Chapter 30

Tracing Problem Evolution: Factors That Impact Design Problem Definition

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ABSTRACT

Design problems evolve throughout many typical design processes. Little research has focused on the extent to which design problems evolve and the role that various factors play in this evolution. In this research, we drew from data gathered for DTRS11 that traced a design team's process as they progressed from the end of a large-scale user data-gathering phase to a deeper understanding of the problems to be addressed. Analysis revealed evidence of three factors that impacted the way the design problem was defined: the structure of the co-creation sessions; cultural perceptions and norms of the team and the users; and user data and its translation by the team. Understanding factors that guide the definition of the design problem can support designers in expanding their awareness in design decision making and problem solving because they can be more reflective and explicit about how and why their understanding of the design problem changes and more intentional about exploring the design problem space.

1 INTRODUCTION

The act of designing involves "searching in a hypothetical space of many possible ideas." This includes exploration of both the problem space and solution space, where the problem space is a hypothetical space representing differing ways to understand the problem, and the solution space contains all possible solutions to the determined problem. Designers must define the size and scope of these spaces, and this definition evolves throughout a design process (Cross, 2004; Cross & Roozenburg, 1992; Dorst & Cross, 2001; Hybs & Gero, 1992). A variety of factors may influence this evolution of the problem space, including data gathered, user feedback, testing, team preferences, and solution ideas (Goel & Pirolli, 1989, 1992; MacLean, Young, Bellotti, & Moran, 1991). The continuous and iterative impact of solutions on the definition of the problem, and vice versa, is known by the term problem-solution co-evolution (Dorst, 2011; Dorst & Cross, 2001; Maher, Poon, & Boulanger, 1996; Maher & Tang, 2003; Wiltschnig, Christensen, & Ball, 2013). While there is a body of work on the way problems and solutions shift in response to one another (Dorst & Cross, 2001), there is limited work on what and how other factors drive or limit changes in designers' understanding.

Thus, our research focused on understanding ways a design problem was defined throughout a design project based on knowledge gathered from lead users in co-creation sessions and design team conversations on those sessions. Specifically, we investigated how the design problem space was decomposed, framed, and structured throughout a team's process and what factors impacted the definition of the problem.

2 BACKGROUND

Defining a design problem includes understanding a design need, background to the need, and solution requirements and constraints (Dieter & Schmidt, 2013; Dym, Little, & Orwin 2013; Fogler, LeBlanc, & Rizzo, 2014; Ulrich & Eppinger, 1995; Yock *et al.*, 2015), which requires synthesis of multiple data sources, including prior knowledge, engineering principles, and contextual information (Howard, Culley, & Dekoninck, 2008; Restrepo & Christiaans, 2004; Simon, 1973). As information is processed and relevant elements are better understood, a redefined design problem is structured. This evolution of the "real" problem can be understood as the exploration of a problem space, which we define as a hypothetical space that represents all potential understandings of a design problem, grounded in Newell and Simon's theoretical description of design spaces (Newell & Simon, 1972; Simon, 1978). This exploration is described as iterations of defining, framing, structuring, and scoping the problem. It does not only dominate the initial steps of the design process, but also re-occurs throughout as designers make decisions about constraints and hone in on certain areas of the space (Brophy, 2001; Cross, 2004; Goel & Pirolli, 1992; King & Sivaloganathan, 1999). At various times throughout a design process, decisions are made and certain aspects of the design problem are considered well understood and "set." Sometimes these "set" aspects of the design problem hold, and other times, they are later iterated upon once again. No matter the phase in a design problem, the current understanding of the problem impacts the direction of the team in solving the problem as well as the possibilities considered for design solutions.

Both internal and external factors shape the ways designers view and navigate problem spaces, and multiple aspects impact design process direction as a whole (e.g., Lopez-Mesa & Thompson, 2006). These factors include: the use of human-centered design tools and approaches, including co-creation sessions and design ethnography techniques; the characteristics of each person on the design team, including their demographics, disciplinary perspectives, and prior experiences; and the environment, including the general atmosphere, company norms and priorities, and team dynamics (Bucciarelli, 1996; Kelley, 2001; Lopez-Mesa & Thompson, 2006; Mohedas, Daly, & Sienko, 2014; Mohedas, Sabet-Sarvestani, Daly, & Sienko, 2015; Rhodes, 1961; Salvador, Bell, & Anderson, 1999; Wiltschnig *et al.*, 2013). Additionally, potential solutions to the version of the design problem that is relevant at the time have also been shown to have an influence on the way a design problem is understood (Dorst & Cross, 2001; Maher *et al.*, 1996).

