Learning From Design Failure, Collaboratively

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Abstract: Effective design requires iterative cycles of learning from failure, where design teams evaluate their designs to identify problems and make iterative improvement. However, existing learning from failure models do not always take collaborative process, a key aspect of design, into account. The ultimate goal is to design tools to better support young design teams' collaborative learning from design failure process in an after-school design club with students in grades 4-6. In this article, we examine how teams use discourse to learn from design failure collaboratively by analyzing video data and group artifacts. Our findings suggest that the specific communication process can support or hinder the learning from failure in design contexts and that there's a need to support team's regulation process so they can benefit from their design failure.

Introduction

With the increasing interest in integrating design thinking into K-12 school settings (National Research Council, 2012), scholars proposed various design skills that need to be supported for effective design, i.e. using sketches to plan ideas (Härkki et al., 2018), creating narrative scenarios for rapid testing (Rosson & Carroll, 2002), as well as design iteration skills (Lewis et al., 2018). Another core yet challenging design skill is learning from failure, a key design process that needs to be supported (Blikstein & Worsely, 2016).

Learning from failure is hard for adults and even harder for children. It is not a natural developmental process for children. They need to be taught how to learn from failure and given opportunities to practice this skill (Blikstein & Worsely, 2016). Therefore, it is critical to design learning contexts that provide students with opportunities to leverage the learning gains from failure (Kapur & Bielaczyc, 2012). However, the process of how groups learn from failure is still not well understood from a pedagogical standpoint. Well known models that theorize critical processes for learning from failure (Cannon & Edmondson, 2005) do not provide pedagogical guidance on how to support this type of learning.

Learning from *design* failure poses additional challenges because design processes are usually collaborative, occurring at the group level (Dym et al., 2005; Stempfle & Badke-Schaub, 2002). Designers often work in teams to unpack problems from users' perspectives to innovate product design or human system design (Brown, 2008). To innovate, design teams need to detect and even actively look for failures and iterate the design to meet clients' needs (Shinohara et al., 2017). When we support learning in groups, we not only need to deal with challenges in cognition, emotion, and metacognition at the group level, but also the interpersonal relationships between members (Baker et al., 2007). However, the learning from failure framework does not focus on examining collaborative processes, even though the collaboration quality can affect learning outcomes (Barron, 2003; Borge, Ong, & Rosé, 2015). To support designers, we need to extend what is known about productive failure to address collaborative learning contexts.

Towards this end, we examine the collaborative learning from design failure process in an after-school club setting. We aim to understand how communication process supports or hinders learning in design contexts to inform pedagogy and tool design to improve how teams learn collaboratively from design failures.

Towards a model of supporting collaborative learning from design failure

Cannon and Edmondson's (2005) model on how to learn from failure at an organizational level informs our understanding of learning from failure process. This model theorized three learning from failure processes - *failure identification*, *failure analysis*, and *deliberate experimentation*. **Failure identification** is a process of recognizing small failure from a complex system. **Failure analysis** is the process of understanding the cause of the failure and extracting lessons to avoid future failure. **Deliberate experiment** encourages organizations to design solution experiments to experience failure early in a safe and controlled setting. This is a critical process to innovate but also a higher-order thinking process that is more likely to be fruitful when people feel it is safe to fail (Baer & Frese, 2003). Unfortunately, this model is theorized to support *adult employees* who are advanced in cognitive, emotion regulation, and metacognitive skills rather than *young learners* at the age of 8 to 11. When applying it to younger learners, we need to consider skills that are needed to support the learning from failure process.

One important process both productive failure design framework and learning from failure model emphasize is collaboration (Kapur & Bielaczyc, 2012; Cannon & Edmondson, 2005). In the productive failure design framework proposed by Kapur and Bielaczyc (2012), collaboration is an effective mechanism to facilitate concept learning such as explanation and elaboration for individual learning purposes. Similarly, learning from failure model which generated from organizational learning argues the importance of collaboration but with a different reason. This model argues that team is the locus of collective innovation and problem solving (Edmondson, 2002). From the collective perspective, how collaboration process plays out affects the whole team's ability to analyze failure and extrapolate lessons (Barron, 2003; Cannon & Edmondson, 2005). Teams need to bring multiple perspectives together to examine what went wrong, make collective interpretation of the causes, and decide what to do in the next step (Boreham, 2004).

