MESSY TALK IN VIRTUAL TEAMS

Achieving Knowledge Synthesis through Shared Visualizations

FINAL DRAFT

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ABSTRACT
Engineering teams collaborating in virtual environments face many technical, social and cultural challenges. In this paper we focus on distributed teams making joint unanticipated discoveries in virtual environments. We operationalize Dossick and Neff's definition of "Messy Talk" as a process in which teams mutually discover issues, critically engage in clarifying and finding solutions to the discovered issues, exchange their knowledge, and resolve the issue. Can globally distributed teams use "Messy Talk" via virtual communication technology? We analyzed the interactions of four distributed student teams collaborating on a complex design and planning project using building information models (BIM) and the CyberGRID, a virtual world specifically developed for collaborative work. Their interactions exhibited all four elements of Messy Talk, even though resolution was the least common. Virtual worlds support real time joint problem solving by 1) providing affordances for talk mediated by shared visualizations, 2) supporting team perceptions of building information models that are mutable and 3) allowing transformations of those models while people were together in real time. Our findings suggest that distributed team collaboration requires technologies that support Messy Talk--and iterative trial-and-error--for complex multidimensional problems.

***Keywords**: building information models; communication; teamwork; digital techniques; Knowledge-based systems*

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INTRODUCTION

Distributed teams rely on communication technologies to mediate their collaboration. However, the affordances of virtual collaboration technologies are at times misaligned with the communication needs of the team. For example, teams sometimes find building information models not flexible or malleable enough to support their joint real-time complex problem-solving even when they meet in person (Dossick and Neff 2011). What do virtual teams need from their communication technologies to support the kinds of interactions that generate solutions?

Researchers know that the biggest challenges virtual teams face are "organizational and people issues" (Erdogan et. al 2008, p. 235). For AEC virtual teams in particular, one of the biggest problems is creating information systems that help teams with "exploiting opportunities. . . [which] requires intuition, flexibility, guesswork, research, curiosity, and often a significant degree of 'tacit' knowledge" (Cleveland 1999, p.28). In design and construction projects, tacit knowledge exchange is key for the collaborative processes (Carrillo and Chinowsky 2006; Ewenstein and Whyte 2009). Virtual teams have the capacity to draw on expertise regardless where it resides, but how virtual collaboration environments support team members sharing expertise and tacit knowledge with each other is not yet understood (Martins et. al. 2004). Within architectural and engineering design work, much of the multidisciplinary collaboration occurs through conversations with and through documents (Harty and Whyte 2008). Given current virtual technology affordances, can distributed teams achieve the rich collaborative interactions needed for complex problem solving?

To investigate this question we conducted a multi-year experiment where students in engineering and construction programs collaborated in virtual worlds. We compared four geographically distributed student teams collaborating on complex engineering problems in a virtual world with shared building information model (BIM) visualizations to test if collaborative interactions emerged and determine both the technological and organizational contexts that support these interactions in virtual teams. We define the iterative collaboration tasks as a construct with four elements: Mutual Discovery ("curiosity"), Critical Engagement ("curiosity about other's scopes of work and guesswork"), Knowledge Exchange ("tacit knowledge and research"), and resolution ("joint decision-making and synthesis of knowledge"). We compare types of exchanges to identify if the affordances of the specific virtual world we studied, CyberGRID, can provide the conditions for rich collaborative interaction in globally distributed teams.

To this end, we define collaborative conversational requirements for design and construction teams. Suwa et. al. described this process as "unexpected discoveries" through designers' rapid-fire process of sketching, analysis, and synthesis (2000, p. 240). We then propose an operational definition of this type of collaborative interaction and then test for the presence of *Messy Talk—discovery, critical engagement, knowledge exchange and synthesis*—in the virtual team interactions.

Literature Review: Collaborative Interactions in Virtual Teams

While there is an extensive research literature on virtual teams, architectural and engineering design and construction planning present particular challenges for work in virtual teams. Previous studies have explored cultural and linguistic differences (Steel and Murray 2000; Comu et al. 2011; Di Marco et. al. 2010), trust development (Jarvenpaa and Leidner 1998), and conflict (Hinds and Mortensen 2005) in distributed virtual teams. Two of the ACE-sector specific challenges for virtual teaming are encouraging multidisciplinary problem solving and using complex visualizations for collaboration. As the use of virtual teams to support design and construction activities increases (Chinowsky and Rojas 2003; Messner 2008), the need for solving these challenges will as well.

Collaborative Interactions

Construction projects require the coordination and synthesis of many disciplines, which makes knowledge management and information exchange vital in design and construction teams (Carrillo and Chinowsky 2006; Javernick-Will and Scott 2010). Collaboration is key for achieving knowledge synthesis in construction, but information technology solutions more readily support the exchange of explicit knowledge, as opposed to tacit knowledge (Carrillo and Chinowsky (2006). Face-to-face contact and communities of practice remain the most effective ways of transferring tacit knowledge (Carillo and Chinowsky 2006). Ingram and Hathorn (2004) define collaboration as having three essential elements: participation, interaction, and synthesis (creation of new knowledge). While participation and interaction may be supported using current collaboration software such as Skype or WebEx, achieving synthesis could be more challenging in virtual spaces where traditional media used for informal and flexible side conversations that are leveraged by collocated teams, such as paper or whiteboards, are not as readily available (Dossick and Neff 2011).

For collocated teams, shared visualizations support knowledge exchange through interaction, collaboration and communication (Henderson 1999; Harty 2005; Liston et. al. 2007; Orlikowski 2000; Taylor 2007; Whyte et. al. 2008). For the practitioner who creates them, visualizations and models serve both as a way to communicate knowledge and as a means of knowing (Whyte et al. 2008). Those who receive a drawing or a model reinterpret it through their own domain lens, their role on the project, and their disciplinary expertise (Dossick and Neff 2011). Consequently, models and documents become “sites for conversation” where meaning is made, in part, through talk when practitioners exchange perspectives, knowledge and interpretations (Neff et al. 2010). Visualizations from sketches and models simultaneously serve the cognitive purposes for their creators, provide a starting point for conversation and collaboration, and fulfill a purpose for documenting work within the project (Ewenstein and Whyte 2007; Neff et. al. 2010; Suwa et al. 2000; Taylor 2007; Whyte et al. 2008).

