Viewing an Interdisciplinary Human-Centered Design Course as a Multiteam System: Perspectives on Cooperation and Information Sharing

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Abstract: *Many design projects, including human-centered design (HCD) projects, incorporate multiple teams cooperating within what is referred to as a Multiteam System (MTS) environment. These teams mutually rely on resources and processes provided by other teams. As an MTS increases in complexity, knowledge is distributed to more individuals. While effectively distributed knowledge increases creativity and productivity, it is also can hinder team effectiveness. Team members may fail to exchange relevant information or to integrate pertinent information into reasoning for design decisions. Our research addresses information sharing among teams and individuals in HCD by examining interactions between and within the MTS (i.e., instructional team, novice designer or student team, and stakeholder team) in an interdisciplinary design course. Specifically, we used a thematic analysis of design reviews to investigate the influence of information requests toward the quality of the information exchanged, the influence of meeting structure and flow on design team interactions and meeting outcomes, and the influence of information sharing on cooperation within the HCD process. The findings align with previous studies about information sharing in a MTS and also contribute to a broad understanding of how an integrated interpretation of information sharing can influence a cooperative design process, such as HCD. Our analysis also suggests that designers must promote a cooperative decision-making process by eliciting open and unique information relevant to the design goals. Finally, design educators can support the development of novice engineers by improving their understanding of how to elicit information from, and share information, with other teams and stakeholders.*

Keywords: Multiteam System (MTS), Human-Centered Design, Information Sharing, Cooperation, Interdisciplinary Design, Cooperative Design, Information Openness, Information Uniqueness

1. Motivation

A human-centered design (HCD) approach brings the concerns of different project stakeholders to the forefront and emphasizes interactions between these stakeholders and the designers throughout the design process (Zoltowski, 2010). This cooperative approach provides designers with an opportunity to design with an understanding of the needs of the critical stakeholders in a project, including the client and the end user. Yet, to adequately define these needs, the designers must engage in a meaningful dialogue with their stakeholders and not assume that the

stakeholders will be provide a list of needs that accurately define the problem to the designers (Gibson, Scherer, & Gibson, 2007).

The social boundaries between entities interacting within an HCD approach can be viewed as a Multiteam System (MTS). Within a MTS, different teams of individuals (e.g., designers, manufacturers, and stakeholders) mutually rely on resources and processes provided by the other teams to contribute toward a final design solution. Yet, while teams within a MTS share at least one distal goal, team-level goals and constraints do not necessarily align (Marks, Mathieu, & Zaccaro, 2001; Mathieu, Marks, & Zaccaro, 2001), which is especially true in complex system design and many HCD projects. For example, the overall goal of commercial aircraft design is a safe and marketable aircraft. In the design of technical components, however, the immediate goals of the propulsion group (an efficient and powerful propulsive device) may not align with regulatory stakeholders such as the Federal Aviation Administration (minimal noise and emissions).

As an MTS increases in complexity, knowledge is distributed to more individuals. While effectively distributed knowledge increases creativity and productivity, it is also can hinder overall team effectiveness (van Ginkel & van Knippenberg, 2009). Team members may fail to exchange relevant information (Stasser & Titus, 1985; van Ginkel & van Knippenberg, 2009) or to integrate pertinent information into reasoning for design decisions (van Ginkel & van Knippenberg, 2009). Team members' approaches to sharing information thus become an important feature of effective team coordination (Bunderson & Sutcliffe, 2002; Jehn & Shah, 1997; Mesmer-Magnus & DeChurch, 2009). Information sharing is defined as the collective exchange and utilization of knowledge and expertise previously held by a limited number of group members (Stasser & Titus, 1985; Miranda & Saunders, 2003; Mesmer-Magnus & DeChurch, 2009). Research in information sharing has demonstrated a need to examine the effects of the relevancy and newness of the information exchanged among teams and team members to support group decision-making and overall performance of the MTS (Stasser & Titus, 1985).

Previous research has investigated the exchange of information along two dimensions, openness and uniqueness, yet limited work has been done to jointly consider these two dimensions (Mesmer-Magnus & DeChurch, 2009). The openness of information sharing broadly describes team communication related to goals, progress, and coordination (Henry, 1995; Jehn & Shah, 1997; Mesmer-Magnus & DeChurch, 2009). The uniqueness of information sharing is related to the number of members with access to a piece of information (Hinsz, Tindale, & Vollrath, 1997; Mesmer-Magnus & DeChurch, 2009). Related to the HCD approach, designers attempt to uncover hidden profiles held by the stakeholder by engaging in a meaningful, open and unique, dialogue. Yet, in discussing alternatives, unique information is often not exchanged in favor of rephrasing and repeating common information (Lightle, Kagel, & Arkes, 2008).

Additionally, it is critical to consider the expertise of the designer, which can cause knowledge needs, awareness, and requests to vary (Ahmed & Wallace, 2004). Novice designers may ask relevant questions when aware of their knowledge needs, leading to pertinent information sharing. However, when novice designers are unaware of their knowledge needs, they are subsequently unable to ask questions or to employ a clear design strategy that is capable of learning to the pertinent information sharing. Conversely, expert designers tend to employ a

well-defined design strategy when problem-solving, without being explicitly aware of the utilized strategic knowledge (Ahmed, Wallace, & Blessing, 2003). Thus, in supporting effective information sharing and promoting cooperative design decisions within HCD, considerations must be made for the expertise of the designer as well as their ability to integrate information from various sources.