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 is "visible" in the discourse (Stahl, 2006). 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 that occurs 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 which is 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 other's statements without providing reasons, ignore other's 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 type of talk, the group does not necessarily establish a shared understanding, depending on whether opinions are elaborated on or justified.

Given that current research has not examined collaborative learning from failure, and we know that discourse patterns can impact collaboration, we need to understand: (RQ) *How are specific communication process support or hinder a team's ability to learn collaboratively from the design failure?*

Method

Curriculum

This study involved an afterschool design club aiming at fostering elementary school students' collaborative learning from design failure skills. Throughout the club sessions, we framed failure as "an opportunity to learn and improve". Club facilitators introduced each challenge with a short live presentation or prerecorded video of a real person discussing a problem and asking the club to devise a solution. These introductions contained limited information about the user or the activities the user would have. Teams had to ask questions to gather additional information that would be needed to inform their design. Teams completed the task on their own with little to no guidance from facilitators, unless teams asked for help. When they finished the design task, teams used tools to evaluate their design, identify problems, and improve their designs.

In the lesson we chose to analyze for this paper, students worked on *the Comfy Chair Challenge*. Teams were asked to evaluate, analyze, and iterate their reading chair design with two tools, a feedback video pre-recorded by a client and a requirements checklist. First, they received video feedback from the user, who went through all the designs each team made and pointing out the pros and cons of each design. Then, teams were given a checklist that contained a list of user needs to evaluate how well their design fulfilled these requirements. For example, some requirements included a cup holder (because the user always drinks coffee), chair mobility (because the user likes to follow the sun), and ergonomic design (because the user has back pain). Teams were asked to use the feedback and self-evaluation outcome to iterate the chairs design.

Participants

We recruited 16 students from 4th grade to 6th grade who signed up the afterschool club voluntarily. There were five female students and eleven male students in total. Four students participated in this afterschool club for over two semesters. The rest students either participated in the club only once or were new. When divided them into four teams, we put four students who have been in the club over two semesters together as an expert group (see Table 1). We assigned the rest twelve students in three groups based on their ages, technical expertise, gender, and interpersonal relationship.

Procedures

We video recorded four teams over the semester, collected approximately 72 hours of video data. We created content logs for all these videos following Jordan and Henderson's (1995) method to describe rather than to evaluate, and to understand the interaction among group members, including verbal and nonverbal interaction, and interaction with artifacts.

Using content logs, we identified data with two criteria: (1) teams were expected to carry out learning from failure processes, (2) two distinct cases could be analyzed: an "expert" team (learners with the most club experience) and a "novice" team (learners with little to no previous experience). These criteria helped us to select the comfy chair design challenge and our two cases. See Table 1 for descriptions of analyzed teams. We focused our analysis on these two teams' discourse during the learning from the design failure session. We observed a wide range of collaboration discourse differences between the expert team and this novice team based on the first author's field note and other facilitators' observation. Even though each novice team faced collaboration challenges, this novice team went through collaboration challenges more frequently throughout the semester. We reviewed both lesson plans and content logs to identify communication rich segments for analysis. We then transcribed each segment's verbal and nonverbal data.

Table 1: Participant list of the expert and novice teams

Team	Name	Grade	Previous Semesters in Design Club
Expert Team	Marcos	4th	4 semesters (2015 Spring – 2016 Fall)
Expert Team	Catherine	5th	3 semesters (2015 Fall – 2016 Fall)
Expert Team	Eric	5th	2 semesters (2015 Fall – 2016 Spring)
Novice Team	Andy	4th	0 semesters
Novice Team	Kiya	5th	0 semesters
Novice Team	Teddy	4th	1 semester (2015 Spring)

Discourse analysis

Within the selected segments, we identified thematic units that directly relate to teams' design failure identification, analysis, and iteration. The thematic unit started with one group member reading aloud the checklist or propose an iteration idea and ended when the conversation was 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 design failure process. After excluding units that had less than two team members in the conversation, we selected 60 thematic units from the expert team and 52 units from the novice team for micro-level analysis. In micro-level discourse analysis, we used Mercer's frame of reference to categorize the conversation quality. Given his framework lacks operational level ability, we adopted Polo et al.'s (2016) five indicators which crystalized this framework into operational signs to categorize three types of talk (see table 2). We then used these five indicators to analyze the team's communication that co-occurred with each thematic unit along with product analysis to understand how discourse supports or hinders collaborative learning from design failure process.

