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# UNDERSTANDING LEARNING FROM FAILURE PROCESS IN THE COLLABORATIVE DESIGN CONTEXT

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**Abstract**

Failure as a path to success is a common belief in literature, our daily life, and educational research. With the advocate of integrating design into K-12 education, scholars who study Maker Movement have argued that involving learners in design practice can foster a positive failure mindset. To make failure productive, scholars have suggested the need to actively create a learning environment, provide opportunities to practice, and build the culture to support this learning process. However, examining the literature, few studies have focused on unpacking learning through the lens of failure in the design context. As design is naturally collaborative, it is also essential to examine design from a group's perspective. Synthesizing from the needs and the challenges from literature, this study focused on understanding group-level learning from failure phenomenon in the collaborative design context. Drawing from a sociocultural learning perspective, I focused my analysis on understanding how learning from failure is mediated by two tools – discourse and physical artifact. To guide the analysis, I proposed two research questions: 1) *How does a specific discourse pattern mediate a team's opportunity and ability to learn from failure in the collaborative design context?* 2) How does the tool configuration mediate teams to learn from failure in the collaborative design context? To answer these two questions, I used the design experiment method to develop a learning space informed by three design principles synthesized from literature. This study recruited 16 students, and they were divided into four teams. As four students were returning students, I decided to group them as an expert team. I followed the interaction analysis approach to select lessons and episodes for analysis from over 75 hours of data in the data analysis. I used discourse analysis and interaction analysis separately to examine the two research questions. In the analysis, I focused on understanding how the moment-to-moment discourse and tool interaction among team members mediate learning from failure. The findings showed that learners could engage in sophisticated

design practices and reasoning. However, their discourse patterns influenced their team's ability to learn from failure. The findings also showed that tools played an essential role in mediating the team's learning process. However, each tool can support and at the same time constrain the learning process depending on the relationship between the learners and the tools. This dissertation findings bring both theoretical and design implications. This study calls for reconceptualizing failure and learning from failure in the collaborative design context from a gap between expected and actual performance to a situational and momentary socio-material interaction phenomenon. This study also provided several design iteration suggestions based on the findings.

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## ACKNOWLEDGEMENT

"It takes a village to raise a child" is often used to describe the need of the entire community of people to provide support for children to grow up. I would say the same to how this work came to be. The "village" includes my family, my research group, all the participants, the school where I conducted this study, my committee members, friends, and teachers who I took class within the College of Education. It takes the whole cosmos to make this happen.

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# Chapter 1

## Introduction

*"Failure is so important. We speak about success all the time. It is the ability to resist failure or use failure that often leads to greater success."*

*- J.K. Rowling*

Learning from failure is a productive process that asks learners to confront and use failure to achieve success. The relationship between failure and success is so interdependent that we have to discuss failure when we discuss success. However, schools often encourage success but avoid failure because failure is often interpreted as evidence of inadequacy (Hochschild & Scovronick, 2004; McDermott & Varenne, 1999). This negative interpretation of failure hurts learners' self-esteem and devalues the learning benefit it brings (Kaplan, Peck, & Kaplan, 1994; Kapur, 2008). Scholars in education argue that we need to reinterpret failure and teach learners strategies to use failure productively (Dweck, 2006; Kapur, 2008).

As Maker Movement becomes popular, scholars argue that engaging learners in design activities might develop new thinking and practice to cope with failure (Blikstein, 2013; Brown, 2008;). Though it is acknowledged that failure is essential to learning (Blikstein, 2013; Cannon & Edmondson, 2005; Kapur, 2008), few of them unpacked the team-level learning from the failure process in the design context.

In this chapter, I begin by defining the problem this study attempts to address. First, failure has ample learning benefits to achieve success. Second, the research community has yet to create an effective way to support learners learning from failure. I follow the problem statement with two research questions to narrow down the focus of this study. Lastly, I close this chapter with an

overview organization of this study.

## Problem Statement

Failure and success are two sides of a coin. Failure is less discussed because it can be detrimental to the individual and society (Sitkin, 1992). On the other hand, success increases reliable and repeatable procedures that bring stability (Baumard & Starbuck, 2005; Sitkin, 1992). These two extreme outcomes make us advocate success and avert failure. In reality, the relationship between success and failure is dialectical (McGrath, 1999; Kapur, 2008; Sitkin, 1992). When we avoid failure, we also resist change, create illusions of success, and hinder long-term learning behaviors (Coelho & Mcclure, 2005; McGrath, 1999; Sitkin, 1992).

The analogy of failure and death is helpful to understand a paradox between failure and change. We usually repeat the successful way of living since it guarantees survival in the past. Change, on the other hand, brings uncertainty, which is against our willingness to stability. However, if we do not change, we lose our competitive edge. The same logic applies to failure. One believes that success conditions are unchangeable by applying “copy the past" (Coelho & McClure, 2005, p.16). Previous standardized procedures would ensure future success (Baumard & Starbuck, 2005). Those afraid of failure would follow the traditional procedures or solutions but fail to respond to new trends. Instead, people would confirm and ignore alternatives rather than changing procedures or strategies (McGrath, 1999). The danger of this unintended bias is that it might lead to blindness to impending failure.

Apart from inertia to change, people who avoid failure create the illusion of success and also try to maintain this illusion. People often attribute success to their hard work and intelligence but failure to external faults (Kaplan et al., 1994). This way of assigning attribution creates the

illusion that they have control over success but no control over failure. The exaggerated individual power blinds them from identifying the needs and seeking new strategies to change when they fail (Baumard & Starbuck, 2005; Holschu et al., 2001). Instead of adapting to the new situation, they might misinterpret the evidence or theories, manipulate the intervention, delaying or hindering actions from maintaining their image of success (Gilovich, 1991).

The short-term success might, in return, hinder long-term learning. Long-term learning requires learners to retain durable information and retrieve information in ways that could transfer to new contexts (Bjork, 1994). Instructions that emphasize short-term performance success focus on reducing the complexity of the structure or providing support to retrieve information easier (Bjork, 1994; Kapur, 2008). As a result, leaners might have the impression that they have mastered the information when in actuality, they only succeeded because of the instructional support (Bjork, 1994). Scholars argue that increasing *desirable learning difficulties* might bring short-term performance failure and increase long-term learning success (Bjork, 1994; Kapur, 2008; 2012). The *desirable difficulties* provide different conditions to apply concepts. Delay feedback to learners might cause short-term failure, but play a critical role in long-term learning success.

Even though we know the importance of failure in change and learning, we seldom discuss failure, given how we perceive failure at school. Studies show that many schools perceive failure as evidence of incapability and obstacle to success that should be avoided (Hochschild & Scovronick, 2004; Litts & Ramirez, 2014; Varenne & McDermott, 1999; Smith & Henriksen, 2016). To prepare an individual for academic success on standardized tests, teachers converge the attention on teaching testing strategies and content-specific knowledge (Collins, 2016). Schools have no time to focus on supporting children to develop practical failure coping mechanisms to gain the learning benefit (Borge et al., 2016; Collins, 2017).

Learners who attribute failure to uncontrollable factors such as ability are more likely to give up trying or develop learned helplessness as time goes by (Dweck, & Leggett, 1988; Holschu et al., 2001; Lin-Siegler et al., 2016). They believe that successful people have high intelligence and never fail (Lin-Siegler et al., 2016). Intelligence is pervasively considered a naturally born fixed trait that cannot be improved (Dweck, & Leggett, 1988). This negative understanding of failure wastes failure's learning benefit and harms learners' self-esteem and creates more failure.

Recently, scholars have proposed integrating design into education, which introduces a positive failure mindset to interpret failure and creates a learning experience to practice effective learning from failure skills (Blikstein, 2013; Martin, 2015). The design brings authentic emotional and technical failure students can practice, which is seldom present in formal education (Blikstein, 2013).

Even though scholars acknowledge the importance of engaging learners in the collaborative design activities to support effective learning from failure, our knowledge in how to support this type of learning is insufficient. The existing failure related research in education either briefly proposes the benefit of learning from failure or places a target on content-specific knowledge learning such as mathematics. Also, they tend to focus on individual failure and individual learning outcomes. Organizational learning literature has extensive representation of failure management studies, but few have a focus on children. Together, we need to understand the collaborative learning process from failure in design contexts and understand what instructional activities might draw learners' attention to failure and failure management.

## Research Questions

In my dissertation, I intend to develop an in-depth understanding of how groups learn from design failure to inform the design and implementation of learning spaces. I use the following research questions to guide this study:

1. How does a specific discourse pattern mediate a team's opportunity and ability to learn from failure in the collaborative design context?
2. How does the evaluation tool mediate teams to learn from failure in the collaborative design context?

## Organization of Chapters

The remainder of this study will be presented in the following six chapters. In Chapter 2, I first review the sociocultural theory as a theoretical foundation in this study. I then review the related literature on learning from failure and collaborative design context, which informs my theoretical understanding and design practices in this study. I also explain my rationale for using the design experiment at the end of this chapter. In Chapter 3, I outline the research design, including the participants and context. I then describe the materials I used in this study. At the end, I describe my data collection and data analysis method. Chapter 4 explores teams' moment-to-moment interaction to understand how specific discourse patterns mediate their learning from failures. I organize this chapter using three learning from failure abilities informed by Cannon and Edmondson's learning model (Campbell et al., 2019; Hakkarainen et al., 2011)– identify, analyze, and iterate. Chapter 5 shifts the focus from discourse to tools. This chapter examines how four types of tools and their configurations mediate the team's learning process. In the last chapter (Chapter 6), I first discuss the findings from Chapter 4 and Chapter 5. I then synthesize the findings and propose the theoretical implications. Following the theoretical implications is my reflection

on the design and implementation of this study using the design experiment method. At last, I propose a future research agenda that builds upon this work.

# Chapter 2

## Literature Review

In this chapter, I first review my interpretation of learning from the sociocultural perspective. This framework serves as a filter that helps me select and review literature critically. Then, I discuss factors that are needed to make failure productive. Synthesizing from the discussion, I propose three design principles to inform the learning space development in this study. In the last session, I explain my rationale for adopting the design experiment method in this study.

## Theorizing Learning from Failure in the Collaborative Design Context

### Learning is Mediated by Discourse and Tools

Rooted in rationalism, modern cognitive learning theorists depict learning as constructing, acquiring, and using mental models to solve problems (Greeno et al., 1996; Stahl & Hakkarainen, 2021). Researchers who take on this view focus on understanding and supporting how individual learners process information in the learning environment (Sfard, 1998). Although acknowledging the individual development by which we internalize knowledge during the learning process, Vygotsky (1978) argued that learning first occurred in the social plane. Through social interaction, which is mediated by symbolic meanings and physical tools, individuals internalize the community's social and cultural practices (Vygotsky, 1978).

Vygotsky (1978) used the term *mediate* to describe the indirect relationship between stimulus and response. He argued that "the immediacy of 'nature' perception is supplanted by a complex mediated process; as such, speech becomes as essential part of the child's cognitive development". In Vygotsky's research, he primarily centered his analysis on language. Werstch (1991) extended Vygotsky's concept of mediation to include technical tools. Another extension which is different from Vygotsky's original concept was to acknowledge the tension between the mediational means that exist in the current sociocultural context and the contextualized use of those means in concrete actions (Werstch, 1994). This tension, as argued by Werstch (1994), could give rise to a transformative and new meaning of language and tools. Though Werstch argued that cognition should not be analyzed isolated from the socio and historical context and the concrete context, individual cognition was his primary focus.

Another similar but different line of research that extended Vygotsky's work came from socio- constructivism scholars. They argued that learning is the change of participation in the community (Lave & Wenger, 1996; Rogoff, 2003). Vygotsky's emphasis informs this view on focusing on the social plane of learning and interacting with more capable peers (Poehner, 2008). Leading scholars such as Rogoff (1995) argued the importance of guided participation and the apprenticeship model in supporting learner's development. Within this view, scholars explore the relationship between individuals and society and how the interaction form and reforms both the individual and specific cultural ways of knowing and practices.

Though scholars from different theoretical traditions argue the role of physical tools and materials differently, they all acknowledge the need to understand how physical tools and materials mediate learning. For example, the concept of distributed cognition expands the locus of cognition not only on the social plane, but also on technologies or materials used in the situation (Hutchins,

2000). Jordan and Henderson (1995) who theorized learning as a distributed and ongoing process argued “artifacts and technologies set up a social field within which certain activities become very likely, others become possible, and still others very improbable or impossible”. Scholars in the collaborative learning field have also argued that groups create and use artifacts during interaction as a form of externalizing their thoughts and allow group members to reflect and critique with tangible objects (Hakkaranien et al., 2013).

Some scholars took a step further and argued that inter-objectivity is what differed human beings from animals rather than intersubjectivity which concerns the semiotic meaning within the social interaction (Latour, 1996; Luria, 1928). Latour (1996) argued that object is a meaningful unit of analysis since it embodies multiple aspects of human activities from the past and present and has the capacity to connect those aspects to the future. With this capacity, we can understand not only the historical, but also the change of the meaning associated with the objects. As Luria (1928) argued, “As a matter of fact, the tools used by man not only radically change his conditions of existence, they even react on him in that they effect a change in him and his psychic condition” (p.493). Mediated by existing tools, rules, norms, and language, the group creates new artifacts through collective effort (Stahl, 2015). At the same time, an artifact created as a group work also serves as a visible and referable tool to mediate a group’s discourse. The visible representation of group artifacts allows groups or others to comment on, reflect on, and provide feedback (Hakkaranien et al., 2013). However, the second part of Luria’s argument discussed how tools could change the practice and psychological conditions. Instead of categorizing the properties or traits of a tool, the studies on tool affordances (Norman, 1998) focus on understanding the relationship between the specific users and the tools. Instead of assuming a priori, this theoretical understanding conceptualized tool mediation as situational and interactive between the human and

tools relationship (Jordan & Henderson, 1995). One of those empirical studies was conducted by Mehto et al.'s (2020). In their study, they examined the tool affordances in a co-invention project within small team collaboration. The study showed that maker tools could provide opportunities to drive collaboration. Their findings also showed that the maker tools could constrain a team's division of labor if not supported.

Though the meaning of mediation was hardly articulated in the literature, Hasan (2002) took a systemic functional linguistics perspective and defined a four relevant process of semiotic mediation. Those four processes are: 1) the mediator; 2) the things being mediated; 3) subject of mediation; 4) the modality and locus of the mediation. Though we might not observe all four processes in all contexts, Hasan (2004) argued that some of them were present. However, this structural definition of mediation did not clarify what it means to mediate. This is because, as Werstch (1991; 1994) argued that the human interaction did not simply reproduce the existed meaning, it also transforms when it is used in unique contexts. Synthesized from the similar but different theoretical understanding of human activities and learning, I define the meaning of mediation as an interactive process that required the participants to constantly construct and negotiate the meanings to accomplish a task.

**Collaborative Learning**

In the last two decades, scholars in Computer-Supported Collaborative Learning have explored Vygotsky's theory from another direction – group interactions and tool-mediation (Stahl & Hakkarainen, 2021; Hakkarainen et al., 2013). They argued that the social interaction at the group level is usually left unexamined (Barron, 2003; Miyake & Kirschner, 2014). A group can

learn from an individual or community and contain the knowledge-building process (Stahl, 2006; Scadamalia & Bereiter, 2014). Stahl (2006) proposed a new paradigm shift of learning from either individual or community level to group level in learning science. He argued that a concept of group cognition differentiated from individual cognition and argued that small groups are the mid-point used to analyze learning.

Group cognition is an integration of individual minds rather than the sum of it. Individual thoughts are not automatically adopted as part of group cognition. Instead, groups need to synthesize externalized individual thoughts and negotiate statements among members to build shared knowledge. Through synthesis and negotiation, parts of individual thoughts are integrated into the knowledge-building process and became an inseparable part of new knowledge.

Group cognition is a meaning-making process through which groups construct knowledge mediated by discourse and artifact. It is different from individual cognition. While individual learning occurs in the internal mind, group learning is observable in the discourse and action (Stahl, 2006). Built on his earlier group cognition theory, Stahl later proposes that group learning occurred when the group enacts new regularities practice. When it comes to group culture, scholars argue the need to consider it not as a simple replica of community culture but negotiated and shared within the group and the community (Stahl, 2006; Borge & Mercier, 2019). Like how individuals make meaning of the culture, groups construct culture and norms through discourse rather than direct transition (Cannon & Edmondson, 2001; Geertz, 1994). Group practice with discourse or action might derive from individual thought or community culture but need to be discussed, negotiated, and adopted as shared knowledge before becoming regular group practice (Stahl, 2017).

However, a collection of individuals does not form groups naturally (Petrovsky, 1983).

Instead of assuming that the group is "ready-made functional," Petrovsky (1983) argued that group formation is an ongoing development. He argued that, through the change of joint activities, the group gradually achieves the collective level in which group members' values align with collective values. During the formation process, scholars argue that multiple dimensions can affect how a group achieves the collective level of cognition.

Roschelle and Teasley's (1995) analysis on the dyad's discourse shows that establishing a joint problem-solving space is critical for advancing the dyad's mutual conceptual understanding of the problem. This study also shows that joint problem-solving space does not generate automatically but required the group to coordinate attention to constructing this space through language and action. Later, Barron (2003) extends the role of social factors in collaborative problem solving and argues that social and cognitive factors intertwine in the social interaction process. She argues that when team members are willing to make an effort to value and incorporate individual inputs, the team has a more successful collaborative learning experience. Similar to Barron's finding, Polo et al. (2016) argued that emotions played social and cognitive functions in mediating group learning.

Discourse is a tool teams use to externalize ideas and think together when collaborating (Mercer & Littleton, 2007; Stahl, 2006). Unlike individual cognition, which is hard to capture, small group cognition can be "visible" in the group's discourse (Stahl, 2006, p3). Individuals make sense of the event and articulate their interpretations to other members. Together, the team synthesizes and negotiates different interpretations to create a shared understanding and collective knowledge. However, discourse patterns can affect these processes (Mercer, 1996). After analyzing groups' dialogue around computer-based collaboration activities, Mercer (1996) identified three discourse patterns associated with quality sense-making: exploratory talk,

disputational talk, and cumulative talk.

Mercer (1996) argued that each pattern embodies a different interpersonal relationship and social mode of thinking. Exploratory talk represents a collective thinking process when group members share and negotiate multiple perspectives critically yet constructively: they challenge each other's statements with rationale, evidence, or alternative ideas. Their argumentation is directed towards a shared goal: to create accountable knowledge within the group rather than a threat to solidarity or individual self-esteem. Groups' ability to challenge each other's rationale enables them to examine individual and group biases before making a decision (Kerr & Tindale, 2004). This heuristic way of exploring each other's statements is critical to collective failure analysis because it avoids the illusion of success (Cannon & Endmondson, 2005). Disputational talk, on the other hand, represents an individualistic way of thinking. Peers form a competitive relationship because they regard competition as the only option to maintain individual self-esteem within the group (Mercer & Littleton, 2007). In the disputational talk, members "flaunt" information they possess (Mercer, 1996, p. 370), reject others' statements without providing reasons, ignore others' statements, or accept the individual decision as to the group decision. Finally, cumulative talk is a type of collective thinking that aims to maintain group solidarity and harmony above all else. As such, they agree with each other's ideas and seldom challenge each other's statements. In this talk, groups do not establish a shared understanding, depending on whether opinions are elaborated or justified.

**Framing Learning from Failure in Human-centered Collaborative Design Context**

Given the challenge of changing the current educational system, scholars propose using

design context as an alternative learning environment to formal education (Borge et al., 2017). Design context provides both failure positive culture and authentic ill-structured problems that, are beneficial in creating suitable learning from a failure environment.

Collaborative design is defined as the process of making joint sense of the situations and the materials, making a joint design decision, and evaluating and reflecting design solutions to improve (Campbell et al., 2019; Hakkarainen et al., 2011). Design teams need to gather information to inform the design, seek feedback from others, and learn from failure.

***Asking questions to situate design ideas on users' needs.*** Designers ask intensive divergent and convergent questioning to unpack the complex, open-ended problem (Dym et al., 2005). They generate design ideas based on information gathered from users (Brown, 2008). It requires designers to ask intensive divergent and convergent questions to situate their ideas on end users' needs (Cross, 2011; Dym et al., 2005). Users' needs are influenced by their social, cultural, and historical backgrounds, sometimes vastly different from those of designers. Designers need to be able to put themselves into users' shoes to understand their requirements. Asking questions is a form of inquiry that is beneficial for designers to understand users' perspectives.

***Seeking feedback and testing to identify the failure.*** Design groups share the collective artifact as prototypes with users to seek feedback, test design, and iterate for improvement based on the failure identified (Brown, 2008). The iterative design provides designers opportunities to refine and revise based on the end-user's feedback. The possibility to revise provides designers a safe nutshell to fail fast and often (Litts & Ramirez, 2014). Iteration is a powerful practice because it generates a safe space that allows failure, which is known as a key to innovation (Litts & Ramires, 2014).

Though there are different ways to fail, one of the most common failure in Human-centered

design is not meeting or satisfying the needs (Adam & Atman, 1999; Braha & Maimon, 1997; Costa & Sobek, 2003; Jain & Sobek, 2006). Braha and Maimon (1997) categorized three situations when feedback from the clients can change the design process. They argued that "in the first case, the design (or form) fails to satisfy one or more of the requirements…. In the second case, new requirements (or constraints) emerge during testing, and the design fails to satisfy one or more of them…. The outer cycle (Fig. 1) demonstrates that the evaluated solution might revise the perceived needs" (p. 154). Jain and Sobek (2006) also argued that the more time designers spent to understand the design problems and the requirements, the greater client satisfaction they would receive. In another article by Costa and Sobek (2003), they argued that a simple repetition or rework of existing design product without changing the conceptualization of the problem and its scope, did not necessarily productive. What makes the iteration meaningful was when designers engage in transformative processes such as synthesizing information to re-define the problem scope or generating new alternatives (Adams & Atman, 1999).

***Learning from failure to innovate and make changes.*** The high degree of freedom that accompanies low structure brings the possibility of failing (Brown, 2008; Dym et al., 2005; Jordan & McDaniel, 2014). Failure lies in the process of innovation and change. Even with extensive questioning to understand user needs, failures are still inevitable, given the complexity of reality. Taking risks to innovate brings the possibility of failure.

In many cases, design teams are eager to avoid "wrong" performance and only do it in the "right way." However, the "right way" is sometimes the conventional problem-solving method that is not helpful for a complex problem. Instead of using statistical and mathematical models to reduce uncertainty suggested by Dym et al. (2005), McGrath (1999) proposes that uncertainty can be managed through weighing high-variance outcomes and taking action when the conditions

support the best outcome. Through this, McGrath (1999) argues that failure can become the path that leads us forward instead of backward. Failure instances are tools designers use to calibrate the desired goals and status and guide their future actions. The calibration process includes identifying failure scenarios, analyzing the cause of failure, and test solutions to reach desired goals (Cannon & Edmondson, 2005).

The opportunity of evaluating their design became critical steps in product design to help hear multiple voices from different stakeholders. It is critical for the designers and the clients to recognize their unchecked assumptions and re-structured the visuals that were yet fully formed (Campbell et al., 2019). Putting their design to the test is a process of communicating with the situation. Kolko (2010) argued that the design solution was not part of the logical premise before the solution or within the problem. The solution was generated through a social process among group members, which emerged and was constructed through the synthesis among design teams (Campbell et al., 2019). The team needs to synthesize information such as their own experiences and the design requirements to make sense of the design implications together. The sense-making process required the group members to 1) prioritize; 2) judge; and 3) forge new connections (Kolko, 2010). The design requirements often include multiple aspects to consider.

Design mindset introduces a new way of interpreting failure that is beneficial to learning from the failure process. Designers interpret failures as opportunities to improve their ability over time. They evaluate the learning progress and apply and change learning strategies accordingly to make failure productive. Even though learners with a designer mindset go through difficult emotions, they tend to re-appraise the meaning of failure, actively investigate the failure situation and learn from it (Brown, 2008; Martin, 2015). The design itself is an iterative process that encourages designers to look for feedback, test out designs, and refine design prototypes.

Designers actively look for failure to improve their design process and product (Brown, 2008). In the book *Designing your life: How to Build a Well-lived, joyful life,* Bill Burnett and Dave Evans (2016) argued that a designer mindset allows us to leap from the situation, not getting stuck by the label and interpretation of the consequences, and move forward. Learning, which from Vygotsky (1978), can ultimately support our development. Development, as a synonym for growth through creation. It is a process of unfolding and growing, which is a process of expansion.

Design activities generate natural ill-structured problems for learners to practice an effective failure management process. Designers usually deal with wicked problems to which conventional problem-solving methods cannot be applied (Buchana, 1992). This type of problem requires designers to think from the end-users perspective, to create a collective artifact to get feedback, to collaborate with other designers, and to embrace uncomfortable feelings such as uncertainty, failure, and ambiguity (Brown, 2008; Brown & Wyatt, 2010; Dym et al., 2005; Jordan & McDaniel, 2014). Through those design practices, design teams can successfully solve problems in ways deeply rooted in users' needs yet remain innovative. Wicked problems have a high level of freedom yet a low level of structure that brings struggle and ample space for innovation (Buchana, 1992; Kapur & Bielaczyc, 2012).

## Making Failure Productive – Learning Environment Design Models

In this section, I first overview the existing learning from failure models from multiple disciplines. I then propose a design model including three design principles to create learning from a failure environment by synthesizing those models.

Most of the research on failure management is done in the business field with adults. Scholars have developed different theoretical perspectives on reconceptualizing failure from

emotion and cognition perspectives and argue failure's positive effect (Shepherd, 2003; McGrath, 1999). In educational contexts with fewer failure management studies with children, studies often focus on individual failure and individual outcomes. There is a lack of sufficient research on how groups cope with failure, a group's ability to manage failure relates to the team's collaborative design process, and what interventions might facilitate children's failure management in this type of context.

Even though failure can be powerful, failure is not always productive (Cannon & Edmondson, 2005; Kapur & Bielaczyc, 2012; Sitkin, 1992). Significant failures such as system security failure would bring detrimental negative consequences and are not encouraged by scholars. In contrast, small failures can alert us to potential problems and are manageable for the group to handle both cognitively and emotionally (Cannon & Edmondson, 2005). Learning from failure is a process of reflecting on past actions and shedding light on future decisions. Therefore, it is critical to initiate the learning process.

Study in mathematics education shows that failure provides hidden benefit in mathematics concepts and associate procedure learning if used productively. Research on mathematic education shows that allowing students to fail in solving ill-structured mathematic problems could benefit learners' mathematics content and procedure learning (Schwartz & Martin, 2004; Kapur, 2008). Schwartz and Martin (2004) found that students who invented mathematic solutions in learning descriptive statistics, even though incorrect, learned better after the canonical solutions were revealed compared to students who received direct instruction.

Built on that study, Kapur (2014) compared learning performance from Productive Failure (PF) instruction and direct instruction in learning high school mathematics. In this study, students in PF condition initially went through problems without support. However, they received

instruction such as modeling at the end. In the direct instruction condition, students received direct instruction on conceptual understanding and went through problems later. As a result, students in the Productive Failure condition outperformed students in the direct instruction condition. He suggested that learning from failure, no matter where the failures come from, is a better instructional strategy than direct instruction when learning new mathematics concepts and associate procedures.

Those study reveals the hidden efficiency of failure. It shows the role of instructional activities in supporting children to make productive use of failure. The instructional activities that occurred after the learner experiences failure play crucial roles in initiating learning from the failure process. This process is what makes failure productive.

Parallel to failure research in mathematics learning, scholars in Maker Space propose other necessary factors to make failure productive. Martin (2015) proposed fostering a positive failure mindset as a need for creativity and innovation. He also argued that overcoming failure helped learners understand the problem structure better and adapt the problem-solving strategies to other situations. However, this article only briefly discussed the need to foster a positive failure mindset rather than unpack how to foster the mindset and how learning occurs.

Another article by Blikstein (2013) points out the importance of creating safe learning culture to support learning from failure. In this study, he reported an instance of how a team dealt with failure in designing and testing a roller coaster using 3D printing and finally solved the problem creatively in Fabrication Lab (FabLab). He argued that a learning environment like FabLab provides emotional and technical support to help teams learn from their failures and achieve desired goals. Further, Blikstein and Worsley (2016) argued that learning from failure is a skill that needs proper guidance. They might simply repeat errors without systematically

investigating their failure rather than understanding the causes to guide future actions. Again, Blikstein and Worsley's (2016) paper only mentioned the need for supporting learning from failure rather than provide knowledge on how to support that learning.

Kapur and Bielaczyc's (2012) *productive failure* design model is one of the few pieces of research that proposes mechanisms to guide the practical design of learning from failure intelligently in education. They propose a design that includes three layers – instructional activity, interaction mode, and culture. The instructional activity includes both generating problems that elicit *productive failure*, and the instructor's facilitation move such as modeling, comparing and contrast, and discussion. For interaction mode, this design model argues for adopting learning through the collaboration method because the process of externalizing, explaining, and evaluating is helpful in problem-solving. They also propose to create a safe environment for learners to explore failure and to learn from failure.

The most significant contribution of this model is to shed light on creating problems that elicit failure for learning. By *productive failure*, Kapur (2008) defines it as the failure that generated from "complex and ill-structured problem without the provisions of support structures" (p. 379). They state that designers should consistently calibrate the complexity of the problems to design "challenging yet frustrated" challenges (Kapur & Bielaczyc, 2012, p.50). He (2008) points out that complex, ill-structured problems associate with a higher degree of uncertainty and more irrelevant or indirect information can generate more productive failure. To design this type of problem scenario, Kapur and Kinzer (2009) state that designers can add "many problem parameters with varying degrees of *relevance* and *specificity*" (p.27). Relevance and specificity speak to the control of implicit and explicit clues in problem scenarios.

However, this design model takes collaboration for granted and assumes the desired

learning outcome would occur as long as students work together. The challenges of successful collaborative problem solving are well documented in learning science literature. As discussed in previous session, the quality of learning is influenced by multiple factors (Barron, 2003; Roschelle & Teasley, 1995).