Our research addresses information sharing in HCD by examining interactions between and within a MTS of instructors, students (i.e., novice designers), and stakeholders in the context of an interdisciplinary design course. Specifically, we used a thematic analysis of design reviews to investigate three research questions:

(1) What characteristics of interactions support or hinder the quality of information sharing in a multidisciplinary Multiteam System?
(2) How do these characteristics specifically affect the cooperation between designers and stakeholders in a human-centered design process?
(3) How could these characteristics impact the structure and flow of design reviews and team meetings?

2. Methods

To examine information sharing in the context of a MTS, we analyzed transcripts of design conversations that took place during a three-week undergraduate interdisciplinary service-learning course. The boundaries of the MTS are comprised of interactions among and between three types of participating entities: instructors, novice designers (i.e. students), and stakeholders. In this case, the term "novice designers" is used to illustrate that many of these students have limited experience and formal training in design. These novice designers used a HCD approach, wherein they interacted frequently with the system users and other stakeholders, to design a treehouse for a local camp serving children with disabilities. The design discussions varied based on meeting purpose and present entities. Table 1 outlines the analyzed meetings, and Table 2 lists the team members and their associated entity.

We used a thematic analysis incorporating two coding schemes to characterize design team interactions. For each meeting, we sorted the conversations using a high-level interpretation of discussion topics that took place within a meeting. Individual statements were coded more thoroughly according to the specific classification of information that was requested or exchanged. The integration of results occurred during the interpretation phase, enabling us to explore the influence of information sharing on the HCD approach and individual meeting outcomes.

Table 1. Detailed overview of analyzed design discussions

Meeting	Involved Entities	Meeting Purpose	Length of Meeting (min)
Partner Debrief 1	Novice Designers, Stakeholders, Instructors	Partner Debrief: Initial meeting to discuss project	40
Brainstorm Meeting	Novice Designers, Instructors	Group Critique: Review results of brainstorming activities	60
Partner Debrief 2	Novice Designers, Instructors, Stakeholders	Partner Debrief: Clarify issues about the project	30
Advisor Debrief 1	Instructors	Advisor Debrief: Discuss student progress	10
Advisor Debrief 2	Novice Designers, Instructors	Group Critique: Debrief current progress and identify next steps	10
Partner Review	Novice Designers, Stakeholders, Instructors	Interim Review: Present progress to stakeholders	20
Experience Debrief	Novice Designers, Instructors	Advisor Debrief: Student reflect on experiences	8
Final Review	Novice Designers, Stakeholders, Instructors	Present work to external reviewers	40

Table 2. Team members and primary entity

Entity	Name
Stakeholder *(STK-Name)*	Dominic, Michael, Todd, Jessica, Charlotte
Facilitator *(FAC-Name)*	Cate, Ellie
Novice Designer *(ND-Name)*	Claire, Clark, Jordan, Jackie, Jia, Mackenzie, Naomi, Richard, Stephen, Cole, Alison, Savannah

2.1 Design Meeting Activity

The design discussions were grouped based on general discussion topics and design meeting activities that took place within a specific design review. From the literature, design meeting activities have historically provided a generalizable interpretation of design discussions (Olson, Olson, Carter, & Storrosten, 1992). The design meeting activities were distinguished from ten categories originally outlined in the work of Olson and colleagues (1992), Table 3, and were coded based on discussions between two researchers:

Table 3. Categories of design meeting activities, from Olson et al (1992)

Issue	Major questions, problems, or aspects to be addressed. This includes the elaboration of the idea, description not in answer to a group member's question. Occasionally, the issues are not stated explicitly but can be inferred by the presentation of two alternative solutions.
Alternative	Solutions or proposals about aspects of the designed object. These are typically either features to offer the user or ways to implement the features decided on so far.
Criterion	The reasons, arguments, or opinions that evaluate an alternative solution or proposal.
Project Management	Statements having to do with activity not directly related to the content of the design, in which people are assigned to perform certain activities, decide when to meet again, report on the activity (free of design content) from previous times, and so on
Meeting Management	Statements having to do with orchestrating the meeting time's activity, indicating that the group members are to brainstorm, decide (and vote), hold off on discussions, and so on.
Summary	Reviews of the state of the design or implementation to date, restating issues, alternatives, and criteria. It is a summary if it is a simple list-like restatement. If it is ordered by steps, it is a walkthrough
Goal	Statement of the purpose of the group's meeting and some of the constraints to work under, such as time to finish or motivating statements about how important this is.
Walkthrough	A gathering of the design so far or the sequence of steps the user will engage in when using the design so far, used to either review or clarify a situation.
General Clarification	Misunderstandings are elucidated. Clarifications serve to clear up misunderstandings from other individuals.