Co-creation is a familiar term in management and marketing research, where it is defined as the joint, collaborative, peer-like process of producing new value, both materially and symbolically (Galvagno & Dalli, 2014), in which the active participation of customers and end users is enabled through multiple interaction channels.

Similarly, design researchers use the term design participation to define a user's integration in the decision-making process (Cross, 1972, 1995), allowing users to build on and provide recommendations based on their own experiences (Bødker, 1996; Sanders & Stappers, 2008; Stappers & Visser, 2007). Prahalad and Ramaswamy (2000, 2004, 2013) adopted the term participatory design for the business community and introduced co-creation as an environment where consumers can have active dialogue and co-construct personalized experiences.

Past work on design cognition has been solution-focused, with little attention being given to facilitating the exploration of problems (Simon, 1995; Studer, Yilmaz, Daly, & Seifert, 2016) and with less therefore being known about the factors that influence the way a design problem evolves and how these factors function. For these reasons our research was guided by the following research questions:

- How does the design problem evolve for a design team as they progress through the design process?
- What factors impact the definition of the design problem?

3 RESEARCH METHODS

3.1 Participants and setting

The dataset included a professional design team's activities during their design process (Christensen & Abildgaard, 2017). The team's goal was to develop a concept package of accessories for premium car users in the Asian market as well as to exemplify how a regional relevant holistic approach would increase brand penetration in Asia.

The design team included eight designers: two from the accessories department, three from the user involvement department, and three external design consultants. A stated company goal of bringing designers from two different departments together was to explore and understand users' behaviors and values through the application of user research methods. The three designers in the user involvement department worked full-time on the project and had expertise in communication and multimedia design. The two designers in the accessories department specialized in car accessories and thus collaborated with the core design team to make decisions on the project's direction and its relation to other stakeholders and its overall implementation. Three external design consultants had expertise in Asian markets and assisted the design team in planning and facilitating the co-creation sessions, as well as translating the language and cultural diversities and traditions. The team members' names (as pseudonyms), their roles in the project, and their nationalities are provided in Table 30.1.

3.2 Data analysis

We identified a subset of the full data based on the design team's discussions on aspects of the problem: co-creation workshop sessions 1 (CC1) and 2 (CC2), insights from both workshops, recaps with consultants and stakeholders, and the design team's brainstorming session on potential concepts and products to pursue (v06, v07, v08, v09, v11, v13, v15, v16, v17, v18, v19, v20, v21), totaling 543 minutes of video recording.

Table 30.1 Project participants.

	Team member	*Role*	*Nationality*
Core Design Team	Ewan	Team Leader/ UX Researcher/Designer	Western
	Abby	UX Researcher/UX Design Specialist	Western
	Kenny	Tech Support/UX Researcher/UX Prototype Engineer	Western and Asian
	Nina	Intern	Western
	David	DTRS11 Observer	Western
External Design Consultants	Rose	Researcher/Cultural Translator and Moderator/Design Thinking Expert	Asian
	Amanda	Design Researcher/Consultant/ Design Thinking Expert	Asian
	Will	Market Researcher/Consultant/ Cultural Translator and Moderator	Asian

Across the dataset two researchers separately characterized the current version of the design problem (based on how it was represented by a member of the design team) throughout the team's work. The two researchers met regularly with each other and with the other two researchers on our team throughout this process to discuss what we noticed across the dataset and to define structures to help us reliably represent patterns we noticed in the data.

