed teammates to represent themselves in a manner highly reminiscent of face-to-face conversations – a more natural communication mode than what is possible in other virtual team environments. One particularly revealing instance occurred when a participant told his teammate that he was going to check with other Second Life scripters outside their work area for additional information regarding the task. He then turned his back to his colleague to chat with other scripters who were not part of the project. When he finished that conversation, he turned back to face his colleague to share what he had learned. This behavior provides a clear example of how the ability to position oneself inside the collaboration environment seems to contribute to the effectiveness of team dialogue.

Many collaboration technologies are designed to replicate face-to-face interaction processes, but they cannot replace important visual cues offered in face-to-face interactions (e.g., Daft & Lengel, 1986; Kiesler, Siegel, & McGuire, 1984). Metaverses such as Second Life offer the ability to invoke nonverbal cues or gestures from an avatar deliberately – such as making your avatar laugh, smile, tap someone on the shoulder, or frown. Although these technology capabilities were not used as expected, we found that face-to-face behaviors are still important in virtual interactions. In addition, team positioning showed how engaged the participant was in the group. Therefore, nonverbal capabilities can influence outcomes such as member support and perceived quality, which are both outcomes of interest in our model. We suggest that the ability to interact in a manner reminiscent of face-to-face influences member support and perceived quality of the outcomes of the project.

Previous studies of nonverbal behavior in distributed environments suggest that social interactions in a VW are governed by the same social interactions as the physical world (Yee, et al., 2007). The absence of social and contextual cues in previous collaboration technologies leads to a reduced impact of social norms and constraints (Spears & Lea, 1992). The ability of VWs to provide social and contextual visual cues could explain the persistence of face-to-face norms and interaction

Many study participants commented that there would have been little or no difference in the team's process had they been co-located for the project. In addition, their work effort and behavior would have been the same if they were co-located in real life. These perceptions are intriguing because not all aspects of face-to-face interaction were transferred to the metaverse environment (e.g., fewer gestures).

Another outcome of interest in our model relates to the interplay of metaverse technology capabilities on cultural synchronicity – *the extent to which people are aligned in their perceptions of others' cultural characteristics* (Davis, et al., 2009). Our subject participants were temporally and globally dispersed. Individuals were randomly assigned to groups comprising people from different locations and cultures. A VW offers the capability to create an avatar with default features and/or customization. In addition, avatars have total anonymity using pseudonyms. Therefore, it is possible that cultural differences that are commonly present in virtual teams are masked by the ability to hide one's true cultural identity. The analysis of our findings did not highlight specific challenges related to cultural diversity. In fact, it appears that cultural synchronicity was high as it related to the use of metaverse capabilities and interaction with team members. All groups were able to complete their project within the time constraint given. We concluded that the groups were able to work together effectively because they not only had a clear understanding of the project requirements, but also had an understanding of each other that was independent of cultural differences. Effective interaction and coordination require group members to know who they work with and how they will interact together. In environments where cultural differences are visually apparent, it may take time to overcome those cultural challenges. Again, the groups in our study completed their projects in a timely manner, potentially at least partly because they did not have to overcome any perceptions (or misperceptions) about culture.

Our findings suggest that even though VWs come close to simulating face-to-face interactions, they also provide important and useful differences that go beyond the ability to replicate face-to-face. The use of nonverbal metaverse technology capabilities provides insight into the social interactions that take place in a VW. These social interactions produce results that can affect outcomes such as member support, perceived quality, and cultural synchronicity. These observations lead us to propose that:

> *Proposition 3: Metaverse technologies provide support for nonverbal communication cues, and the on-going use of these capabilities affects the outcomes of virtual project teams in terms of member support, perceived quality, and cultural synchronicity.*

5. Conclusions

Our purpose was to examine how the use of metaverse technology capabilities affects virtual team project processes and outcomes. The results provide support for our conceptual model and demonstrate the interplay among technology capabilities, behaviors, and outcomes. While each individual technology capability contributed to project execution and outcomes, much of the power of the environment emerged through this interplay. Our findings suggest a new way of thinking about how to leverage the power of a visual, three-dimensional environment. VWs are different from traditional collaboration technologies, though not necessarily in the ways we might expect. Communication, rendering, and interaction capabilities allowed participants to blend communication techniques while dynamically producing real-time, three-dimensional, visual artifacts. These capabilities reduced reliance on traditional textual or verbal communication to build shared understanding. Instead, they established shared understanding through the ability to see and touch an object. Similarly, the visualization of ideas using objects offered a unique way to enhance role clarity and coordination. Participants used the capabilities of the environment to demonstrate their skills and abilities, instead of assigning roles through discussion. Leaders emerged based on their ability to lead the team through a specific task, and leaders did not use traditional reliance on nonverbal cues. Avatars interacted in ways that mimicked face-to-face behaviors and they positioned themselves accordingly when communicating with others or working together on a task. However, even though VWs may be the closest thing to face-to-face interaction, they also offer interesting new features that may reduce challenges related to cultural differences, leading to cultural synchronicity.