2.2 Information Request and Exchange

The conversations were categorized based on the type of information that was requested (i.e., requests) and the type of information that was exchanged (i.e., exchanges). Specifically, an individual speaker's statements were segmented into blocks of data (e.g., single sentence, multiple sentences, or paragraph) depending on whether the statements represented an information request or exchange within the overall conversation. The types of information requests and exchanges were adapted from the Collaborative Learning Conversation Skill Taxonomy (McManus & Aiken, Richard, 1995; Soller, 2002). Two researchers piloted the code presented in Soller, (2002) using excerpts from three design meetings. Through an initial assessment of interrater reliability, the researchers acclimated to the categories and adapted them for use with the design discussions. Specifically, the code descriptions were expanded to better articulate how the research team interpreted the categories and the types of information requests and exchanges occurring within the data. For example, during Partner Debrief 2, ND-Clark asks STK-Todd, "What do you see as emergency strategies or what would be most effective?" This question was coded as a Request-Opinion. ND-Clark was asking for STK-Todd's opinion on emergency strategies. In response to the information request, STK-Todd responded "I think one

of the things Dominic's talked about was just, you know, they have all their emergency stuff with them..." STK-Todd's response was coded as an Exchange-Rephrase. STK-Todd rephrased information STK-Dominic previously gave the designers. Cohen's Kappa for the final assessment of the design meeting excerpts was 0.8 for the "Exchange" categories and 0.84 for the "Request" categories. Finally, the transcripts were divided among the two researchers and coded separately. The final coding scheme is outlined in Table 4.

Table 4. Information Request and Exchange coding scheme adapted from the Collaborative Learning Conversation Skill Taxonomy used in Soller, 2001

Request	Information-based	Ask 'What', 'When', 'Where'
	Elaboration	Requests to expand information, add more detail
	Clarification	Ask 'Why' or 'How'
	Justification	Why questions associated to someone's perspective or opinion
	Opinion	Ask for someone else's opinion
	Illustration	Asking to physically show an example
	Elicit	Statement that is NOT a question and would otherwise be coded as elaboration or justification
Exchange	Rephrase	Repeating the same thing without new information
	Lead	Evidence of taking control of the conversation, tasks, or project
	Suggest	One thought or sentence with an alternative or choice
	Elaborate	New information embedded in old information. Includes illustrations if text is elaborating on the artifact being displayed
	Explain	New objective information
	Justify	Why something was mentioned or suggested
	Assert	Opinion statement or a statement of agreement/disagreement
	Inadequate	Inadequate information or response that evades directly answering the question. Using humor to deflect.
	No Info	Can't provide the requested information

2.3 Data Analysis and Interpretation

The next phase of the analysis process included a holistic evaluation of the quality and use of information shared through design team interactions within each design review and across design reviews. We analyzed the eight design discussions, listed in Table 1, focusing on the types of information requests and exchanges that were made in each meeting. Within our analysis, a high quality of information sharing was evidenced by conversations that provided relevant information requests and exchanges contributing to the overall decision-making and the development of a final design solution. To understand the quality of information sharing in this context, we examined several factors: (1) the breadth and depth of the conversation following information requests, (2) the evolution of the conversation following the request for or exchange of new information, (3) the alignment between the meeting purpose and the depth and breadth of

information exchanges, and (4) the overall openness and uniqueness of the information sharing during the design meeting.

Breadth and depth are related to how many topics were covered in one discussion and how extensively those topics were discussed (Miranda & Saunders, 2003). Further, depth and breadth are noticeable through the evolution of a conversation. As speakers elaborate on one topic or change topics, the conversation naturally flows into new, unshared knowledge. The purpose of a meeting has impact on the type of information shared within a discussion and subsequently the breadth and depth of the conversation. For example, a design status review might cover many topics (high breadth) but not deeply elaborate on any particular concept (low depth). Finally, the openness of information sharing broadly describes team communication related to goals, progress, and coordination (Henry, 1995; Jehn & Shah, 1997; Mesmer-Magnus & DeChurch, 2009). The uniqueness of information sharing is related to the number of members with access to a piece of information (Hinsz, Tindale, & Vollrath, 1997; Mesmer-Magnus & DeChurch, 2009).

Within-case and cross-case analysis methods from Miles & Huberman (1984) provided an opportunity to more closely examine the uniqueness and openness of the information shared within and across the different design team meetings and for the different teams. These methods allowed us to study the entire flow of conversation within a particular meeting and, for instance, compare it to the meeting purpose. In addition, affinity diagrams (Beyer & Holtzblatt, 1998) and code mapping (Miles & Huberman, 1984) supported our individual and collective exploration of the interplay of key attributes of information sharing with critical characteristics of design team interactions. The speaker's entity (i.e., novice designer, instructor, or stakeholder), for instance, was considered and conversations were evaluated for how information was shared across entity boundaries. As an example, one analysis was based on how the novice designers shared information with each other compared to how the novice designers shared information with the stakeholders.