Virtual teams then must find new ways via electronic tools to achieve effective knowledge exchange and synthesis. Consequently, we need to understand the necessary technological and organizational conditions for synthesis in order to understand how tools in the virtual environment can support collaborative dialogue.

Virtual Teams

Virtual teams of geographically distributed members who collaborate to accomplish organizational tasks are more prevalent in global engineering projects (Gibson and Gibbs 2006; Kirkman et al. 2002; Nayak and Taylor 2009). Virtual teams require increased management emphasis, social and cultural understanding, and emphasis on common goals as well as technical elements such as compatibility of systems, security, and the selection of appropriate technologies (Chinowsky and Rojas 2003). Much of the subsequent discussion has focused on these issues including overcoming cultural and linguistic barriers (Comu et al. 2011) and leveraging cultural boundary spanners (Di Marco et. al. 2010; Ramalingam and Mahalingam 2011).

Facilitation of virtual teams has also garnered much attention for the management of complex design and engineering projects. In their study, Iorio et al. (2012) found that when non-content expert facilitators were more central in task interactions, they extended the duration of conflicts, thereby creating less effective exchanges in the teams. There is a gap in what we know about distributed engineering work in virtual teams and how to best support these tasks. In this paper we frame what we know about face-to-face collaboration in engineering and construction, and then test to see if teams achieve these same interactions in virtual teams.

Part of the challenge for virtual teams in the architecture, engineering, and construction (AEC) industries is that these teams are most commonly organized in medium-term temporary teams or project networks that rely heavily on the process of documentation (Neff et al. 2010; Taylor and Levitt 2007). Dossick and Neff (2011) suggest that current BIM technologies do not support collaborative interactions because the BIM projected on the screen during MEP coordination meetings seemed fixed and immutable, while the messy problem solving discussions happened outside of the BIM interaction on whiteboards and paper. Visual materials, such as Building Information Models, have traditionally been created by participants independently and brought into coordination meetings where they are treated as static entities for team review (Aspin 2007; Whyte et.al. 2008). While BIM supports problem definition and explicit knowledge creation, its static (i.e. passive) and "formal" appearance makes it less powerful for joint problem solving (Dossick and Neff 2011). Dossick and Neff argued that active, informal and flexible documents and visualizations support Messy Talk by allowing people to draw, write, sketch, talk, or otherwise modify shared knowledge together. This may foreshorten conversation because, as currently used, these tools limit opportunities for "messier" mutual discovery and unanticipated problem solving at the expense of more efficient or "cleaner" documentation (Dossick and Neff 2011). Whyte et al. (2008) found that when visual materials were owned and negotiated by the team, as opposed to being created independently as described above, a more effective knowledge development emerged through exploration. From this we hypothesize that BIM (or any other medium) may be used for "messy" problem-solving if it is created by the team interdependently through mutual discovery and negotiation. To achieve this, the medium must necessarily be active, informal, and flexible.

In virtual teams, where members are geographically separated, and communication is technologically mediated, 1) can synthesis be achieved, and 2) what types of technological affordances support these collaborative, at times messy, discussions? Through the research presented in this paper, we seek to operationalize and extend the definition of Messy Talk. In line with Dossick and Neff's (2011) position that the material site of conversation needs to be active, informal and flexible, we argue that when visualizations are co-created through a discursive process in multidisciplinary settings, new ways of identifying, analyzing, and resolving problems can occur in virtual teams. We explore this conjecture in the CyberGRID (Cyber-enabled Global Research Infrastructure for Design), a virtual work environment specifically designed to support virtual engineering team interaction (Iorio et al. 2011). The CyberGRID provides a virtual interactive space that is informal and active through avatar interaction, and is flexible through iterative use of a shared "team wall" with virtual pen functionality.

RESEARCH METHOD

In this paper, we used qualitative, online ethnographic data and content analysis to characterize and understand Messy Talk interactions among members of geographically distributed teams who met electronically to coordinate building construction activities.

Research Design

During the winter/spring of 2011, thirty-one graduate and undergraduate students from the University of Washington (UW) and Columbia University (CU) met in eight teams composed of students from both universities. The same experiment was repeated in winter/spring of 2012 with twenty graduate students from the University of Washington and Virginia Tech (VT), meeting in four teams of five members each. Participants in the 2011 and 2012 experiments were graduate students or seniors from architecture, engineering and construction management departments. We analyzed six teams from the CyberGRID classes offered in 2011 and 2012. Some members of each team had experience in virtual worlds, and the prior industry experience ranged from none to 5 years, see Table 1.

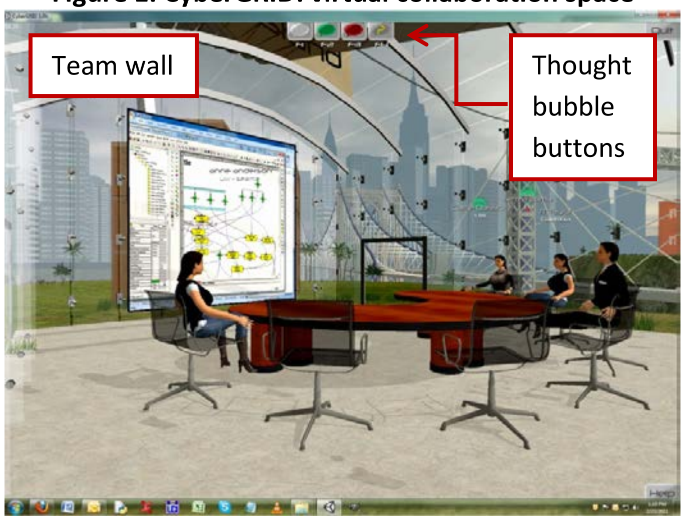
Table 1. Team Experience

Category	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6
Combined years in industry	5	3	3	0.5	1	2
Members with virtual world experience	100%	60%	60%	75%	80%	80%

Each team met once a week for ten weeks in the CyberGRID, an online 3D virtual world developed and maintained by researchers at Virginia Tech. Participants entered the CyberGRID in the form of an avatar—a 3D representation of a human—and were able to see and interact with their teammates who were also represented by avatars. In the CyberGRID, 3D building models can be imported into the space and explored by the team as avatars. Each team was given training on the use of the CyberGRID at their first team meeting in the virtual workspace.