We defined aspects of the design problem definition to include design needs, relevant background to the needs, and solution requirements and constraints, in alignment with descriptions of design problems from design texts (Dieter & Schmidt, 2013; Dym, Little, & Orwin 2013; Fogler, LeBlanc, & Rizzo, 2014; Ulrich & Eppinger, 1995; Yock *et al.*, 2015). In our analysis, we focused on identifying "shifts" in the design problem. A shift in the design problem was considered to represent exploration of the problem space, and included defining and/or changing focus, priorities, emphases, scope, and boundaries.

As an example of a shift, during a team discussion on requirements for car accessories, the team enlarged the scope of the design problem (representing a shift in the design need) to include redefining and branding the company values:

> *"We kind of want to change [the company] values, and for this project it's kind of possible… I'm just thinking we need to find some way where we can actually … [still have the kind of normal value] [the company] values, but also have these … extra values …"* [v9, 237].

We recognized that not all team members likely had the same conceptualization of the problem as the individual speaking, however, our analysis focused on the most recently presented version of the problem so then we could also track what factors may have prompted this new version. Based on this approach, three people expressing three

Table 30.2 Factors that impacted shifts in the problem space.

Factor in problem evolution	*Definition of factor*
Structure of co-creation sessions	How the two co-creation sessions were planned and executed by the design team
Cultural perceptions and norms	How the design team perceived and interpreted their own culture compared to other cultures
User data translation	How the design team incorporated data collected from users

different ideas about some aspect of the problem one after the other was recorded as three different shifts in the problem space. The majority of shifts in the problem space were related to solution requirements and constraints.

As we identified shifts in the problem, we also described reasons suggested by the data that the design problem was understood in its current form. Using an inductive coding approach (Creswell, 2013; Patton, 2002), we grouped the reasons into categories, which we called "factors impacting problem exploration." Factors were defined as reasons the design team viewed the problem in a particular way. Factors could prompt a shift in the understanding of an aspect of the design problem or limit the extent to which aspects of the problem space were further explored. Thus, a factor could prompt a revision to the design problem or set a boundary to how the problem was understood. We did not evaluate either impact of the factor as good or bad, as there are times in design when ideas should be explored as well as times when choices should be made and parameters are set (Brophy, 2001; Cross, 2001; Guilford, 1984).

Through multiple rounds of discussions and reviewing the data, we iterated on our list of factors and definitions of those factors. We ultimately identified three factors that explained many of the shifts in the team's understanding of the problem space.

4 FINDINGS

Three key factors emerged in driving the evolution of the problem space: (1) structure of the co-creation sessions; (2) cultural perceptions and norms; and (3) user data translation. These factors are defined in Table 30.2 and described in the following subsections with regards to their impacts on the evolution of the problem. We included several examples of how each factor caused shifts in the ways the team understood design needs, relevant background, and requirements and constraints in the problem space.

4.1 Structure of the co-creation sessions

The design team's approach in developing the co-creation sessions impacted how the design problem was perceived and shaped. This was most evident in the themes on which the design team focused in the sessions. The team developed the co-creation structure in two phases, the initial creation of both sessions, and additional development of CC2 after CC1. During the initial creation of the sessions, the team designated 7 pillars to guide the discussion: environment/sustainability; wellbeing; health;

social versus individual; comfort and convenience; safety and security; and evolving status. CC1 was structured around the participants confirming and/or rejecting the current pillars and/or creating alternative pillars:

> *"I'm thinking hopefully they will not because hopefully so maybe they're there to validate the themes that we have actually selected"* [v5, 131].

These pillars represented the team's understanding of the problem space at the time. The team discussed the impact that these pillars might have on the data they yielded. For example:

> *"I think we also need to be careful not to prime them too much because… if we prime them too much this is just … what they will come up with."* [v4,104]
>
> *"So if they see a picture of a happy family then they will say 'a family!' … is really important to me."* [v4, 106]
>
> *"We- we should not tell them [prompt them to think of other ideas], because if it's not really important if it's just like a random thought they have, then they'll forget it if it's not important. But if it is something that they really feel "why is this not here?", and they keep thinking the same thing, for sure they'll remember it when we reach 'this' point, and then they get the opportunity in the end to unload the-"* [v4, 263]
>
> *"[But I think] that Mia she referred to these as assumptions, and I think that's totally right now, in the- in this way. And they are assumptions, and that's fine, and we need to [verify and validate that assumptions are true or- or not:, in the end]."* [v4, 586]

This structural decision likely impacted how and to what extent the problem space evolved. When participants were asked to define "good life," they were presented with the seven pillars and the team planned to limit their discussion to these topics. After discussing these pillars, the team then asked the participants to identify anything else that was missing. In their earlier conversations, they said that often the answer to this type of question was "no":

> *"typically a question where people … even though they thought of something, they typically will say, "no, no, nothing." "But if they don't have anything, do we want to provoke anything?"* [v4, 458].