Sitkin (1992) introduces a concept similar to Kapur's *productive failure - intelligent failure* or *strategic failure* in his work. Regarded as a small failure, it is less threatening. It generates less negative affect but at the same time has the power to get people's attention on recognizing and interpreting problems, initiating searching for alternative solutions, adopting the change, increasing risk-taking behaviors in the decision-making process, and practicing the ability to handle uncertainty in the future. He states five characters that contribute to *intelligent failure*: 1) it results from systemic planned actions; 2) it produces uncertain outcomes; 3) it falls into manageable failure scales; 4) it enacts from the *action – failure - action* cycles; 5) it relates to familiar domains. Also, Sitkin (1992) argues that organization plays a critical role in supporting learning from *intelligent failure*.

Even though what Sitkin proposed might not be appropriate to collaborative design context, there are several implications. First, he argues that a structured organizational system will generate *intelligent failure* that consists of sufficient uncertain outcomes. Second, the organization should make their encouragement of exploring intelligent failure visible to the members. It would set up a supportive culture for those willing to take the risk and learn from it. Third, the organization should help the individual change their perception of failure and facilitate them to commit to discovering failure. Finally, the failure management system should happen at the organization level instead of the individual level. Sitkin's article only provides a theoretical model for building a system that incubates *intelligent failure*. It is still unclear how practitioners can reify this model

for designing context, especially for children.

In organizational research, Cannon and Edmondson (2005) argue that acknowledging the value of failure is not enough for effective learning. The learning should be broken down into a manageable process. They propose that failure can be learned intelligently through three distinctive but interdependent processes: 1) identify failure; 2) analyze failure; 3) deliberate experimentation.

As the first step, groups should be able to identify the failure. Apart from changing the group's negative perception of failure which results in cognitive bias, organizations should provide access to collective data such as success or failure cases to identify failures. It is helpful to make the failures transparent to groups. Also, if groups can adopt the habit of seeking feedback, they will identify failures easily. The core of analyzing failure is the inquiry and group sense-making process. The group members should have the patience and the tolerance to dig deeper and make sense of the cause and consequences of the failure. Deliberate experimentation is the third process that requires a set of experiment design skills. They view deliberate experimentation as an intentional act on experiencing failures to improve. Cannon and Edmondson (2005) state that identifying failure to analyze failure and deliberate experimentation requires teams to gradually increase their competence. In addition to the competence model, they also argue that the group should rephrase the failure from unacceptable outcomes to a positive learning-oriented process that values failure as a byproduct of experimentation that leads to innovation and growth. However, the competence model proposed in their article is too theoretical to guide actual practice.

## Design Model for Creating Learning from Failure Environment

The above literature review on different models sheds light on the learning from failure process and factors that can influence this process. Synthesized from the literature, I propose

three design principles to guide the learning environment design. In this session, I unpack each design principle and my design rationales.

**Design Principle 1: Challenge should be hard enough to create failure**

As Kapur & Bielaczyc (2014) argued, designers would need to conduct several iterations to find the design challenges' "sweet spot," which would produce "challenging yet not frustrated" hard fun challenges. Even though the original principle was used to design mathematic ill-structured problems, this principle can also be applied to designing challenges in this study. Sitkin (1992) also argued that organizations should create artificial challenges for learners to fail and learn.

**Design Principle 2: Make failure visible**

One obstacle that hinders individuals or groups from learning from failure is the invisibility of failures. To encourage organizations to learn from failure, Sitkin (1992) suggested that they act and reflect quickly to learn from small and manageable failures before turning into catastrophic failures. Cannon & Edmondson (2005) also suggest that organizations make small failures visible quickly to manage on time. They also point out that one barrier to identifying failure is members' inaccessibility of data necessary to identify the failure.

**Design Principle 3: create a safe environment for the participants**

Failure is a gap between desired goal and actual performance. The individual interprets the meaning of failure after internalizing how failure is presented in the culture through symbolic action –language and gestures (Geertz, 1994). When working in groups, the interpretation of failure does not depend on an individual's interpretation but the collaborative sense-making process that creates a shared belief of failure.

The class should set up certain social discourse norms to mediate the interaction. A trust and respect interpersonal relationship is fundamental for effective group collaboration (Barron, 2003; Edmondson, 2004; Kozlowski & Ilgen, 2006). This relationship forms a psychological safety space for team members to feel accepted as being themselves (Edmondson & Lei, 2014). When trust is not perceived, team members hardly initiate learning behaviors such as speaking up, discussing mistakes, seeking help, looking for feedback, or taking risks (Barron, 2003; Edmondson, 2004; Jordan & McDaniel, 2014).

**The rationale to Adopt Design Experiment to Create Learning Environment**

Design an experiment that values dynamic, and flexibility is a good fit. The iteration and calibration feature of the design experiment do not constrain activities to pre-determined plans but value the immediate feedback from implementation and encourage the calibration of the design along the way. I used this principle through both my challenge design and curriculum design.

The discussion on integrating theory and practice has led to a new methodological reform – Design-Based Research (Collective, 2003). Design-Based Research (DBR) uses a systemic design method to contextualize the intervention. Brown (1992) argues that theory can be generated from both laboratory settings and real-life settings. This notion reconsiders the power

of practical intelligence and credits its contribution to theory development. However, it is not an easy task to design interventions within and for the context. It is because, unlike laboratory, researchers have little control in real-life settings.

Collins, Joseph, and Bielaczyc's (2004) *design experiment* model seek to bridge the gap. They propose six guidelines for design research: 1) implement a design; 2) modify a design; 3) multiples ways of analyzing the design; 4) measuring dependent variables; 5) measuring independent variables; 6) reporting on design research. First, they argue that researchers should create a stable environment before the intervention can work smoothly (Brown, 1992; Collins et al., 2004). In the system, critical dependent variables such as student engagement, skill development, and perception change, and critical, independent variables such as infrastructure support, classroom space setting, and facilitator training, are working together. The classroom setting is a complex system. Every aspect is related, the change in one aspect will change how the whole system functions. Therefore, researchers should keep refining the design until the "bugs" work out in the context even if the design has been implemented. They encourage researchers to modify their design and document the rationale behind the modification.

### *Models of design experiment*

Engeström (2007) critiqued this approach as a linear process that fails to include the other participants in the design phase. Influenced by Vygotsky, he argues that humans can use flexible, ambiguous, and loosely defined tools to serve their purpose in a given situation. While practicing activities with the tool, participants redefine and recreate the use of the tool. Upon the physical tool, they create their symbolic meaning to the tools. Instead of imposing researchers' proactive

prediction of the use of the tool on the participants, Engeström argues that interventionists should include participants in the intervention design. The role of interventionist becomes a facilitator who is regarded as an experienced mentor rather than a knowledge creator. The final solutions come from the internal structure, which is from participants generated rather than the external structure, solely from the interventionist. It is not to say that there is no need for guidance, but it implies who holds the authority of the knowledge. The implication of Engeström's critique for this study is that the intervention design should invite children as designers.

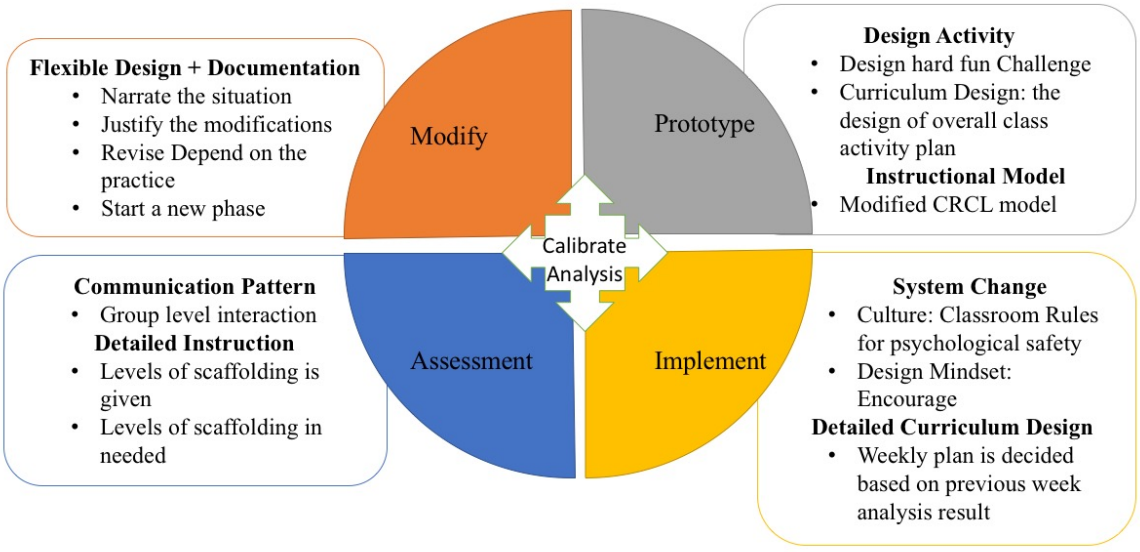


Figure 2-1. Four-phase Design Experiment Model Describes the Design Experiment Process Used in This Study.

# Chapter 3

## Methods

This study aims to understand the group's learning from the failure process and the affordance or constrain of the evaluation tools implemented. Previously, I have described three elements of the learning from failure design model – activity design, enable collaboration as participant structure, and social surroundings that encourage exploration. This chapter describes the research design, including the research design principles and goals, population and context and materials with curriculum design, data collection process, and method of data analysis.

## Research Design

In this study, I follow the design experiment method to design the collaborative learning from the design failure environment and refine the theoretical understanding of learning from failure process (Brown, 1992; Collins et al., 2004).

### Overview of Design

Collins et al. (2004) proposed a *progressive refinement* approach that argues the constant refinement of the educational design. Bell (2004) also argued that "in specific efforts, more of the intervention is responsively produced during the intervention itself than in advance. It is accomplished through microcycles of design (Cobb, 2001) (p.247)". When educational designers

operationalizes this approach, they closely observe and reflect on students' learning needs and creates new interventions or modify existing designs till the "bugs" work out in the context.

The design of this study intends to achieve two objectives: 1) create a learning space that includes activities, participant structure, and culture to support learning from failure in the collaborative design context; 2) create tools to support groups' learning from the design failure process through observation and reflection.

## Population and Context

### *Settings*

The data was collected in an afterschool club I have been working for since 2015. This afterschool club was hosted in a charter school in Central Pennsylvania. This charter school is located in a college town near a tier-one research institute. This school has a diversified student and staff population from over 80 countries. Students were allowed to choose one to two activities from about 40 various club activities based on their interests for the extended day program.

The entire afterschool club often lasted 14 to 16 weeks, depending on the school calendar and weather. We hosted our club each Tuesday afternoon from 3:50 PM to 5:15 PM. When I collected my dissertation data, the afterschool club was originally planned for 16 weeks. In the end, we hosted 15 sessions because school was canceled due to heavy snow.

### *Spatial Arrangement*

To encourage interaction among group members, our research group arranged the group seating in ways that allow each group member in the peripheral vision of the rest group members. At the beginning of the club, we were assigned to a classroom that had individual seating chairs (see Figure 3-1). To enable each group member within the peripheral vision of other members, we combined four individual seating chairs. When we distributed the physical artifacts, we encouraged them to place them in the center, so all members could see them.

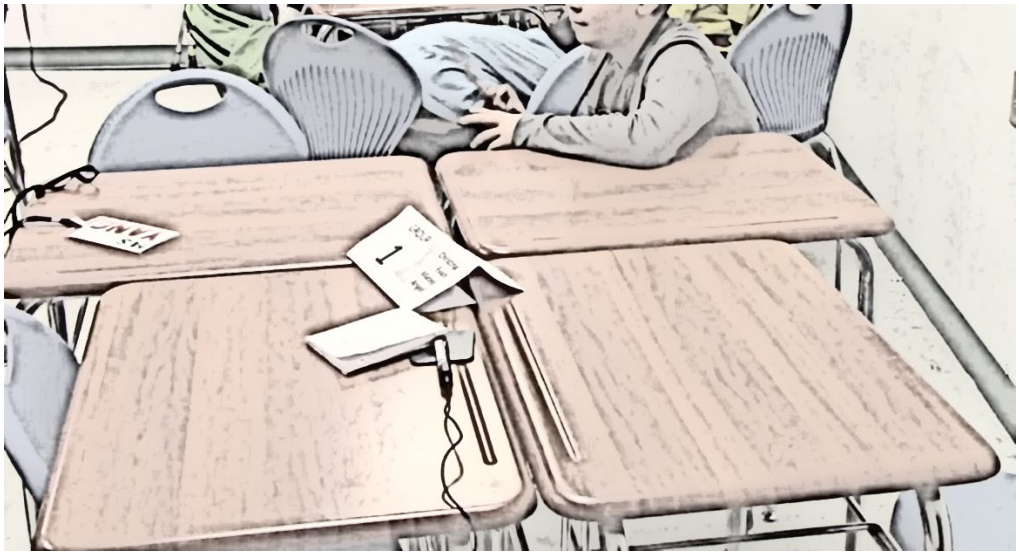


Figure 3-1. A Photo of the Spatial Arrangement for Lesson 1 to Lesson 5.

Due to the small size of the original classroom, the sound quality from each group was poor. So, we requested another classroom with a larger size (see Figure 3-2). We were placed in another classroom with four large rectangle tables. We assigned two group members who sat on each long side of the table. Together, they had more physical space between and around them.

Figure 3-2. A Photo of the Spatial Arrangement for Lesson 6 to Lesson 15.

***The Participation Structures***

The whole club, including the facilitators, was learning and growing with students each semester. In the club, facilitators who participated in this project often came with a variety of personal and professional experiences, as well as a variety of experiences with the school, its staff, students, and this club. The different expertise and perception of facilitator roles lead to different interaction approaches they took when working with the group. In one way, they were facilitators who intended to support young designers' learning; in another way, they were learning how to facilitate to support young designers' learning. Often, their interaction approaches changed over time.

Dialogic teaching is often used in this after-school club. With the understanding of creating a safe and interactive learning environment, facilitators were trained to take on knowledge co-constructor rather than knowledge transmitter. One of the goals for the after-school club is to support children's higher-order thinking skills. Therefore, when facilitators sat with each group,

facilitators often prompted the groups to externalize their reasons. When groups only answered "yes, we have that" or "no, we do not have that," facilitators often prompted groups to externalize their evaluation rationales. Their facilitation often focused more on the quality of the argument, such as asking groups to explain their designs. To help groups clarify their iteration plan, facilitators prompted the groups to externalize their reasons on how their design met or unmet the clients' needs. This prompt required the groups to unpack their design rationales. These moves often triggered facilitators or other group members to challenge the rationale.

Even though facilitators were often regarded as the authorities who can decide if an argument is valid, all facilitators had increasing awareness of allowing children to evaluate their group design performance. Despite different interaction approaches and roles each facilitator took, there were several commonalities among all facilitators. First, facilitators attempted to use questions to prompt groups' discussion. Instead of evaluating the group's claims as "right" or "wrong," facilitators encouraged groups to provide rationales and persuade the facilitators. Second, facilitators tried to reframe their intervention with groups as much as they can. In our research group meetings, we often reflected on our facilitation style. Individuals shared experiences, interpreted the event, and discussed solutions to benefit future facilitation. One of my excerpts from field notes reflected how I deprived groups of learning opportunities when I intervened too much.

> "The struggle came from the internal debate – product or process? The concern of not letting them finish their project is the old mindset of product-oriented rather than process-oriented, I believe in. My traditional way of thinking inevitably drove my motivation in this situation. I had the strong intention to help them problem solve rather than guide them to solve the problem. It is difficult to see them struggle without taking any problem-

solving action. I take pride in solving puzzles myself. I think my ego did get in the way. I have to remind myself that the struggle is part of children's learning process and have to regulate my intention of solving the problem for them." (Excerpt from Analytical Memo, 05/19/2017)

This type of reflection was common in our research group meeting. With the constant conversation, facilitators gradually started questioning the traditional view of teachers as authorities and practice to embody a role as facilitators.

***Participants characteristics chart and grouping.***

Participants registered for this club based on their interests. In this study, I recruited 16 students initially. One student dropped the club because of her time conflict after lesson 5. This left group 4 with three members. Among the 15 students who participated in the club till the end of the semester, we had eleven male students and four female students (Table 3-1).

We divided participants into four groups in the second week based on four criteria: gender, grade, interpersonal relationship, and special needs if applicable (table 3-1). The knowledge of interpersonal relationships and special needs, which helped us decide on grouping, came from four sources: 1) observation from the first week's interpersonal interaction; 2) observation from interpersonal interaction from previous semesters (old comers); 3) information from after school club coordinator; 4) one expert facilitator's knowledge of the interpersonal relationship history among some children. We categorized four recurring participants as experts given that they participated this club more than once and were familiar with the design process.

Table 3-1: Participant Characteristics Chart

| Group Number | Group Member (Pseudonym) | Gender | Grade | Previous Club Experience (semester) |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| 1 | Marcos | M | 4th | 4 |
| 1 | Catherine | F | 5th | 3 |
| 1 | Eric | M | 5th | 2 |
| 1 | Aron | M | 5th | 3 |
| 2 | Juba | M | 4th | 1 |
| 2 | Ekon[1] | M | 4th | 1 |
| 2 | Gary | M | 4th | New |
| 2 | Jake | M | 4th | New |
| 3 | Kiya | F | 5th | New |
| 3 | Andy | M | 4th | New |
| 3 | Teddy | M | 4th | 1 |
| 3 | Cameo | F | 5th | 1 |
| 4 | Sebrina | F | 6th | New |
| 4 | Adben[1] | M | 5th | 1 |
| 4 | Rick | M | 4th | New |

Note: Ekon[1] and Adben[1] are siblings.

***Curriculum.*** I designed a 16 week, semester-long curriculum with three design challenges at the beginning of the semester. I intended to increase the complexity of the three design challenges and enable students to experience the design cycle as often as possible. As I implemented the plan into the club, I had to adjust the curriculum timeline because of uncontrollable factors such as school cancelation and conference time conflict. Eventually, I went through a 15 week curriculum with three design challenges as planned (see Figure 3-3).

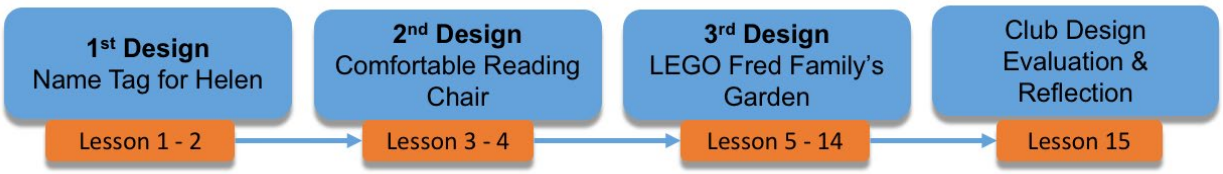



Figure 3-3. A Visual Representation of the Ultimate Curriculum Timeline.

I followed Collins et al.'s *progressive refinement* approach and created a detailed plan after identifying learners' needs by observing students' performance and reviewing my analytic memos. I created a curriculum document that recorded the orchestration of the lesson with seven columns: the lesson (date), research plan, curriculum plan, notes, preparation, materials checklist, and remark/recording notes (see Figure 3-4). *The lesson* indicates the lesson number and the date of the lesson. *The research plan* showed the research-related activities. This column also documented the progress of the design phases. With the overview, I adjusted the time allocation of each design challenge and the number of activities planned for each session. *Notes* documented important activities that occurred in that lesson. It was a quick note we jotted down after the lesson. *Preparation* was a to-do list to remind myself and other team members of things to be prepared before the lesson. *Materials Checklist* showed what materials students would need for design.

| Lesson (Date) | Research Plan | Curriculum Plan | Notes | Preparation | Materials Checklist |
|---|---|---|---|---|---|
| L1<br>01/26/2017 | Consent Form | **Before the class:**<br>Give Mrs. Khan's students list to bring parents to the room and sign the consent form (10 students)<br>**During the class:**<br>**3:50 - 4:00** Welcome new and old members & Club Introduction<br>**4:00 - 4: 45** Design Name Tag for Helen who is deaf-blind<br>**Scenario:**<br>Helen is 10 years old and she just moved to your neighbourhood. You want to make friends with her. However, she is deaf-blind. For her condition, she has little sight. She can see blurry words but only if she's close enough and with specific designs of the texts. She has no hearing. To be able to introduce yourself, you decide to create a name tag for her.<br>• Strong Color contrast<br>http://webaim.org/resources/contrastchecker/<br>• Large Text<br><br>**4:45 - 5:05** Reflection: Making Rules? Or Next Week?<br>**After the class:**<br>Marcela & Shulong: talk to parents and ask for permission (Sign up consent form)<br>Wendy: dismiss children to MPR<br>All: clean up the tape. Mona and Shulong bring cleaning oil and scratch. | MB's assessment: Children stand near the wall. She measured the distance of clearance of the name tag. Also, she give stars to those who include the design with things Helen like. | 1.Consent Form<br>2. Coconut Oil and Sponge to clean the tape<br>3. Big Posters<br>4. Copy Student List (consent forms)<br>5. Copy Attendance | Consent forms (print at school);<br>Name Tag;<br>Pens |

Figure 3-4. A Screenshot of the Detailed Curriculum Plan.

***Activities.*** Students were given three design challenges (see Figure 3-3) – name tag challenge, comfortable reading chair challenge, and LEGO Fred Family's Butterfly Garden. The implementation of the small challenge allows groups to go through the design cycle, get to the testing stage, and seek feedback. Their design was evaluated through criteria set in advance. Groups then moved to a discussion on failure management activities. At all three time points, no instruction such as modeling, scaffolding, or intervening was given. After the unguided small group discussion, the facilitator started a whole class reflection. The whole class evaluated the difficulties of the design, the process of failure management, and suggestions on change from children as co-designers.

The first challenge was a name tag design challenge. This challenge was implemented for three reasons. As club tradition, we asked children to design a name tag that showed their idiosyncrasies. For this semester, I also created a specific client for the name tag challenge – Helen. She was deaf and blind but could see text with good color contrast between the text color and background color. I gave children different art supplies to design the name tag. One facilitator assessed their design with visibility, including font size and the color contrast. I considered this activity an ice-breaker activity that allowed us to get to know the children and for the children to get to know each other. Therefore, none of the supporting tools was designed and implemented for this challenge.

The second challenge was a comfortable reading chair challenge. The goal of this activity was to help children be aware of different perspectives beyond their own experience. Overall, each design group went through three design phases – design prototype, design feedback, and design iteration (see Figure 3-5). Children went through the three phases in two weeks. For each phase, one to two activities and corresponding tools were designed and implemented.

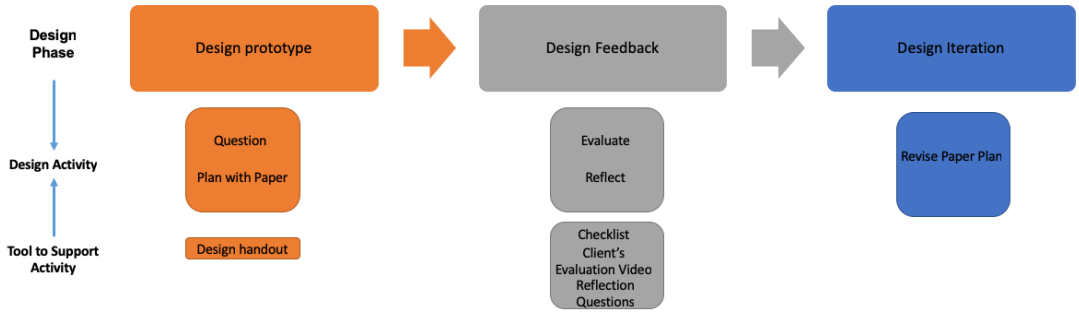



Figure 3-5. A Visual Representation of the Comfortable Reading Chair Design Phrases.

In Lesson 3, each group was asked to create a comfortable reading chair prototype using paper and pencils. At the beginning of the class, I asked children to recall their experience of sitting in a chair to read or play for a long time. They were given handouts to help articulate problems they identified, needs they wanted the chair design to meet, and then to generate a design sketch (see Figure 3-6).

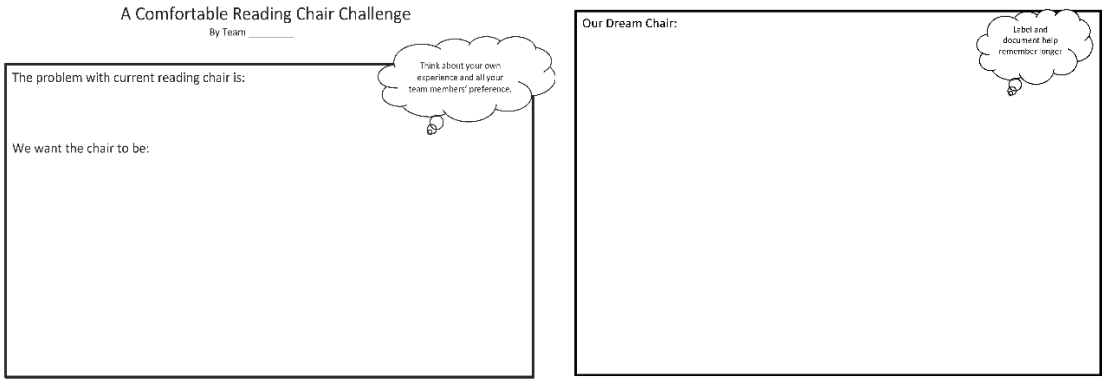



Figure 3-6. A Photo showing the Comfortable Reading Chair Challenge Handout.

Between Lesson 3 and Lesson 4, I asked one of our facilitators to act as a client. I created a list of needs based on her experience (see Figure 3-7). We compared the checklist with each group's design plan to identify their design strength and weakness. I asked the same facilitator to create a video to deliver the evaluation result with the comparison result. In Lesson 4, we first

played the evaluation video and discussed lessons learned from the video with the whole class. Then we distributed the checklist to each group and asked them to evaluate their design within the group. In the second session of Lesson 4, we wrote down three reflection questions on the whiteboard. These three questions were: 1) *should we start from scratch or revise the original plan? Why?* 2) *What would we do differently?* 3) *What do we learn from the failure?* These three questions were intended to guide each group to reflect on their design process. Finally, each group was asked to iterate based on the evaluation and the client's feedback.

02/23/2017
Comfortable Reading Chair

**Team** _____

**This is a checklist to compare your design with Needs Ms. Mona has with her chair. Compare your design with her design problem to see how much your design meets her needs.**

| **Needs** | **Values of Solutions that solve the problem** | **Our Points** |
|---|---|---|
| Reading with computers and a keyboard, need something to hold them | 2 | |
| Not a tall person so if the chair is too tall, feet gets numb and uncomfortable | 2 | |
| Would like to rest the arm while reading | 2 | |
| Can sit long without discomfortable but also not too comfortable so she won't fall asleep | 3 | |
| Dodo, the cat would like to share the chair. However, the chair is too small so he would sit on my keyboard or in front of my screen when I have to finish my reading. | 3 | |
| The space in the apartment is limited, so can't fit in big piece. | 2 | |
| I love drinking coffee and have snacks while sitting on the chair reading. but sometimes they make my computer dirty or damaged. Also, Dodo once spilled my coffee. | 3 | |
| I like to move my chair around so I can enjoy sunshine sometimes or get closer to the light | 2 | |
| I injured my back so it hurts if there's no support on my back. I usually would put a cushion on my back to give some support, but not very helpful if I sit for a long time. | 3 | |
| I love natural materials | 2 | |
| Visual Appealing | 3 | |
| | Totals | |

Figure 3-7. A Photo of the Comfortable Reading Chair Checklist.

The third challenge was a LEGO Fred family's butterfly garden challenge. This activity allowed young designers to go through design feedback and design iteration phases, including

evaluating, reflecting, and revising the design to improve the design process and product (Figure 3-8). In this challenge, each group used paper and pencil to create a design prototype, used LEGO blocks to create the first iteration, and used Minecraft to create a second-round iteration. Between design prototype and first iteration or two iterations, we asked each group to evaluate their design products and reflect on their design process.

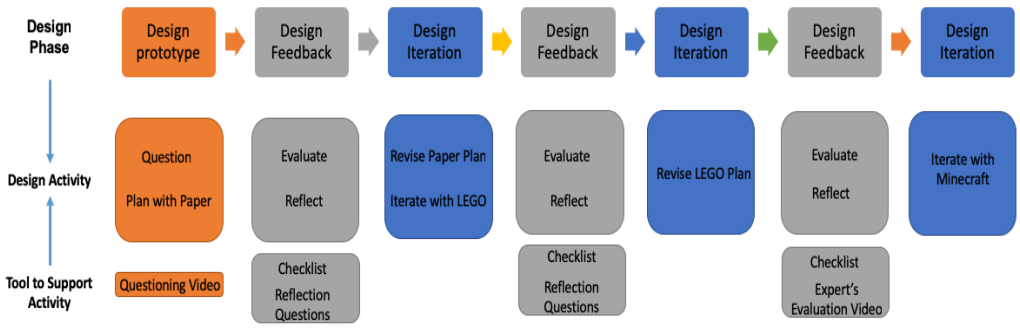



Figure 3-8. A Visual Representation of the Fred Family's Butterfly Garden Design Phrases.

We decided to play a questioning video after observing that novice designers had challenges understanding the importance of taking the client's perspective in design (see Figure 3-8). This video first introduced questioning functions, such as unpacking design challenges and understanding the client's needs (see left side of Figure 3-9). To make the video more engaging, we told a story about how two design members collect information from the client to inform their design. At the beginning of the story, we designed a conversation between two design members to manifest that the consequence of not asking questions is failing to understand the client's needs. The right side of figure 3-9 is a screenshot representing the difference between a designer's view and a client's view. It was intended to help children be aware of the view difference between themselves and the people they designed for.


Figure 3-9. A Screenshot Showing Design Questioning Video.