Communication affordances in the CyberGRID included voice, text chat, thought bubbles and file exchange (Iorio et al., 2011). When a team member used voice, green waves appeared above their avatar thus identifying the speaker to other members. Team members could communicate nonverbally by displaying a thought bubble over the avatar's head designating agreement, disagreement, or a raised hand. The position or movement of one's avatar was also effective at communicating nonverbally (Anderson et al. 2011). The teams each met in a virtual conference room within the CyberGRID equipped with a team wall on which members could share their computer desktop in real time. Figure 1 shows a typical meeting space.

Figure 1. CyberGRID: virtual collaboration space



Each team was asked to complete an iterative, interdependent construction planning tasks (construction scheduling and 4D modeling); with each university sub-team being responsible for one component of the task. Subsequent iterations of each component were dependent on work by their teammates, which necessitated joint work and shared information between universities. Participants were asked to complete all of their assigned work during their weekly meetings so they would be virtually collocated as they worked. The teams worked with simple 3D models that had been created in Maya and imported into the 3D virtual world.

Students at Columbia University in 2011 and Virginia Tech in 2012 were responsible for creating the baseline schedule and organizational analysis in SimVision, a commercial software tool used for simulation of team behavior and human work performance in construction projects. Students at the University of Washington were responsible for combining the baseline schedule with the 3D geometry to create a 4D model in Autodesk Navisworks®, a commercial 4D modeling software. Each team was then asked to optimize their models by reviewing the 4D model to find inefficiencies in the schedule, update their work (both the SimVision schedule and the Navisworks 4D model), and resubmit. It was during the optimization process in particular that we expected to see Messy Talk emerge as these were the types of tasks for which Dossick and Neff (2011) observed collocated teams leverage Messy Talk.

Data Collection

All interactions that took place in the virtual collaboration space were audio and video recorded. Additionally, researchers observed the meetings in the virtual world, as avatars, and took detailed ethnographic notes of meeting activities. Typically, only one researcher was present at each meeting and observations were distributed among researchers at the participating universities. An ethnographic observation template was created prior to experiment start for the purpose of taking detailed notes and ensuring that each observer was noting items relevant to the research question. Categories in the observation template include meeting goals, use of communication tools, and demonstration of specialized knowledge. Self-reported information from the participants was collected in two ways: a demographic survey administered prior to the start of the experiment and a team building exercise in the first CyberGRID meeting in which they shared academic goals, industry experience, virtual world experience, and hobbies. These self-reported results are summarized in 1.

Operationalization of Messy Talk

The next phase of research was to determine specific, measureable interaction elements so Messy Talk could be identified in the data (de Vaus, 2001). Using team interactions from the 2011 experiment, we operationalized Messy Talk by analyzing team interactions that Cleveland 1999 characterizes as “intuition, flexibility, guesswork, research, and curiosity.” With this operationalization, we then identified if and when these types of interactions occurred in the 2012 CyberGRID teams. Building from Ingram and Hathorn (2004) definition of collaboration as having three essential elements: participation, interaction, and synthesis (creation of new knowledge), we refined the elements of Messy Talk through the examination of the interactions between collocated team members described in the Messy Talk study by Dossick and Neff (2011), the literature and analysis of the 2011 CyberGRID team interactions. The collocated teams in the Dossick and Neff study were composed of design and construction professionals from multiple disciplines who met to coordinate construction activities for a complex building project. Meetings took place in a conference room where they could project a BIM model on the screen and also had access to paper documents such as drawings, logs, correspondence and agendas. Messy Talk exchanges in these collocated teams involved team members huddling over paper documents, writing on whiteboards, pointing, questioning, discussing, and debating, culminating in a documented decision. Dossick and Neff defined *Messy Talk* as talk that is “unplanned, unforeseen and unanticipated,” supporting brainstorming and mutual discovery (2011, p. 85). Consequently, the element of discovery emerged as important to construction teams. From Carrillo and Chinowsky (2003) we also know that tacit knowledge exchange and synthesis is vital to construction team interaction. Emerging from the literature, we had elements of discovery, participation, knowledge exchange and synthesis.

The definition of Messy Talk elements were refined in analysis of the 2011 CyberGRID experiment through exemplar interactions from teams 1 and 2 (discussed in Section 4), we finalized the operational definition of Messy Talk as comprised of; 1) Mutual Discovery (MD), 2) Critical Engagement (CE), 3) Knowledge Exchange (KE), and 4) Resolution (R) (See Table 2). Building from Ingram and Hathorn (2004)'s definition, *participation* in these teams included elements of discovery (Dossick and Neff 2011, Suwa et. al. 2000) as well as critique of each subteam's work. From this observation emerged our first two elements: Mutual Discovery and Critical Engagement. Meaningful *interaction*, Ingram and Hathorn (2004)'s second factor, was observed in our teams as having two types which became the second and third elements in our Messy Talk model: Critical Engagement as well as Knowledge Exchange (Carrillo and Chinowsky 2003). In our fourth element, Resolution, we expand upon Ingram and Hathorn's third element, *synthesis*, to include a simple statement of next steps or a more complex statement of knowledge synthesis.

Sample Frame

In an effort to examine meetings where Messy Talk would be most likely to occur, we chose to analyze the 2012 CyberGRID experiment optimization meetings during which team members had to reevaluate the SimVision schedule after viewing the 4D model created by UW participants. One optimization meeting from each of the four teams was transcribed and coded.

ELAN, a linguistic annotator software, was used to annotate exchanges between team members and assign Messy Talk categories to individual statements. These categories were mutually exclusive and each statement was coded with one element. There were statements that did not fall into any of the categories and were not considered part of interactions of interest in this study (e.g, statements about the weather).