3. Results and Discussion

A tabulation of the types of information requests organized by meeting is depicted in Table 5. The types of information exchanges organized by meeting is depicted in Table 6. Within the design meetings, the number of requests and exchanges varied by the meeting purpose and the attending entities. Moreover, the information sharing that occurred within every meeting included very few requests, with most of them being specifically information-based requests, when compared to the other categories (i.e. requests for opinion, elaboration, clarification, illustration, or justification or an information elicitation).

While the tabulation of information requests and exchanges gives an insightful overview of design team interactions, a more comprehensive picture emerges when considering the quality of those interactions. This lens allowed for characterizations of design team interactions as revealed through information requests and exchanges. Three major themes emerged from this characterization: 1) Eliciting Relevant Information Sharing, 2) Aligning Meeting Purpose and Information Sharing, 3) Using Information to Make Design Decisions. Particularly, these themes highlighted the influence of information requests toward the quality of the information exchanged, the influence of information sharing on cooperation within the HCD process, and the influence of meeting structure and flow on design team interactions and meeting outcomes.

Table 5. Requests organized by meeting

	Total		Partner Debrief 1		Brainstorm		Partner Debrief 2		Advisor Debrief 1		Advisor Debrief 2		Partner Review		Advisor Debrief 3		Final Review	
Information-Based	88	49%	11	44%	21	54%	19	39%	3	60%	5	36%	4	67%	9	90%	16	52%
Opinion	35	20%	4	16%	7	18%	19	39%	1	20%	3	21%	1	17%	0	0%	0	0%
Elicit	18	10%	4	16%	3	8%	6	12%	0	0%	0	0%	1	17%	1	10%	3	10%
Elaboration	17	9%	3	12%	5	13%	2	4%	1	20%	2	14%	0	0%	0	0%	4	13%
Clarification	15	8%	2	8%	2	5%	1	2%	0	0%	4	29%	0	0%	0	0%	6	19%
Illustration	4	2%	1	4%	1	3%	1	2%	0	0%	0	0%	0	0%	0	0%	1	3%
Justification	2	1%	0	0%	0	0%	1	2%	0	0%	0	0%	0	0%	0	0%	1	3%
Total	179		25		39		49		5		14		6		10		31	

Table 6. Exchanges organized by meeting

	Total		Partner Debrief 1		Brainstorm		Partner Debrief 2		Advisor Debrief 1		Advisor Debrief 2		Partner Review		Advisor Debrief 3		Final Review	
Elaborate	429	24%	42	21%	153	25%	56	21%	25	22%	12	14%	25	19%	18	23%	98	36%
Assert	342	19%	36	18%	132	21%	50	19%	42	36%	17	20%	17	13%	32	41%	16	6%
Justify	274	16%	20	10%	87	14%	45	17%	11	9%	16	19%	32	25%	12	15%	51	19%
Explain	205	12%	24	12%	56	9%	13	5%	4	3%	8	9%	15	12%	13	16%	72	27%
Rephrase	202	11%	41	21%	68	11%	37	14%	15	13%	8	9%	12	9%	2	3%	19	7%
Suggest	176	10%	20	10%	82	13%	31	12%	13	11%	5	6%	18	14%	1	1%	6	2%
Lead	102	6%	2	1%	37	6%	21	8%	5	4%	20	23%	10	8%	1	1%	6	2%
Inadequate	20	1%	8	4%	1	0%	9	3%	0	0%	0	0%	0	0%	0	0%	2	1%
No info	10	1%	3	2%	3	0%	2	1%	1	1%	0	0%	0	0%	0	0%	1	0%
Total	1760		196		619		264		116		86		129		79		271	

3.1 Eliciting Relevant Information Sharing

As previously noted, the HCD approach provides designers with an opportunity to design with an understanding of the needs of the critical stakeholders in a project, including the client and the end user. The literature emphasizes the use of conversations among designers and stakeholders to solicit information to improve design decisions and ideation (Maguire, 2001; Titus, Zoltowski, & Oakes, 2011). Our analysis of design meeting conversations illustrated that **the types of requests made by the novice designers limited the information shared by the stakeholders** and subsequently limited the designers' access to unique and open information.

In the Partner Debrief 2, for instance, the openness of the conversation was limited by the novice designers' primarily opinion and information-based requests. The novice designers' requests focused on one-dimensional design considerations and posed issues that appeared to be trivial to the stakeholder. When ND-Jackie inquired about overnight considerations, for example, her question didn't focus on any particular aspect of the design. Subsequently, STK-Todd gave a response that provided little understanding of the stakeholders' needs.

> *ND-Jackie*: And any overnight considerations. You guys were saying that they want the campers to stay overnight.
> *STK-Todd*: Um, no. I mean I think the concerns, you know, being up there overnight are really the same as they are if they're during the day. I mean can, can you fall over? Can you get hurt?

In the remainder of the conversation, the designer did not ask the stakeholder to clarify or elaborate his response. Without a more probing follow-up request, the designer was unable to identify other contributing characteristics of the design problem. This also influenced the discussion later during the Partner Review when the designers noted confusion about the availability of electricity. This design characteristic may have been addressed during Partner Debrief 2 through a request to elaborate further on what the stakeholder meant by daytime and nighttime concerns.