I implemented a checklist three times for the butterfly garden challenge. The checklist was distributed after the design prototype and the first and the second design iterations. After groups finished a paper and pencil plan, we implemented the first checklist to ask groups to evaluate their design. Compared to the comfortable reading chair challenge, the checklist in the butterfly garden challenge was more complex in two ways. First, there were more needs to be met, and second, several needs were interconnected or conflicted. For example, Fred, the dad, wanted to prioritize the mom's interest and needs in the butterfly garden design. Design groups were expected to pay attention to the mom's needs and interests from the checklist to inform their design. Alternatively, the family wanted to attract birds and butterflies, but they had an outdoor cat. As we know, birds eat butterflies, and cats eat birds in nature. With the conflict, design groups should take necessary design to allow all three creatures to co-exist. The same checklist was again implemented after iterated with LEGO blocks and revised the LEGO blocks (see Figure 3-7).

We also distributed question handouts to guide group reflection. The handout was divided into two parts – reflections of the process and a list of questions groups could use to check their process in the future. For example, after groups evaluated the design plan, they were asked to reflect on their questioning process guided by the first part of questions within the group (see left side in Figure 3-10). The questions in figure 3-10 show what general questions designers could ask to unpack the design problems and understand their clients. I have also created a similar

handout for planning and creating processes used the same template. Those two handouts were distributed a week after using LEGO to iterate the garden design (see Figure 3-10).

I also created an evaluation video when the third round of the checklist was implemented. The decision to create this video was based on two observations from design learning and instruction perspectives. First, not many groups evaluated their design critically, even though I had tried to prompt this behavior several times. Second, children instantly judged and made fun of others' design weaknesses without pointing out the strengths or providing constructive feedback. I viewed this way of giving feedback as a challenge of creating a psychologically safe environment in the community. So, I asked a design expert to evaluate each group's design, explain design principles using groups' failure examples. After playing the video, we asked the whole class to reflect on ways the expert designer gave feedback.

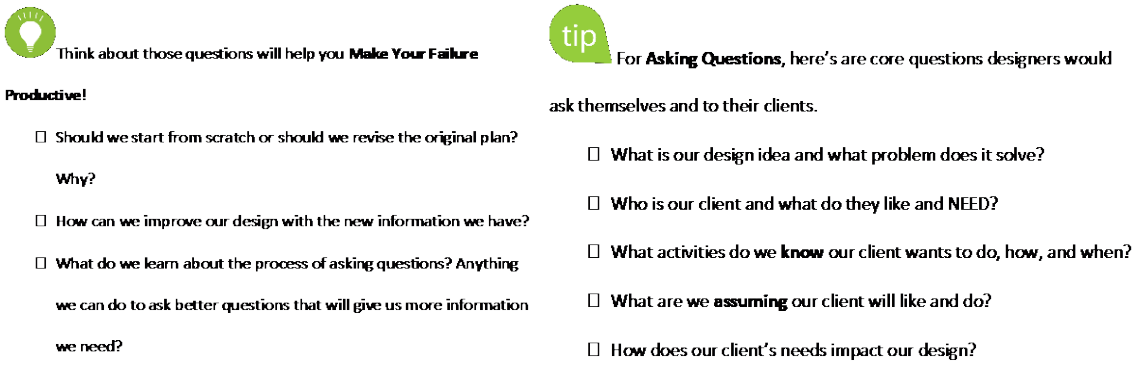



Figure 3-10. A Photo of the Reflection Questions and List of Design Questions to Ask.

## Method

### *Data Collection*

I collected four data types in this study – video and audio recordings, memos, design documents, and group artifacts. Each type of data was used for different purposes. In this session, I described 1) the rationale of collecting each type of data; 2) the process of collecting each type of data; 3) the sample of each type of data.

***Video and audio recording.*** The use of video recording has become a prevailing practice in the learning science field. As early as 1995, Jordan and Henderson argued that video recording provides *verifiable observation,* which is useful to examine the interaction closely. Derry et al. (2010) also argued that video recording could serve as a *boundary object* that allows diversified perspectives to arise and facilitates the scholars to create a shared understanding and accountable scientific knowledge.

***Equipment.*** I placed one camera to record each group's interaction. Each camera was connected to a tripod to stabilize the camera. Also, I connected the Pressure Zone Microphone (PZM) directly to the camera. However, I used an external audio recorder to record two groups' dialogue due to the PZM defect.

***Camera.*** The general principle of setting up the table for each group is to allow group members' face-to-face discussion (see Figure 3-11). There was one camera on the Tripod for each group. One was placed on each table to record audio data directly in sync with the video data. However, due to the PZM problem, we lost audio data from group three and group four's lessons. I also placed one conference camera to focus on recording the facilitator's instruction. One rule I followed to position the group camera was to capture as much facial expression as possible.

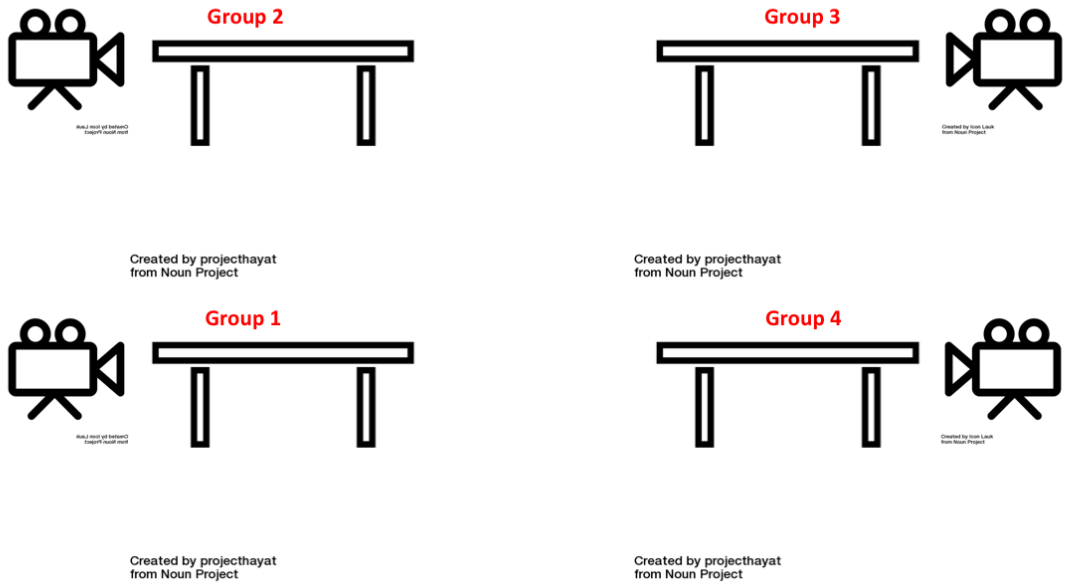



Figure 3-11. A Visual Representation Showing How Four Cameras were Set Up for Each Team.

***Indexing.*** I created an index for all video and audio data after each club (see Figure 3-12). I created an excel sheet to track and manage the data and marked down recording. There are eight big columns in the index in the index – date, lesson, document/artifact, raw individual group video/audio, merged individual group video, the person in charge of the data, and data location. The naming of video and audio followed the convention: Year_Date_LessonNumber_GroupNumber_VolumeNumber_Format. After each club, I merged the two videos and audio data, if applicable, together and saved them into a new file.

| Date | Lesson | Document/Artefact | | | Raw Individual group video/Audio | | | | Merged Individual group video | | | | Data Incharge | | Data Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lesson Plan | Artefact (pictures, drawings, paper plans etc) | Field Notes/ Reflection | Group 1 | Group 2 | Group 3 | Group 4 | Group 1 | Group 2 | Group 3 | Group 4 | Main | Assistant | |
| 01/23/2017 | L1 | √ | Name Tag | √ | No Recording | | | | No Recording | | | | | | |
| 2/2/2017 | L2 | √ | Individual Productive Failure drawing | √ | 2017_0202_L2_G1_V1-2.MP4 | 2017_0202_L2_G3_V1-2.MP4 | 2017_0202_L2_G2_V1-2.MP4 | 2017_0202_L2_G4_V1-2.MP4 | 2017_0202_L2_G1_merged.MP4 | 2017_0202_L2_G2_merged.MP4 | 2017_0202_L2_G3_merged.MP4 | 2017_0202_L2_G4_merged.MP4 | SY | | 8HD, Box, SYHD |
| 2/16/2017 | L3 | √ | Comfortable chair (Group) | √ | 2017_0216_L3_G1_V1.MP4 | | 2017_0216_L3_G3_V1-2.MP4 | 2017_0216_L3_G4_V1-2.MP4 | 2017_0216_L3_G1_V1.MP4 | | 2017_0216_L3_G3_MERGED.mp4 | 2017_0216_L3_G4_MERGED.mp4 | SY | | 8HD, Box, SYHD |
| 2/23/2017 | L4 | √ | Checklist | √ | 2017_0223_L4_G1_V1-2.MP4 | 2017_0223_L4_G2_V1-2.MP4 | 2017_0223_L4_G3_V1-2.MP4 + 2017_0302_L4_G3_A1.WMA/MP3 | 2017_0223_L4_G4_V1-2.MP4 | 2017_0223_L4_G1_MERGED.MP4 | 2017_0223_L4_G2_MERGED.MP4 | 2017_0223_L4_G3_MERGED.MP4 | 2017_0223_L4_G4_MERGED.MP4 | SY | | 8HD, Box, SYHD |

Figure 3- 12. A Screenshot for Data Index.

**Memos**. I used the memo as a reflection and documentary tool. The memo can serve as a

written reflection for generating analytic insight (Maxwell, 2015). I reflected on my reaction to certain events, including examining the possible assumptions I made and the emotions I experienced in those events. I documented my thoughts about certain events design the decision-making process. Also, the memo can serve as an instance log that noted down interesting events during club time. It was beneficial for selecting sessions to review.

After every club, I wrote a memo of my observation with the following information: date, lesson, difficulties I encountered as a facilitator and designer, observations I made during facilitation, feelings I had, and actions I took. In 15 weeks, I collected 25 pages of the memo. To follow confidential protocol, I used the children's pseudonym in the memo. The memo served two purposes. It is a reflection for me as a designer and a facilitator. Here is an example of the memo:

> "*It is a valuable moment when I see Gary's eyes light up, and I know that he is thinking, he is making connections with what he learns with that particular experience. The enlighten is that I have to give up my expectation and fixed mindset – a picture or an artifact that I expect from children to create. It is so powerful when I follow their flow instead of asking them to follow mine. Applying my understanding of productive failure and asking questions to help them use their artifact to make sense of the experience and productive failure seems like working well.*"

**Group Artifacts**. I collected three types of artifacts - a collection of drawings from each group (Figure 3-13), notes (Figure 3-14), handouts (Figure 3-15), and photos for LEGO 3-D model (Figure 3-16). At the end of the class, I took pictures of all drawings and notes, name them, and uploaded them into the hard drive. The camera captured children's 3D artifacts such as LEGO model or Minecraft design.

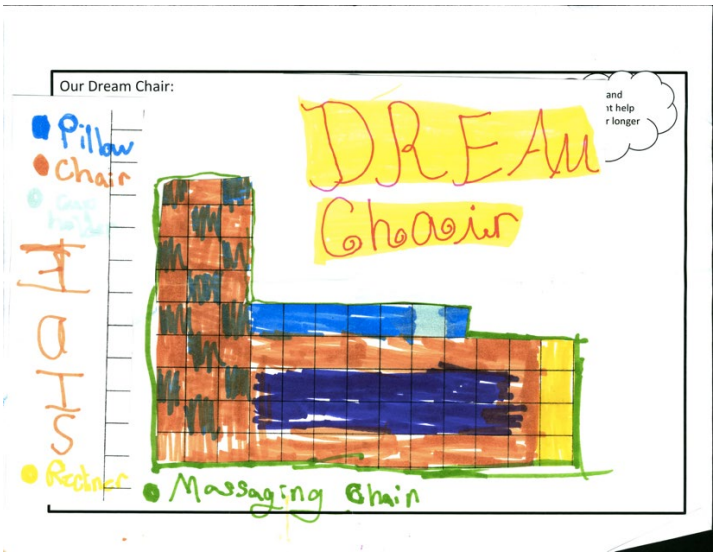



Figure 3-13. A Scan Copy Showing Group's Sketch for the Comfortable Reading Chair Design.

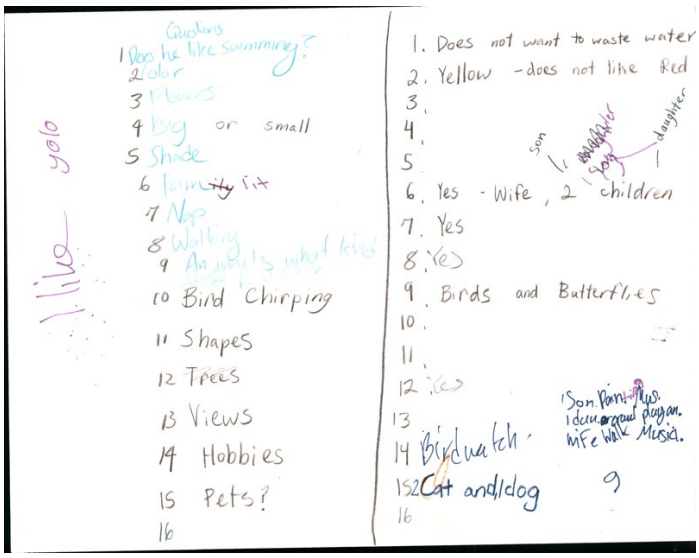



Figure 3-14. A scan Copy Showing Group's Notes on Fred Family's Information.

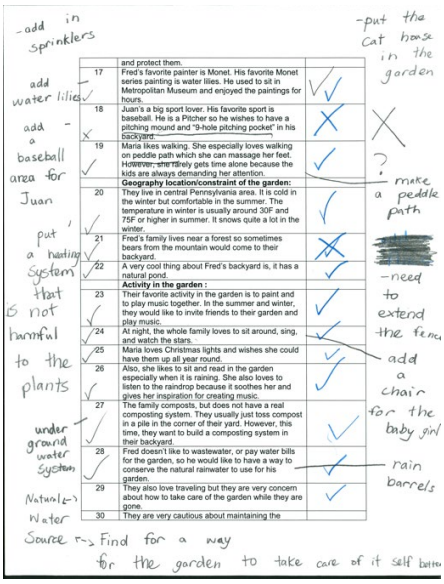



Figure 3-15. A Scan Copy Showing Group's Notes on the Fred Family's Checklist.

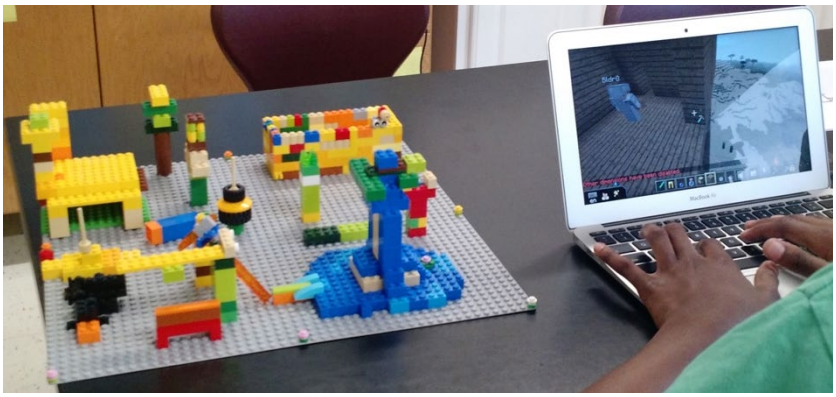


Figure 3-16. A Photo Showing Group's 3D Artifacts on the Fred Family's Butterfly Garden Design (left: LEGO; right: Minecraft).

### *Data Analysis*

In this session, I discuss the data analysis in two aspects – lesson selection, episode selection, and analysis, guided by Derry and colleagues' (2010) guidance on video research in learning science and Jordan and Henderson's (1995) interaction analysis.

***Lesson selection.*** I went through two rounds of data selection. The first selection round intended to select the "hot spot," which contains rich discourse around learning from design

failure events (Jordan & Henderson, 1995). To guide the selection, I used three types of data – video recording, memo, and curriculum documents. As I stated earlier, memos and curriculum documents documented my observation, reflection, and groups activities. On the other hand, video recording helps me decide the number of participants and a brief view of the interaction.

After going through the memo and curriculum documents, I selected three lessons (lesson 4, lesson 6, and lesson 10) as main lessons. The reflection tools such as a checklist, feedback videos, and reflection questions were implemented in those five lessons. Those three lessons were selected based on the assumption that the evaluation and reflection tools would support groups to initiate and maintain the learning from design failure discussion.

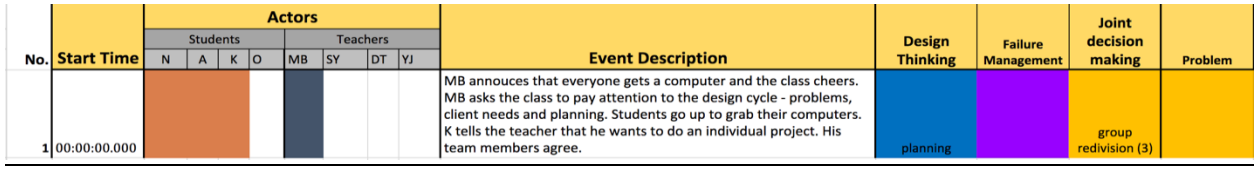
The second round of selection focused on the videos that were not selected in the first round. The purpose of the second-round selection is to identify learning from design failure events that were not intentionally supported by the reflection tools. Given that the other facilitators and I were constantly converging our reflection on the theme of learning from failure, I assumed that those reflections might trigger students' discussion and reflection on the topic. For the second-round selection, I mainly relied on video recording and curriculum documents. I first reviewed the curriculum document to select lessons with learning from failure-related reflection. I then watched those lessons to verify the selection lists. Eventually, I selected three more lessons – lesson 2, lesson 3, and lesson 14 to analyze.

***Episode Selection.*** After selecting the lessons and groups, I created a content log to further refine the episode selection. With the refined selection, I then transcribed or revised transcripts for detailed analysis.

The level of details logs in the eight lessons selected varied according to the relatedness to the learning from the failure event. If the episodes were learning from failure event-related

such as facilitators discussed learning from failure with the whole class and groups discussed design failures. I used the ethnography field notes-taking method introduced by Emerson et al. (2011) for a detailed log. The log used the field note technique to describe rather than evaluate. For example, instead of using "confusion," I used "frown" to describe students' facial expressions. An open-sourced software, called Datavyu, was used for logging the data (Figure 3-17).

After finishing the content logs for videos selected from the first and second rounds, I used the content logs to further narrow down specific episodes for transcriptions (Jordan & Henderson, 1995).



| No. | Start Time | Actors: Students N | A | K | O | Actors: Teachers MB | SY | DT | YJ | Event Description | Design Thinking | Failure Management | Joint decision making | Problem |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 00:00:00.000 | | | | | | | | | MB annouces that everyone gets a computer and the class cheers. MB asks the class to pay attention to the design cycle - problems, client needs and planning. Students go up to grab their computers. K tells the teacher that he wants to do an individual project. His team members agree. | planning | | group redivision (3) | |

Figure 3-17. A Screen Shot Showing the Content Log.

***Transcription.*** Episodes selected for micro-analysis were transcribed following established conventions (Bezemer and Mavers's 2011; Jordan & Henerson, 1995). In the transcripts, I identified the time, speaker, utterance, actions, and artifacts manipulated in the scene. The time marked down when the utterance or action occurred. The speaker marked down who is talking. The utterance documented a verbatim report of the conversation from the speaker (as accurate as possible). Actions noted posture and gaze. Also, I marked down the artifacts used and actions towards the artifacts, such as looking, pointing, circulating, and inscribing.

I defined a turn as starting when a speaker used verbal expression or nonverbal expression only within a conversation or in individual work. A turn ended when a new speaker responded to the speaker verbally or nonverbally. When verbal or nonverbal expressions were

overlapped, I treated each speaker's verbal expression or nonverbal expression as one turn. However, I marked down the same time for all speakers to indicate the synchronicity of the turn.

***Discourse dimension interaction patterns.*** I analyzed the discourse level interaction patterns to answer the first research question: *How does a specific discourse pattern mediate a team's opportunity and ability to learn from failure in the collaborative design context*? I adopted Mercer's (1996) three types of talk as the analytical framework to conceptualize discourse in this study to answer this question. In Mercer's (1996) framework, he mainly considered discourse as verbal talk. However, Mercer's framework mainly focused on verbal communication. I then adopted the multimodal discourse analysis upon Mercer's framework, which extended the discourse from verbal talk into other modes (Bezemer & Mavers, 2011).

To operationalize Mercer's framework, I created a two phrase coding schemes informed by Barron (2003) and Polo et al.'s (2016) works. Polo et al.'s article used Mercer's types of talk to analyze emotions' social and cognitive functions in argumentation with five indicators. The five indicators are *(1) Are assertions and refutations justified? (2) Do the participants elaborate on the content of previous turns? (3) Do they critically evaluate each other's arguments (4) Do the group explore everyone's idea before making a collective decision?(5) Do the individual's contribution integrate group's conversation in previous turns? Or do they only voice the speaker's initial ideas?*

An Inter-Rater Reliability (IRR) was established for two rounds of coding between two coders. When creating the two coding schemes, the second coder and I used a small amount of data to code using the scheme. For the first phase of the coding scheme, the second coder and I used the percentage match method to check reliability. When trained by Dr. Borge on the

communication analysis coding scheme, which informed the first phase coding scheme development, I reached 0.755 Cohen's kappa with the expert coder. To ensure reliability, the second coder and I used the percentage match method to compare our analysis. Using 20% of the total data, we reached a high percentage match for each code (table 3-2). I then coded the rest data independently. We met regularly and used Cohen's Kappa to check the reliability of the coding scheme.

Table 3-2: 1st phase coding Percentage Match Result

| | Claims | Justified | Questions |
|---|---|---|---|
| **total of match** | 1613 | 1685 | 1721 |
| **percentage of match** | 89.56% | 93.56% | 95.56% |

After I differentiated the claims from the rest, I then identified thematic units or meanings within the selected segments related to teams' design failure identification, analysis, and iteration. Thematic unit is "the thematic meaning unit rather than message, paragraph or sentence" (Arvaja, 2007; 2012). In this study, I identified the thematic unit as starting from one team member reading aloud the checklist or proposing an iteration idea and ending when the conversation was interrupted. It could be interrupted by a new checklist item was read or a new topic was discussed. Each unit was marked down with one or multiple collaborative learning from the design failure process. The thematic unit was used for the second coding phase. Within each unit, I marked down claims for the second phase coding.

In the second phase, I worked with another colleague to code how the team members responded to the claims identified in round one. I also established the IRR when creating the coding scheme for the second coding phase (table 3-4). Like the first phase, the second coder and I tested the coding scheme until we reached a substantial agreement (0.61 – 0.8). Using crosstab on SPSS, the second coder was also given 20% of the transcripts data to establish an IRR. As a result, we

established a substantial agreement, r = .666 (N=552) (see Figure 3-18). I then coded the rest of the data independently.

**Case Processing Summary**

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| SY * YX | 552 | 99.5% | 3 | 0.5% | 555 | 100.0% |

**SY * YX Crosstabulation**

Count

| | | YX | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | Total |
| SY | 1 | 98 | 4 | 1 | 8 | 111 |
| | 2 | 4 | 55 | 0 | 46 | 105 |
| | 3 | 1 | 2 | 52 | 27 | 82 |
| | 4 | 4 | 21 | 4 | 225 | 254 |
| Total | | 107 | 82 | 57 | 306 | 552 |

**Symmetric Measures**

| | | Value | Asymptotic Standard Error[a] | Approximate T[b] | Approximate Significance |
|---|---|---|---|---|---|
| Measure of Agreement | Kappa | .666 | .027 | 25.599 | .000 |
| N of Valid Cases | | 552 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Figure 3-18. A Screen Shot Showing Cohen's Kappa Result for 2nd Phase Coding.

After I coded all data using 1st and 2nd round of coding scheme, I then mapped the utterance level response to Mercer's three types of talk to conceptualize the discourse (table 3-5). At last, I synthesized the learning from failure model proposed by Cannon & Edmondson (2005) and Adam & Atman's (1999) cognitive design model to create a collaborative learning from design failure process framework (table 3-6) to identify team's learning processes (Figure 3-19).

***Tool dimensions interaction patterns.*** I analyzed the tool dimension interaction patterns to answer the second research question: *How does the tool configuration mediate teams to learn from failure in the collaborative design context*? To answer this question, I used the interaction analysis approach (Jordan & Henderson, 1995). I centered the analysis on the following aspects from Jorand & Hendeson's (1995) work (p. 76):

1. What is their trajectory?
2. How do they get into and out of the scene?
3. Who are their human hosts?
4. Are they uniformly or hierarchically distributed?
5. How do they function in structuring interaction?

Those five questions were used analytically to select episodes from the data. While analyzing data for the discourse pattern chapter, I marked down episodes that had tools involved in the transcripts. I went back to the videos to note when the tools got in and out of the space. While watching the video, I marked down the tools used in Column L – Tool in Figure 3-19. I watched the video multiple times to pay attention to team members' nonverbal language, especially how they manipulated (such as, moving or pointing). When analyzing the discourse patterns, I also complied episodes that 1) showed signs of change of group dynamics, such as the tensions or conflicts introduced by the tools; 2) reacted to certain tool configurations that related to the learning from failure process (Figure 3-20).

| A | B | C | E | F | I | J | K | L | M | P | S | V | W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Event Topic (I=Identify; A=Analyze; E=Experiment; P=Process) | 3 types of talk (D=Disputational; C=Cumulative; E=Exploratory | Tool (C=checklist; EV=expert video; CV=client video) | | | | | |
| Lesson | Group | Line | Speake | Utterance & Action | | | | | Claim | Justified | Question | Respon | Response_ |
| L6 | G1 | 81 | Catherine | But there's the water right? | | A | C | | 0 | 0 | 1 | 4 | 4 |
| L6 | G1 | 82 | Marcos | True, so I think we get two for that but we (don't) like this | | A | C | | 1 | 0 | 0 | 2 | 2 |
| L6 | G1 | 83 | Catherine | Ah! ((points at the checklist)) I was talking about orange! ((puts her hand on her chin)) The flowers ((looks at Marcos)). | | A | C | C | 1 | 0 | 0 | 0 | |
| L6 | G1 | 84 | Marcos | ///((In excitement)) Wait, ((points at the design plan)) I did write orange, I did write orange, I wrote orange. | | A | C | | 1 | 1 | 0 | 2 | 2 |
| L6 | G1 | 85 | Catherine | //Wait | | A | C | | 1 | 0 | 0 | 0 | |
| L6 | G1 | 86 | Catherine | Ok | | A | C | | 0 | 0 | 0 | 1 | 1 |
| L6 | G1 | 87 | Marcos | ((cheers)) Yes! | | A | C | | 0 | 0 | 0 | 0 | |
| L6 | G1 | 88 | Aron | Oh yeah! ((cheers)) | | A | C | | 0 | 0 | 0 | 0 | |
| L6 | G1 | 89 | Aron | ((Reading from the checklist)) His son likes black, but d. | | I | C | C | 0 | 0 | 0 | 0 | |
| L6 | G1 | 90 | Aron | We didn't get, black | | I | C | | 1 | 0 | 0 | 0 | |
| L6 | G1 | 91 | Marcos | //Yeah, we didn't get black | | I | C | | 1 | 0 | 0 | 1 | 1 |
| L6 | G1 | 92 | Catherine | //We didn't get black | | I | C | | 1 | 0 | 0 | 1 | 1 |
| L6 | G1 | 93 | Marcos | ((reads from the checklist)) Life style. (?) organic food. | | I | | C | 0 | 0 | 0 | 0 | |
| L6 | G1 | 94 | Marcos | ((points at the design plan)) Apple. Boom! | | I | | | 1 | 0 | 0 | 0 | |
| L6 | G1 | 95 | Eric | ((Laughs)) | | I | | | 0 | 0 | 0 | 0 | |
| L6 | G1 | 96 | Catherine | ((reading from checklist)) Also, they love bar, barbeque grills with charcoal, but they don't feel like buying the expensive charcoal. | | I | E | C | 0 | 0 | 0 | 0 | |
| L6 | G1 | 97 | Eric | So they, we didn't put that in there. | | I | E | | 1 | 0 | 0 | 0 | |
| L6 | G1 | 98 | Marcos | We didn't put that, but we got like, what 2 and 2 and half. | | I | E | | 1 | 0 | 0 | 4 | 2 |
| L6 | G1 | 99 | Catherine | Organic food ((looks at the checklist)) | | I | E | C | 1 | 0 | 0 | 2 | 2 |
| L6 | G1 | 100 | Marcos | We got, we got 2 of them, so that mean, 2 and 2, 2, 2 ((writes the score down)) | | I | E | | 1 | 0 | 0 | 2 | 2 |
| L6 | G1 | 101 | Catherine | Ok | | I | E | | 1 | 0 | 0 | 1 | 1 |

Figure 3-19. A Screenshot Showing the Coding for Research Question 1.

| Theme | Episode |
|---|---|
| calculate score | L4G4_line221-239 |
| calculate score | L6G1_line257-269 |
| calculate score | L10G4_line228-233 |
| calculate score | L6G1_line96-101 |
| comparison | L4G1_line235-237 |
| decide how many points shoud they receive | L6G3_line395-418 |
| decide how many points shoud they receive | L6G2_line45-49 |
| decide how many points shoud they receive | L6G3_line425-456 |
| decide how many points shoud they receive | L6G2_line425-478 |
| decide how many points shoud they receive | L6G2_line161-166 |
| decide how many points shoud they receive | L6G2_line171-178 |
| decide how many points shoud they receive | L10G3_line176-199 |
| decide how many points shoud they receive | L4G4_line155-165 |
| cheer on their score | L6G2_line106-107 |
| what we learn from our past design | L4G1_line364-376; L6G1 |
| secretely add design for certain needs to get points | L6G2 |
| get bored at the checklist | L10G3_line731-751 |
| Can we count a design real if it is not documented? | L4G3_37-46 |

Figure 3-20. A Screenshot of Episodes and Themes Identified from Video and Transcripts.