A primary coder analyzed interactions, line by line (roughly 15,000 words total), from the four 2012 teams using the operationalized definitions developed from the 2011 CyberGRID study as outlined in section 3.3. A second coder independently coded 10% of the interactions reviewed by the primary coder. A direct comparison between coders yielded an initial agreement of 64%. The research team discussed differences in the coding then refined and clarified the definitions of team interaction elements. The primary and secondary coders then conducted a second cycle of coding using the revised definitions. Agreement between coders increased to 77%. We then looked more closely at the element-by-element differences and found that a majority of them were differences in how the coder interpreted critical engagement. When the coders reviewed the interactions as a whole (a sequence of elements the started with a question or discovery and ended with a resolution), there was 75% agreement that each interaction that was coded was a Messy Talk interaction. We can conclude then that Messy Talk was observed in these teams.

Intercoder reliability in qualitative work often involves iterative processes that result in theoretical refinement and “categories often exist in an interdependent, discursive relationship to each other. These issues, which would be a major impediment for a quantitative study, are not weaknesses in qualitative inquiry; they are in fact a linchpin of the process” (Lindlof and Taylor, 2011, p. 272). For this study, what was powerful about the intercoder reliability coding process was the development and refinement of the operational definitions. The process allowed us to validate the constructs (Lucko and Rojas, 2010) and contribute to the refinement of the analytical framework as well as our conceptual understanding of Messy Talk (i.e. what qualifies as Messy Talk and what does not). The final operationalized definition of the four Messy Talk elements is shown in Table 2.

Mutual discovery (MD) occurred when an issue or problem was discovered in the course of work related to a team task. Cues for discovery include discussion as well as shared visualizations. While *discovery* indicates a realization, *mutual* denotes the requirement that more than one team member is present when the discovery occurs. Mutual discovery was often made by one of the team members in the absence of others' attention, and was subsequently acknowledged by others when identified. Mutual discovery can also be the result of team efforts in troubleshooting a technical problem through trial and error because they discover, together, the outcome of testing a solution or idea. The discovery of a solution through trial and error was serendipitous and not the result of specialized knowledge.

Critical engagement (CE) was closely associated with mutual discovery in that team members noticed, questioned, and reflected upon each other's work. Critical engagement may take the form of a question, an answer, an idea or a suggestion. The team members were *critically* thinking about the issue at hand, and, through discussion, understanding of the issue was refined or the issue was corrected. Critical engagement usually entailed multiple exchanges in which participants responded to a question or stepped through their own reasoning to elucidate the issue. Because of this, critical engagement discussions theoretically compose a major part of Messy Talk interactions as the team engages with the problem.

Knowledge exchange (KE) occurred when a team member shared prior experience or understanding related to the issue. In multi-disciplinary teams, each member has specialized knowledge. In our analysis, comments and statements that conveyed specialized knowledge were coded as knowledge exchange. Unlike critical engagement, a knowledge exchange statement was usually not challenged by others, but the two categories overlapped when team members' understanding differed. Knowledge exchange was characterized by the contribution of a key piece of information that helped the team resolve the question at hand. Because knowledge exchange is requisite for attaining resolution, we assert that knowledge exchange is a key element of Messy Talk.

Resolution (R) took place when the team members found a solution to the problem or decided on a course of action. This type of exchange often signaled the end of a Messy Talk exchange and was indicated by one or more concluding statements; however, in more complex exchanges, resolutions occurred at various points in the Messy Talk exchange after which additional mutual discovery or critical engagement exchanges occurred as others expanded upon and questioned the proposed resolution statement(s). Resolutions varied from simple statements of a plan of action such as "let's ask the teacher," to complex statements that synthesized knowledge from multiple team members.

Table 2. Operationalization Definition of 'Messy Talk'

ELEMENT	OPERATIONAL DEFINITION	EXAMPLE FROM 2011 CYBERGRID DATA
Mutual Discovery	An issue/problem, related to the aspects of an assignment or existing in the response to that assignment, which a team member highlights but other members have not noticed. Everyone in the team then agrees that it is an issue/problem.	UW3: OK. So, geometry does not… it had a task that also tied… CU3: Interesting. Is that a problem? UW3: Yeah. …
OR	A practical resolution that team members find to troubleshoot a technical problem.	UW4: I guess what I have to do is connect the new… UW5: You mean rebuild the link? ... UW4: Do you think I should rebuild the task … to the link? UW5: I'd try to rebuild. That's how it is supposed to work. So, I would try that one.
Critical Engagement	A statement to clarify a mutually discovered issue/problem, which is followed by a question or an opposing statement/explanation.	UW3: What's the end date? CU3: Oct 7th. UW3: So does that mean we went longer? CU3: Yes. UW3: What is the total length of our schedule right now? 7 months? CU3: 5 months, 5 days.
OR	A question whose answer is challenged or supplemented.	UW3: It leaves the ceiling to exist. CU3b: Exist? What do you mean by exist?
OR	A suggestion not accepted by the others which leads to reasoning by others	UW3: I think he said make an assumption. CU3: That was what he said? UW3: I think it was something like that. That was what I remember. I don't know.
OR	A suggestion accepted by others but is complemented by others as well.	UW4: Do we do walls one … first floor walls for exterior doors and windows? UW5: Instead of walls? Yeah, that makes sense but you mean are we going one? UW4: Yeah because we're breaking doors and windows by floors as well …
Knowledge Exchange	A fact related to one aspect of the assignment	The way to fix it is to go to configuration and change the end appearance to…
OR	A true statement sharing a personal experience or understanding.	UW3: … it seems like that if you have these many people, sequentially you could do it in 4 of 5 months or something like that. I don't think the project is that big. The part that seems very long is the wall finishing.
Resolution	A solution suggested by a team member and agreed upon or not challenged by others, which solves a mutually-discovered problem.	CU3: I went to the chart that when they're doing these, carpenter 1 is one of them but they are not happening at the same time. So, I put secondary assignment. UW3: Oh, ok. Nice.
OR	A resolution agreed upon by everyone to be followed in order to achieve a final solution.	UW4: So I'll attach this in the first floor. The first floor, I'll attached to the slab on grade? CU4: Yes. That's what I would do.