Table 2: Mapping five indicators to Mercer's Three Types of Talk

Five Indicators	Exploratory Talk	Cumulative Talk	Disputational Talk
1. Are assertions and refutations justified?	Yes	Yes or No	Yes or No
2. Do the participants elaborate on the content of previous turns?	Yes	Yes or No	No
3. Do they critically evaluate each other's arguments?	Yes	No	Yes
4. Do the group explore everyone's idea before making a collective decision?	Yes	Yes or No	No
5.1 Do the individual's contribution integrate group's	Yes	Yes	No

conversation in previous turns?			
5.2 Or do they only voice the speaker's own initial ideas?	No	No	Yes

Findings

There were two main findings from our analysis. The first finding describes how exploratory and cumulative talk affected collective design creation and identification/analysis. The second finding focuses on disputational talk and its impacts on interactional processes.

Finding 1: Both exploratory talk and cumulative talk help teams make collective decisions which lead to productivity, but they have different influence on the quality of the design decision.

Both exploratory talk and cumulative talk allowed the group to reach consensus. The consensus among the team members often resulted in creating collective artifacts – documents or design sketches which leads to productivity. Cumulative talk is a time-saving way to communicate but lacking critical evaluation among group members often hindered them to examine if shared understanding was established and to explore multiple design paths before making collective design decisions.

The following excerpt depicts how cumulative talk can result in the collective decision – design artifact but hinders teams to examine if shared understanding was established among each other.

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, and 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, Andy looked at the checklist and immediately generated and shared his iteration ideas to Kiya (line 8, 9, & 10). Without asking for clarification or challenging Andy, Kiya documented what Andy said to her best capacity (line 11). Eventually, they created a list of elements to include in the chair redesign (see figure 1, left). Compared to their dialogue and this document, we found that Kiya missed out 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.

Figure 1. Kiya and Andy's Pair Design Document (left) & Teddy's Individual Design Sketch (right).

The following episode exemplifies how the expert team used cumulative talk to *identify* a design failure. In the design evaluation phase, the expert group discussed one user need: *the user wanted to move her chair around so she could enjoy sunshine sometimes or get closer to the light.* They agreed that their design did not meet the client's needs without further analysis.

7. Catherine: ((reads from the checklist)) So I like to move my chair around so I can enjoy sunshine (?) sometimes get close to the light. (*read aloud checklist item*)

8. Catherine: Zero? (*propose individual evaluation result*)

9. Marcos: Zero. (*agree*)

10. Catherine: Or two. (*alternative idea 1*)

11. *Catherine: ((*looks at Eric and waits for his reply*)) (turn taking and explore everyone's idea before making decision*)

12. Eric: Zero. (*agree*)

13. Catherine: ((writes the score down on the checklist)) (*reach consensus*)

To help the group measure their design, we assigned values to each item. The points the group earned depended on how much the design met the client's need. The score was within the range of zero to two meaning not meeting the needs at all to meeting the need fully. Catherine started evaluation by reading the checklist out loud for Marcos and Eric. Catherine proposed "zero" as her evaluation score after reading it (line 2). Marcos and Catherine had an agreement (line 3). Catherine proposed an alternative score – "two" (line 4) but her proposal was not followed up, however. Before she documented zero as the final score, she waited for Eric to share his opinion. After Eric agreed on "zero" (line 6), Catherine put the final score down (line 7). At this point, expert group reached consensus through the signal of inscribing the design idea on the shared document.