Table 3-3: First Phase Coding for Discourse Patterns (Adopted from Dr. Borge's Communication Analysis Coding Scheme)

| **Behaviors** | **Definition** | **Example** | **Citation** |
|---|---|---|---|
| make a claim | Make a claim describes the action of adding new facts with or without prompting response, or stating individual opinion, idea, evaluation, conclusion, or proposal to process or content. The claim includes both process and content related claims. | "But if they want to build it, then we shouldn't build it. (opinion) They just need space to do it."<br>" We got that…Total 60, we missed 1, 2, you missed 2. (fact)"<br>"I am going to make an individual sketch." (process related) | |
| Justify a claim | Justifying a claim describes providing rationale and/or evidence, an example to support the claim. The justification can be verbal and/or nonverbal actions. | "But of course, we did write to meet the needs of hummingbirds cause hummingbirds like red"(justify the claim that the design meets the need). | |
| Question | Ask a question to gather more information, confirm, doubt or convey an opinion (rhetorical question), and regulate.<br><br>It still qualifies as a question even if the sentence is declarative sentence, but ends with a question mark. | "Is metal heavier than wood?"<br>"Why would you erase it?"<br>"What is it?"<br>"Should we do it individually?" | |

Table 3-4: Second Phase Coding for Discourse Pattern

| **Types of Response** | **Definition** |
|---|---|
| Simple Accept | This response includes<br>1) simple verbal accept without providing details, examples, evidences, or rationales<br>2) document the previous claim (idea, solution, evaluation result) in a paper; follow the previous claim with action.<br>3) simple repetition<br>4) simple verbal accept to a yes or no closed-ended question |

| | |
|---|---|
| Accept with elaboration | This response indicates agreement with actions that<br>1) add details, examples, evidence, or rationales to clarify one's or other's thought or explain why he/she did something.<br>2) propose next step or generate a new idea/solution/proposal based on the previous claim<br>The premise of elaboration is an agreement of the previous claim no matter whether the agreement is explicitly or implicitly.<br><br>*Note: agree with elaboration only applies to situations when respondents extend other's claim.* |
| Reject with or without justification | This response includes actions that direct verbal reject, disagree, or object one's or other's claims or a yes or no closed-ended questions with or without justification or action that reject or object other's request or actions. |
| Explore | This response opens up discussion to present alternative opinions/claims/ideas, point out problems with an idea, question the logic/rationale behind it, or rewording/rephrasing/asking for clarification of claim/eliciting more information/asking for confirmation to make sure they understand it.<br>(The key to differentiate between accept with elaboration and explore is to identify if the respondent is pushing the team to reconsider or analyze the quality of the original idea, which is an "explore act"; or whether they are simply agreeing and then extending it, which is "accept with elaboration act".)<br><br>*Note: unlike agree with elaboration, one can explore their claims. If someone elaborates their claims, that would count as explore act.* |
| Integrate | This behavior includes actions that combine at least two claims from different group members to decide or propose a new idea that includes parts of each claim.<br><br>The level of the integration varies from:<br>1) incorporate previous claims into a new idea but can still identify those claims easily;<br>2) fuse into a total new entity that the previous claims cannot be recognized easily. |

Table 3-5: Map the Types of Responses to Mercer's Framework

| | **Disputational** | **Cumulative** | **Exploratory** |
|---|---|---|---|
| **Simple Accept** | rarely | majority | moderate |
| **Accept with elaboration** | rarely | moderate | moderate |
| **Reject with or without justification** | majority | rarely | moderate |
| **Explore** | rarely | occasionally | majority |
| **Integrate** | rarely | rarely | occasionally |
| | | | |

Table 3-6: Coding Scheme for Learning from Failure Process (adopted from Cannon & Edmondson, 2005; Adam & Atman, 1999)

| **Collaborative Learning from Design Failure Process** | **Detailed Moves** | **Citation** |
|---|---|---|
| Identify design failures | 1. Identify what specific design features failed to meet the needs without further analysis | Cannon & Edmondson, 2005; |
| Analyze Solutions generated from past prototype or iteration | 1. Review current design' features and their forms and functions.<br>2. Evaluate how current design's forms and functions meet or unmet the client's needs.<br>3. Define or redefine client's needs and the solution implications to analyze current design solutions. | |
| Iterate design | 1. Decide what and how to modify the current designs concerning the failures of solutions or refine or enhance current design.<br>2. Specify design forms and functions to add to the current designs.<br>3. Propose or/and select alternative design solution to meet certain needs or without specific design rationales<br>4. Gather more information to ideate. | |

| | | |
|---|---|---|
| | 5. Define or redefine client's needs and design implications to modify current design solutions or propose new design ideas. | |

# Chapter 4

## Discourse Mediates Learning from Failure in the Collaborative Design Context

In this chapter, I answer my first research question – *how does a specific discourse pattern mediate a team's opportunity and ability to learn from failure in the collaborative design context*? I examined the role of the discourse in learning from failure as teams design collaboratively. Mainly, this chapter illustrates how specific discourse patterns enhance and diminish a team's ability to identify, analyze, and iterate their design in the collaborative design context. I analyzed four young design groups' video and audio data within three learning from design failure lessons. I organize this chapter into two parts. The first part reports the overall discourse patterns observed in all groups across three selected lessons. In this part, I also provide context to describe some characteristics of each group I observed. I then zoom in team's moment-to-moment interaction to demonstrate how the team used different discourse patterns to identify, analyze, and iterate designs and the consequences

## General Discourse Patterns

I observed all three types of discourse patterns in all four design groups (see Figure 4-1). In general, cumulative talk is the most frequently observed type of talk among all groups, following by exploratory talk. Disputational talk was the least frequently observed talk in the data analyzed. The cumulative talk was the most dominant discourse pattern observed throughout all three lessons selected. However, multiple degrees of cumulative talk existed in the

data and varied from simple agreement to elaboration and clarification. The same pattern existed in the other two types of talk as well. The exploratory talk was the second dominant discourse pattern observed. From the analysis, the team's exploratory talk ranged from constructive and critical but without an agreement to achieve consensus and documentation. Disputational talk existed in all groups and notably higher frequency in team 3. Though simple rejection was often used to categorize disputational talk, the data showed that team members could reject rationally. However, it sometimes led to an emotional breakdown. However, the frequency of disputational talk observed in team three decreased over time. Fourth, the disputational talk episodes identified in the data range from simple rejection without reasoning to sophisticated reasoning.

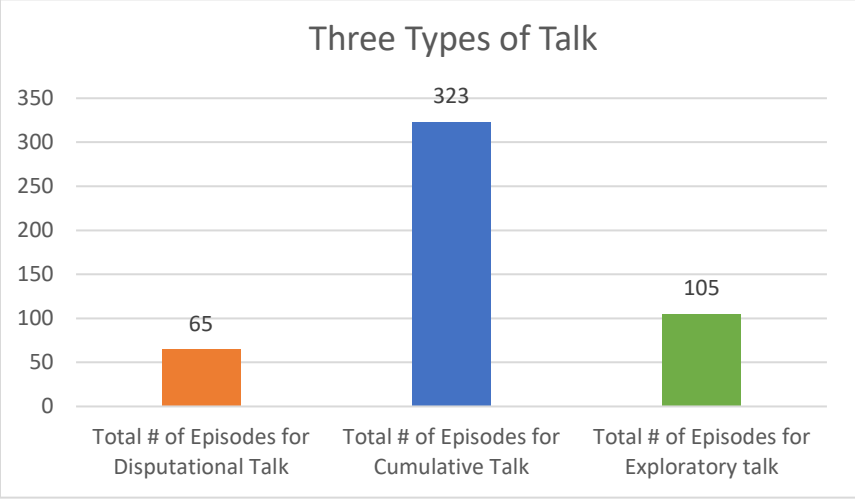



Figure 4-1. This Figure Shows the Frequency Counts for Three Types of Talk.

**Specific Discourse Patterns Meditate Learning from Failure**

This section presents multiple cases from the data to discuss how specific discourse patterns support and constrain the team's ability to learn from failure in the collaborative design context. A team's ability to learn is conceptualized as identifying and analyzing design failures and iterating their design. To identify what failed, analyze how the design did not meet the

needs, and know what changes to make, the design teams need to constantly make sense of what failed and decide how to iterate. I start the section by reporting how specific discourse patterns mediated joint identifying design success and failure from moment-to-moment interaction. Following that, I then move to the process of joint analyzing success and failure. I describe the third ability – joint iterating design at last.

## Joint Identifying Design Success and Failure

### *Cumulative talk supports joint decision-making but might constrain teams from foregrounding rationales to make collective sense.*

The way teams use cumulative talk to identify design success or failure fell into two spectrums jointly. These two spectrums differed from how many details team members draw to identify the success or failure of their design. They are: 1) identifying design success or failure without elaboration; 2) listing design features or functions as an evidence to support whether they met or unmet the design needs. They either claimed their design met or unmet the needs within their conversation, or they searched for evidence to support their claim.

Identifying design failure jointly without elaboration is one of the high-frequency patterns. It is primarily observed in lesson 4 and lesson 6. Overall, I found that 23 instances fell under this pattern across all four teams. I observed team one using this strategy the most ($n = 14$). The following episode exemplifies how the expert team uses this strategy to *identify* a design failure and the potential risk.

The instance below occurred when the expert team evaluated the comfortable reading chair design in lesson 4. The expert team sat together to evaluate one user's need: "I like to move my chair around so I can enjoy sunshine sometimes or get closer to the light." challenge, client, explain checklist items/scores When the team first evaluated this need, they quickly agreed that their design did not meet it.

| Turn | Speaker | Verbal and Non-Verbal Transcript |
|---|---|---|
| 1 | Catherine | ((reads from the checklist)) So I like to move my chair around so I can enjoy sunshine (?) sometimes get close to the light. |
| 2 | Catherine | ((looks at Marcos)) Zero? |
| 3 | Marcos | ((looks at the checklist and turns to his right side and turns back)) Zero. |
| 4 | Catherine | Or two. |
| 5 | Catherine | ((looks at Eric and waits for his reply)) |
| 6 | Eric | ((looks at the checklist)) Zero. |
| 7 | Catherine | ((writes the score down on the checklist)) |

Catherine started the evaluation by reading the checklist aloud for Marcos and Eric. Then, she immediately proposed "zero" as her evaluation score (line 2). Zero means that they did not meet the need. Marcos and Catherine had an agreement (line 3). Catherine, however, proposed an alternative score – "two" (line 4). For this item, two means their design met the need. This idea was ignored, however. Before she documented zero as the final score, she waited for Eric to share his opinion. After Eric also proposed "zero" as their score (line 6), Catherine put the final score down (line 7).

After team one completed checking the rest needs, they calculated the total score. While Catherine documented the final score, Eric looked at their design prototype for a couple of seconds and then looked at the checklist. Suddenly, he grabbed the checklist and yelled, "Wait! There are points for the moving cause it hovers". He pointed at the checklist, and Catherine looks at where Eric pointed. She shifted her gaze to the prototype, which was covered under Eric's arms. Eric moved away, pointed at the text on the prototype, and showed Catherine, "It can hover." Two seconds later, Catherine turned around and called Marcos back to the team. She told Marcos about Eric's discovery. However, Marcos disagreed with Eric's rationale that the hovering function can solve the client's mobility need. This disagreement led to 47 turns of exploratory talk among the expert team. Overall, their conversation was centered around what the design need meant and what were the design implications.

In the excerpt above, even though the expert team respected individual member's opinions before making a joint decision, their quick consensus was at the cost of developing shared understanding. They quickly reached the consensus and moved on without critically evaluating their stances or justified their claims. They neither referring to their design prototype as evidence to support their failure identification nor discussing what the design need means as a team. At this point, the team's cumulative talk mode allowed them to make efficient identification decisions but failed to unpack the design need. They failed to develop a joint understanding of why their design failed to meet this. It was evidenced by the follow-up episode when Eric discovered the hovering feature and connected this feature and the client's mobility need. Marcos, however, disagreed with Eric's interpretation which forced the team to re-examine their design prototype, the client needs, and design implications together.

Team members often listed design features and design functions to evaluate whether they

met the clients' needs without elaborating their rationales. It was also one of the most observable patterns using cumulative talk in the data (*N = 42*). Interestingly, this pattern was the most observable in lesson 10 (*n = 26*) when the Fred family's garden checklist was distributed the third time. Often, when one team member or the facilitator read the client's need aloud, team members responded with specific design features. They listed the design features or functions as evidence to support their design met or does not meet the client's need. However, even though it allowed some articulation of individual thoughts, the simple listing is still limited in terms of supporting teams understand the deeper individual design rationales, especially articulated the logical connection between the design features or functions and the client's needs.

This section used one instance from novice team four to show how this pattern can be problematic. In this excerpt, team members were evaluating their butterfly garden 3-D LEGO model using the checklist. As I mentioned in earlier sections, team four members formed a harmonious team dynamic compared to teams two and three. Throughout the semester, I hardly observed visible conflict in this team. Even though the team member Rick and Adben had some tensions, they could regulate or be regulated by Sebrina or the facilitators.

| **Turn** | **Speaker** | **Verbal and Non-Verbal Transcript** |
|---|---|---|
| 8 | Sebrina | ((reads out loud from the checklist)) Baby girl, the baby girl, Marianna, likes to crawl and play with animals. |
| 9 | Sebrina | That's… ((pauses and looks at the LEGO model)) |
| 10 | Rick | ((shows the LEGO child to Adben)) Juan. |
| 11 | Adben | We should have the animals. ((laughs)) |
| 12 | Sebrina | ((points at one yellow design)) We already. This is the animal pen, remember? |

| | | |
|---|---|---|
| 13 | Rick | ((shows the LEGO child to Sebrina)) Juan. ((Sebrina turns around and looks at the LEGO on Rick's hand)) |
| 14 | Adben | ((looks at the left side of the LEGO model and moves one LEGO inside the pen)) There's an animal. |
| 15 | Sebrina | Yeah exactly. |

Unlike Team one's approach of sharing only individual claims in the episode I presented above, Sebrina and Adben's conversation took a step further and identified what design features they had or did not have in the LEGO model to support their claims. For example, after Sebrina read the client's information out loud (line 1), she paused and looked at the LEGO model to find if they had a specific LEGO design that associates with this information. Historically, Sebrina often elaborated her thoughts when she talked to other team members. The word "animal" from the checklist triggered Adben. He shared that the original LEGO model lacks LEGO animals to imply that their design did not meet the need (line 3). This reminded Sebrina that they did create an animal pen (line 5). Adben found a LEGO piece, assigned it as a LEGO animal, and placed it in the animal pen (line 8). From their interaction, Sebrina and Adben understood the importance of listing design features as evidence to support their argument that their design met the need.

However, neither Adben nor Sebrina elaborated or discussed the logical connections between the design feature - animal pen and the information about the baby girl Mariana – she likes to crawl in the garden and play with the animal. More importantly, they did not spend time defining or re-defining the client's needs and the design implications. Interestingly, the team's conversation around this information shifted when the facilitator A proposed a critical question to team four: "How are you protecting the baby girl who likes to crawl and play from the water hazard"? In the beginning, Sebrina referred to the animal pen with a newly added feature she did

not mention before - it was "pretty human-friendly." This was the first connection Sebrina made between the animal pen and the client's information. It implied that the baby girl Mariana could play in the animal pen safely, solving the facilitator's safety concern and satisfying the second part of the need. The facilitator A raised another concern: "But what about..., when they are out enjoying stuff, are you gonna keep her from falling into the water"? Facilitator A elaborated the "water hazard" by creating a concrete embodiment scenario to clarify the facilitator's original concern: protecting the baby girl. The second question also forged a new connection between the current information about the baby girl and team four's other design feature – the water fountain. This new connection opened a sophisticated exploratory talk among team four and the facilitator A about design trade-offs and ways to reconcile tensions among multiple design needs.

***Disputational talk might constrain the team's ability to make sense of their collective design ideas.***

When teams encounter conflicted views during the planning phase, instead of reaching a joint consensus, some teams created multiple individual design sketches to deal with the differences. This individualistic approach might bring peace but postpone the conflict until they were asked to evaluate the team's design with the checklist consisting of the client's needs. The individual sketch became the source of conflicts in the design reflection activities. I will show how teams deal with the conflicts when identifying design failures using disputational talk.

Teams who created individual design sketches before evaluating the design for the first time often argued whether specific designs existed. A similar challenge also occurred when teams used LEGO blocks to create 3-D models for their design. Without an agreement on the

design, team three members took independent creation paths in the building section. They went through the confusion on what specific design was in the later evaluation session. Throughout the data, I observed this type of disagreement raised primarily on team three. From the observation, team three went through many conflicts throughout the planning phase. The following excerpt occurred in lesson 6 when they were asked to evaluate the Fred family's butterfly garden paper sketch. This excerpt occurred as a continuity of unresolved conflict between Kiya and Cameo from an earlier time when they fought overdrawing on one paper to create the design sketch.

When they started evaluating, all members except Andy leaned toward the checklist. After Cameo and Kiya agreed that their design met the first need, the facilitator F instructed them to move to the second need and walked away. The second need stated, "Juan is now 6th grade and interested in painting, music, and sports".

| **Turn** | **Speaker** | **Verbal and Non-verbal Transcript** |
|---|---|---|
| 1 | Facilitator F | ((looks at the checklist)) And the second, Jean. |
| 2 | Cameo & Kiya | ((look at the checklist and Kiya mumbles)) |
| 3 | Cameo | There. There's space to play sports for him. There. There was supposed to be a music box. |
| 4 | Kiya | No, there wasn't. |
| 5 | Cameo | Yes, there was. On my copy, there was a music box ((looks at Kiya)). |
| 6 | Kiya | No, there was not. |
| 7 | Cameo | Yes, there was. |

| | | |
|---|---|---|
| 8 | Cameo | ((stands up and asks facilitator F)) Can I see my copy? |
| 9 | Facilitator F | ((gives Cameo her copy)) |
| 10 | Cameo | ((puts her drawing on the table and points at something)) There was. So... |
| 11 | Teddy | ((after whistling for a bit, Teddy turned his gaze at where Cameo pointed)) There was a (beat) box? |
| 12 | Kiya | ((replies to Cameo)) You said not to look at that. |
| 13 | Teddy | ((leaned toward the checklist and read aloud)) Painting, music, (inaudible) |
| 14 | Cameo | (Well, then) nothing. |
| 15 | Kiya | (It is a) zero. |
| 16 | Cameo | ((writes something down)) |

Cameo recognized that her design sketch included a music box to meet the need (line 3). However, Kiya rejected Cameo's claim because she did not see it on the sketch (line 4). Even though Cameo explained that her original copy had the music box, Kiya still rejected Cameo's claim (line 6). Cameo asked her copy back from Facilitator F and pointed it to Kiya (line 8 and line 10) to prove her point. Kiya defended herself and blamed Cameo for forbidden others to look at the copy (line 12). Eventually, the team counted the design as not meeting the needs (lines 14 to 16).

Between the first and the second excerpt presented later, Cameo repetitively blamed Kiya for not including the music box design into the joint. By the time they moved to the second excerpt, the reading aloud and inscribing score roles were distributed between Kiya and Cameo. The second excerpt started with Kiya read aloud another design need – "Fred usually works at

home but mostly sit in front of his computer in his House office."

| Turn | Speaker | Verbal and Non-verbal Transcript |
|---|---|---|
| 17 | Kiya | ((reads from the checklist)) Fred usually works at home but mostly sits in front of his computer and his... house office. |
| 18 | Kiya | So, what's that mean? |
| 19 | Cameo | I put a laptop outside for him. |
| 20 | Facilitator F | Hmm, yup yup. |
| 21 | Cameo | ((starts writing)) |
| 22 | Facilitator F | ((reaches her hand forward to the checklist under Cameo)) //And, wait a minute. |
| 23 | Kiya | //There's no. //There's no >> laptop. |
| 24 | Teddy | >> ((talks to Kiya)) He doesn't (need) lap. Laptops are portable. |
| 25 | Cameo | ((looks at Kiya)) You didn't care to look at mine, so you>> |
| 26 | Teddy | >>((addresses it to the group)) Laptops are portable. |
| 27 | Facilitator F | ((lifts Cameo's sketch in front of Cameo)) In the, in the? In the draft? |
| 28 | Cameo | Mine has laptop, music box... |
| 29 | Facilitator F | ((looks at Kiya)) And you have the (?). So... |
| 30 | Teddy | ((looks at the facilitator F)) Laptops are portable. |
| 31 | Andy | ((covers his mouth with his nametag)) Of course, they |

| | | |
|---|---|---|
| | | are! |
| 32 | Facilitator F | Sure, you can have this one. |
| 33 | Teddy | And laptops are portable. |
| 34 | Facilitator F | Hmm. |
| 35 | Andy | (Yeah! Why do you think they are called) laptop? |

Kiya proposed a question to define the client's needs (line 18). Without following up on this question, Cameo shifted the focus to evaluate their current design solutions (line 19). Similar to the last episode, Kiya rejected Cameo's claim (line 23). Cameo again blamed Kiya for not caring about her work (line25). Teddy interrupted and shifted the conversation to whether the laptop was what the client needed based on the profile but was ignored by the team (line 24 and line 26). After confirming that the laptop existed in Cameo's design sketch, the facilitator F granted the team that their design met Fred's need (line 32). At this point, the facilitator F treated all drafts as joint and agreed that if they existed in one's drawing, the team could get the total score. Compared to the final evaluation between the "music box" and "laptop," both designs existed only in Cameo's draft, leading to two evaluation results.

Teddy tried multiple times to get his teammate's attention but failed (lines 24, 26, and 30). Andy finally responded to Teddy's claim but with a rising tone (line 31). Andy's replied sounded like an agreement but was with a degree of disdain. His second response supported this after Teddy's fourth repetition of his claim (line 33). Andy used a rhetorical question (line 35) to state that the laptop is called a laptop because it is portable.

In this excerpt, two critical moments were missed by the team. The first moment was when Kiya asked to interpret the design need. Cameo blamed Kiya for failing the design because Kiya did not include Cameo's version. This blame was a consequence of the power struggle

between two girls. Before this episode, two girls encountered several instances of fighting over the materials, the legitimacy of ideas, or control in this lesson. Even though the facilitator F granted Cameo's laptop design as part of the joint design decision and agreed that this design met the client's need, the team did not take a step back and analyze the laptop solution. Teddy, on the contrary, asked to evaluate if the laptop was even needed since it was portable. This was a second critical moment team three missed.

### *Summary*

Identifying design success and failure required far more communication in the collaborative design context than the organizational learning setting. In the collaborative design context, identifying design success and failure at the team level includes making collective sense of team members' design features and functions. Often, the act of identification is a conclusion design teams draw after an in-depth analysis of their design and the clients' requirements. Therefore, identification as a form of decision-making often required teams to reach a certain level of consensus to call something "failure." The data analysis used cumulative talk extensively to decide whether their design met the client's requirement in the design evaluation activities. The analysis also showed that if teams` always agreed without critical reflection, they might miss meaningful opportunities to develop shared views and improve the design products. On the contrary, teams who used disputational talk went through emotional challenges and brought up unequal team participation.

## Joint Analyzing Design Success and Failure

***Cumulative talk supports the team's joint sense-making of their design rationales but might reinforce the collective biases.***

Examining the pattern of using cumulative talk to analyze design success and failure, I found majorities of the episodes shared one common characteristic: teams often reached a joint sense-making through externalizing rationales. More interestingly, when teams elaborated their design rationales, they recognized their design assumptions and developed a shared understanding of the design features and functions. They clarified and confirmed with each other and sustained those collectively shared understandings to their future discussions and actions. In the following episode, I used the expert team's instance to evaluate their paper butterfly garden prototype in lesson 6. In the following episode, the expert team members recognized that they misinterpreted the information provided by the client as a team.

| Turn | Speaker | Verbal and Non-Verbal Transcript |
|---|---|---|
| 1 | Catherine | ((reading from checklist)) Fred's family lives near forest, so sometimes bears from the mountain would come to their backyard. |
| 2 | Marcos | ((grabs the design plans closer and checks)) Thought he has a fence. |
| 3 | Aron | (They do have) a fence around the pool. |
| 4 | Marcos | Huh? |
| 5 | Eric | ((looks at Marcos)) We have trees he can climb. |
| 6 | Aron | ((points at the design plan)) |
| 7 | Marcos | Oh yeah. |

| | | |
|---|---|---|
| 8 | Eric | We have trees he can climb. |
| 9 | Marcos | But then also, we automatically assume that he had a fence, right? |
| 10 | Catherine | Yeah. ((looks at her front)) |
| 11 | Aron | Yeah. ((looks at Marcos)) |

After Catherine read the information out loud, Marcos made a claim (line 2) which included several design assumptions – 1) bears are threats to the family; 2) a fence around the garden can protect the family from the bear; 3) the client already had an existing fence. Aron confirmed Marcos's third assumption that the fence already existed in the garden (line 3). Eric attempted to propose an alternative design implication – "he can climb" (line 5). Even though accepting Eric's alternative proposal, Marcos did not follow up with Eric's claim. Instead, he re-focused the conversation back to the fence. He initiated a confirmation act with the team to agree that they assumed the family already had a fence (line 9). Even though both Catherine and Aron confirmed Marcos's question (line 10 and line 11), Marcos still seemed unsure about his claim. He looked around, picked up a satellite view of Fred's Garden, and examined it.

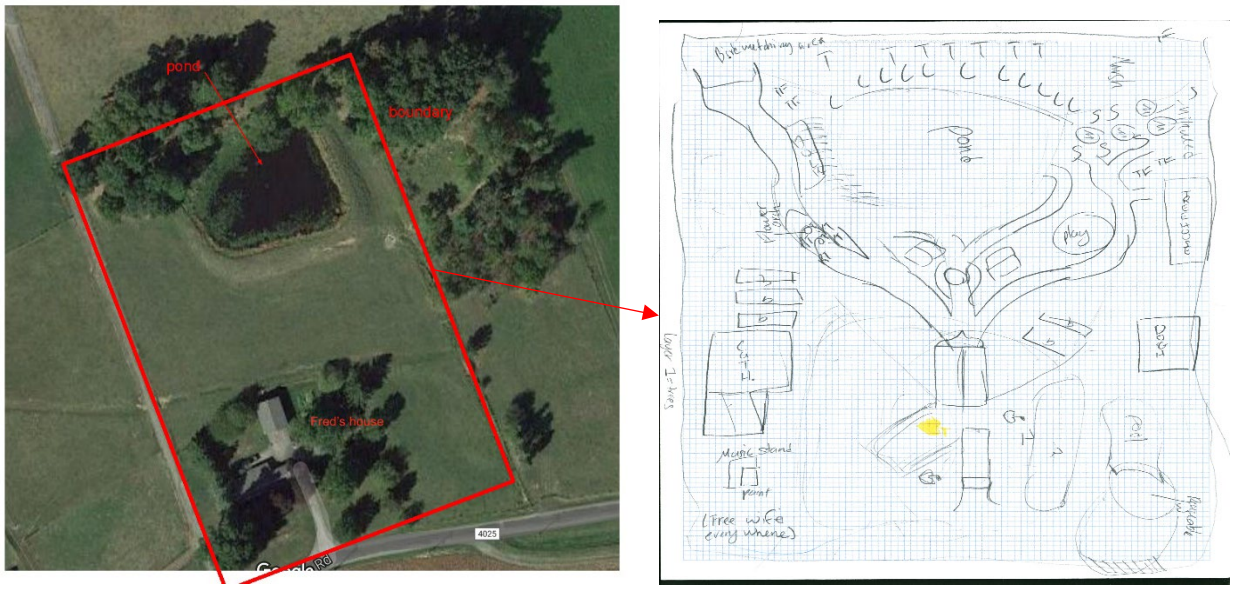


Figure 4-2: Fred's Family House Satellite View and Team one's Design Plan Draft Comparison.

| Turn | Speaker | Verbal and Non-Verbal Transcript |
|---|---|---|
| 12 | Marcos | What did we…where is the…yeah, ((picks up the satellite view of Fred's Garden)) we would automatically assume that he has a fence, hmm? |
| 13 | Catherine | ((leans closer to Marcos and looks at the satellite view of the map)) |
| 14 | Marcos | ((picks up the map and looks at it)) Oh no, he doesn't. |
| 15 | Catherine | ((continues looking at the map and frowns)) |
| 16 | Aron | I thought that red thing was a fence. |
| 17 | Marcos | Yeah, that's what I thought. ((about to put away the map to his right side)) |
| 18 | Catherine | Wait ((takes over the map and look closely at the map)) |
| 19 | Aron | Ok, ((waves his left hand from left to right)) so that red thing is a fence now. |
| 20 | Marcos | Yeah, there was a fence around this entire thing, right? ((starts drawing a line on the design plan)) |
| 21 | All | ((Eric, Aron, and Catherine all paid attention to Marco's hands. After finishing the drawing, Marcos wrote an "F" next to the line on the design paper. At last, Marcos put down 2 points for this item)) |

Marcos realized that his assumption that Fred's Garden had an existing fence was inaccurate and shared (line 14). Looking at the satellite map, Aron shared that he interpreted the

red boundary line as a fence (line 16, Figure 4-2). Marcos voiced that that was his assumption, too (line 17). After hearing that Marcos shared the same assumption, Aron then re-purposed the red line as the fence (line 19). Even if the red boundary line on the map was the fence as originally thought, they recognized that they failed to add the fence into the plan. While confirming Aron's claim in turn 19 and again seeking confirmation from the team, Marcos documented this design idea into the plan and a score on the checklist (line 20 and line 21). The expert team sustained this idea in their future design. It was evidenced by Catherine and Marco's conversation about lacking time to build the fence when they evaluated the 3-D LEGO model in lesson 10.