To quantify the amount of Messy Talk exchanges that each team experienced, the time duration for each of the coded statements was measured to find the aggregate time in a Messy Talk exchange spent on each of the four elements specifically. We also noted when interactions occurred between students from different schools (interdisciplinary exchanges). This allowed us to identify Messy Talk interactions as well as characterize Messy Talk formation. Items measured were:

a. Time percentage of Messy Talk interactions in four virtual team meetings,
b. Time percentage of Messy Talk interactions that occurred in interdisciplinary exchanges,
c. Ratio of Messy Talk interactions to non-Messy Talk interactions. (Messy Talk interactions must include all four elements of Messy Talk defined in section 3.3. Non-Messy Talk interactions are often related to the meeting goals and may include some but not all elements of Messy Talk such as troubleshooting dialog).

In Section 4 we describe the operational definition development through the identification of team interaction typologies. In Section 5, we present the quantitative data collected in terms of the time each team spent in Messy Talk interactions specifically.

TEAM INTERACTION TYPOLOGIES

As described in section 3.3, our first step was to determine the components of Messy Talk by examining collocated team interactions because Dossick and Neff (2011) demonstrated that Messy Talk can occur in these non-mediated settings. We piloted the operational definition with teams 1 and 2 and refined the four elements of: Mutual Discovery, Critical Engagement, Knowledge Exchange, and Resolution. Using those four components, three team interaction typologies emerged that contain various combinations of the four Messy Talk interaction elements: Discovery (MD), Troubleshooting (MD + CE + R), and Messy Talk (MD + CE + KE + R). While discovery was useful, it did not result in team-based problem solving. Troubleshooting seemed to be the least efficient and effective use of the team's time as they worked through technical issues in a trial and error process. Of the three typologies, Messy Talk is the most effective at resolving issues that emerge during team discussions when the knowledge was within the team, when team members engaged in each other's work and when the resolution was a synthesis of distributed knowledge. In this section, we define the three typologies, provide examples of each from the data, and discuss how discovery and troubleshooting can be distinguished from Messy Talk interactions.

Table 3. Team Interaction Typologies: Discovery, Troubleshooting, and Messy Talk

Category	Interaction 1: Discovery	Interaction 2: Troubleshooting	Interaction 3: Messy Talk
Team Setting	CU students realize they are missing the stairs in their model as they watch the UW students work on the 4D model. No subsequent discussion about the problem	CU projects MS project on team wall. The team reviews together. UW1 makes suggestions and CU students follow her instructions through a drawn out trial and error troubleshooting process	CU3 shares SimVision model with team and asks others "are these the same crew?" UW3 defines what a carpenter does. They agree that all of the activities could be carpenter crew
Transcript Excerpts	CU2a: Ohhhh [groans] [MD] CU2b: What's up? [MD] CU2a: You know where the stairs go? …in SimVision … so I'm going to have to redo it. [MD] CU2b: Sorry. Not mentioned again, UW students continue to work on the Navisworks model.	UW1: What happens when you do that? [CE] CU1: It just highlights the whole column… [CE] UW1: Yeah, I get something different. I get more than a day… [MD] UW1: Can you try exporting again?… [CE] CU1: so you think … is … correct?... I think our duration should first… [CE] … CU1: Can you start working … now? [R] UW1; Sure, yeah. I can [R]	UW3: All of these? … [CE] CU3: Um, no not the …MEP. I just mean the cladding and the exterior doors. [CE] UW3: Sure, yeah you could, … could do all the same stuff. … be a carpenter. [KE] CU3: Cool. Carpenter. That's the word I was looking for… [MD] UW3: They'll also do all the windows. The roofing. [KE] CU3: I'm just going to … concrete, roofing, cladding, windows, finishing. [R] UW3: Ok, that sounds good. [R]
Interaction Elements	MD	MD + CE + R	MD+CE+KE+R

Discovery (MD)

One of the salient themes from Dossick and Neff (2011) was the idea of unanticipated discoveries -- that by working together, a team of experts discovers important aspects of the project at hand. In the CyberGRID teams, discovery occurred when team members observed each other's work as it developed on the shared visualization projected on the team wall or when they discovered something new through discussion with their teammates.

In this analysis, we have determined that discovery is a necessary, although not sufficient, characteristic of Messy Talk. We found instances when a team jointly discovered issues, only to have those absorbed back into individual problem solving resolution and not discussed by the team. Interaction 1, shown in Table 3, is based on the need for others to engage in the newly discovered problem. In some cases, there was no need for the team to engage, while in others (such as Interactions 2 and 3) the team needed to discuss the issue. The team members in the Interaction 1 example were all present in the CyberGRID at the same time, but worked independently on their tasks. In this example, UW students projected the Navisworks model on the team wall. While the two UW students were working together on the model discussing possible improvements, one of the CU students suddenly realized the stairs were missing in the SimVision model. A CU student, CU2a, states, "You know where the stairs go?. . . in SimVision. . . so I'm going to have to redo it." The discussion about the stairs ends there; the UW students did not respond and continued to work on the Navisworks model that had been projected on the team wall during the exchange. The CU student made the correction in the SimVision model on his own computer, which was not shared with his teammates in the CyberGRID. This example shows discovery as a relatively quick interaction of mutual discovery without subsequent team discussion (i.e. critical engagement), knowledge exchange, or synthesis. For the discovery of missing stairs to occur, the CU team members had to be engaged in the UW students' work by watching the 4D modeling efforts via the shared screen.

Teams that created a divide-and-conquer approach to their division of labor, as opposed to more richly collaborating, typically arrived at discoveries that were not resolved through Messy Talk. While discoveries are invaluable in practice and will occur when team members with different but interrelated disciplinary scopes actively watch or review each other's work, they do not always lead to Messy Talk exchanges that synthesize the team's knowledge into a shared solution. Sometimes synthesis is not needed, and discovery is what the team needed from the interaction.