5.1. Limitations

Several limitations apply to this exploratory study and each limitation offers an opportunity for future research. Individual participants in this study had reasonable experience building VW artifacts, but the teams did not have a history of working together. Furthermore, the limited amount of time that participants could devote to the study drove a comparatively small-scope project. The artificial nature of the project is also a limitation, in that the task was not one that most virtual project teams would find themselves doing. The project and its deliverables were totally contained within the VW itself. While the project deliverable in the study may be considered a limitation, this presents an opportunity to redefine the notion of tasks and task-related artifacts. On the surface, some tasks may appear unsuitable for a VW, e.g., developing a project schedule. The information processing that is required to develop a project schedule is typically intangible in nature. However, one can make the process tangible in a VW using visual artifacts and three-dimensional objects. Finally, one of the limitations of the study was the inability to verify cultural identity of the participants. Our subject participants were temporally and globally dispersed, however, we were unable to verify their true cultural identify. In addition, in a VW individuals can choose to take on a cultural identify different from their own. This limitation poses opportunities for future study in terms of how participants represent themselves in a VW. For example, does someone choose an avatar that represents a different cultural identity? How does identity of one's avatar affect group interactions? Does avatar identity have a stronger influence than individual identity?

Measurement also presented both a challenge and an opportunity. Metaverse technology capabilities tend to overlap and reinforce each other in ways that make it difficult to attribute effects precisely to individual technology capabilities. The measures used in this study were largely taken from previous studies of traditional and virtual teams. New measures specifically tailored to the VW environment may be needed to capture meaningful data accurately in this new environment. The lack of control groups was a necessary limitation because of the exploratory nature of the study. However, the ability to triangulate multiple types of data did prove to strengthen the study.

5.2. Contributions and Implications

The results have relevance to both theoretical and applied understanding of virtual project teams. The study provides empirical support for our conceptual model, and is one of the first to explore the effects of metaverse technology capabilities on team processes and outcomes. We found that each technology capability represents new opportunities in collaborative technology, however the real benefit comes from their interaction and the synergistic effect they have in creating a new work environment. The study furthers our understanding of how project teams interact in a virtual environment by providing support for what we currently know about virtual project teams. The study also provides insight into how VWs are unique, and the propositions provide a starting point for future research.

On a practical level, our findings indicate that there is value in using a metaverse environment to conduct projects. We demonstrated that conducting projects wholly or partially in a VW is not only possible, but offers opportunities for coordination and control of project work in a new way. Whereas other collaborative work environments predominantly emphasize task productivity, this new environment seems to provide more balanced support for social and task performance. While most projects do not lend themselves to full execution within a VW, there are situations for VWs to enhance projects and project outcomes in the real world. Examples of applying metaverses in a real project include scenarios for team building, establishing trust, or building understanding of team member skills and abilities. The visual nature of the environment provides unique opportunities to demonstrate one's skills and abilities as well as to develop trust. A VW experience could be used to help identify leaders in the team as well as team members who are not as engaged in activities.

The findings identified and helped improve our understanding of key features that are important to team development and outcomes. For example, rendering and interaction capabilities are important and can facilitate shared understanding and role clarity. On the other hand, the complexity inherent to these technologies requires considerable time before people can take full advantage of the new capabilities. People need time to learn how to move seamlessly in the environment, accessing tools and capabilities without significant cognitive effort. It also takes time to achieve a critical mass with the right skill levels to develop new team practices that more fully exploit metaverse capabilities. New business practices may emerge as teams apply the tools and adjust to the peculiarities of their respective environments, and the tools themselves will change because of these new uses.

Some organizations are already taking advantage of the benefits awarded by such an environment. For example, the IBM Academy of Technology has held major events in Second

Life including a Virtual World Conference and a general meeting for the Academy. IBM and Linden Labs estimated that the event saved $320,000 in travel and venue expenses and provided productivity gains, since the participants could go right back to work when the conference concluded (News, 2009). QTLabs also holds meetings in Second Life to enhance and visualize discussions. They have taken advantage of the immediacy of artifacts, concluding that “holding a discussion in a VW gives you the opportunity to create three-dimensional diagrams of what you’re describing” (Wagner, 2007). Meeting participants use moving diagrams of business process workflow which provide the opportunity for participants to visualize the process and allow others to view and comment. These examples illustrate how metaverse technology capabilities provide a unique environment with real potential for enhancing not only the conduct of virtual projects, but virtual team interactions. VWs can also be explored for use in knowledge transfer and collaboration. Second Life works well as a platform for real-time meetings with others. Presentations, planning sessions, team building and conferences are examples of how such an environment can be used. Ultimately, the VW is a space in which participants can experience virtual team interactions and projects in new ways.