In this episode, the expert team used cumulative talk to mediate several sophisticated design practices. First, they recognized design assumptions and design failure (lines 2, 3, 14, 16, and 17). Second, they investigated the information provided as (lines 12 and 18), documented the change of design (lines 19, 20, and 21). Interestingly, Marcos confirmed three times with his team that the fence already existed to justify that their design did not fail to meet the client's needs (lines 9, 12, and 20). As a team, they agreed that they did not fail the client, which is evidenced by Marcos's documentation of score (line 21). Even though Marcos and Aron recognized that they should have created the boundary and documented the change, they still marked their design as meeting the client's need (lines 20 and 21). As a team, they successfully sustained this design idea through time.

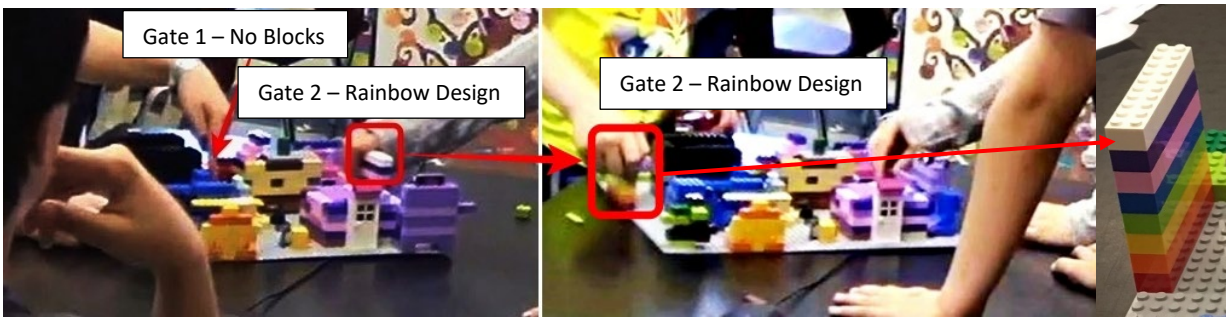
This episode highlighted one potential challenge of using cumulative talk to mediate design conversation in teams – satisfying with one design idea. The expert team converged their attention on maintaining success rather than critically evaluating the potential risk of the current design solutions. They ceased to explore alternative design implications once majorities of team

members fixed on one design idea – a fence to protect the family from bears. Even though Eric proposed an alternative design implication (turn5 and 8), other team members did not follow up with this proposal. They successfully converged the design solution and completed the task quickly by reaching an agreement. However, they failed to think divergently to propose more design paths.

***Disputational talk supports surfacing individual design rationales but constrains a team's joint sense-making***

Among all teams and lessons, I observed 5 instances of using disputational talk to analyze design rationales from teams one, two, and three. In the following section, I present an excerpt from team three that discussed whether their design met the need of "Fred's family lives near a forest so sometimes bears from the mountain would come to their backyard." There were multiple versions of rationales team three members provided on how their design took this need into considerations throughout time. The first time they discussed this need was during the 3-D LEGO model building session in lesson 8. Even though they were given the checklist in lesson 6, team three ran out of time without discussing this need. When they evaluated it again in the instance I present here, Kiya claimed that they did not design anything to keep the bear away. Other teammates proposed that the robot and the dog can prevent potential harm in their design. Kiya rejected those rationales. She argued that the dog can only bark to alert the family but cannot keep the bears away because the bear is stronger than the dog. Teddy argued that the robot is stronger than the dog, which Andy supported. Without further discussion, the team and the facilitator D moved on to the next item on the checklist.

At the beginning of evaluating the 3-D LEGO model in lesson 10, Andy and Kiya took over the evaluation responsibilities. At the same time, Cameo and Teddy repaired the broken LEGO model. During the evaluation, a piece of information caught Andy's eye - "Fred's family lives in the forest. Sometimes, bears from the mountain would come down to the backyard". He looked up and called his teammate with excitement. He told others that they need to add a fence in their design and leaned forward to grab the checklist from Kiya so he could read the need out loud. Kiya looked at Andy and asked, "The bear?". Andy confirmed and took the checklist from Kiya. Kiya shared the information with the rest of the teammates: "they live by a forest, so the bears come to their house." With Kiya's help, Andy found the text and read it out loud to the team. He pointed out that the bear would come to the side of the backyard. With this information, Teddy picked up the rainbow gate and moved it to the other side of the LEGO board (new location for gate 2, Figure 4-3). Andy pointed out that the gate cannot cover the whole backyard, and the bear could go around the gate and entered the garden. This conversation was interrupted by two facilitators when they asked team members to go through the checklist together.




Locations of Two Gates New Location for Gate 2 G2 Detail

Figure 4-3. A Screen Shot Showing the Change of Location of the Gate 2 Team Built.

During the evaluation, facilitator D connected the team's discussion to another information about the client - the bear coming to the backyard as a potential safety hazard.

Facilitator D asked if the team took this information into design consideration. Andy shared that they just discussed it, and they yet created anything to solve the problem. Kiya, on the other hand, stated that they "will have this as a gate," by "this," she meant the rainbow gate (gate 2 on Figure 4-3). She also added new details of the gate: the gate would "close around" the garden. Before Kiya finished her turn, Cameo interrupted her and added that they also added a sensor so the gate would go to that location where it sensed the bear. Disagreed with the gate idea earlier, Andy again brought up that the bear can go around the gate and enter the garden. Andy's critique led to Teddy's improvisation. Teddy argued that the gate is lightning fast so that the gate can move around quickly. This argument did solve the problem Andy stated earlier but raised another critique from Andy. This critique then led to a fight over the design rationale between Andy and Teddy in the following excerpt.

| **Turn** | **Speaker** | **Verbal and Non-verbal Transcript** |
|---|---|---|
| 1 | Teddy | But it will be lightning fast. |
| 2 | Andy | Lightning-fast gates. They don't even have lightning-fast cars. |
| 3 | Teddy | Race cars. |
| 4 | Andy | Race cars aren't lightning fast. Lightning fast, takes about... 5, like 3 milliseconds to strike. |
| 5 | Teddy | Yes, that's how fast it is. If a bear (was supposed to) walk around it, it will (?)/ |
| 6 | Facilitator D | Okay. If there's only one gate... Okay. |
| 7 | Andy | You can't make up fictional thing. It has to be real light. A gate can't be fast, like, about this speed. |

| | | |
|---|---|---|
| 8 | Teddy | No. Yes, it can. |
| 9 | Facilitator D | I think it is a good point because we have buildings, and we also have to consider, the reality that you can build here, here. And also in Minecraft. |
| 10 | Teddy | It isn't the reality! |
| 11 | Andy | ((replies to Teddy) Yes, it is! |
| 12 | Teddy | It is not reality! ((points at the LEGO plan)) LEGO.... LEGO... ((raises voices)) <<(is) not reality. |
| 13 | Facilitator D | <<We also... |
| 14 | Andy | ((raises voices)) Yes, but we suppose to make it as close as we can to reality. |
| 15 | Teddy | And it is not even (close to) reality. |
| 16 | Andy | We are supposed to make it looks like reality because we are building (?) real. |

Andy argued that lightning-fast gates did not exist because even lightning-fast cars did not exist (line 2). Teddy provided a race car as an example to counter-argue Andy's point (line 3). Andy pointed out the flaw of Teddy's race car example and argued that lightning-fast strikes in 3 milliseconds (line 4). Teddy then used Andy's information to support his original claim that the lightning-fast gate with 3-millisecond speed can prevent the bear from walking around the gate, as Andy critiqued at the beginning (line 5). Andy then raised another problem with Teddy's rationale – their design should base on reality. From Andy, a lightning-fast gate is a fictional design and cannot solve the problem because it cannot be built in reality (line 7). Trying to mediate Andy and Teddy's argument, Facilitator D pointed out that the team should consider

actualizing the design using LEGO and Minecraft (line 9). Teddy argued that the LEGO blocks are not the reality (line 10). With the constant rejection from Andy and me, Teddy started to show frustration by raising his voice (line 12). The polarized fight over reality vs. fictional between Andy and Teddy led to frustration and no joint sense-making established. Later, I asked if they would cover around the backyard with the gate as Kiya and Andy suggested or have just one gate as Teddy suggested. Kiya took the rainbow gate in her hand and shared that the gate was just a design demo. They would build more rainbow gates to cover LEGO Fred's property to protect the family. Kiya's claim triggered a conflict within the team. It led to Teddy's emotional breakdown, which I will dive into in the next section.

Team three's rationales on how their design took the information - bears visited the backyard - into consideration did not form concretely as a joint sense-making. It is still unknown if team three members reached a consensus on putting up a wall around the garden as the solution since they did not document it anywhere and they did not finish building the Minecraft model at the end. However, the conversation around this information was by far the most extensive one. Through the conversation, team three from lesson 8, when they discussed this information the first time, there had no closure to this need. As a team, they brought up multiple solutions in two rounds of evaluation: robot, fences, gates circle around the backyard, gates with sensors, and lightning-fast gates. Many of those solutions proposed were contingent.

In the end, Andy and Teddy did not reach a joint solution on overcoming the dichotomy to neither identify if the design failed to meet the needs nor come up with design solutions to incorporate both sides of views for improvement. Without a shared goal of establishing joint decision-making, team three members chose to defend their ideas. They pointed out other's logical flaws to win. For Andy, who brought up the fence idea in the later lesson, the rationales

emerged because of momentary interaction and thought. Without documenting or consensus, the team did not give the design solution a form to sustain over time within the team. The design idea faded when the dialogue ended.

***Exploratory talk supports teams to evaluate design rationales critically and explore alternative design perspectives.***

Even though not exclusive only to exploratory talk, teams brought up or recognized the clients' needs more often when they engaged in exploratory talk. Instead of interpreting the client's needs to favor individual or teams' solutions, they used the checklist to define the design problems, critically examine existing solutions, and explore alternative design paths. One of the representative cases came from team three in lesson 6 when they evaluated the Fred family's butterfly garden with their paper sketch.

The information team three discussed was "They live in central Pennsylvania area. It is cold in the winter but comfortable in the summer. The temperature in winter is usually around 30F and 75F or higher in summer. It snows quite a lot in the winter". After Teddy read the information aloud, he voiced "one point five for this" and started writing down the score. Teddy volunteered to take over the responsibility after Cameo refused to lead. In the beginning, Teddy would make an evaluation decision without consulting his teammates. The facilitator F who sat next to the team, encouraged him to explain his rationales and seek agreement from his team. This time, Cameo spoke up and disagreed with the score Teddy proposed. Facilitator F stepped in and asked Teddy, "why do you think it is 1.5". With the prompt, Teddy explained that the fish would die when it was freezing in winter. What he meant was, the fish in the garden pond would

die because of the low temperature. He took 0.5 away (the value listed on the checklist was 2.0) because he thought their design did not consider this risk. At this point, Teddy defined a problem they failed to solve in their design.

| **Turn** | **Speaker** | **Verbal and nonverbal utterance** |
|---|---|---|
| 1 | Cameo | ((looks at Teddy)) But there's like a cover for it, like you can put over it. |
| 2 | Kiya | ((replies to Cameo)) I don't see. I don't see a cover. |
| 3 | Teddy | //((looks at Cameo)) Like a clear cover, like a clear. Like a clear protected cover? |
| 4 | Cameo | ((looks at Kiya)) Like you can put it over ((uses hand to gesture the top)) |
| 5 | Teddy | ((looks at Cameo)) Is it a clear protected cover? |
| 6 | Cameo | ((looks at Kiya)) But! But there's a clear cover on it. |
| 7 | Kiya | ((replies to Cameo)) I don't see a clear cover. |
| 8 | Cameo | // ((looks at Kiya)) Because it is clear! |
| 9 | Teddy | // ((looks at Kiya)) Because it is clear! |
| ((Facilitator also tried to explain to Kiya)) | | |
| 10 | Andy | ((looks at Kiya)) It. That means it is transparent. |
| 11 | Kiya | But can it still get cold because like, like the outside is still cold? |
| 12 | Cameo | ((looks at Kiya)) But! //But you put pond warmer in the pond. |
| 13 | Andy | // ((while Cameo’s talking, Andy addresses to the whole |

| | | |
|---|---|---|
| | | team)) Oh yeah, yeah. It is a... Guys, guys! It is like a bed sheet. |
| 14 | Teddy | Or, it is like a... |
| 15 | Kiya | ((looks at their design sketch)) There's no. There's nothing in that show it though. |
| 16 | Teddy | ((replies to Andy)) No, it is not like a bed sheet. It is like. It is like... |
| 17 | Teddy | ((looks at Andy)) It is like a heat blanket. |
| 18 | Andy | ((looks at Teddy)) Heat blanket? ((makes a face with confusion)) Where are they gonna' get (electricity)? |
| 19 | Cameo | But either way, we put like pond warmer thing. |

Cameo argued that they should get two points because they had a cover on top of the pond (line 1). Kiya disagreed with Cameo because she did not see the cover (line 2). Teddy asked Cameo to clarify if the cover was clear (line 3 and line 5). Kiya still argued that she did not see the clear cover (line 7). Cameo, Teddy, and Andy collectively explained that clear means it was transparent, and the transparency of the cover made it hard to see (lines 8, 9, and 10). Later, Andy extended that the clear cover could serve as a "bedsheet" for the fish (line 13). Teddy disagreed with Andy's "bedsheet" metaphor (line 16) and argued that it was like a "heat blanket" (line 17). Andy questioned Teddy's metaphor and asked where the family could get electricity to heat the cover (line 18). While Teddy and Andy discussed whether the "sheet" should be heated, Kiya brought up that the cover solution might not be enough to keep the pond warm for the fish since the temperature was still low outside (line 11). Cameo then proposed an alternative to Kiya's critique, adding a pond warmer (line 12). Kiya argued that the pond warmer idea was not

reflected in their current design solution (line 15). When facilitator F checked with the team to see if they had the pond warmer design later, Kiya and Cameo claimed that their current design did not include it.

Starting from Cameo's Pond warmer solution and Teddy's Heated Blanket idea, the team shifted from analyzing their existing solution – clear cover to discuss the alternative design solutions – add a heating system to the pond. The highlights for this episode were twofold. First, members critically evaluated their existing design solutions and questioned each other's claims instead of simply agreeing (lines 2, 7, 11, 15, 16, 17, and 18). At the same time, they were able to make an effort to clarify and rephrase other's claims to understand each other (line 3, 5, and 13), foreground explanations (line 8, 9, and 10), and focused on solving the design problems (line 1 and12) rather than protecting either individual's or team's one design solution.

***Summary***

Articulating design rationales in teams is crucial to understand why individuals or teams designed the way it was and inform how to alter the design in the future. Instead of simply identifying whether the team's designs addressed the need, teams' conversations often articulate design rationales, especially when prompted. I intentionally distinguished between identifying design success or failure and analyzing design rationales based on whether the team elaborated. Once the design rationale was made public by individuals, the other teammates can respond to the statement.

In general, when teams started unpacking the design rationales, they had opportunities to engage in sophisticated design processes such as reflecting on their design assumptions and

recognizing their design failure, even checked their individual or group assumptions. However, different types of talk often led to various consequences. When teams prioritized harmony and agreement, they might reinforce each other's biases and assumptions and compromise the client's actual needs. Suppose team members prioritized individual ideas rather than opening up to others' ideas. In that case, they might harm the teams' psychological safety and lead to an emotional breakdown. On the other hand, explanatory talk might allow teams to examine their design solutions critically while exploring alternative design solutions.

**Joint Iterating Design**

***Cumulative talk supports the team to make and sustain joint decision-making but at the cost of developing shared views and design perspective-taking.***

Another privileging discourse type teams used to make design changes is cumulative talk. This often occurred during or after teams went through their design with a checklist. Together, teams extended, validated, and converged with one's idea and moved the design decision forward. However, one of the distinctive characteristics of using cumulative talk is that teams did not spend too much time exploring alternative ideas or sometimes assume they had shared views on the ideas. I use the following excerpt to depict how cumulative talk could facilitate a collective decision – the production of a design artifact--- yet hinder the team from examining if shared understanding was established or taking multiple design perspectives.

At the beginning of the lesson, team three agreed that they would create individual designs, and each of them had their paper and pencil to work with. Reminded by the facilitator to

reflect on three questions listed on the board as part of the club activity, Kiya asked Teddy and Andy to work together. Eventually, she got Andy's attention, so they two teamed up to create a design sketch.

| Turn | Speaker | Verbal and nonverbal transcripts |
|---|---|---|
| 1 | Andy | ((looks at the checklist)) Also it's the apartment is very limited, so not too much stuff... (*share idea)* |
| 2 | Andy | ((looks at the checklist)) But also the back support is ((leans towards Kiya)) not very helpful if she sits for too long, so… (*share idea)* |
| 3 | Andy | ((looks at the checklist)) And also, there's a chance of the, of her chair getting dirty so add some sort of like… (*share idea)* |
| 4 | Kiya | ((stops writing and looks up at Andy)) |
| 5 | Andy | There's a chance for her, for the thing to get dirty because of her cat. She likes drinking and eating snacks and stuff so add like a cleaning supply somewhere close, maybe like under the bed, beside the bed, some place that's easy to reach. (*share idea)* |
| 6 | Kiya | ((looks down and writes on the document)) |

In this excerpt, team three-member Andy looked at the checklist and immediately generated and shared his iteration ideas to Kiya (lines 1, 2, & 3). Kiya documented what Andy said to her best capacity (line 4). Eventually, they created a list of elements to include in the chair re-design (see Figure 4-4, left). Compared to their dialogue and this document, Kiya missed out

on some ideas and details Andy shared. Even though it is unclear if Kiya missed those details because she disagreed with Andy, it is observable from their dialogue and artifact that there's a gap between Kiya's documentation and Andy's idea that was not discussed. Therefore, the shared understanding was not successfully established even though Kiya inscribed Andy's ideas into their collective artifact.

Even though Andy and Kiya's pair seemed to work in harmony, Andy's idea was voiced and heard, and Kiya was the information recorder rather than a participant. As a pair, their iteration document did list full of details and looked productive. However, only when I examined their discourse, I found the cost of the harmony – single voice and lack of shared understanding.

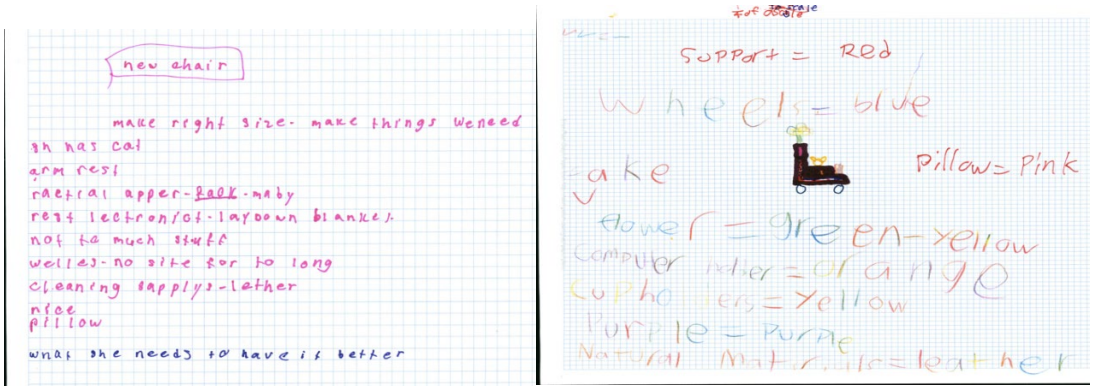



Figure 4-4. Kiya and Andy's Pair Design Document (left) & Teddy's Individual Design Sketch (right).

Interestingly, one specific way of using cumulative talk to mediate teams' learning from design failure activity is to double-check the design plan. Double-checking occurred when teams used it to ensure their design included all the features discussed earlier or listed on the client profile checklist. This alignment check conversation was only observed in team one, the expert team when they iterated the comfortable reading chair in lesson 4. They were also the only team who created two sketches (Figure 4-5 - down). The conversation pattern often started with one team member reading through each checklist item or going through their previous design

sketches to the team. Another team member, primarily the member responsible for documenting or sketching the design, would check with the current version to ensure they included the design features and functions. Here is an example: Catherine held the checklist and said "visual appeal" without making eye contact with Eric and Marcos. Eric shouted out, "yeah, visually appealing." Marcos added, "oh, yeah, pretty… and sky blue". Sky blue was new information they gathered about the client in the last iteration. They now made sure to add that design detail to their new version (Figure 4-5, blue square). In this excerpt, team one successfully used cumulative talk to make and sustain their joint design ideas through time.

***Disputational talk can lead to an emotional breakdown in teams: "He thinks my design is horrible just because I'm younger than her!"***

The conflicts among individual ideas in the iteration process are more observant than the other two learning from failure processes. Even the team categorized as "expert" in the data encountered individual conflicts when iterating designs. The influences of disputational talk varied from breaking down the teamwork process to verbally articulate frustration. There were 4 out of 17 instances in the data that had observable frustration that team members vocalized. In the following section, I use episodes of team three's conflict on design details and how it escalated to a level of frustration as a representative case.

As I mentioned in the last section, Andy and Kiya decided to work together since Teddy claimed to create his iteration sketch. After about 4 minutes of working independently, Teddy participated in Kiya and Andy's conversation. The participation had reinforced the participation when she asked the team to consider Teddy's idea. Without Andy's attention, the facilitator again

brought up Teddy's wheel ideas to the team. This facilitator transitioned the team members from the independent design space to the joint design space. Observing the team yet established a turn-taking norm in the joint space, the facilitator co-regulated team three's discussions by going through Andy and Kiya's design ideas first. After Kiya listed all the design ideas she and Andy generated, Andy commented that "I think I like hers (Kiya) better." This comment frustrated Teddy, and he yelled, "I didn't even say mine!". After Teddy's verbal protest, the team asked Teddy to share his ideas. Teddy stated that his chair design provided much support to the client because she hurts her back.

| **Turn** | **Speaker** | **Verbal and Non-verbal Transcript** |
|---|---|---|
| 1 | Teddy | //It has, it has a lot of support so if she, her her, so she hurt her back a little<< |
| 2 | Andy | << No, she said only a little pillow should be nice. |
| | | *(4 turns in between)* |
| 7 | Teddy | There's a pillow on it, there's support, so it doesn't just sag << |
| 8 | Andy | << Ok, it also, like it has to be, the pillow has to be easily removable, if she sits too long on it, her back starts hurting again (?). |
| 9 | Teddy | Oh yeah, it'll have a, yeah that's what I need to add, ((grabs a color pen)), a timer ((writes on the paper)). |
| | | *(Andy and Teddy talked back and forth for 16 rounds)* |
| 16 | Teddy | //I added purple, a (?), I mean less purple because (?) << |
| 17 | Andy | << I mean look, ((holds the original design plan up and looks at it, then looks back at Teddy)) Teddy, if she has too much support, just |

| | | |
|---|---|---|
| | | listen Teddy! If she has too much support, then it will be harder for her to move. |
| 18 | Teddy | ((raises his voice)) Don't interrupt me! |
| 19 | Andy | (You weren't) talking. |
| 20 | Teddy | I was talking. |

*(The facilitator prompted Andy to share his rationale on why he rejected Teddy's idea)*

| | | |
|---|---|---|
| 21 | Andy | I still like hers better ((points to Kiya, curls his lips and shrugs his shoulder)) |
| 22 | Teddy | ((raises his voice)) (I) didn't even (explain) it! |
| 23 | Facilitator | Ok, so a very important thing, a very important thing guys while you're designing, it's not about her plan or his plan, but what you can get the best out of the two plans. So, you should try to put them together because I think Teddy's plan has many good things. |
| | | *(2 turns in between)* |
| 26 | Teddy | ((raises his voice)) He thinks my design is horrible just because I'm younger than her. |
| 27 | Andy | Hey, you're older than me. |
| 28 | Teddy | And I'm younger than her ((points to Kiya)). You want to go with (?) the older one. |

Even though the facilitator attempted to establish the turn-taking norm earlier, the individual turn-taking was interrupted. Before Teddy finished his utterances from the excerpt, Andy interrupted Teddy and voiced his opinions multiple times (line 1 - 2, line 7 - 8, and line 16 - 17). This interruption contributed to the discontinuity and divergence of the team's focus of

discussion. The conversation between Andy and Teddy oscillated between multiple topics. For example, after Andy interrupted Teddy's talk in line 8, he brought up a condition the client mentioned – cannot sit too long. Andy mentioned this condition to argue that they should make the pillow removable. The phrase "too long" inspired Teddy to add a new feature to the chair – timer. This new solution diverged the center of focus from the pillow as back support to add a timer to record how long the client sat on the chair. It triggered several turns of debate around 1) is a timer needed? 2) can the timer solve back pain or butt pain? The debate then gave rise to another debate around if extra support is needed in the design.

The interruption and constant critique from Andy built up Teddy's frustration. The first time Teddy vocalized his frustration and asked Andy not to interrupt him (line 18) was not emphasized by Andy. On the contrary, Andy defended himself (line 19). The second time Teddy blamed Andy was triggered by Andy's favor of his and Kiya's design over Teddy's. This pick and choose approach led to Teddy's frustration. He blamed Andy for being biased against his ideas because Teddy was younger than Kiya (line 26 - 28).

Team three's conversations shifted from discussing the design solutions to winning and blaming. The facilitator who sat in the group constantly regulated their talk by guiding the group's attention back to design discussion and providing strategies to integrate solutions. However, the heated-up debate between Teddy and Andy shifted the conversation into an altercation or verbal fight. Instead of centering the debate on reasoning to understand and respect, two boys initiated emotional talk, which led to one member's emotional breakdown. Given the evidence, this type of talk failed to produce joint artifacts and develop a shared understanding and disrupted the collaboration process because team members were dominated by intensified emotions, making it hard to concentrate on the contents they discussed. The tension would disrupt team members from

making decisions together without being appropriately resolved. As a result, the novice team did not get time to either create a joint design or iterate individual designs (see Figure 4-4).

***Exploratory talk supports teams to take not only each other's perspectives but also the client's perspectives.***

Like disputational talk, exploratory talk also allows team members to articulate different design ideas and rationales. The difference is, teams who engaged in exploratory talk often spent time understanding each other's perspectives. Teams must establish shared design views. Also, perspective-taking is the critical practice for a designer to empathize with their clients when ideating. It is also critical in the iterating phase because it would allow the designers to gather the necessary information they identified from the evaluation. It also allowed the designers to imagine designs the client might enjoy. Among all three types of talk, exploratory talk is the discourse pattern that allows the perspective-taking practice to occur the most. In the following section, I use two excerpts from the expert team – team one to illustrate how exploratory talk supports the team's perspective-taking practice.

Since exploratory talk foregrounds rationales and does not shy away from critical evaluation, teams were able to consider multiple design paths to refine their design ideas and evaluate if needed. The following excerpt showed how the expert team extended and challenged each other's ideas to explore multiple design ideas before making collective decisions.

| Turn | Speaker | Verbal and Non-verbal Transcript |
|---|---|---|
| 1 | Marcos | Oh!! (What if there's) like a black out? Should we have like a flashlight? (*hypothesize a situation*) |

| | | |
|---|---|---|
| 2 | Catherine | Oh, no. Like maybe, like around at edges. Like (…). (I am thinking). (*Alternative idea 1*) |
| 3 | Marcos: | Oh! Around the edge we can have like bowling lights. (*Elaborate on Alternative idea 1 in line 2*) |
| 4 | Catherine | OR (we can) do (?). |
| 5 | Marcos | (But) that will be too much (distraction). (*challenge Alternative idea 1*) |
| 6 | Catherine | Maybe the pillow can light up. (*Alternative idea 2*) |
| 7 | Marcos | Oh, yeah. That's a good idea. (*agreement*) |
| 8 | Eric | What if she's (leaning) on it? (*challenge Alternative idea 2*) |
| 9 | Marco | Where's the heart pillow? |
| 10 | Catherine | ((looks at Marcos)) She doesn't have to be, it could be on her lap.(*justify Alternative idea 2*) |
| 11 | Eric | Oh, yeah, that's true. Especially (the chair is) made out of Egyptian cotton. (*Agree and elaborate – final group decision)* |

In their second round of iteration, Marcos hypothesized a blackout situation not mentioned anywhere in the checklist. He proposed adding a flashlight to their design (line 1). Catherine proposed an alternative idea –do something with the edges of the chair instead of using a flashlight (line 2). Marcos added that they could light up the edges of the chair (line 3) but immediately challenged himself because the light might cause too much distraction (line 4). Catherine proposed a second alternative idea (line 6), which not only integrated the solutions discussed earlier (light up the edges) but also solved the challenge Marcos proposed with a new

idea (light up the pillow instead) (line 5). This idea was accepted by Marcos (line 7). At this point, the shared understanding of the design was achieved among Catherine and Marcos. Eric challenged the idea Catherine proposed by hypothesizing the client's possible activity, which indicates a possible downside of the design (line 8). Catherine justified her idea (line 10), which persuaded Eric successfully (line 11). In 11 turns, the expert group explored two alternative design ideas with elaboration and negotiation strategies. The design idea was included in their final design sketch. Eventually, the expert team managed to go through two rounds of design iteration systematically (see Figure 4-5).