The team decided to focus the conversation on "good life" to the seven pillars. For example, the team did not want the conversation to surround money and luxury:

> *So that we have narrowed the "good life" down a little bit, when we start, so that they don't come in and say 'okay, what is good life to you?' 'It's money and being able to spend everything on luxury."* [v4, 234]

The team made the decision to start with the pillars knowing that this would shape their problem space, but decided it was the best decision to optimize the time they had with users and where they were in the design process.

"Yeah, and we want them to gravatize around something. And we want that something to- since we are limited on time we can't start from everything, we need to start from something." [v4, 240]

"And we- since we've done the research before, we think that these pillars will represent what they will gravatize around, but we don't know the specifics of it." [v4, 242]

CC2 was structured around the top-voted theme from the CC1, "Freedom/Enjoy life." This theme was the over-arching goal for the CC2 participants to keep in mind for the day's activities. The design team prompted CC2 participants to create a company centered around '(Evolving) Status Symbol' and 'Health/Well-being'. The goal was to create a 'fictional' company with its own product-line, purpose, mission, values, and culture. Participants were also tasked with developing a preliminary product that would be manufactured by their company. Four constraints were placed on the participants in the activity: safety/security; comfort and convenience; environment/sustainability; and 'sexy commitment'.

The comfort and convenience constraint was introduced by the team but never brought up by the participants. The team incorporated comfort and convenience as customer priorities important in understanding the problem. The only time participants discussed comfort and convenience was when it was introduced by the team. [v14, 206].

A: *"Yeah… I think the convenience here, to be focused even more, is more about- it's not just a pointless add-on, it has to be a seamlessly integrated… kind of convenience"*
E: *"Yeah, mmm"*
A: *"And Yen also said that he didn't want to choose between comfort and convenience"*
E: *"Okay, so he- no compromise"*
A: *"Yeah but Rose forced him"*

The design team structured the CC sessions specifically by grounding them in the seven pillars identified from Phase 1 work. Thus, Phase 1 guided the CC sessions, and the CC session structures facilitated certain priorities in the problem space to remain present. This statement is not intended to be an evaluative one, that is, it's neither "good" nor "bad" that the team made this decision, but rather, this choice had an impact of the exploration of the problem space throughout the rest of their process.

4.2 Cultural perceptions and norms

Cultural perceptions and norms also played a crucial role in shaping the problem. There were cultural differences between the design team (Western culture) and the lead-users (East Asian culture). East Asian cultures traditionally view the world as the sum of many parts and emphasize how parts fit into the whole enabling it to function, while Western cultures focus on objects (Gautam & Blessing, 2007; Kuhnen *et al.*, 2001; Nisbett, 2003). Western culture is rooted in individualism, while East Asian culture is rooted in collectivism. These Western cultural characteristics contributed to how

East Asian culture was understood throughout the design process and represented by the team in the final deliverable. Cultural perceptions and norms impacted the design team's understanding of multiple aspects in the problem space; here we highlight how it shaped the team's understanding of solution requirements such as the environment, role of status, and user freedom.

Environment was initially defined by the team as 'green' environmentalism, which involves protecting and improving the health of the natural environment. This was challenged by participants' holistic perspective of the environment as including additional elements in their understanding of environment beyond the natural environment, such as political and societal spheres, and also included the relationship of these components to one another. For example, one of the participants referred back to her experience of teaching recycling to her child and that the goal was not to do it for others to see it.:

> *"… they also talked about environment, but in the big picture environment so like, political stability for example: and, ehm yeah, overall societal progression, yeah that was when "good life" went together with society, and all four of them surprisingly talked about that, like, once there is-, they really saw it as like the whole society moving up together and having a more harmonious …"* [v8, 294]

The team questioned why the users did not talk about environment in terms of solving environmental issues like the air pollution. While the team noticed the difference, they did not immediately shift their understanding of the problem. The team's Western cultural background conflicted with this alternative view, and the team maintained a priority on green environmentalism:

> *"Food, water, and air… Maybe ASIAN CITY [is] not as bad, but generally the environment and what you consume. I think that consumption, environment is pre that."* [v7, 89].