Additionally, the novice designers' requests in Partner Debrief 2 limited the uniqueness of the information shared by the stakeholder. Specifically, the novice designers tended to precede or justify questions with other (non-present) stakeholders' preferences and suggestions. For example, in a meeting with STK-Todd, ND-Clark inquired about emergency exits by discussing STK-Dominic's preferences. STK-Todd responded by rephrasing STK-Dominic and expressing his lack of concern for that issue.

> *ND-Clark*: So in our meeting yesterday with Dominic, a question came up about maybe emergency exits. ... I mean – that was what I got out of it. He seemed to think a ramp would be enough. What do you see as emergency strategies or what would be the most effective?
> *STK-Todd*: Yeah. And I, I think one of the things Dominic talked about was just, you know, they have all their emergency stuff with them, so if something were to happen, it mostly would be with it right there. So there's not necessarily this huge concern that, 'Oh, my gosh. We gotta get them down to get to X.' You know what I mean?

As the conversation continued, the novice designers attempted to elicit more information from STK-Todd. However, STK-Todd continued to repeat information that was already available to the novice designers. The initial comment about STK-Dominic's preferences may have caused STK-Todd to not offer any novel considerations. The designers could have rephrased their initial question to request an elaboration or clarification. For example, the novice designers could have asked, "Can you tell us about your emergency procedures?" or "How do you plan for emergencies?"

A critical moment to increasing the openness and uniqueness of information sharing in Partner Debrief 2 occurred when the stakeholder proceeded to perform an illustrated design walkthrough. **A design walkthrough was found to be beneficial in eliciting information exchange across entity boundaries and uncovering potential design issues**. At one point, ND-Stephen asked STK-Todd about access prevention. STK-Todd responded with "It depends" and then initiated an illustrated example to elaborate on the complexities of access prevention.

> *ND-Stephen*: Yeah, but I, I think maybe a more directed question would be should the access prevention be at the platform or at the treehouse...."
> *STK-Todd*: …It depends which way, which, which way you go here. It can go either way.
> *ND-Stephen*: Okay.
> *STK-Todd*: Yep. So, because you're going to have a zip line. *[Todd drawing on paper]* If this is the current zip platform, here's the current zip line that goes this way, some way, shape, or form, it may end up looking – this is kind of to be determined either zip lines can go this way. … But, um, if you restrict access to that platform, that works just a well, and may be easier to plan on right now since the second zip line isn't in place.

STK-Todd's initiation of an illustrated design walkthrough evolved into multiple topics and design issues, such as storage, lighting, and a wheelchair ramp. Yet, since the stakeholder led the design walkthrough, much of the exchanged information was not necessarily relevant to the novice designers, as the end design did not incorporate many of the design features referred to by STK-Todd during the walkthrough. Thus, the designers might have elicited more relevant information had they led the design walkthrough.

At multiple points in the design meetings, the novice designers noted confusion about the desired design specifications and final product. In the Partner Debrief 1, for example, the novice designers asked the stakeholders for the preferred format of the final product. The stakeholders noted that they were not concerned with the details of the design.

> *ND-Mackenzie*: I have a question for you guys. So in terms of like – well, like what exactly would you like the most useful thing we can give to you to use? Do you want an actual kind of undeveloped design that's kind of rough? Do you want a list of ideas or things that we think would be great to incorporate? I mean what is going to be most useful to you in terms of making this real?
> *STK-Dominic*: I could say yes to all the above.
> *STK-Michael*: …This is a big great space so design elements whether particularly interesting or innovative that you might be able to dream up to we may not think of or the designers may not think of specifically with assisting these kids that might not be

> common sense to us with creating lot of design over and over, but this is something unique that you can wrap your minds around. But as far as getting into the detail design or structural *[unintelligible]* or spatial relationships, um, it could be generalizable.

However, in the Partner Review, the stakeholders requested a more detailed design product.

> *STK-Unknown*: Great. Will your model be – will it – you know, I want to give this to Abby Inc. and one of the things they need to know is how long and how wide, the interaction of trees. Will it include all those specs in it?
> *ND- Naomi*: Well, a lot of that we didn't do because we weren't, architecture is not really our expertise. And so our kind of focus was mainly the conceptual design and then our initial intent was just the architect would kind of take care of details, especially with the different numbers of capacity. You know, we weren't really sure how big to build it and how to make it – you know, make sure it could hold the weight. We don't really have that expertise, so we didn't want to tread on anybody's shoes.
> *STK-Unknown*: Sure, sure. Okay.
> *FAC-Cate*: I think there's some general ideas from, you know, where you've pointed out and that Todd has pointed out about where outlook points would be that we could incorporate with that, and we have measured where specific trees are...But some of those really fine details of exactly where that layout, you know, we have not done.
> *STK-Unknown*: Yeah, just a rough estimate would actually help for building materials.

In this scenario, **the distribution of knowledge between designers and stakeholders led to an unshared representation of the design task** (van Ginkel & van Knippenberg, 2009). Further, even in recognizing the unshared task representation, the novice designers did not adequately request an elaboration on the desired design product. The design team (designers and stakeholders) might have reflected on the design task earlier in the process, leading to an improved elaboration of the task requirements (van Ginkel & van Knippenberg, 2009). For example, the novice designers might have asked "How will our design be incorporated?" or "Can you tell us more about design expectations and how the design artifacts will be used?"