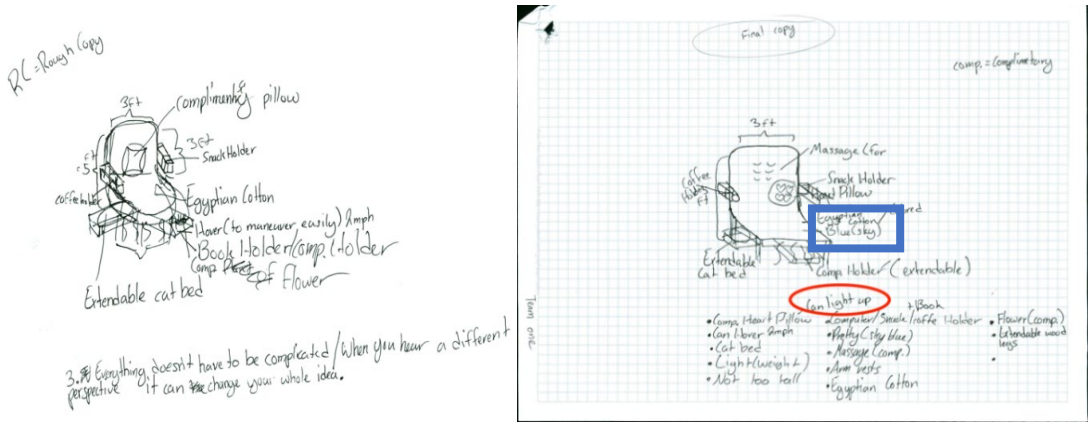



Figure 4-5. Expert Team Iteration 1 Sketch (left) & Iteration 2 Sketch (right).

Another meaningful way the exploratory talk supported the team's learning from design failure practice is to focus on design practice, taking the client's perspectives. In practice, teams need to interpret clients' needs and imagine how to optimize client's experiences in their design. The first part of the excerpt from the expert team illustrated how teams spent time understanding the client's needs.

| Turn | Speaker | Verbal and nonverbal transcript |
|---|---|---|
| 12 | Catherine | ((reads from the checklist)) He usually works from home |

| | | |
|---|---|---|
| | | mostly in front of his office in his house. |
| 13 | Marcos | What? |
| 14 | Catherine | ((rereads from the checklist)) his com, computer and his house office. |
| 15 | Catherine | We need more windows in our house. |
| 16 | Marcos | Yeah... but I don't get that. |
| 17 | Catherine | ((read again)) Usually works at home, but most in front of his computer and he is... |
| 18 | Catherine | I don't think (this should) be a house. It should be, in his office. |
| 19 | Catherine | So, he wants… |
| 20 | Marcos | I don't know. Let's ask them. I don't know if he (wants) a house office … You know, like an office in the house. |
| 21 | Catherine | He said it… Because… |
| 22 | Marcos | ((raises his hand)) But also like the house. How big can the house be when you have this small of space? |
| 23 | Catherine | I know |

Catherine read the need aloud to Marcos (line 12). Marcos was confused (line 13). Catherine repeated the need (line 14). She then proposed that they needed to add more windows in Fred's house without explanation (line 15). Marcos shared that he did not understand the information Catherine just read (line 16). The third time, Catherine read the information to Marcos (line 17) and shared that the client wanted the office rather than a house. Marcos shared his confusion to Catherine that he was unclear if "an office in the house" was what the client

needed (line 20). He also pointed out that the house idea might not be reasonable given the limited space (line 22). Without a conclusion, Marcos reached out to the facilitator for clarification (line 22).

Catherine asked if the client wanted "sunlight to see his garden" and "a way to get out" of the office. The facilitator answered, "probably." Catherine then turned towards Marcos and shared a new design solution. She said, "what if we put the... the office in the indoors? He can still see the plant everything and enjoy nature while working". Here, she not only proposed a potential design solution but also externalize her rationales. However, Marcos was not satisfied with the confirmation and was skeptical about Catherine's suggestion. The two interpretations Marcos tried to differentiate apart were: 1) the client requested they build an office; 2) the client spent much time working from the home office. Hearing his confusion, the facilitator rephrased her explanation. She told Marcos that "he sitting mostly at home and working in that house office, you might want to have something (for example) the garden faces the house office or the garden is very easy accessible from the house office." While the facilitator was making design suggestions, Marcos looked at Catherine. He pointed at the indoor garden and the back of the LEGO house to indicate that their current design already put the house and the indoor garden right next to each other. Without agreeing or disagreeing with Marcos's claim, Catherine proposed a similar but different design idea.

| **Turn** | **Speaker** | **Verbal and nonverbal transcripts** |
|---|---|---|
| 24 | Catherine | Marcos, what if we just connect the house to the garden? ((points at the house and the garden)) |
| 25 | Marcos | It's basically...it's three steps all right. One, two, three ((counts the steps from the LEGO house to the LEGO |

| | | |
|---|---|---|
| | | indoor garden)) |
| 26 | Catherine | (They still have a) driveway too. He (needs) to walk out right? |
| 27 | Catherine | ((points at grave blocks on the side of the house)) This is the driveway, to get in. |
| 28 | Marcos | Yeah. Hyeah. |

Catherine again used "what if" to suggest an alternative design solution – connect the house to the garden (line 24). Marcos looked at their LEGO model and argued that the house was already connected to the garden because it was three steps distance apart from each other (line 24). Catherine argued that the problem with the current idea was that they still needed to preserve the driveway, which was the space between two buildings (lines 26 and 27). Marcos agreed with Catherine's claim, and they moved forward to the next design need.

***Summary***

A critical aspect of learning from failure is to make changes through iteration. Based on the identification and analysis, teams modify existing design ideas to account for new insights such as the costs, add detailed forms and functions to abstract design ideas, and generate alternative design ideas to meet clients' needs. From design perspective, the act of iterating is another round of ideating. The difference was that teams gathered more information about the clients than the initial ideation phase. However, with the increasing brainstorming and design decision-making in this stage, the conflicts among individual ideas in the iteration process are more observant than the other two learning from failure processes. Even the team categorized as

"expert" in the data encountered the individual conflicts when iterating designs.

# Chapter 5

## Tools Mediates Learning from Failure in the Collaborative Design Context

The previous chapter explored how the discursive practice mediates the team's ability to learn from failure in the collaborative design context. In this chapter, I answer my second research question – *How does the evaluation tool configuration mediate teams to learn from failure in the collaborative design context?* I used interaction analysis to examine how the evaluation tools support and constrain the team's joint learning from design failure from a macro and micro level. The macro-level configuration focuses on how teams used the tools. In contrast, the micro-level focuses on the detailed design configuration of the objects. This chapter shifts the focus extend the interaction from within team members to their surroundings. As an emerging theme from the analysis, I also expand my analysis to include tools present and accessible in the space. This shift allowed me to understand how failure is constructed, negotiated, and managed through human interaction and the tools in the learning space. Besides the discourse perspective I examined from the previous chapter, I also examined the socio-emotional, socio-cognitive, and power dynamics perspectives in the analysis.

I foreground the findings on four tools which include (1) the client feedback video, (2) the checklist printed on an 8 x 11 inches paper which includes clients' profiles, (3) the designing tools including paper & pencil and the LEGO blocks, and (4) the reflection question that distributed either on the whiteboard or on an 8 x 11 inches paper. Even though I focused on those four objects, each object is an assemblage that includes others. For example, the client feedback video also includes the whiteboard and the projectors and the layout of the four groups. The

building tools also include the checklist on the table. The checklist also includes the physical layout of the teams.

## The Client Feedback

To help teams understand the difference between designing for themselves and designing for others, I asked a colleague to evaluate each team's comfortable reading chair design and recorded it as a video. Following the previous tradition in the club and the convenience of the existing club technology setting, I played the video at the club using the afterschool's whiteboard and projector. In the feedback video, my colleague went through each team's design and pointed out the pros and cons of their designs. She started her feedback with what she liked about each design and then pointed out the possible drawbacks. The whiteboard was hung at the front of the room (Figure 5-1). All children from different seats had good visibility if they turned towards the big screen. We grouped four individual desks to make a square like space for each team.

Figure 5-1: A Screen Shot Showing the Position of the Whiteboard in the Room.

In the next section, I report a case study from team one, the expert team, on their response before, during, and after the video was played. From the data analysis, I found that even though this activity attracted children's attention and promoted more critical design reflection in teams, it came with the cost of emotional discomfort. Generally, using the client feedback with the video as a medium successfully grabbed and maintained children's attention Judging from their body positions. For example, comparing children's body positions, all children faced directly towards the video. In contrast, only some of them faced towards the facilitator when she was leading the discussion. The moment the video started playing, children quieted down, stopped what they did, and gazed at the whiteboard. At the same time, the client feedback video also triggered young designers' emotional responses. When the individual team was mentioned, team members displayed nervousness even before the client shared any comments. They covered their

faces or mouths, screamed out “no,” laughing with high pitch, or breathed heavily. Interestingly, these emotional responses might, on the other hand, promote their critical self-reflection on the design.

Before showing the client feedback video, Facilitator A reflected with the children that the biggest mistake designers make is lack of empathy. She told the children to help them see the difference between designing for themselves and designing for others. We asked a colleague to serve as an authentic user to give each team design feedback. Hearing that their design was “evaluated,” Eric sighed, “oh come on!” and shouted, “we were told we were designing FOR OURSELVES!”. Other children in the club advocated his statement. Eric continued shouting, “that was a lie!”. The facilitator ensured that they would not be assessed for “failure” because criteria changed, and they could still iterate to “win the game.” However, children continued shouting that the activity was unfair.

After the facilitator managed to calm the whole class down, she started playing the pre-recorded client feedback video. Marcos stopped writing things on the paper and looked up when the video started (Figure 5-2-1). The feedback started from team one. As soon as Marcos heard his team was called, he put up his hand on his forehead and said, “are you kidding me.” Eric followed and punched the desk with his fist. He turned around and looked at Marcos. Shortly, both Marcos and Eric covered faces with hands (Figure 5-2-2), Marcos’s hand was on his forehead, and Eric’s hand was on top of his head. When the client listed the design features team one’s design had, Marcos suddenly buried his head into his arms, moved to the side, and bent to hid behind the desk (Figure 5-2-3). He made a high pitch laugh. The client mentioned that she liked that team one used Egyptian cotton as a tool for the chair. Eric cheered and smiled, and Marcos thumbed his chest and clapped (Figure 5-2-4).

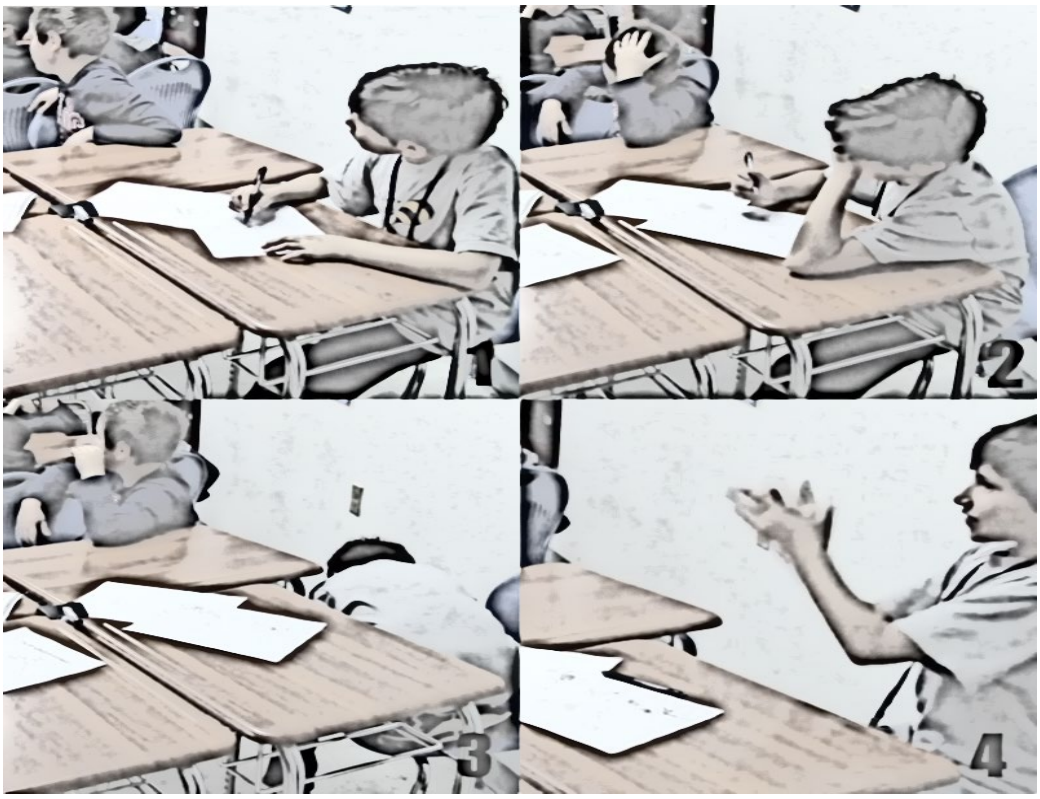



Figure 5-2. Eric and Marcos's Reactions Towards The Client's Feedbacks.

Before the evaluation activity started, Marcos continued arguing that the client "was confusing beyond words" because she wanted a "comfortable chair but not too comfortable." Marcos argued that this statement was self-contradicting.

Even though this team was skeptical of the client feedback, they nonetheless used it to be critical when evaluating themselves. Marcos, in particular, became quite critical. One of the needs on the checklist was "I love drinking coffee and have snacks while sitting on the chair reading, but sometimes they make my computer dirty or damaged. Also, Dodo once spilled my coffee". Before Catherine finishing reading the need, Eric shouted "yeah, yeah, yeah" to indicate that their design met this need. After Marcos questioned Eric's statement, Eric said, "sandwicher" to indicate that this design feature can satisfy the client's need to "have a snack." Marcos pointed out that, even if they had the "sandwicher," they "don't have space to put

coffee." "We have a cup holder," Eric said. Marcos rejected this statement. From their original design sketch, there was no documentation of a cup holder as Marcos suggested but included the word "snacks" (Figure 5-3). Without an agreement, the Facilitator Asked if the design had a snack holder. Marcos claimed they did not have one, but Eric again brought up the "sandwicher" design idea.

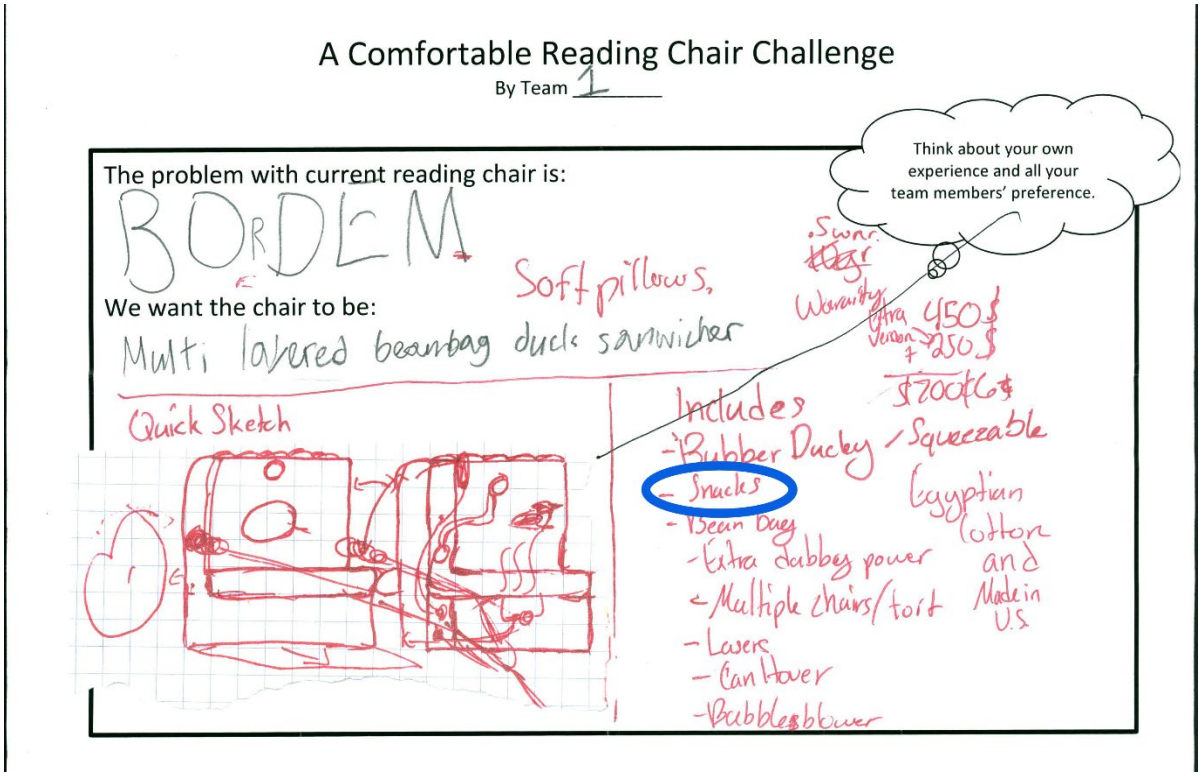



Figure 5-3. Team 1's Original Comfortable Reading Chair Design Sketch.

Marcos argued against Eric's "sandwicher" comment. He pointed out that it did not satisfy the need to have "somewhere to put coffee." Facilitator B suggested that the team can earn 1.5 points which is half the value for this item. Marcos disagreed with facilitator B and argued that their design did not qualify for earning 1.5 points but 0.5 because their design did not solve the second half of the challenge – coffee spilled on the computer. Marcos's critical reflection seemed to surprise the facilitator. She asked, "what are you trying to do, Marcos?" to understand why he suggested a lower point. Replied to the facilitator, Marcos made an

interesting comment about his teammate. He said, “I'm just saying geez, these people are trying to get as many points as possible, trying to get as many points as possible.” Later, he argued that a snack feeder was not the same as the snack holder, which the client asked for.

Interestingly, Marcos’s attitude changed when he reflected on the butterfly garden design challenge two weeks later. As I reported in the last chapter, teams used cumulative talk extensively as a whole. Marcos’s team, mainly, used this talk as their dominant talk when they evaluated the design with the checklist. This time, the checklist was introduced differently. First, the clients from the butterfly garden were imagined figures. Second, teams received the checklist and were self-evaluated a couple of weeks before receiving any external feedback. Therefore, there was no public critique in the club compared to the comfortable reading chair challenge.

Rather than work to identify failure, as Marcos did in the previous episode, Marcos and teammates collectively reconstructed memories of their past discourse to justify points for their undocumented design. For example, they requested the facilitator to check the video recording from the previous week to verify that they did discuss adding waterlily to the butterfly garden to satisfy the client’s need. Or they argued that it was the facilitator’s fault for not giving them the complete information about the client’s interest since they asked for it. Therefore, they should’ve not to be punished for losing points because of external reasons.

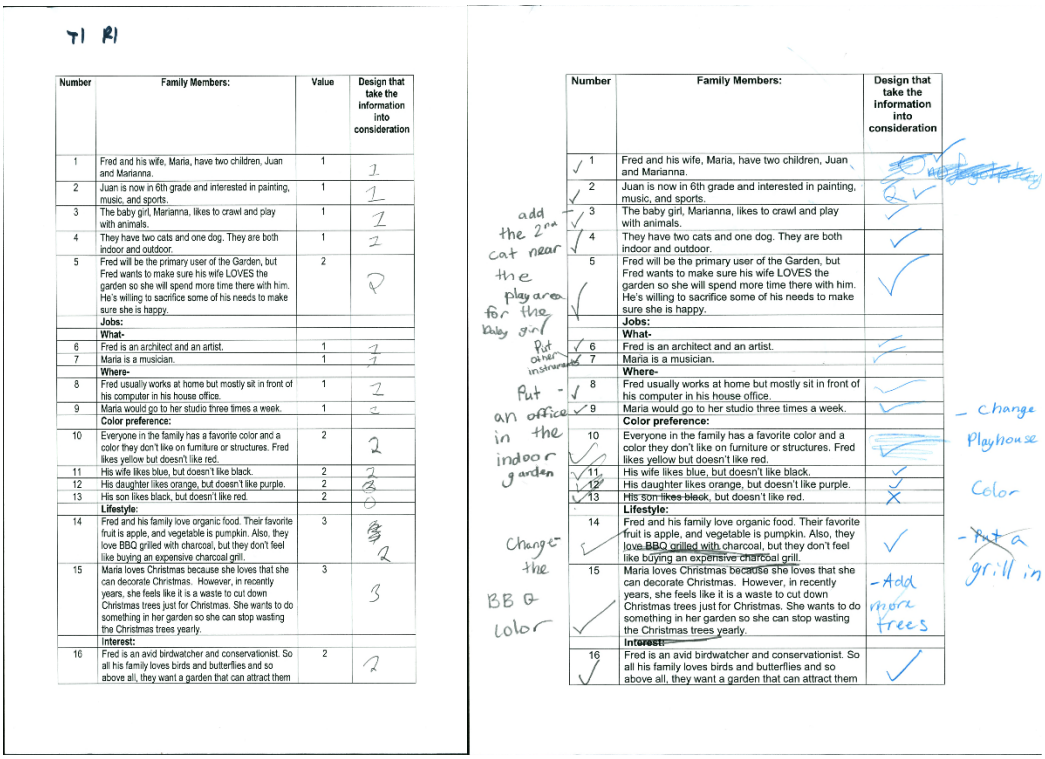
## The Client Profile Checklist

Alongside the client feedback video, I also created a client profile checklist which contains information such as lifestyles and color preferences. The checklist was then printed on 8 x 11 inches size paper and distributed to each team after prototyping. To differentiate the importance of each piece of information, I assigned a numerical value to each entry on majorities

of the checklist. However, I took away the numerical values for the second-round butterfly garden evaluation after observing several trade-offs, including the numerical system. In this session, I report how two design configurations – numerical values and printing on an 8 x 11 inches size influence team's ability to learn from failure in the collaborative design context.

**Numerical Values**

In general, the checklist with numerical values created the sense of competition. It allowed teams to identify failure and success using the reference system (Figure 5-4). From the analysis, I found that the checklist with numerical values assigned to each task/design element provided a reference system that required teams to compare and compete to identify their status. They either competed with other teams or compared the points they earned to the sum values of the checklist. This pattern occurred in all four teams with both lessons when the numerical values were present. There were multiple instances of team members claimed that their design failed after calculating points they earned or the ratio of their points to the total values. In the following session, I followed the expert team member Eric. He asked around other team's points to describe how the checklist with numerical values engender the comparison and competition.



| Number | Family Members: | Value | Design that take the information into consideration |
|---|---|---|---|
| 1 | Fred and his wife, Maria, have two children, Juan and Marianna. | 1 | 1 |
| 2 | Juan is now in 6th grade and interested in painting, music, and sports. | 1 | 1 |
| 3 | The baby girl, Marianna, likes to crawl and play with animals. | 1 | 1 |
| 4 | They have two cats and one dog. They are both indoor and outdoor. | 1 | 1 |
| 5 | Fred will be the primary user of the Garden, but Fred wants to make sure his wife LOVES the garden so she will spend more time there with him. He's willing to sacrifice some of his needs to make sure she is happy. | 2 | 2 |
| | **Jobs:** | | |
| | **What-** | | |
| 6 | Fred is an architect and an artist. | 1 | 1 |
| 7 | Maria is a musician. | 1 | 1 |
| | **Where-** | | |
| 8 | Fred usually works at home but mostly sit in front of his computer in his house office. | 1 | 1 |
| 9 | Maria would go to her studio three times a week. | 1 | 1 |
| | **Color preference:** | | |
| 10 | Everyone in the family has a favorite color and a color they don't like on furniture or structures. Fred likes yellow but doesn't like red. | 2 | 2 |
| 11 | His wife likes blue, but doesn't like black. | 2 | 2 |
| 12 | His daughter likes orange, but doesn't like purple. | 2 | 2 |
| 13 | His son likes black, but doesn't like red. | 2 | 0 |
| | **Lifestyle:** | | |
| 14 | Fred and his family love organic food. Their favorite fruit is apple, and vegetable is pumpkin. Also, they love BBQ grilled with charcoal, but they don't feel like buying an expensive charcoal grill. | 3 | 2 |
| 15 | Maria loves Christmas because she loves that she can decorate Christmas. However, in recently years, she feels like it is a waste to cut down Christmas trees just for Christmas. She wants to do something in her garden so she can stop wasting the Christmas trees yearly. | 3 | 3 |
| | **Interest:** | | |
| 16 | Fred is an avid birdwatcher and conservationist. So all his family loves birds and butterflies and so above all, they want a garden that can attract them | 2 | 2 |

| Number | Family Members: | Design that take the information into consideration |
|---|---|---|
| 1 | Fred and his wife, Maria, have two children, Juan and Marianna. | |
| 2 | Juan is now in 6th grade and interested in painting, music, and sports. | |
| 3 | The baby girl, Marianna, likes to crawl and play with animals. | |
| 4 | They have two cats and one dog. They are both indoor and outdoor. | |
| 5 | Fred will be the primary user of the Garden, but Fred wants to make sure his wife LOVES the garden so she will spend more time there with him. He's willing to sacrifice some of his needs to make sure she is happy. | |
| | **Jobs:** | |
| | **What-** | |
| 6 | Fred is an architect and an artist. | |
| 7 | Maria is a musician. | |
| | **Where-** | |
| 8 | Fred usually works at home but mostly sit in front of his computer in his house office. | |
| 9 | Maria would go to her studio three times a week. | |
| | **Color preference:** | |
| 10 | Everyone in the family has a favorite color and a color they don't like on furniture or structures. Fred likes yellow but doesn't like red. | |
| 11 | His wife likes blue, but doesn't like black. | |
| 12 | His daughter likes orange, but doesn't like purple. | |
| 13 | His son likes black, but doesn't like red. | |
| | **Lifestyle:** | |
| 14 | Fred and his family love organic food. Their favorite fruit is apple, and vegetable is pumpkin. Also, they love BBQ grilled with charcoal, but they don't feel like buying an expensive charcoal grill. | |
| 15 | Maria loves Christmas because she loves that she can decorate Christmas. However, in recently years, she feels like it is a waste to cut down Christmas trees just for Christmas. She wants to do something in her garden so she can stop wasting the Christmas trees yearly. | |
| | **Interest:** | |
| 16 | Fred is an avid birdwatcher and conservationist. So all his family loves birds and butterflies and so above all, they want a garden that can attract them | |

Figure 5-4. Two Versions of Butterfly Garden Checklist from Team 1.

After the expert team finished the scoring, Eric walked around the room. He first stopped by team three. “How many points you got?” Eric asked Andy from team three. Before Eric walked into Andy’s team, Andy had a recognition of failure, he told the facilitator that “We are finished. We did terrible though”. Eric’s question brought Andy discomfort. Andy leaned his body forward and covered their checklist with his hand (Figure 5-5). He told Eric that, “maybe you should not.” Here, Andy refused to reveal their team’s score to Eric. After Eric walked away, Andy retracted his body and sat back in his seat.

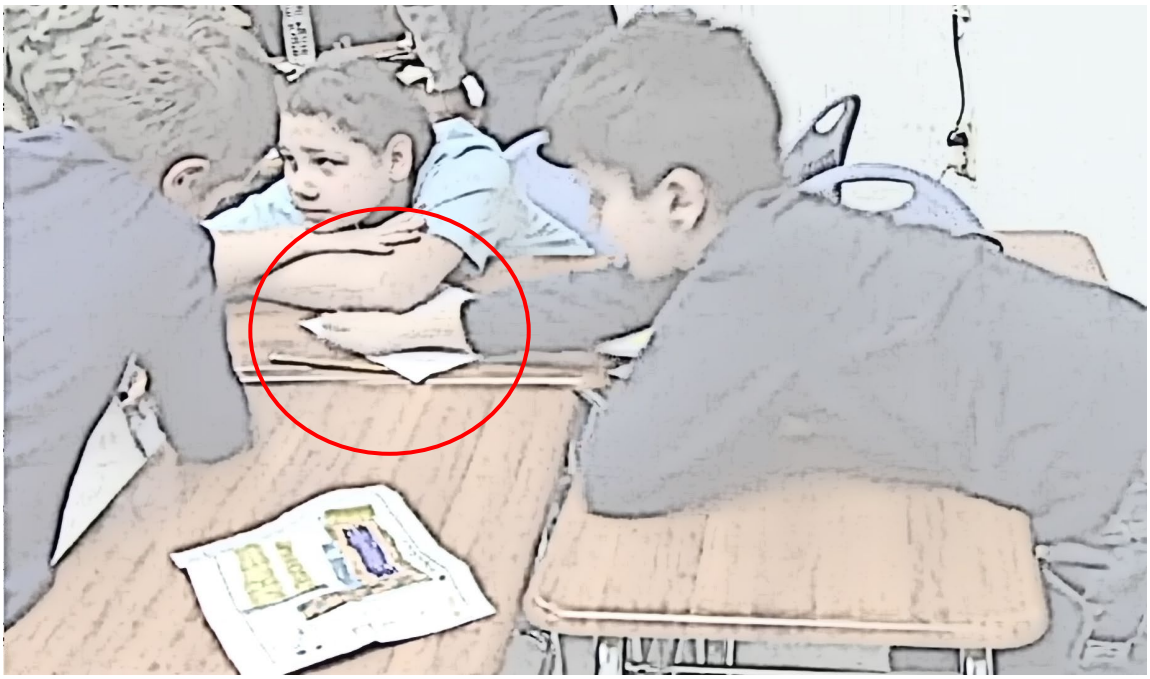


Figure 5-5. Andy Covered the Score when Eric Visited.

Eric then walked to team four. When Eric got closer, team four was calculating their total points. He heard Rick shared that they earned 13.5 points in total. With confusion, Eric asked Rick why they got the point and a half. Kate explained that half-point came from design that partially met the need. Rick raised his voice and looked up at Eric with confidence, “We got 13.5!” Eric pointed himself with his thumb and told Rick that, “We got 14!” (Figure 5-6). Knowing that they were 0.5 short compared to team one, Rick sounded discouraged, and he replied with a soft “oh” and looked down. In a later conversation with one facilitator, Eric shared, “We beat team four (by) point five points!” While Eric and Rick were talking, Adben (Figure 5-6, boy with glasses) looked down on a piece of paper. Later, he asked the team, “13.5 out of what?” Rick added all values and told Adben that the total was thirty. “So, we failed,” Adben told the team.

Figure 5-6. Eric and Rick's Competition and Adben's Recognition.