5.3. Future Research

There is still much to explore about how teams interact in a metaverse environment. This study examined only some of the components of our conceptual model and there is more to be done. For example, there are opportunities for further exploration of the interrelationships between cultural synchronicity and coordination. There are also opportunities to study process losses and gains. We did not specifically measure process gains and losses (Nunamaker, et al., 1991), however, based on the data collected there is indirect evidence to support process gains related to synergy. Synergy is a process gain where members use information in a way that the original holder did not because that member has different information or skills. There is also evidence to support process losses related to socializing, i.e., non-task discussion that reduces task performance (Nunamaker, et al., 1991). We recommend further research to explore these concepts and others. Additional questions to consider include the following: Do these environments offer their own unique social norms that minimize the effects of cultural differences? How does the environment shape the way leaders emerge and interact with the team? What new skills and competencies will leaders need to succeed in an increasingly virtual and distributed environment and what environmental factors are necessary to facilitate effective leadership? What complex relationships exist between the characteristics of virtual teams and characteristics of the environment?

The literature on project management has provided a variety of characteristics of successful projects. Future research needs to examine how VW technology capabilities can be utilized to promote those characteristics. For example, how are outcomes in a VWP different from outcomes in a traditional virtual project? What is the ideal mix of in-world and out-world activity? Do the size and complexity of the project offer different opportunities for the use of VWs? How does the nature of interaction affect the project, specifically the ability to mimic face-to-face interaction? Are team members who use more face-to-face interaction also more satisfied with project outcomes? Are these team members more engaged in the project? These are all examples of questions that can help to provide more depth to future studies in the context of the new environment of virtual worlds.

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Appendix A: Demographic Data from Exit Survey

How many years of experience do you have using Second Life?	**Total**
Less than 6 months	2
6 months to 1 year	8
1 to 2 years	10
2 to 3 years	0
More than 3 years	1

Table A1: Participant Experience (# of respondents)

For each of the activities, rank the activities in order of where you spend your most time.	**Total**
Building things (including texture design, etc)	20
Random wandering	15
Participating in meetings	15
Meeting new people	14
Owning and working on my own property	14
Shopping	13
Dancing	13
Attending music/art performances	11
Managing projects	11
Listening to presentations and talks	10
Selling things I created	10
Other (education, learning, teaching, research, scripting, skateboarding, working at a foundation, just being)	6

Table A2: Participant Activities of Interest (# of respondents)

In what ways do you interact with friends/contacts?	**Total**
I send instant messages when I see they are logged in	21
I share objects from my inventory with them	20
I offer them teleports to join me in different locations	18
Other (planning, building, face to face in Second Life, voice, note cards, blog)	6

Table A3: Types of Participant Interactions in Second Life (# of respondents)

Appendix B: Task Materials

Task Instructions

You will be working as a team and together your team's task is to design and build a "Rube Goldberg" machine. If you are not sure what such a device might be, please click here (http://www.youtube.com/watch?v=RouXygRcRC4) to see a short video. As a part of this task, each of you will receive a note with some additional specifications for your machine. After you've compared notes with each other you will be able to determine the overall design specifications. We have provided collaboration tools for you to use on this project. Please browse around the sandbox and take a look at them. You are free to communicate with each other in whatever way you choose including IM, voice, group note, etc. When your machine is complete, please set it in the area beside these instructions and complete the exit survey. Later we intend to have an art show to display your work, after which all of the machines built as part of this project will be judged on uniqueness, creativity, and complexity. Maverick Howley is available to get you started and answer questions. Remember, you MUST complete the exit survey in order to complete this project and be paid for your participation.

Supplementary Task Instructions

Team Member 1: Your machine must have at least 4 different components or stops.

Team Member 2: Your machine must have at least three different colors or textures.

Team Member 3: Your machine must contain at least one circular object and one rectangle.

Team Member 4: Your machine should have the ability to be started and stopped by an observer or avatar.

Appendix C: Sample Coded Text Chat Log and Cohen's Kappa Calculation

Cohen's (1960) coefficient kappa is calculated as:

$$K = \frac{\sum Pii - \sum Pi\ Pi}{1 - \sum Pi\ Pi}$$

"where $\sum Pii$ is the observed proportion of agreement, or 'hit rate,' and $\sum Pi\ Pi$ is the 'chance' proportion of agreement" (Brennan & Prediger, 1981, p. 688). Cohen interprets the value of kappa (*K)* as the proportion of agreement between the assigners after chance agreement is removed from consideration (Brennan & Prediger, 1981).

					Comm		Tools	Rep	Role Clarity			Shared Understanding		Coord	Gesture
ID	Gp ID	time	speaker	text	Internet lingo	Exchange	Tools	Appearance	Assign resp	Question role/task	Time	Comment	Question	Coord	
20	1.1	[8:11]	P4	This is a working machine?									1		
21	1.1	[8:11]	P3	Scripted/								1			
22	1.1	[8:11]	P3	?								1			
23	1.1	[8:11]	Lab Assistant	yes, or at least has the illusion of a working machine								1			
BREAK IN SEQUENCE															
47	1.1	[8:16]	P2	What skills are we bringing to the mix?						1					
BREAK IN SEQUENCE															
53	1.1	[8:17]	P4	I'm mainly build but i am familiar with scripting thgat I have taken apart, etc								1			