3.2 Aligning Meeting Purpose and Information Sharing

The purpose of a meeting can influence the present entities and the incorporated boundary objects, artifacts, and meeting activities. Within this instance of a MTS, **the outcomes of a meeting were found to be influenced by the implicit and explicit meeting purpose, as well as the alignment of information sharing strategies and the meeting purpose**.

One example of successful alignment and the use of an explicit meeting purpose is the Brainstorming Meeting. The purpose of the Brainstorming Meeting was to brainstorm potential design features and identify potential design considerations. The novice designers also wanted to ensure that all team members shared ideas equally. ND-Jia provided the general meeting structure to the group, "So now, we just roughly see what the other group member thinks and get some inspiration and get more sketches and find out what problem we may face." The information exchanges were primarily elaborations on a proposed design feature and opinion-based assertions from the other designers about discussed design features. **The explicitly stated**

purpose of the Brainstorming Meeting appeared to encourage open and targeted information sharing.

The implicit purpose of the Partner Review, on the other hand, was to present designer progress to the stakeholders and gather stakeholder feedback on proposed design ideas. As such, we might expect the stakeholders to request elaboration or justification of design decisions, and novice designers to request more detailed information to address misunderstandings. However, very few information requests happened during the meeting. The analysis illustrated how the meeting purpose was not well aligned with the information sharing strategies used by either entity. Moreover, at one point in the meeting, the novice designers acknowledged conflicting information without requesting a resolution,

> *ND-Naomi*: Okay. So the first two things, the reason we have a question mark, we actually got different specs from different people we talked to. We just kind of want to make you guys aware of that, that there was –... Kind of ideas from Todd and Dominic. Some people said 10, some said 20, some said 40-person capacity. And then electricity, I know when we were talking with you, you said no electricity, but we were talking with Dominic he actually said if we have camper we have to have electricity there. So just something for you guys to consider.

The Experience Debrief was a unique meeting in relation to the other meetings examined in this study. The purpose of the meeting was not to come to a particular design decision, but to reflect on the impact of the designers' experiences with the stakeholders and to share those experiences with one another and with the instructional team. The instructors could then use the reflections from this meeting in the design of future iterations of the course. Throughout the meeting, the facilitator, FAC-Cate, attempted to create an "open" environment for the designers to share their experiences with one another. For example, she shared her thoughts and experiences, in an effort to make students feel comfortable and to give them a model of the type of experiences they could share and how to share those experiences. However, only a few students shared. This lack of sharing could be attributed to the information request strategy she employed (i.e. the types of questions she posed to the group). For instance, she began the meeting eliciting information from the students, rather than posing a question.

> *FAC-Cate*: If there is just a camper that really struck you, an experience that really struck you, um, if you just wanted to share that and just have this as a time, um, to kind of think about any of those. So anybody can go, it's just really informal kind of thing.

When she asked other students to share, she utilized only information-based requests. "Any other stories, favorite campers?" Thus, similarly to the novice designers' experiences requesting information from stakeholders, **the types of questions used by the instructor may not have supported the type of reflection that was desired within this meeting**.

3.3 Using Information to Make Design Decisions

Throughout the design meetings, the novice designers, instructors, and stakeholders incorporated a variety of boundary objects and activities to elicit relevant and useful information sharing. In

Advisor Debrief 2, for instance, the designers mentioned using a variety of communication methods and activities to elicit design features from the children who would be using the treehouse.

> *ND-Richard*: I think the diversity and multiple means of communication. We had them drawing, we had them writing the words. We went around and talked with them. Some kids can't draw and some kids can't verbalize ideas as well, so giving them a different means of communicating.

Subsequently, in the Final Design Review, the novice designers referenced stakeholder information as a justification for design decisions.

> *ND-Stephen:* Sensory. So a lot of our stakeholders really wanted, something that the kids could touch and see and play with physically and interact with. … And also playing with instruments. Being able to play with music was big for them. So some of the concepts that we came up with based on their ideas was a sensory wall. … And then musical boards, this was a great one that someone came up with, where someone on a wheelchair could actually roll over the floor and it would make a song, like from musical piano or something like that.

By using a variety of boundary objects to request information about the design problem, the designers elicited relevant and useful information from the stakeholders.

Within the Brainstorming Meeting, the designers used stakeholder considerations in constructing initial ideas for design features. Often, suggested features were justified by rephrasing conversations with stakeholders or by describing the feature from a stakeholder's point-of-view. For example, at one point in the meeting, ND-Jia discussed the importance of including the surrounding environment of the design.

> *ND-Jia*: But another problem that I saw from here is the lake – we did not consider that. Why they choose position next to the lake… I mean most of our idea do not have a concern about this position. And I think that's a very important point for presentation tonight with [the stakeholders]. Because that's why they choose that place. So, for example, the ramp design. Or the observation view can have a lake consideration…

Following ND-Jia's comment, the novice designers incorporated the lake more explicitly in the treehouse design when describing design features to the stakeholders in the Partner Review.