The highlights of these episodes were threefold. First, when Eric inquired about team three's total score, Andy's refusal to share his team's score might have been due to the feeling of shame, given that it occurred after Andy identified his team's design as "finished." Second, Rick and Eric's verbal and nonverbal interaction indicated competing, and Eric's team was the winner. Third, Adben identified his team's design as a failure only after he realized his team only earned 45% (13.5 out of 30) out of the total score. All three highlights illustrated how the numerical value system, on the one hand, prompted the competition. On the other hand, it helped make failure identifiable to teams.

In general, teams used the checklist as a summative tool to evaluate the group's design performance rather than as a formative tool to improve the design. While comparison and competition might motivate teams to improve, these attitudes can also detract from their focus on the design itself. As a result, the evaluation activity became a means to an end. The tool did not succeed in pushing teams to empathize with and take the client's perspective. Instead, teams framed the evaluation as a judgment of their ability. They focused on finding ways to gain more

points to avoid failure. One of the examples came from team two. In the following session, I report an instance from team two to illustrate how teams evaluated their design using numerical values.

| Turn | Speaker | Verbal and nonverbal transcript |
|---|---|---|
| 1 | Gary | ((reads from checklist)) His favorite Monet series painting is water lilies |
| 2 | Ekon | ((whispers to Gary and checks if anyone is seeing him)) The waterlily isn't there |
| 3 | Gary | Oh my god ... I don't know, what are water lilies? |
| 4 | Ekon | They're just circles |
| 5 | Gary | Lilly pads? |
| 6 | Ekon | ((whispers to Gary)) Yeah Lilly pads, just add circles |
| 7 | Gary | There! ((sketches something on the plan quickly with a smirk on his face)) |
| 8 | Facilitator | ((walks behind Ekon and talks to facilitator C)) |
| 9 | Ekon | ((peeks at facilitator B with his peripheral)) |

After Gary read the information aloud, Ekon whispered to Gary and made sure no one saw him (line 2). Gary sounded anxious and asked what water lilies are. Ekon suggested adding circles to represent water lilies (line 4 and line 6). While Gary quickly added circles on their sketch (line 7), Ekon took the guarding role to ensure they did not get caught (line 9). Gary and Ekon first recognized a potential design failure and modified the design immediately in a brief period. Even though never been told that they were not allowed to modify their designs, Gary

and Ekon felt that they needed to “cheat” to not fail. Gary and Ekon’s behaviors resembled how children and adults reacted to the summative assessment widely used in society.

**8 x 11 Inches Print Size**

To promote the team’s collective decision, I limited only one copy of the checklist on the 8 x 11 inches size paper to each team. With the 8 x 11 inches size, only one team member would have full access to the contents visually to inscribe easily. Also, the contents were not accessible to other teammates if they sat across the table because the texts were reversed. As I discussed previously, the difference between the team’s use of the paper sketch and LEGO model in the design evaluation session, team members had easy peripheral access to the LEGO model even though they sat further away from it compared to the paper sketch. This design configuration required the teams to be able to deal with conflict with psychological safety. In the following session, I used two different episodes from team one and three to illustrate this finding.

As I mentioned, team one members participated in the club for at least two semesters compared to other teams. Also, they were familiar with each other, because all four were teammates from previous semesters. Marcos enjoyed planning and documenting, so he often took up the role of the inscriber. In one of the class reflection sessions, he even joked about him “hoarding” this role. When they started evaluating the first round of butterfly garden design in lesson 6, Marcos naturally took up the inscriber’s role since he sketched the team’s ideas earlier. Facilitator C placed the checklist almost in the center but slightly closer to Marcos. Marcos picked the checklist up and looked at it for one second before Catherine dragged the paper closer to her. Eric leaned his body on the table and got closer to the checklist. Marcos let go of his

hands and shifted his body to his right side towards Catherine. He repositioned the pen in his hand and said, “We got that.” “Okay, wait, wait, wait.” Eric pushed the checklist down and readjusted it again on the table, “Okay.” Marcos looked at the checklist and said, “we got to start with that. We got this.” He placed his arm on top of her to write on the checklist, “One” (Figure 5-7). While Marcos is writing, Eric told Marcos, “Read it.” Marcos, who had direct access to the checklist, started reading the information out loud.


Figure 5-7. Team 1 Evaluated Design with Checklist.

In the episode illustrated above, even though most team members struggled to have access to the information, they were able to regulate their activity to make it work. Even with the limited space, the expert team adjusted either their bodies or positioning the tools to access the information without experiencing interactional problems. In the beginning, Catherine repositioned the checklist so she could read it. Marcos, instead of fighting against her, let go of the tool and adjusted his own body. Eric, who sat on the other side of the table, also repositioned his body to get access. When he heard that Marcos started evaluating, he communicated verbally

to ask him to pause and resume once he changed the tool positioning. Eric also asked Marcos to read the information out loud after, and Marcos followed Eric's suggestion.

In contrast, the limited accessibility to the information caused problems for novice teams, especially when they were already struggling to establish psychological safety within the team. A similar accessibility issue was observed in team three but was not managed as well. At the beginning of the event, the facilitator placed a checklist in front of Cameo and Kiya and asked if they could evaluate together. The facilitator placed the checklist down but did not move her hand away from the paper until Cameo and Kiya settled on a way of working together – Cameo led the discussion.

Cameo dragged the checklist closer to her and claimed that she would lead the evaluation. Kiya reminded Cameo that "But we all need to see it." The facilitator, still had her hand on the paper, looked at Came and said, "Okay, can you see it… read it to everyone?". After their fight over the drawing access, the facilitator managed to get Kiya and Cameo to work together and encouraged Kiya and Cameo to share the role. Observing Cameo hoarding the checklist, the facilitator reminded Cameo that this was a joint task rather than an individual decision. Kiya confirmed with the facilitator that all other team members should be able to read the information. The facilitator again instructed Cameo to read aloud for all members and lead the discussion.

Figure 5-8. Team 3 Evaluated Design with Checklist.

After discussing the first item, Cameo put a checkmark next to the item. Before the Facilitator got a chance to instruct Cameo to use a number rather than a checkmark, Kiya corrected Cameo, stating, “what” While Cameo was erasing the checkmark, Kiya helped. “Here!” Kiya extended her arm and started erasing the mark using her pencil without asking Cameo’s permission. “Use this. It works better.” Kiya told Cameo. Cameo retracted her arms and sat back in her chair. At this point, Cameo started feeling upset about Kiya. Another peak of their conflict occurred seconds later. Cameo murmured, “there are animals,” and wrote down the score without reading the information aloud and seeking consensus from the team. Kiya called Cameo out and told her that they all need to agree with the score. To defend herself, Cameo blamed the team for not paying attention. Kiya defended herself and other teammates and blamed Cameo for failing to read aloud for them. Hearing Kiya’s complaint, Cameo read the information out loud but with a soft voice. Not satisfied with Cameo’s volume, Kiya read the information with a louder voice. The conflict between Kiya and Cameo continued to escalate. Later in the session, Cameo picked up the checklist with two fingers, threw the paper to Kiya, and commanded Kiya to finish the rest. “STOP IT!” Kiya yelled at Cameo, “You are supposed to do it! Do it!” Kiya

then picked up the checklist and put it down in front of Cameo.

The conflicts that ensued between Kiya and cameo when using the checklist extended their existing power struggle and a catalyst of communication breakdowns. As evidenced in Kiya and Cameo's multiple conflicts over leading the evaluation, the checklist served as more than a tool containing information about the client, but a symbol of power. Even though the facilitator suggested Kiya and Cameo share the evaluation task, Cameo immediately claimed her leadership. However, this leadership role was constantly challenged by Kiya, which was evident by Kiya's initiation of erasing and reading aloud without asking Cameo's permission. Eventually, Cameo refused to continue leading the discussion and gave away the leading role to Kiya passive-aggressively. In the episode from team three, instead of negotiating and communicating, Kiya and Cameo's finger-pointing and commanding interaction finally led to the complete breakdown in their collaboration process.

## The Building Tools

In general, LEGO as a 3D modeling tool supports the visual clarity and engagement for teams in learning from failure activities. LEGO blocks embodied the abstract design ideas through the shapes and colors, allowing teams to instantly perceive the design failures compared to paper design sketches. Teams also used and manipulated the LEGO model, such as pointing at and moving or adding blocks around the model intensively to communicate and modify designs ideas when evaluated their designs. However, At the same time, when the information was not shared among team members, LEGO 3D modeling might increase the confusion among team members. In the following section, I zoomed in on three cases to illustrate my above claims.

***The LEGO 3-D modeling supports visual clarity compared to the paper sketch***

When teams created design sketches using paper and pencil, they mainly focused on the abstract level design, including what specific designs and where to put the design. It was a common practice among all teams. Take team three's design sketch as an example. In Figure 5-9 (left), team three used different shapes to indicate different design ideas. On the right side, they put a key to explain what each shape meant. This sketch consisted of three essential design elements: design ideas and their 2-D spatial locations and the rough shape of each design. Once the team concretizes their design ideas, they added more details to the LEGO 3-D model (right side of Figure 5-9) than the paper sketch. One of the most observant added details was the color.

In the checklist, there was a section about Fred's family members' color preferences. One of the pieces of information was that Fred's daughter likes orange but doesn't like purple. When team three first evaluated their design with the paper sketch in lesson 6, they marked down a checkmark next to the information indicated that their design met this need. After Teddy, leading the evaluation, read the information aloud, he pointed at the design paper and said, "orange." The facilitator F made a "wow" sound but did not explain what she meant. Teddy then claimed that they had "no purple" and wrote down "2" on the checklist to indicate that their design met the daughter's need – had orange she liked and had no purple she disliked. Cameo commented that their design did not have a lot of colors Teddy listed earlier. Teddy disagreed and reminded Cameo that they had orange. Cameo pointed out that their design did not have purple. Andy and the facilitator reminded Cameo that the daughter did not like purple. It was a good thing that they did not use purple in the design.

Interestingly, when team three used the same checklist to evaluate again, but with the LEGO 3-D model, the purple color again became the focus. The excerpt below started from facilitator D reading the daughter's color preference aloud to the team.

| Turn | Speaker | Verbal and nonverbal transcripts |
|---|---|---|
| 1 | Facilitator D | ((looks up)) And the daughter likes orange but doesn't like purple. |
| 2 | Andy | ((looks at the LEGO plan)) A lot of oranges…. More purple… ((Sighs)) |
| 3 | Facilitator D | So maybe we can<< |
| 4 | Andy | <<Why do we have to make everything like purple? ((Waves his head)) |
| 5 | Cameo | (Because that's) Kiya's favorite color (is purple) ((smiles and looks at Kiya)). |
| 6 | Facilitator D | Ohhh! Then that's a problem! Girls. |
| 7 | Kiya | ((looks at the facilitator D)) What? |
| 8 | Facilitator D | That's a problem! Because are we making it for ourselves? Or making it for Fred's family? |
| 9 | Kiya | ((looks at Facilitator D and smiles embarrassedly)) Fred's family. |

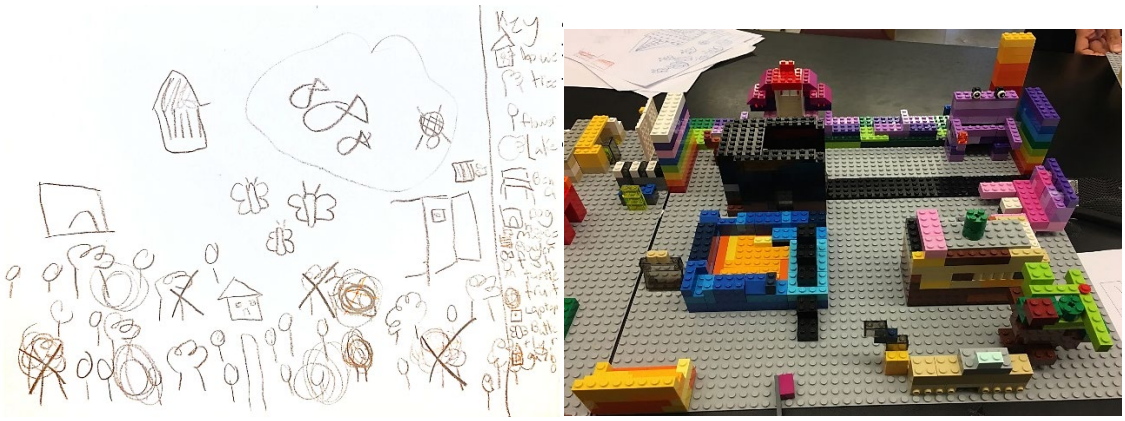


Figure 5-9. Team three's Fred Family's Butterfly Garden Design (Sketch – left; LEGO model - right).

After facilitator D read the information aloud, Andy looked at their LEGO model and recognized that they failed to meet the daughter's need because they used a lot of purple in the design (line 2). He used a rhetorical question to externalize his frustration (line 4). Cameo heard his blame and shared that they used many purposes because it was Kiya's favorite color (line 5). The facilitator D seized the opportunity and asked the team to reflect on whom they designed for (line 8). This question helped Kiya recognized the mistake she made while building the LEGO model. She smiled, embarrassed, and shared that the design was for the client rather than herself (line 9).

Compared the discussion on the same client information, but in two situations, team four members identified the design success and failure differently. Teams started concretizing the abstract design ideas as they continued iterating the design using different tools. The concept of "purple" was not perceivable anywhere in the paper sketch. When team three claimed that they did not have any "purple," their perceptions were limited to the pen color they used and the labels they created. However, the most evident claim supported by these two elements was that their design indeed did not use any purple. The LEGO 3-D model representing increasing fidelity

supported teams to recognize the design failures yet perceived or created in the paper design sketch documenting key design ideas. As the abstract word “purple” was embodied in the visible LEGO blocks and identified by the team in a later session, purple came alive, and the design failure became identifiable.

***Teams engaged LEGO models more often when evaluating their design***

Even though some teams intensively referred to their paper sketches while evaluating with a checklist, many team members focused attention only on the checklist. They left out the sketches in the discussion process (Figure 5-10). Instead of referring to their design sketches, team members simply relied on their memories of design features to evaluate the design using the checklist. One of those examples was expert team members first agreed that their chair design failed to meet the mobility need without looking at the sketch but discovered later that they had hovering function as described in the previous chapter. Figure 5-10 shows another example from team four members. The screenshot shows that team members placed their design sketches and satellite map aside and converged their gaze at the checklist.

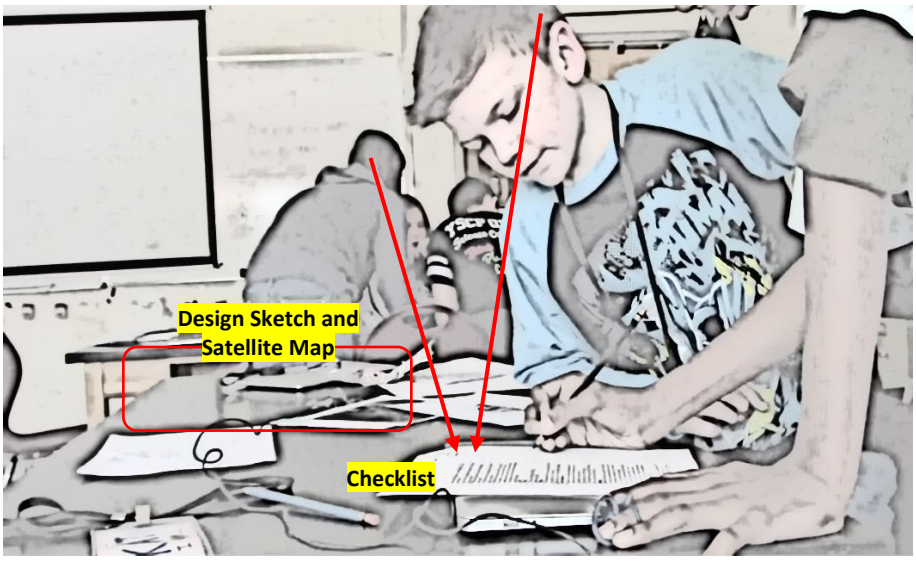



Figure 5-10. Rick and Adben Gazed at the Checklist.

On the contrary, all four teams constantly engaged with the LEGO 3-D models to provide evidence and modify designs. Since the LEGO model required an ample physical space, it was often placed either in the center of the table or at the corner with high visibility. During the evaluation, team members would point at, look at, or modify the LEGO 3-D models. As shown in Figure 5-11, while facilitator E was working with team four to evaluate their design, Sebrina held a LEGO block piece. The LEGO 3-D model was placed right in front of Sebrina and Adben. Even though further away from the LEGO model, Rick still had good visibility to the design (Figure 5-11).

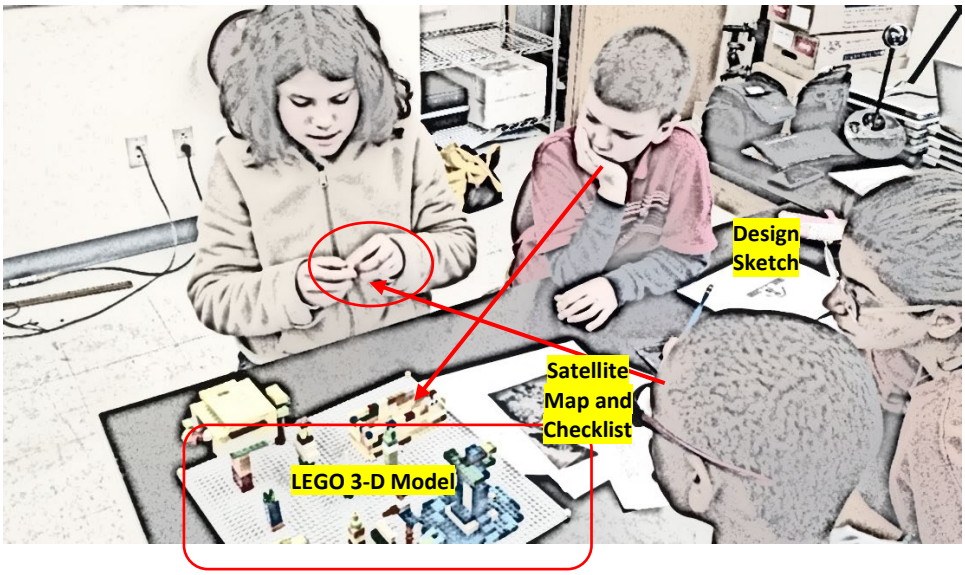



Figure 5-11. Team Four Members Gazed at the 3-D LEGO Model.

***The LEGO 3D model might increase the ambiguity within team members, especially when shared design views were not established***

As I discussed in the previous chapter, teams who approached the design from an individualistic approach encountered a challenge in identifying design failures since they did not have shared views of design ideas. The LEGO 3-D model, even though it included more visual details such as colors and shapes, is still low fidelity. It failed to help convey precise information about the design to team members, especially to those who did not share the same information. When looked at the LEGO model, it was hard to tell what a design was without additional verbal description.

The following excerpt came from team two when they evaluated the 3-D LEGO model with the checklist. After finishing up LEGO models, we asked each team to go over the design checklist to document changes they would make in the next iteration using Minecraft. The third

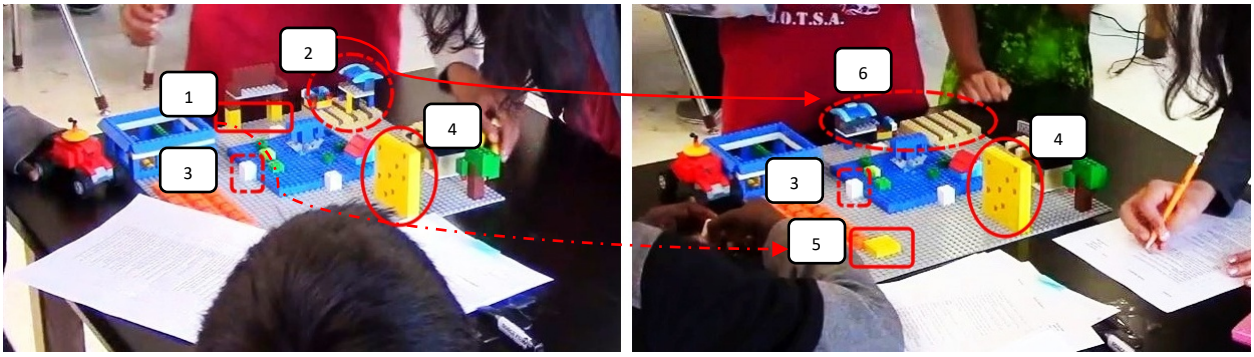
time they evaluated the design with the checklist but the first time evaluating with the finished LEGO model. This episode demonstrated how the absence of shared understanding in the past lead to the team's repurposing LEGO design while evaluating the design in the present.

In the beginning, Juba volunteered to lead the evaluation. He read aloud the need – "Juan is now in 6th grade and interested in painting, music, and sports" to the team. Ekon pointed at the white LEGO blocks (#3 – Figure 5-12– a rectangle with dash line) and said, "we have that." At the same time, Gary blamed Ekon for "stealing" the pitching mound pieces to create LEGO bench legs (#1 - Figure 5-12 - solid line). Ekon made an "aww" sound, dissembled the legs, and made a square/rectangle on number 5 in Figure 5-12. Interestingly when Ekon dissembled the pitching mound and added it to the bench earlier, Gary did not stop him till this moment.

The facilitator recited the need again and asked whether team two had done anything for music, painting, and sports. The Facilitator Added that she remembered they created something for the music. Gary pointed at the patio design on his right upper corner. He shared that the patio was designed initially for music but was turned into a spot for the grill (# 2 - Figure 5-12- oval with dash line). Later, Gary walked next to Ekon and re-positioned the grill next to the patio on the LEGO board (#6 – Figure 5-12– oval with dash line). When I traced the history of the patio idea, I found that it was documented in the paper sketch by Gary. From the video recorded in previous lessons, the idea of creating a patio for music purposes was not verbally discussed among members in team two. When they used LEGO to build, Gary built the patio all by himself. With these three pieces of information, I concluded that the patio idea was proposed and documented by Gary as a joint decision without discussion with the other teammates. This information only existed in Gary's mind.

Seconds before Gary pointed out the patio problem, Juba shared that they got sports

without elaborating the details. After staring at the LEGO model for around 20 seconds, Juba yanked some white LEGO blocks (# 3 – Figure 5-12– a rectangle with dash line) and shared with the team that he could make a soccer ball field. Ekon raised his voice and shouted, “No! No, leave that! Cuz, that's for…for, that's for his baseball”. Juba placed those blocks back to their original location. The facilitator reminded Juba not to destroy anything while creating a new design.




Before evaluation During evaluation

Figure 5-12. Changes on 3-D LEGO Model.

| Turn | Speaker | Verbal and nonverbal transcripts |
|---|---|---|
| 1 | Facilitator B | You got something for sports ((marks a check)). You got something for the music ((marks a check)). Anything to do with painting that you have? |
| 2 | Gary | I don't think we have. |
| 3 | Ekon | He could (have) painted at that ((points at a yellow building)) (Figure 5-12 solid line) |
| 4 | Gary | No, that's the nine-hole pitching. |
| 5 | Facilitator B | ((writes something down)) |

| | | |
|---|---|---|
| 6 | Ekon | Yeah, he could paint at it. |
| 7 | Gary | No ((extends arms and palms then covers his face with his palms)) |
| 8 | Facilitator B | Okay no, that's (not happen). So… We don't have anything for painting so you might want to think about that. |

Gary shared his evaluation with the team (line 2). Alternatively, Ekon claimed the yellow building (#2 - Figure 5-12- solid line) as a canvas (line 3). Gary rejected Ekon's repurposing and shared information that Ekon would not know - the yellow building was 9-hole pitching (line 4). Ekon still insisted that the yellow building could be used as a canvas (line 6). Gary again rejected Ekon's interpretation of the yellow building (line 7). Eventually, the facilitator closed the conversation by stating that team two did not build anything for Juan's painting need (line 8). Historically, Jack, another team member who was absent in this lesson, created the 9-hole pitching in a previous lesson. Ekon was absent, but Gary, who stood next to Jace, briefly participated in the conversation between Facilitator B and Jace. Ekon, who did not know the history of this creation, assigned a new function to the existing building in the present moment.

The team was yet to transcend the individual knowing to collective shared understanding till they encountered the ambiguity. In the beginning, Gary pointed out that the LEGO design was re-purposed for an unknown reason – turning a baseball mound to bench feet and turning a patio for music into a grilling spot. Then, Juba attempted to deconstruct the pitching mound into a soccer field even though other team members already pointed at the yellow designs as three bases. At last, Ekon referred to the 9-hole pitching as a canvas. These three confusions indicated one critical contradiction – individual minds vs. collective sense-making. Historically, Juba had several conflicts with the rest of the team at the beginning. The challenging interpersonal

relationship Juba had with his teammate lead to much solo work. When asked to make collective sense of their design, Juba did not share equal information about the LEGO design as his other teammates. Without knowing that Jack built the 9-hole pitching. Ekon disassembled the pitching mound and name the yellow 9-hole pitching as a canvas.

The highlight of this excerpt is that, when information was not shared equally within the team, the seemingly complete LEGO 3-D model served as a collection of individual ideas rather than a collective artifact. Team members shared the LEGO board and carved out their own space. However, they struggled when they were asked to perform as a unit, which includes, explain, or defend their ideas. In this case, the reasonably simple LEGO model made it even more challenging to discern what the design was without verbal description. Even though more details were added - shape, colors, and positions using LEGO 3-D modeling tools, the designs were still low fidelity prototypes.

## The Reflection Questions

Even though teams hardly used the reflection questions handout as I intended, there were two instances from the expert teams that showed that the reflection questions, if in use, can help the team's reflection on their designing process. There was a glimpse of process reflection that occurred after they encountered design failure. In one instance, the expert team used the questions to reflect on the design process. It sustained the lesson they learned to influence their decision-making in the iteration phase. In the following session, I zoom in on this episode from the expert team to illustrate how their reflection supported their iteration ideation and decision-making in the future.

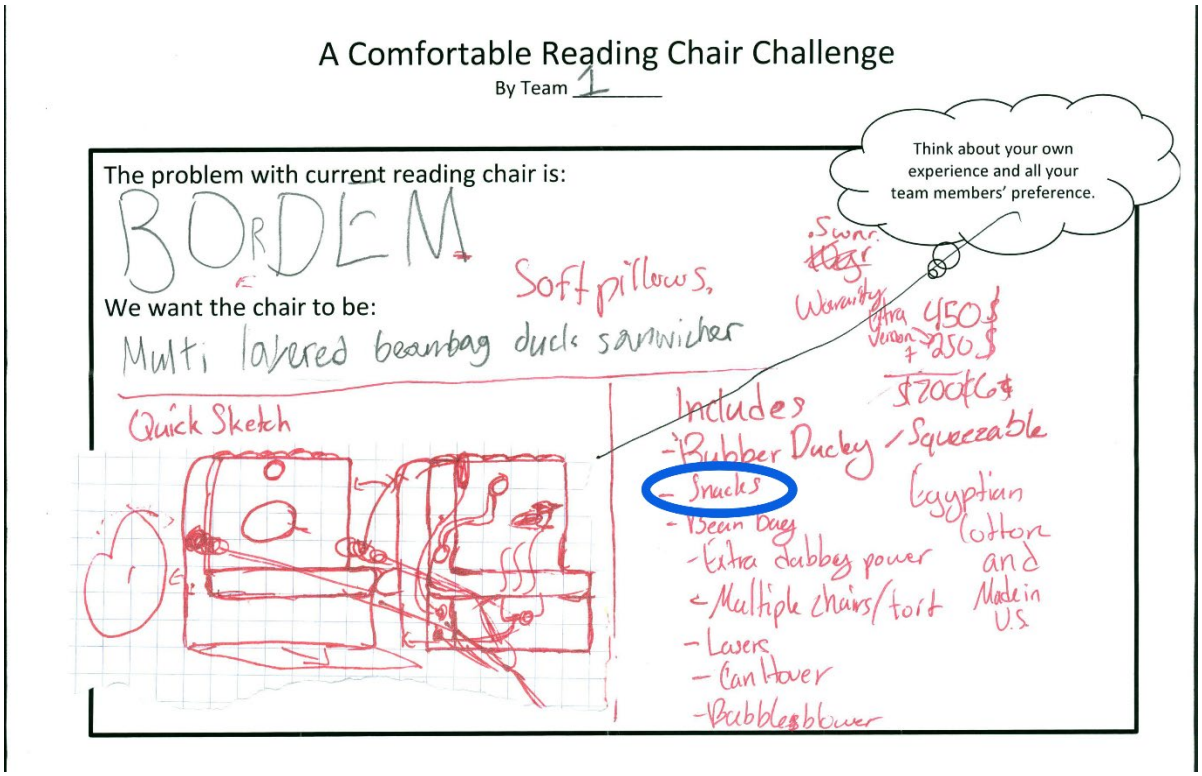
Facilitator A called the whole club for attention and wrote the reflection questions on the

whiteboard. When the iteration activity started, teams were primarily engaged in re-designing the comfortable reading chair rather than reflecting. By the time the facilitator walked into the expert team's space, they have almost finished their first iteration. Facilitator A prompted the team to discuss the reflection questions listed on the whiteboard. For the record, as shown in Figure 5-3, the expert team's original design was designed for boredom and had features such as a squeezable rubber ducky or laser.

| **Turn** | **Speaker** | **Verbal and nonverbal transcripts** |
|---|---|---|
| 1 | Facilitator A | Did you guys talk about the three questions? |
| 2 | Eric | ((looks at FACILITATOR A)) Yeah. |
| 3 | Facilitator A | Ok |
| 4 | Eric | ((looks at the questions on the white board)) We're starting from scratch because ((looks at FACILITATOR A)) the last thing we made it was too big (and too complicated). |
| 5 | Marcos | //((looks at FACILITATOR A)) We got, we got natural. We got extendable cabinet. |
| 6 | Catherine | //Ok, (?) ((grabs a paper)) |
| 7 | Marcos | (?) book holder and we have what, extendable, hmm ((Marcos slides two hands up and down to indicate something)) stands. |
| 8 | Eric | //(?) |
| 9 | Catherine | // (?) |
| 10 | Facilitator A | Yeah ((raises her tone)) |
| 11 | Catherine | (?), right? |

| | | |
|---|---|---|
| 12 | Marcos | Yes, we do right here ((points something for Catherine)) |
| 13 | Facilitator A | ((looks at the questions on the whiteboard)) That's what you do differently? (?) talk about what you've learn? |
| 14 | Eric | We learned that not everything >> |
| 15 | Marcos | ((looks at Eric and finishes Eric's sentence)) >> has to be super-complicated |
| 16 | Eric | Yeah |
| 17 | Facilitator A | That's a good (?). |
| 18 | Marcos | Sometimes, if you look from your perspective, it, it,>> looking at some... |
| 19 | Eric | >>Show Empathy |
| 20 | Marcos | Looking at some, looking at someone's other's perspectives, and change your entire idea |

Eric shared with the facilitator that they decided to iterate from scratch because their original design was too big and complicated (line 1). Marcos listed several design ideas they included in the iteration (line 5 and line 7). The facilitator then prompted the team to reflect on what lesson they've learned from the experience (line 13). Before Eric finished his response, Marcos added that the design did not need to be complicated (line 15). He then mentioned that taking others' perspectives can change the design ideas (line 18 and line 20). Eric used the word "empathy" to capsulate Marcos' idea (line 19). As a team, they reflected on two lessons they learned: 1) the design did not need to be complicated; 2) empathizing with the client can change design ideas.