Troubleshooting (MD + CE + R)

Some of the interactions in the CyberGRID did not meet the criteria for Messy Talk, but did contain elements of mutual discovery, critical engagement and resolution. Even when students were engaged and talking with each other, they occasionally lacked the needed information or knowledge to complete their tasks. In these cases, teamwork was characterized by trial and error troubleshooting, exploring together different technical options, working together in joint learning and exploration. For example, all of the teams had to work through interoperability issues in transferring data between SimVision and Navisworks. In Interaction 2 (Table 3), the team tried to figure out why the schedule they exported from SimVision did not have the correct data needed for Navisworks, and this excerpt exemplifies typical troubleshooting interactions. A student from Columbia projected the MS Project schedule on the team wall and the team reviewed it together. A student from UW led the discussion, using the pens to circle on the virtually shared document. What followed was the team jointly experimenting within the models in real time, with each member suggesting various ideas for trial. Their solution was the result of trial and error, not a synthesis of team knowledge. Even though this was a team effort, what was missing was technical know-how. Although they worked through the problem as a team and collectively brainstormed ideas as to what to try next, they did not synthesize knowledge that is characteristic of powerful generative Messy Talk. When tackling this same problem, other teams sought out a teaching assistant or professor for the answer, thereby seeking out the knowledge to resolve the issue. Of course, without the answer residing within the team, talk could not get them to a solution.

From this analysis, we can enrich our understanding of Messy Talk as a synthesis of knowledge. When left without the technical know-how the teams either tried to work it out through trial and error or sought out the relevant knowledge outside of their team. Resolution in this case is a statement by the team that they have agreed on a course of action but does not include knowledge exchange or synthesis that Carrillo and Chinowski (2003) find vital to industry practices.

Messy Talk (MD + CE + KE + R)

Messy Talk is characterized by the combination of all four interaction elements: mutual discovery, critical engagement, knowledge exchange, and synthesis. In Table 3, the team in Interaction 3 used the CyberGRID and worked independently on their tasks, but called the team together when they had something they wanted to talk through. Interactions of this team often started with students calling out to their teammates through the CyberGRID, asking if they were available to talk. In the example, a CU student, CU3, was unsure about which crews should be allocated to schedule activities. He knew that a UW teammate, UW3 had some construction experience and asked about crews for different schedule activities projected on the team wall. “All of these?” UW3 responded. “Sure, yeah you could, I mean … carpenters could do all the same stuff….” CU3 said, “Cool. Carpenter. That’s the word I was looking for.” The team agreed that all of the activities CU3 was projecting should be assigned to the carpenter crew. This exchange meets the operational definition of Messy Talk. The students were critically engaged. They asked questions of each other’s models, asked each other for help and made suggestions for solutions, which the team then discussed. The team sought a resolution to CU3’s known problem—what are the correct crews for the schedule? Knowledge was distributed across the team, such that students sought out each other for their perspective and opinion. CU3 had knowledge of SimVision and understood that the crew loading impacted the schedule performance, while UW3 had industry experience to share with his team. Both students were working toward improving the SimVision model. This is in direct contrast with team interactions from the first two examples in Table 3 who worked on their models independently and didn’t have a shared sense of purpose around the models but only shared data (Interaction 1) or coordinated their assignments through joint troubleshooting (Interaction 2). Even in the short example of Interaction 3 the team acknowledged the shared resolution that was a synthesis of distributed team knowledge. CU3 stated the solution they had been discussing and UW3 acknowledged this solution by saying, “Ok, that sounds good.” While the team did not discover the problem together—rather CU3 brought it to the attention the team for discussion—they resolved the issue collectively and the solution was a synthesis of the team's conversation.

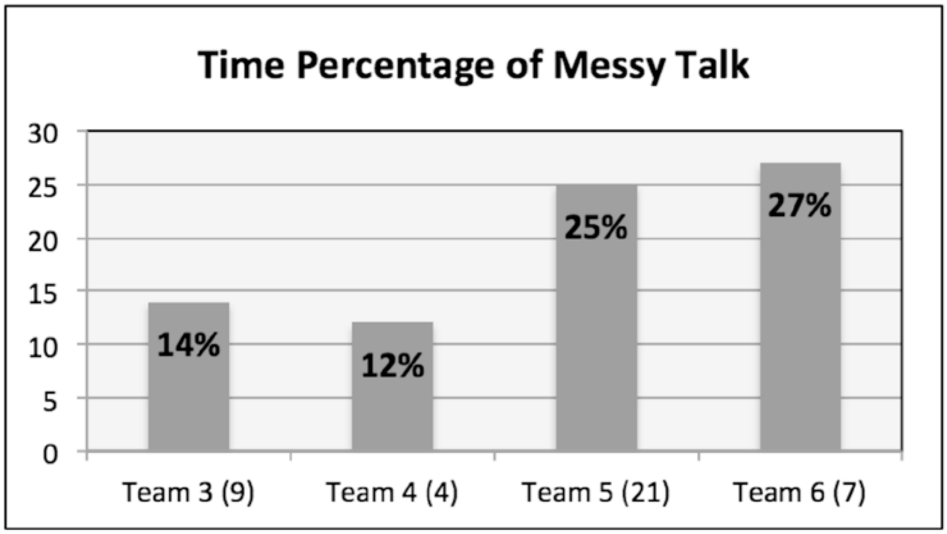
FINDINGS: MESSY TALK IN VIRTUAL TEAMS

When taken as a whole, we found a significant amount of Messy Talk interactions in the virtual world setting, (as high as 27% in Team 6.) The CyberGRID was designed to support team interaction (Iorio et.al 2011), and it appears that CyberGRID interaction affordances (e.g., avatars and the team wall) allowed these teams to transcend the prescribed boundaries imposed by "clean technology" used in the virtual world (Dossick and Neff, 2011) and engage actively, informally and flexibly. In this section, we focus on the higher level coding for each team and illustrate that (a) Messy Talk existed in each team and (b) teams varied in interaction style. This establishes a unique team "culture" that emerged from their work together. Understanding the latter will help us determine team composition, facilitation and leadership strategies that result in higher amounts of Messy Talk.