> *ND-Clark*: So after talking with you guys and the campers, it seemed one of the main objectives was to get the kiddos off the ground and into the trees and connect more with nature. [S*howing a paper with a picture on it*] So just one example here is, um, this is actually illustrating a cheering platform… but it can also represent, you know, maybe on the other side of the ramp, uh, an observation deck. So they could look out over the lake, they're looking in the treetops...

As discussed earlier, the purpose of the Brainstorming Meeting was to brainstorm potential design features and identify potential design considerations. The meeting purpose aligned well with the open approach to information sharing. **Overall, the open information sharing among**

the designers contributed to an aligned understanding of potential stakeholder considerations, and ultimately to cooperative design decisions.

One outcome of the design project was a list of raw ideas that could be potentially incorporated into future, detailed designs. Many of these ideas were generated during the Brainstorming Meeting, but were not abstracted on in later phases of design. For example, the novice designers discussed incorporating handprint wall as a way for campers to leave a small memory at the campsite. FAC-Ellie elaborates on this suggestion by discussion the meaning behind the handprint wall.

> *ND-Clark*: It'd be really cool if each kid could make their handprint and put it on, and ... come back and be like, 'Hey, there's my handprint on part of this.'
> *FAC-Ellie*: I think it might be cool if there's a way to encourage kids to come back, if maybe that's a good graduation thing. So that's part of you graduating... this is your mark on the camp.

Later, the novice designers suggest including a handprint wall in the final design. However, the concept of the handprint wall, as a way for the campers to leave a mark after graduation and encourage them to return, was never abstracted beyond the initial idea.

The novice designers selected design features through a voting system. At the end of the Brainstorming Meeting, the designers each voted for their three favorite ideas, and those ideas that had the most votes were presented to the stakeholders. **If the novice designers wanted to incorporate a more detailed design, or abstract on the generated ideas, the method of decision making may have excluded additional opportunities for elaborating and clarifying critical design features.** This approach was suggested by one novice designer but was not used by the design team.

> *ND-Jia*: I have suggestion, like probably, you can choose one of the cool idea, and really build a quick mockups off that. So using the paper that we have, like just build a quick mockup of that to show your idea in a more clear way, because this drawing is not enough. So that's one suggestion, another suggestion you can – if you don't like really mockup, you can just draw it in a clear way...
> *ND-Naomi*: Okay, What – can you explain that check system?
> *ND-Jia*: Oh, we also have the check system for choosing the idea, sorry.

4. Implications and Contributions

Through this thematic analysis of design team meetings among a MTS within an interdisciplinary HCD design course, we examined three key relationships: the relationship between information requests and the quality of information exchanged, the relationship between information sharing and cooperation within the HCD process, and the relationship between meeting outcomes and the meeting structure and flow. The analysis revealed three major themes related to (1) eliciting relevant information sharing between teams and team members, (2) aligning meeting purpose and information sharing, and (3) using information to make design decisions. These results have implications on the approaches used by designers on MTS and

HCD projects as well as on design educators as they support the development of novice designers.

The role of information requests and strategies for eliciting information has been acknowledged as an essential component to guiding the outcome of design discussions (Cardosa et al, 2014). Incorporating information request strategies that elicit reflection from the respondent, when applied to a HCD approach or MTS context, can support collective reflection toward shared representation within and among the teams. In the context of a HCD approach to design, designers engage in design as a learning process, learning more about the stakeholders and possible solutions within each stage of the design (Adams & Atman, 2000; Crismond & Adams, 2012). This learning process requires designers to practice reflective inquiry both individually and collectively. "Informed designers practice reflective thinking by keeping tabs on their own and others' design work in a metacognitive way and reviewing their processes and products once they have completed their work." (Crismond & Adams, 2012, p.772).

The literature also indicates the importance of considering the most appropriate information request strategy for supporting reflective thinking by the respondent (Walther, Sochacka, & Kellam, 2011; Yilmaz & Daly, 2014). The novice designers within this study, as part of the HCD approach, engaged with stakeholders throughout the design process. Yet, these designers' strategies for collecting information from stakeholders did not provide opportunities for stakeholders to reflect about the importance of the information and preferences being gathered. From the analysis of the design meetings, the novice designers could have utilized more diverse information request strategies to ask stakeholders to clarify thoughts, elaborate on ideas, or justify opinions. By embedding reflection into the team-processes and interactions with critical stakeholders, designers may become more knowledgeable of their own information needs and minimize potential instances of conflicting information or misunderstandings.

Ahmed et al., (2003) concluded that while novice designers were aware of their knowledge needs, they didn't necessarily know the precise questions to ask. Our analysis of interactions among a novice design team participating in HCD found similar conclusions related to knowledge needs, especially when needing to clarify misunderstandings or resolve conflicting information. To support novice designers' interactions with experts or stakeholders, facilitators could guide reflection about the types of information requests or provide opportunities to practice different information request strategies that include, for instance, elaboration and clarification requests. For instance, the designers could utilize elaboration requests (e.g., can you tell me more about…) to uncover the reasoning behind potentially conflicting information.