In the excerpt above, without critical evaluating their stances or justifying their claims, expert group quickly reached the consensus and moved on. The expert group's cumulative talk allowed them to make efficient identification decision but failed to evaluate the design need and their own design further. The expert team neither discussing what the design need means as a team or refer to their design prototype to cross check if their failure identification is supported by any evidence or rationale.

Exploratory talk, on the other hand, not only supports teams to make collective decisions including creating shared artifacts but also allows teams to create shared understanding. Teams were also able to consider multiple design paths to refine their design ideas and evaluate if the design ideas are needed. We observed at least two instances of exploratory talk from the expert group. The following excerpt showed how the expert team extended and challenged each other's ideas to explore multiple design ideas before making collective decision.

14. Marcos: Oh!! (What if there's) like a black out? Should we have like a flashlight? (*hypothesize a situation*)

15. Catherine: Oh, no. Like maybe, like around at edges. Like (…). (I am thinking). (*Alternative idea 1*)

16. Marcos: Oh! Around the edge we can have like bowling lights. (*Elaborate on Alternative idea 1 in line 2*)

17. Catherine: OR (we can) do (?).

18. Marcos: (But) that will be too much (distraction).(*challenge Alternative idea 1*)

19. Catherine: Maybe the pillow can light up. (*Alternative idea 2*)

20. Marcos: Oh, yeah. That's a good idea. (*agreement*)

21. Eric: What if she's (leaning) on it? (*challenge Alternative idea 2*)

22. Marcos: Where's the heart pillow?

23. Catherine: ((looks at Marcos)) She doesn't have to be, it could be on her lap.(*justify Alternative idea 2*)

24. 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 that was not mentioned anywhere in the checklist and proposed adding a flashlight to their design (line 14). Catherine proposed an alternative idea – do something with the edges of the chair instead of using flashlight (line 15). Marcos added that they can light up the edges of the chair (line 16) but immediately challenged himself because the light might cause too much distraction (line 17). Catherine proposed a second alternative idea (line 19) 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 18). This idea was accepted by Marcos (line 20). 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 possible downside of the design (line 21). Catherine justified her idea (line 23) which persuaded Eric successfully (line 24). In 11 turns, 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 2).
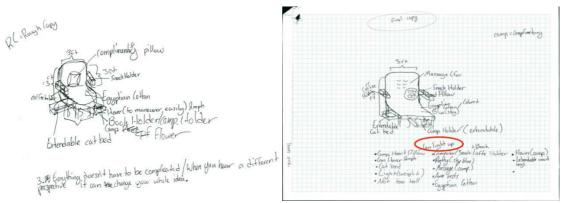

Figure 3. Expert Team Iteration 1 Sketch (left) & Iteration 2 Sketch (right).

Finding 2: Disputational hindered the creation of collective artifacts and the development of shared understanding and negatively impacted the future collaboration process.

Disputational talk is the least desirable talk in Mercer's framework. When used disputational talk, team members exchanged short assertions and argued back and forth without moving the conversation further. Even though the content exchanged in disputational talk might contain reasonable arguments, it focused on finding each one's logical flaws which often leads to emotional breakdown if not managed successfully. As a result, rather than focusing on design task, they used up the time blaming each other.

In the design iteration phase, novice team members Andy and Teddy both shared that they would create individual designs. This individual design approach created a big challenge in their later design iteration process. The challenge of integrating everyone's design ideas became the main source of their conflict. In the following excerpt, Teddy and Andy debated if Teddy's design would solve the client's back pain problem.

25. Teddy: //It has, it has a lot of support so if she, her her, so she hurt her back a little… (*share idea*)

26. Andy: No, she said only a little pillow should be nice. (*refute and justified*)

27. Teddy: I HAVE a PILLOW! ((raises his voice)) (*refute emotionally*)

28. Andy: Just one pillow! (*refute emotionally*)

29. Teddy: A pillow! ((raises his voice)) (*refutation emotionally*)

30. Andy: Yeah (?) ((shrugs his shoulders))

31. Teddy: There's a pillow on it, there's support, so it doesn't just sag

32. 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 (?)