Copy of Figure 5-3. Team 1's Original Comfortable Reading Chair Design Sketch.

In a later session, the expert team decided to initiate the second round of the iteration. In this round, they started ideating new design ideas referred to from the checklist rather than merely descriptive ideas. For example, I discussed the expert team's conversation about lighting up the edges of the pillow in case there was a blackout in the previous chapter. In the blackout episode, the expert team imagined a hypothetical situation that the client might encounter and ideated design solutions. Another similar instance was when the team discussed if they should add a page-turner for the client. In the checklist, the client shared that she needed something to hold her computer and keyboards, and she also liked to drink coffee and have snacks when reading. The expert team included a book and computer holder in their first round of iteration to meet her needs. In the second round, Catherine proposed a book-turner idea to the team. Marcos rejected Catherine's idea and explained that the idea was too complicated. Even though her team rejected her idea, Catherine did not give up and continue persuading her teammate through

imaging several other hypothetical scenarios that the book turner might be a good design solution for the client.

| Turn | Speaker | Verbal and nonverbal transcript |
|---|---|---|
| 21 | Catherine | Ok, so what if (she's eating a snack or drink coffee simultaneously to read). ((swipes her finger in the air)) |
| 22 | Marcos | //It's like, it's like ((pretends to hold a coffee on his right hand and pretends to sip the coffee)) (?) snack and coffee, and you (are like) watching |
| 23 | Eric | //((talks to Catherine)) Isn’t' that why we have, have the snack and coffee holder? |
| 24 | Catherine | I know, but what if she wants to eat and read at the same time? Like holding a coffee, (?). |
| 25 | Marcos | You can do this. You look at it, (?) next page ((grabs something from the air and puts it into his mouse)), and (turn) next page, ((again, grabs something from the air and puts it into his mouse)). |
| 26 | Catherine | What if (?)? |
| 27 | Marcos | Okay ((looks at Catherine and raises his voice)) |
| 28 | Catherine | I don't know, I don't know. Don't add it. I'm just saying |
| 29 | Marcos | Ok. |

In this excerpt, Catherine used the “what if” sentence to illustrate scenarios that the design solution might be helpful (line 21, line 24, and line 26). Catherine’s book turner idea was not a direct translation of the need but a synthesis of two needs – reading on the chair while

drinking and snacking (line 21). At first glance, Marcos rejected her idea because it sounded too complicated, which resonated with their early reflection (line 15). Later, Catherine further concertized the scenario by adding “like holding a coffee” (line 24). Marcos responded to Catherine by engaging in her imagination and embodied the design solutions to persuade Catherine that their current design was enough to meet the client’s needs (line 22 and line 25). Even though the team dismissed the idea eventually, they performed sophisticated design practices together.

# Chapter 6

## Discussion and Implication

In this dissertation, I investigated how teams learn from failure in the collaborative design context by focusing on groups discourse and their tool use. By adopting a socio-cultural view of learning, I focused on understanding how discourse and tools present in the learning spaces mediate teams' learning from failure activities. I followed discourse analysis along with interaction analysis to analyze the data. In this chapter, I first discuss the findings of two research questions. I then discuss and synthesize literature to propose implications from theoretical and design perspectives. I end the chapter by highlighting the future work needed to deepen our understanding and design to support teams to learn from failure in the collaborative design context.

## Learning from failure and Group Discourse

The findings from Chapter 5 suggest that children in the design club could make sophisticated design arguments, despite the team dynamics and the types of talk they engaged in (Wendell et al., 2017). Unlike Mercer (1996) observed in the science inquiry context, groups' reasoning was only foregrounded in the exploratory talk. The findings show that even the least desirable disputational talk could afford complex design ideas and rationales. In many cases observed, teams engaged in this type of talk did not simply reject others' ideas without explaining. They took time to articulate their reasons and persist in persuading their teammates.

It indicates that the design activity itself could support creating a more equitable learning space for learners.

This is probably because most research on reasoning is primarily conducted in mathematic or scientific inquiry studies that often advocate canonical answers and general logic (Mercer, 1996). Design, on the contrary, is a synthesis process that thrives by integrating designers' personal experiences and the joint process of sense-making and decision-making from information (Boland, 2008; Kolko, 2010). Roozenburg (1993) argued that reasoning in design is "plausible reasoning, in particular the reasoning towards tentative solutions for design problems" (p.4). The "plausible reasoning" and "tentative solutions" speak for design's nature – the solution is provisional.

The findings also indicate that even teams with challenging dynamics traditionally categorized as "problematic" could discuss sophisticated design ideas and externalize their logic, and vice versa. The three types of talk, even though often observed in one team and less in another, the three types of talk could not be used as static characteristics to describe each individual. However, the findings also indicated that the ways design teams communicate to make sense and make design decisions can support and constrain how they experience learning from failure.

From a micro communication process perspective, cumulative talk can support the team's joint decision-making by identifying design failures and ideating new solutions in the iteration phase (Campbell et al., 2019; Wegerif & Mercer, 1997). At the same time, there is a danger of engaging only cumulative talk. The teams might fail to establish a shared understanding of design ideas and rationales or explore multiple design perspectives before making decisions. For example, the expert team quickly identified that their chair design did not support mobility in the

evaluation session without elaboration. They later revoked this identification after an extensive discussion on their interpretation of the client's profile. With the tendency to maintain harmony and collective, team members tend to agree with each other, increasing individual biases (Kerr & Tindale, 2004). The expert team also illustrated this potential risk in the episode as they confirmed their design assumptions. In the episode, the team identified that their design met the client's need to protect the family from bears even after recognizing that they falsely assumed the client had a fence.

Disputational talk can bring forth different individual perspectives but at the cost of establishing psychological safety, which could interrupt future team collaboration. Without a successful regulation of the collaboration process, disputational talk could lead to emotional breakdowns. The breakdown can further constrain team's ability to 1) establish a shared view of their design to identify design failures, 2) collectively make sense of their design rationales to analyze their designs, and 3) negotiate and integrate multiple perspectives to iterate their design (Barron, 2003; Edmondson, 2004). The outcomes of the rising tensions resulting from an increased dispute are evident by episodes such as the conflicts between Kiya and Cameo or between Teddy and Andy. Even though not all instances ended with emotional breakdown, the findings show signs of frustration, falling in a loop of fighting and blaming, and having difficulty responding to the facilitator's support. Consequently, the team was often exhausted from the fight and could not make a design decision together. In some cases, individual team members even stopped participating in the activities.

Exploratory talk, while enhancing the development of shared understanding and perspectives negotiation, can be time-consuming. Exploratory talk is argued as the most desirable talk pattern since it foregrounds the reasoning in the discussion (Mercer, 1996). From

my analysis, exploratory talk allowed teams to define a problem space, critically evaluate their design solutions, including their rationales, and discuss alternative solutions to modify. Through exploratory talk, groups prioritize the task while designing for the client's needs rather than fixating on individual or collective gains.

## Learning from Failure and the Mediation of Tools and Artifacts

Though my original research focus was on the design evaluation tools – client feedback video and the checklist, the preliminary analysis showed the need to expand the focus to other tools presence in this learning space. I then expanded my analysis to also include tools that were presented in the data selected. This expansion allows several important themes to emerge. First, the findings from Chapter 6 indicated that tools played an active role in learning from failure, along with the team's social interaction and the nature of the design process in the collaborative design context. More importantly, physical tools and discourse were so entangled in the collaborative design context that it is impossible to isolate one from the other. Second, the findings showed that the discussion of one tool could not stand alone without mentioning how they relate to other tools. Each relationship they have with one and the other then formed a unique relationship with the learners to construct, negotiate, and manage design failures. Third, the findings also show the unintended consequences of an evaluative tool designed in this space based on children's prior sociocultural experiences.

In the collaborative design, teams used both discourse and materials to make sense of and make design decisions. This resonates with Richard & Giri's (2019) study on using multimodal learning analysis to understand computational thinking through Bidirectionally Responsive Design. They argued that "looking at the artifacts alone did not reveal all of their computational

thinking processes. By using observational analyses and interviews, we came to a better understanding of their knowledge and application of computational concepts, practices, perspectives, and perceptions" (p. 17:29). This again, indicated the entanglement between social and materials runs so deep in collaborative design to a point that defining "any component as either material or social ceased to make sense" (Sørensen, 2009, p. 60). However, the materiality process of design can both support and constrain the collaborative design (Kumpulainen & Kajamaa, 2020; Mehto et al., 2020). Cross and Roozenburg (1992) argued that the design process proceeds from abstract representations to concrete representations. As teams moved the design process forward, their design products became more concrete, which constructed design failures that did not exist before. In this study, teams started the design with paper sketches then shifted to creating 3-D models using LEGO blocks. The shift from creating sketches with paper to creating 3-D modeling with LEGO blocks allowed the team to increase design fidelity from abstract to more specific and concrete. However, this shift also became the source of team conflicts, especially teams who took an individualistic approach in previous building activities. Team two and team three skipped the planning process and built their designs individually. Without either verbal agreement or disagreement, they reached a silent agreement that each member would approach the creation with an individual taking over part of the design. Eventually, the 3-D LEGO model became a collection of individual designs rather than a collective design built upon shared understanding/common ground. Majorities of designs resembled the paper sketches but with more emerging designs throughout the building process.

Second, the finding showed that individual tool did not function alone but is constantly in relation with other tools such as technologies exist in the classroom, the participant structure and their discourse patterns, to form a complex system (Sørensen, 2009). In Litts et al.'s (2021) study

on design scaffolds in supporting youth's computational making ability, they found that individual design scaffolds were insufficient in supporting the learning and called for a systems of design scaffolds. Similar to their findings, this study also showed how combination of tools formed various learning conditions to mediate team's learning from failure activity differently. For example, compared the combination of client profile checklist and paper sketch to checklist and 3-D LEGO model, some types of failure were more visible than the others. As one of the lessons Sørensen (2009) shared, to be sensitive "to materials and to materiality as performed, as emerging through the socio-material arrangement that materials are part of, which is studied with a minimal methodology" (p.193). In the context of learning from failure in collaborative design, failure came to being through relations that formed by different parts.

This study also showed that there were unintended consequences of tools designed and implemented in the context such as agency and equity. Evaluation tools with configurations that resemble school experiences can trigger learners' emotional reactions. As evident in the findings, tools such as the client feedback and the client profile checklist with a numerical system might trigger learners' emotions such as resistance and a sense of competition. Teachers evaluate learners' performances using assessment tools that use a numerical grading system (Edsmonde, 2009). Even though receiving feedback and self-evaluating the products are standard practices in design (Razavian et al., 2016), they were perceived differently by children. Children experienced those activities as judgments of their personal and collective competence rather than a way to empathize with the client and advance their design. When they received feedback from an external source, they moved around, hid their faces, covered their mouths, and compared their teams to others. When the numerical system appeared on the checklist, the team's conversation around whether their designs met the client's needs became a means to an end. It is subordinated

to serve other goals – to defend, to compare, and to win. To cope with the feeling of failure and the threat to their self-esteem (Cannon & Edmondson, 2005), teams defended themselves or strived to score higher on the evaluation. They needed to beat other teams to win. The win or loss was relative to who is competing and what is the total points. However, teams were not just sat and waited to accept a score. They fought fiercely to defend their design products or cautiously cheated not to get caught. On the other hand, tools that facilitate practices not resembling central practice at school might get neglected. Reflection, even though central to design practices (Razavian et al., 2015; Schön, 2017; Wendell et al., 2017; Adams et al., 2003), is not typical at school (DeLiema, 2017). However, the limited instance of how reflection questions mediated the team's learning from failure showed how this tool could support the team's design practice. As the expert team reflected on the comfortable reading chair design with the facilitator's prompt, they actively used their reflection to guide the future iteration design decisions.

## Theoretical implications

My findings suggest a need to reconceptualize what it means to fail and what learning from failure looks like in the collaborative design context. Cannon and Edmonson's article (2005) defined failure generally as the gap between the desired goal and the actual outcome. In the chapter, I also extended this definition. I argued that we should not only define failure as a product but also as a process. However, my findings further suggest that failure in the collaborative design context needs to be reconceptualized as both a product and a process of socio-material interaction.

With its ill-structured or wicked nature, what differentiates a good design from a bad one is often intuitive and elusive (Eilouti, 2020; Sawyer, 2019; Dym et al., 2005). Compared to fields

such as organizations or STEM where the outcomes are often measurable (Kapur, 2008), the evaluation criteria in design were often contextual and subjective (Eilouti, 2020). Kolko (2010) argued that design requires an abductive reasoning method to "organizing complexity or finding clarity in chaos" (Kolko, 2010, p.15). Sawyer (2019) argued that "failure is considered to be a small moment in the context of an iterative, wandering, and unpredictable creative process" in art and design (p. 4). Unlike the existence of wrong answers in math and science, failures are "usually recognized when they have encountered a dead end" (Sawyer, 2019, p. 7). However, human-centered design as a unique approach is still not the same as design products for others. When artists engaged in the design, the goal of their designs is often for self-expression. Compared to product design, either graphic design, architecture design, or any other "wicked problems," the "dead end" is often not present in the early stage, especially in the prototyping phase.

From this sense, neither Cannon and Edmonson's (2005) definition nor my original extension on the process was enough to conceptualize failure in the collaborative design context. First, the definition proposed in Cannon and Edmonson's work indicated three abilities needed to identify failure successfully: 1) the ability to clarify expected results before enacting the performance; 2) the ability to assess the actual results after enacted the performance; 3) the ability to compare the expected results and actual results to identify the gap. This rigid and objective definition of failure not only misaligns with the design nature but can also constrain the design process. Taking a socio-cultural perspective, the findings in this study show that the study of failure should take the tool mediation into theoretical consideration.

Findings in this work indicated that failure in the collaborative design activity goes beyond the binary differentiation between product and process, but a dialectical and interactive relationship. Failure in a collaborative design context is both a product of the previous design

process and a decision-making process of future design products. With this definition, I argue that failures should be defined, not by the past actions and existing criteria, but by momentary sense-making and decision-making process that is bounded by the material conditions. This reframing can contribute to the filed in two folds. In a sense, this way of defining failure as the consequence of emerging social and material interaction also allowed the spatiality between failure and learner, that would otherwise be strongly tied together (Varenne & McDermott, 1998). The notion of "material-to-develop-with" concept proposed by Keune and Peppler (2019) could also extend to define failure in collaborative design context. Acknowledging this co-development between people and materials in makerspaces could allow researchers to tinker around the learning environment by reconfiguring the materials learners use to form new relationship. Also, this reconceptualization of failure would allow researchers to potentially leap from the using mediational means as the single data analysis approach to embrace a more complex analytical approach in the collaborative design context (Barad, 2003). This expansion might allow us to view failure also as a mediated action which involves "a kind of tension between the mediational means as provided in the sociocultural setting, and the unique contextualized use of these means in carrying out particular, concrete actions" (Werstch, 1994, p.205). This tension, rather than destructive, could be the source of creativity and innovation (Werstch, 1994)

The findings also show that learning from failure is both a knowledge building and a knowledge creation activity (Hakkaraein et al., 2013). It is a knowledge-building process because identifying and analyzing design failures in the collaborative design context always occurred in the social plane. The two finding chapters show that what teams perceive is confined mainly by how they communicate and the tool configurations (Stahl, 2006; Sørensen, 2009). It is a knowledge creation process because teams make sense of the existing physical and abstract design ideas and

rationales and decide on new design solutions.

From a macro design process perspective, the learning activity allows teams to reflect on their existing design solutions and make conscious design decisions to move the design task forward. When they created the prototype, team members often did not completely understand their design (Kolko, 2010). However, teams could make design decisions by externalizing the abstract ideas and materializing them into tangible artifacts. The decisions could include whether their design met the client's needs or generated alternative design solutions. At the same time, design teams could recognize that they might lack a shared understanding of the agreed design ideas. Or they needed to make more detailed design decisions to materialize the design ideas.

From a micro communication process perspective, learning from failure allowed the teams to recognize the social failures they encountered as a team (Hod et al., 2018). The joint identification and analysis of design failures forced teams to externalize individual ideas and within the group. Though the externalization process might escalate team conflicts at the moment, it might prompt the establishment of a shared view in the long run. It provides a critical moment for teams to recognize the individual differences when they started elaborating design details and externalizing design rationales. Allowing individuals to express diversified opinions and perspectives is a good indicator of a healthy society and flourishing as individuals. Many design literatures argue that this diversity is also encouraged and needed in design practices (Kolko, 2010; Stempfle & Badke-Schaub, 2002; Arias et al., 2000). Learning from failure brings teams another opportunity to establish a shared view of individual perspectives and integrate multiple paths into the design decision (Fisher et al., 1991; Gillespie & Cornish, 2009).

## Design and Implementation implications

This study adopted the design-based experiment approach (Brown, 1992; Collins et al., 2005), which focused on designing a natural learning space for the intended purpose. Synthesizing from literature from fields such as organizational learning and learning sciences, I proposed three design principles to guide the design and implementation of this study. As I argued in my introduction and literature reviews, although the existing literature supported my theoretical understanding, it was insufficient to guide the design and implementation process. In this section, I reflect on my experiences and proposed suggestions from design and implementation perspectives. I first revisit three design principles proposed in chapter 2 and discuss changes I would make. Then I propose two additional thoughts and reflections on the design and implementation of the learning space.

## Revisit design principles and propose implementation suggestions

### *Revisit Design Principle 1: The challenge should be hard enough to create failure*

Revisiting the design principle on the challenge design I originally proposed, I offer a revision. Instead of creating a standardized challenge for all teams, the challenge should be hard enough for individual small groups. Second, instead of increasing the challenge by simply adding more information on fictional clients, I recommend using authentic human-centered designs as challenges for teams to work on as they are naturally ill-structured and complex.

Kapur and Bielaczyc (2014) argued a learning benefit of allowing learners to struggle with ill-structured mathematics problems before providing canonical answers as an alternative to direct instruction. They claimed to find the “sweet spot” of design, which is challenging yet too

frustrated. This metaphor resembles Ericsson and Pool's (2016) deliberate practice concept. As Ericsson and Pool argued, Deliberate practice allowed the learners to progress from a novice to an expert. One of the critical principles of deliberate practice is to step out of one's comfort zone. They argued that the area where learners needed to challenge themselves to grow. Vygotsky (1978) conceptualized this area as a zone of proximal development and argued that the way to advance learners was to allow them to be guided by a mentor. Informing by the findings, I observed that teams with various collaborative design skills responded to the challenges differently, which is evident in the several cases presented in disputation and exploratory talks. Although all teams were capable of designing without being told how to design, they needed support tailored to their needs. Teams who have challenging interpersonal relationships might need support to regulate their emotions and communication process. Other teams might benefit from supporting their perspective-taking skills to foster empathy (Haag & Marsden, 2019).

Haag and Marsden's (2019) study showed that creating user personas can support designers to develop empathy in design education. Their study showed, however, it was easier for novice learners to empathize with personas that were similar to them. They suggested that design education should foreground empathy rather than relying on designers' reactions and intuitions. Zahavi (2010), on the other hand, argued that empathy arrived when we had a direct and embodied experience with others. Build on Zahavi's argument, Heyligen and Dong (2019) called for shifting from the cognitive perspective of empathy to an embodiment. They argued that "In practical terms, the consideration of empathy is active by requiring designers to live the experience of the mind and body of the end-user(s) whose cognitive and/or affective state they are supposed to be affected by" (p.119). Supported in the findings, when team members put aside their individual or collective win or lose, they started imaging and taking the client's

perspectives. Their imagination did not rely on discourse only but also their body positioning, including hands-on manipulation of the physical tools. They acted and performed to design, and they crafted and modified artifacts to represent. However, those instances were hardly observed using a checklist only evaluation activities, but either at the beginning of the design club, but often at the end.

One potential re-design that synthesize the above-mentioned re-design suggestions is to allow each team to build their portfolios over time (Peppler & Keune, 2019). In Peppler and Kenue's (2019) study on youth making portfolios, they framed the motivation from the sociocultural perspective and argued that the connection youth could form with the larger community through their portfolios motivate them to perform ways that exceeded the adult scaffolding. The original design though took children's interest into consideration was still limited. The consequence of this more top-down design approach, not only conflicted with the Human-centered design approach, but also hindered design teams from emotionally engaged with the design activities. By shifting from a researcher-initiated design to portfolio type of project, might be a solution to solve both the inequity of using standardized design challenges and the difficulty of empathizing with a fictional character to engage in the learning activities. Tseng (2016) discussed one particular portfolio web-based tools called "Build in Progress" which encourages young makers to document, share, seek feedback, and reflect on their design processes.

***Revisit Design Principle 2: Make failure visible***

As suggested in much literature, I created the client profile checklist for teams to

facilitate teams' design evaluation to make failure visible. I also invited colleagues to provide design feedback to design teams. As the findings show, there were mixed consequences of those efforts. In the next section, I discuss the consequences and suggest revisions.

The first consideration focuses on what and how teams access the information. As I discussed in the general discussion section, team members react emotionally to failure when their teams' performance was evaluated in public and externally. Even scholars (Cannon & Edmondson, 2005; Kapur & Biechachy, 2012) advocate the need to establish a culture that allows learners to be comfortable with failure or overcome self-esteem obstacles. The findings show that failure is only visible if teams identify it jointly. It is probably more helpful if each design team has the opportunity to evaluate and reflect before receiving feedback in the private team space. Another consideration focuses on how teams access the information. As I argued, even though displaying the external feedback on a wide screen allowed all members to access their teams and feedback for other teams, it brought privacy issues. On the other end, when only limited team members had access to the information such as client profiles, they created unequal participant structures and power struggles within the teams. Therefore, the future design should balance team privacy and at the same time ensure accessibility in a shared learning space. The possible solution is to distribute a digital device such as a laptop or a tablet for each team to watch the video.

The second redesign consideration focuses on whether I should abandon the checklist design in the future. From the findings, although groups reacted to the checklist the same way they reacted to school evaluation, the findings show signs of them learning from failure processes. Though it might be boring, the iterative use of the checklist allowed multiple design interpretations and design solutions to emerge. Therefore, it doesn't matter if they admit the

failure or not at the first time, what matters is if they take any actions to revise. As the concern of teams turns the design evaluation from making changes and improving their design to winning the game when using a checklist with a scoring system, I argued that this might bring opportunities for reframing and redefining the scoring system. This is to say, we can seize the opportunity brought by the resemblance of school practice and support learners to assign new meanings and interpretations of those practices. Hopefully, this new perspective will disrupt the traditional view on failure and free children from the interpretation that evaluation is a way to judge capabilities and failure is an indicator of deficiency.

Last but not least, consideration should focus on the building tool affordances. Paper, pencil, and LEGO blocks are simple building tools that require little to no learning, given that they were common objects in learners' life. However, the use of those tools can, at the same time, be constrained by the designer's current design abilities. Moreover, the decision of what tools to choose when designing the learning space require researchers to be critical about the tradeoffs of the physical tools selected (Peppler et al., 2016). Scholars who study Makerspace had extensive research on multiple tools affordances on maker activity, such as on maker's identities (Richard & Giri, 2019; Weidler-Lewis et al., 2021) and the issue of equity such as accessibility (Seo & Richard, 2020). For example, professional designers could use paper and pencil to create 3-D dimensional sketches or documents with training. Or masterpiece anatomical sketches created by Leonardo Da Vinci included both precisions of sciences and arts. Children with little or no training in design have total capacity to imagine abstractly and discuss sophisticated design rationales, as shown in the study, might be constrained by their design-related domain skills when interacting with the building tools. Paper, even though full of possibility, could be daunting to children given the lack of structure. LEGO can only create

certain forms depends on the how children received from the club. However, with the perceivable information right in front of them, children might be able to perceive the constraints that paper could not provide. Therefore, researchers should also consider the building tools and constantly pay attention to how learners interact with the tools and provide support when needed.

A potential solution to the challenge of balancing the tradeoff of tools is to allow designers to access to diverse materials, from both visual accessibility and resource availability perspectives (Richard et al., 2015; Richard & Giri, 2019). Comparing three makerspaces, Sheridan et al. (2014) discussed how the makerspaces they observed all supported "diversity of learning arrangements" (p. 528). One of the distinctive features that allow all three spaces to support the diversity is the variations of tools available. They varied in terms of level of expertise needed or purposes. With this diversity, the space was able to expand and adapt to different makers based on their genders, ages and expertise (Richard et al., 2015; Sheridan et al., 2014;)

***Revisit Design Principle 3: Create a safe environment for the participants***

My original understanding of creating a safe environment for the participants was limited to establishing a productive failure culture for design teams to fail and learn. However, creating a safe environment that allows learners to fail and learn should also extend to the small group interaction with discourse. Observing multiple instances of disputational talk, I recognize that the idea of a safe environment should also extend to small group interaction (Edmondson, 1999). Borge and Mercier's (2010) argued in their micro-ecological framework of CSCL article that collaboration is a multi-layered and nested phenomenon. Learning is trans ecological through individual to the small group, and the community with learning objects. From the socio-cultural

perspective, learning first happens in the social plane (Vygotsky, 1978). In the collaborative design, the small group is often the first social plane individuals. In this club, children also spent the majority of their time with their teammates on design projects. As shown in the findings, how teams communicate can lead to different learning consequences, and their psychological safety is the foundation to allow the sophisticated collaborative design processes to emerge.

## Conclusion

Even though scholars recognized the importance of fostering a designer or maker mindset, especially the designer's way to reframe failure in the process, the findings in this study show that the shift of mindset takes constant practice and guidance to develop. I argued in resign principle two that the problematic tools could be a gateway to disrupt participant's past experiences and adopt the designer's way of viewing the world. However, this process needed to be guided at the right time (Tremmel, R. 1993). It required facilitators to let go of their assumptions and pay attention to what's in front of them and meet learners where they are. Instead of separating themselves from the situations, facilitators have to be with them, including their own emotions and vulnerabilities. Their ways of being could provide practices models, such as dealing with design conflicts and managing design failures (Sheridan et al., 2014).

The glimpse at how reflection can support learning indicates that the re-design should reinforce and guide the reflective practice. As the social interaction and design practice intertwin deeply and inseparable, the reflection should include both micro communication levels such as joint sense-making and decision-making, and macro design process levels such as perspective-taking, feedback, and evaluation (Haag & Marsden, 2018; Schön, 1979; Wendell et al., 2017; Adams et al., 2003). However, it should not be coming from a model designer's mindset and

practice on reflecting design with a variety of tools (Martin et al., 2019; Schon, 1979; Wendell et al., 2017; Adams et al., 2003; DeLiema, 2019).

At last, this study also points out one critical element in learning – time. In the book *Late Bloomer*, Karlgaard (2019) explored the phenomenon of success in the later time. He argued that we live in a society of praising and rewarding early achievers and publish late bloomers. Consequently, we favor shortcuts to success, are unsatisfied with our own pace to knowing and understanding, and avoid learning that makes us failures. Learning from failure is a skill and process and a choice we have to make in every situation. In educational research, scholars start acknowledging how understanding takes time (Ludvigsen et al., 2021) and the importance of creating time and space to allow individuals and teams to grow in their paces (Mercer, 2008).

## Future Work

Even though topics such as agency, equity, and inclusivity were not the focus of this study when I started this research couple years ago, the findings show a vital sign of how learning from failure has a strong connection to those topics. In this study, the problems of inequity occurred in learning spaces such as the design of activities, the tool configurations, or team members' teamwork. This study adopted Brown (1992) and Collins et al.'s (2005) definition of Design-based research or design experiment, which focuses on the socio-cognitive aspect of learning. With the themes on agency, equity, and inclusivity that emerged from the findings, I call for adopting the socio design experiment approach or participatory design approach in the future, which put the learners' empowerment and the issue of equity at the center of the design (Gutiérrez & Jurow, 2016).

A future line of research that can build upon this study is to work with marginalized

learners. More work should be done with non-dominant learners to understand how success and failure are constructed in their daily life experience and how they position themselves in those critical events. Empower marginalized learners using a designed way of thinking and living, especially adopting a designer's view on failure (Gutiérrez & Jurow, 2016; Burnett & Evans, 2016). As an implication of this study, I call for critical examination of our shared beliefs, such as failure is a path of success or learners with grit and a growth mindset are more likely to succeed. In the earlier section, I discussed that failure is constructed and negotiated at the moment-to-moment socio-material interaction. This statement implies that when we start discussing success and failure in our dialogue, we also need to be critical about the momentary learning conditions that create success and failure in the first place (Martin & Dixon, 2019; Ryoo et al., 2015; Uttamchandani et al. l, 2021; DiGiacomo & Gutierrez, 2016).

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## SELECTED PUBLICATIONS

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