Further, metacognitive reflection on the design process and team interactions affords an opportunity for designers to consider the role of converging and diverging design thinking (Yilmaz & Daly, 2014). For example, the purpose of the Brainstorming Meeting was to open the design space and encourage concept generation and ideation. This diverging design thinking was promoted by connecting the stated meeting purpose to the method of facilitating team member interactions. Through team member facilitation, designers were asked to explore the design space, consider alternate design options, and share external sources of inspiration, all characteristics of promoting diverging thinking (Yilmaz & Daly, 2014). Similarly, the role of question asking on designer ideation has implications toward educators' interactions with novice designers (Cardosa et al, 2014; Yilmaz & Daly, 2014). Working towards an understanding of

how to best structure design reviews to encourage question asking (Sonalkar, Mabogunje, and Leifer, 2014), educators should model positive person-to-person behaviors in their interactions with student (i.e. novice) designers and exhibit effective methods for requesting information about a student's design during the design reviews.

Open information sharing did allow the designers to gain knowledge about potential stakeholder considerations and develop an empathic understanding of the stakeholders (Fila & Hess, 2014), without requiring each individual designer to speak with each stakeholder. Additionally, this open information sharing within design team meetings, which was especially successful in the Brainstorming Meeting, contributed to cooperative design decisions. The analysis discussed in this paper uncovered enablers for supporting open information sharing among adjacent teams in a MTS (e.g., among designers and stakeholders). These enablers include the use of boundary objects, the inclusion of design walkthroughs to guide discussions, and the alignment between the desired meeting purpose and information sharing strategies. Beyond these enablers, teams may also consider reflecting on the desired meeting outcomes and meeting purpose with attendees before starting discussion (Van Ginkel & van Knippenberg, 2009). This strategy was used within the Brainstorming Meeting and contributed to a very open environment for discussion.

While sharing unique information does correlate to increased team performance (Mesmer-Magnus & DeChurch, 2009), results of this study increase our understanding of the negative impact of oversharing unique information. Within this study, oversharing information was found to overload decision-makers, bias design discussions with stakeholders, and prevent innovative ideation. Further, extensive sharing can drown pertinent design information in overly-detailed and irrelevant knowledge and can lead to a chaotic design process (Kleinsmann et al, 2012). Thus, designers should attempt to limit oversharing by guiding information exchange to gain unique and relevant information that could be integrated into design decisions. When performing design ideation, for example, the designers should request unique information from the stakeholders, independent from others' preferences. Another approach to stimulating unique and relevant information sharing is for the designers to strategically consider the most appropriate questions for requesting information in their particular context. This approach could also encourage a cooperative design-process, since the elicited information is relevant to the designers' concerns.

Despite early conversations of how design features or information might be integrated into the larger treehouse design, many of the discussed ideas by all entities on the project persisted as independent design features. This focus on independent design features may be partially attributed to the novice designers' perception of project deliverables as a piecemeal design (Secules, Gupta, & Elby, 2014). Our investigation of design artifacts (i.e. design sketches) and conversations also found little evidence of how the designers' ideas and stakeholders' information were abstracted beyond initial discussions and incorporated (or not) into the final design. To support innovative ideation and cooperation between designers and stakeholders, designers could abstract on ideas (see Kramer, Daly, Yilmaz, & Seifert, 2014), which would allow heuristic-inspired ideas to be carried through to later stages of design and integrated into the final design.

Prior research has investigated openness and uniqueness independently, but limited work has been done to jointly consider these two dimensions (Mesmer-Magnus & DeChurch, 2009). The research discussed in this paper used a qualitative approach to jointly consider openness and uniqueness in the field, which differs from previous work in laboratory settings. The findings from this qualitative study suggest future research should incorporate expanded definitions of openness and uniqueness that incorporate aspects of relevancy. To operationalize the relevancy of information sharing, a consideration must be made for how the information is integrated or abstracted in the final decision. For the case of HCD, relevancy could be measured as the number of independent pieces of information that were incorporated in the final design. Or, the relevancy of a conversation could be measured subjectively using a self-report scale at the end of the design process. It should be noted that relevancy should not be measured as an explicit indicator in the midst of the design process. Occasionally, information initially perceived as irrelevant may be unexpectedly incorporated subsequently leading to an innovative creation. Thus, relevancy is a measure of how the final design incorporates information exchanged throughout the entire process. Designers could promote relevancy throughout the design process by both guiding discussions and incorporating elaboration and clarification requests to elicit a comprehensive understanding of the needs of critical stakeholders.

Many of our findings support previous conclusions regarding information sharing within a MTS, however our results also contribute to a broad understanding of how an integrated interpretation of information sharing, specifically the openness and uniqueness of conversations, can influence a cooperative design process, such as HCD. Within HCD stakeholders may not be able to fully describe problems and preferences, thus designers must promote a cooperative decision-making process by eliciting open and unique information that is relevant to the design goals. Through effective information sharing, designers (both novices and experts) can generate an innovative design that meets the stakeholders' needs.

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