   (*After 24 turns of talking back and forth including facilitator's regulation acts*)

33. Andy: I still like hers better ((points to Kiya, curls his lips and shrugs his shoulder)) (*vote to decide*)

34. Teddy: ((raises his voice)) (I) didn't even (explain) it! (*defense his turn taking right emotionally*)

35. 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 a lot of good things. (*facilitate to integrate ideas*)

36. Andy: ((takes Teddy's design and reads it)) Can I read this?

37. Facilitator: And I think her plan also has a lot of good things. So what do you think goes very well from his plan with MA's (client) needs? (*facilitate to integrate ideas*)

38. Teddy: ((raises his voice)) He thinks my design is horrible just because I'm younger than her. (*blame*)

39. Andy: Hey, you're older than me. (*refute*)

40. Teddy: And I'm younger than her ((points to Kiya)). You want to go with (?) the older one.

From line 25 to line 30, Teddy and Andy exchanged short assertions to argue with each other. Andy refuted Teddy's idea by quoting the client's feedback (line 26). This refutation made Teddy raised his voice twice to defend his design idea (line 27 & 29). Eventually, Andy agreed with Teddy and extended his idea upon Teddy's (line 32). At this point, Teddy calmed down and proposed that he should add a timer. Andy again questioned Teddy's idea which leads them into 24 turns conversation among Teddy, Andy, and the facilitator. Within the 24 turns, Teddy came up with two new ideas, but all rejected by Andy immediately. Teddy raised his voice and blamed Andy for interrupting him. When the facilitator asked Andy and Teddy to provide rationales to support their argument, Andy shared that he favored Kiya and his collective design (line 36). This made Teddy emotional and blamed Andy for discriminating against his design because of Teddy's age (line 38 – line 40).

Novice team's conversations shifted from discussing the design ideas to winning and blaming. The facilitator who sat in the group constantly regulated their talk by guiding the group attention back to design discussion and providing strategies to integrate ideas. However, the heated-up debate between Teddy and Andy made the team unable to respond to the facilitator's help. Given the evidence, this type of talk not only failed to produce collective artifact and develop shared understanding but disrupted the collaboration process because team members were dominated by intensified emotions which made it hard to concentrate on the contents they discussed. The tension, without proper resolution, disrupted team members from making decisions together. As a result, the novice team didn't get time to either create a collective design or iterate individual designs (Figure 1).

Discussion

Even though previous literature acknowledges the importance of collaboration, there's no studies dedicated unpacking the collaboration process in learning from failure together. Suggested by collaboration literature in the learning science field (Barron, 2003; Borge et al., 2015), we sought to understand how the communication process inherent to the learning from failure event helped or hindered a team's ability to learn collaboratively from the design failure.

Our findings suggest that the quality of the team's communication affects how teams identify, analyze, and experiment with different design ideas. From our analysis, we found that exploratory talk and cumulative talk might support team's collective decision making especially creating collective artifacts (Wegerif & Mercer, 1997). However, the danger of engaging only cumulative talk is that teams might fail to establish shared understanding or evaluate/analyze different paths before making decisions. Disputational talk might surface the discrepancy of individual understandings and ideas among group members, but it might hinder the team from creating collective artifacts and shared understanding and impede them moving the tasks forward.

Our study broadens productive failure design model (Kapur & Bielaczyc, 2012) by arguing the need for providing supports to the team's communication process, especially their ability to regulate. As shown in the first finding, accepting one idea and seldom evaluated each one's statement critically might be a time-saving decision-making approach but might accumulates misunderstanding among each other with the potential to turn small failures into a fatal one (Borge et al., 2012). However, if behaviors such as disagreeing other design possibilities are not managed well, they might disrupt the team's productivity and quality of work even though team members evaluated each one's stance. As shown in our second finding, when the team fell into the loop of debating and blaming, they had a hard time responding to the facilitator's support. There's a need to co-regulate their emotions before helping them make sense of each other's ideas (Toprani, Borge, & Xia, 2018; Hadwin, Järvelä, & Miller, 2011). It might also be fruitful to scaffold teams to develop social norms and awareness of the social role of emotions (Mercer & Littleton, 2007; Polo et al., 2016).

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