Messy Talk Can Occur in Virtual Teams

Messy Talk occurred in all four teams and the amount, as measured by time duration, varied from team to team. As shown in Figure 2, the four teams spent between 10 and 27 percent of their active dialog time in Messy Talk interactions. In this analysis, only active, intelligible discussion was coded, i.e. we removed the silences and muffled speech were discounted so that the percentages shown in Figure 2 pertain to active discussions the team members had over a 2.5 hour working meeting. The balance of discussion that did not fall under the category of Messy Talk included (1) the time the teams discussed issues and subjects that did not possess all four elements of Messy Talk and (2) time that the discussion was not related to the task such as talking about the weather or current events.

Figure 2. Percentage of messy talk duration / total meeting time

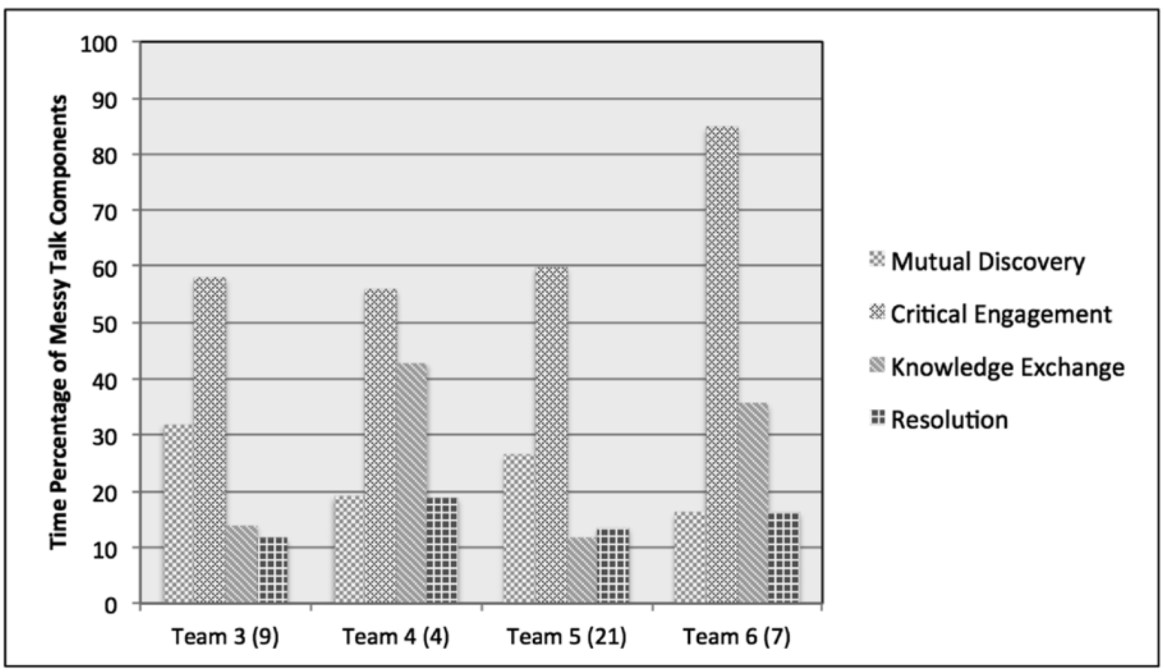


The number of Messy Talk interactions that were identified in the coding is shown in parentheses under the team identifiers in Figure 2. With regards to the ratio of Messy Talk duration and the number of interactions, Teams 4, 5, and 6 provide an interesting contrast. While each of these teams spent about a quarter of their time in Messy Talk interactions, Team 5 had a relatively high number of interactions, while Teams 4 and 6 had relatively few. In other words, Team 5 spent less time per Messy Talk interaction, while teams 4 and 6 spent more time in each discussion. Patterns of unique team styles emerged with the varying numbers of interactions and percentages of Messy Talk engagement.

Team Styles

To better understand individual team interaction, we then compared the four Messy Talk elements (MD, CE, KE, and R) across all four teams (Figure 3). There appears to be a diverse range in distributions across the four Messy Talk elements. Mutual discovery ranges from 16-32% of the Messy Talk; critical engagement interactions compose between 56 to 85% of a team's Messy Talk; while knowledge exchange and resolution discussions range between 12-43% and 13-19%, respectively. Critical engagement forms the biggest portion of Messy Talk duration in all 4 teams and also has the largest variation (29%). Resolution interactions have the lowest variation (27%) among all components of Messy Talk.

Figure 3. Messy talk performance of the teams



Each team had a style of Messy Talk pattern. While most teams have high percentages of critical engagement, some teams privilege mutual discovery (3 and 5), while others favor knowledge exchange (4 and 6). Team 5 has higher resolution than knowledge exchange. What emerged from this arrangement of the data is a possible inverse relationship between critical engagement and mutual discovery, which merits further study as this is a non-intuitive finding. One would expect that if a team is critically engaged, they would have higher levels of mutual discovery as well. But that is not the case in this data set. To understand the mechanisms behind the teams use of these Messy Talk elements, we propose that in future research we correlate these element with work place design in general and shared visualizations specifically. To learn more about constructive team interaction, we envision further study into the relationships between the four Messy Talk elements and workplace design (Whyte et al. 2008) and facilitation (Iorio et al. 2012).

From the unique Messy Talk patterns we can conclude that each team has a unique style of engaging with each other. Team 4, for example, has the highest levels of critical engagement. They question each other and reflect on the work at hand, while at the same time, their levels of mutual discovery are relatively low. In other words, they made relatively fewer discoveries, but discussed each of those discoveries at great length. This mirrors our qualitative assessment of the teams. Each team's collaboration style varied significantly. For example, Team 4 worked quietly on their individual tasks during the team session. When a team member had a question, they asked if others could "meet" and they would discuss the issue, often discovering issues together and working through them as a team. Although they worked individually, they seemed to have a strong culture of mutual responsibility for the team's work product as a whole, sharing decision-making with a relatively high level of synthesis.

DISCUSSION AND CONCLUSION

Although different collaboration and Messy Talk styles emerged for each of the teams we examined, each team worked on the same task with the same affordances of the CyberGRID virtual world. By studying teams in a virtual world we can contribute new knowledge in two key ways. The first contribution of our research is to find evidence that synthesis (Ingram and Hawthorn 2004) can occur through Messy Talk in virtual teams. As globally distributed teams mediated through technology become increasingly common, understanding whether and how virtual teams can achieve synthesis is critical. A second contribution of this research is to extend the work of Dossick and Neff (2011) to further define and operationalize the concept of Messy Talk, as well is identify the conditions under which it emerges in the work of virtual teams. Messy Talk requires that participants have knowledge that is relevant to the problem at hand and this access to knowledge directly impacted the quality of engagement (troubleshooting versus Messy Talk). From the theory building research presented in this paper, new questions emerge. We recognize that there are a variety of independent variables including industry experience, leadership, and tool usage that may impact the emergence and quality of Messy Talk.

Talk mediated by shared visualizations

Shared visualizations were used in the CyberGRID to project active model activities, as well as draft lists, e.g. list of construction activities or of questions for the client. In the three 2011 exchanges (Section 4 above), we see the shared visualizations working to support mutual discovery and critical engagement. First, in Interaction 1: Discovery, the CU students watch the UW team work on the 4D model. From viewing this shared visual representation of the 4D model through their own domain lens, SimVision schedule development, they realize the stairs are missing from their own model. This connects with Suwa et.al. (2000)'s notion of "unexpected discoveries", but lacked tacit knowledge exchange (Whyte et. al. 2008) that makes team collaboration so powerful.   Second, in the Interaction 2: Troubleshooting, there is active use of the shared visualizations. The team shares their screens in an iterative fashion to show the others what the data looks like, first in SimVision, then in Microsoft Project and then in Navisworks. They use the digital pens to point out the problems with the data, and update the models in real time as they go through the trial and error process to fix the issue. This interaction illustrates the team's use of a flexible medium that Dossick and Neff (2011) argue is so important, but lack the knowledge within the team to resolve the issues. In Interaction 3, the team shares the SimVision model that shows a list of activities, and the team discusses crews and activities as they are shown on the screen. This team establishes a shared context through the team screen, and then uses this shared visualization both communicate knowledge and learn as a team (Whyte et. al. 2008).

Just at the work of Whyte et. al. (2008) suggests, in this study we can conclude that the student teams in CyberGRID actively used their shared visualizations for mutual discovery, critical engagement and knowledge exchange with each other’s documents and models. We propose that the active use of the models during meeting sessions made them active and flexible, and thereby supported Messy Talk interactions (Dossick and Neff 2011). Throughout the collaborations, the student teams in CyberGRID sought active, flexible and informal means to collaborate in the virtual world, and the pen based affordances enabled virtual “white board” work and the corresponding Messy Talk that occurs there (see Figure 4). For example, some of the teams chose to use shared google docs, to jointly edit their reports and presentations in real time. In this study, the affordances of the CyberGRID (Iorio et. al. 2011) including team screens, voice, avatars and models, support Messy Talk; from this we conclude that the CyberGRID affordances provide flexible and active work spaces (Dossick and Neff 2011) that engender Messy Talk for distributed teams.

Figure 4. Team 1 working in the CyberGRID Collaboration space

Future Research

Many questions emerged throughout this study that merit further analysis. Through this process we have gained a much more detailed and concrete understanding of how to identify

Messy Talk. This research opens up questions about how the technological affordances support the emergence of Messy Talk interactions. Furthermore, questions remain as to the quality of the Messy Talk exchanges themselves as well as the quality of resolutions that emerge from virtual team interactions. Design and construction is a collaborative process. Ingram and Hathorn (2004) define rich collaboration as including synthesis of new knowledge. While we see some of the team interactions in this study stop at simpler problem resolution through individual decision-making, the questions remain as to if virtual teams can achieve meaningful and engaged Messy Talk that engenders synthesis of new knowledge. The quality of synthesis could be based on the level of innovation, how directly synthesis impacts achievement of assignment solution, and to what extent it is driven by the exchange of knowledge. Do the four elements of Messy Talk need to appear in sequence, or are there preferable Messy Talk element sequences? If there are preferable sequences, how are these supported by technology, facilitation and leadership? Furthermore, since knowledge exchange is a critical aspect of Messy Talk and key to meaningful synthesis, a comparative study of novice versus experienced team members may shed light on the relationship between of industry experience and Messy Talk development. As a social process, other variables may also significantly impact the team interaction. For example, leadership and team facilitation may play a role in the ways that the team overcome technical limitations and engages in Messy Talk. What are the benefits of Messy Talk that may outweigh the effort and expense of dialog between experts around shared problems? There are a number of questions here that can be categorized by 1) how to we achieve Messy Talk through workspace design, visualization and management strategies? And 2) what are the benefits of Messy Talk?

Conclusion

This paper outlines theory-building research in virtual AEC teams that contributes a framework for characterizing team interactions. The operational definition shown in Table 2 allows us to use Messy Talk to identify when teams are synthesizing knowledge. These are interactions that Cleveland (1999) characterizes as "intuition, flexibility, guesswork, research, and curiosity." With this operational definition, then, we are able to identify instances of guesswork, research and curiosity (in Messy Talk terms: discovery, critical engagement, knowledge exchange and resolution (synthesis)). We can then see if virtual teams are able to work in these ways, or if, as some of the literature suggests (e.g. Dossick and Neff 2011), they might be discouraged by the technology affordances to interact. We have shown that Messy Talk can occur in virtual student design and construction teams. The nature of this Messy Talk interaction is emergent and varied across the teams. We observed active engagement in real time model development as a means to breaking down the formal perception of shared models. We also saw teams creatively use alternative tools such as a shared whiteboard and shared document for collaborative work. There are future research opportunities to study how and in what ways industry experience, leadership and technical affordances of virtual worlds impact the development of Messy Talk and the qualities of synthesis team members are able to achieve.

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