This demonstrated that the team believed that environment was before the actual consumption with the product and theorized that Asian cities are more focused on the environment at the point of consumption. As the team's work continued, the team leader indicated several times that the team's environmental understanding was a Western view:

> *"A lot of Asian people are not one hundred percent embracing… 'I should recycle, or I should do the right thing' … because not everyone is doing it"* [v21, 12].

Collectivism was evident in the team's description of the environment feature of the problem space when discussing the scope of environment according to the users:

> *"… we talk about environment and like this clean eco through- all the way, and then there's a bit about protection that you just mentioned, it's not just- they're doing it for its own sake but in return you know you'll always benefit, you and your future generations …"* [v19, 150].

While the team ultimately made this shift in their understanding of the environment, this also caused another shift in the problem space, as they incorporated their 'green' definition of environment into the competitive theme of the *status* feature. The team used the term 'sexy commitment' to describe the status potential through 'green' environmentalism, translated as people see what you are doing and your values, therefore, you gain status in society because these actions and values make you attractable to others:

> *"It's not just- they're doing it for its own sake but in return you know you'll always benefit, you and your future generations, and also they're sexy compliment, and the leadership, and the role-modeling as well."* [v19, 21].

Green environmentalism as perceived in the Western culture was incorporated into the team's understanding of the status requirement in the problem space. Therefore, when speaking about status, the team continued to emphasize caring for the environment in the status definition, which is contradictory of how the Asian culture views the environment and how status is manifested in Asian culture. The problem space ultimately included both the team's Western view of environment and their understanding of the Asian environment definition.

The team's understanding of the design requirement of freedom also evolved due to cultural perspectives and norms. Early in the process, the team's Western individualist cultural background and their interpretation of the collectivist culture drove the freedom requirement to represent a release from responsibilities, including family:

> *"Taking a long drive at night, on the express way for an hour … he's had a lot to do in the time, like him and the lady who's got a kid, I think they're very concerned about, you know "where's my freedom? I do not have autonomy anymore. So that all the things are- you know, what will be my control?"* [v7, 28].

The team interpreted participant comments from the first co-creation session as the participants wanting to feel in control and make their own decisions, and not wanting to think about family:

> *"The other part was the family thing which Amanda mentioned… I think some subconscious they want some freedom or way from (..) some liberation from, but I … think the way we written it, may have been kind of extreme, or may not be something that is (INAUDIBLE) correct to say – Yeah, it sounds more like a burden"* [v14, 291–292].

However, this contradicts cultural norms in the collectivist society. The team seemed to adapt the Western value of freedom to the Asian culture, defining freedom in the problem space as participants wanting to break free of family constraints:

> *"… of course they don't see that you need to really break free from old bonds whether it of family or- … Shackles! The shackles of family"* [v14, 295–296].

While the participants emphasized family and diligence as values, the team pushed the problem space more to align with Western norms of freedom:

> *"We totally respect about family and it is about enduring … but it is also about enjoying and living life to fullest"* [v11, 243] and *"he likes to feel that he's in control … so he say 'don't tell me what to do, don't try to sell me stuff. I will decide what I want' so, there's a lot more: of, his own decision making … and not wanting to feel like he has been pressured into making some kind of commercial decision or purchase decision, or don't want other people to influence his choice, he likes to find time, you know at home, well either at home or out, you know, at night, because that's the only time he can find some escape from his child, from his wife, and everything else, so he spoke a little about, you know, going out on a cruise in a car for an hour, on highway."* [v8, 4]

To push against the team's emphasis on this Western value of "*enjoying and living life to the fullest*," one of the external consultants stated the team's perception had the "*connotation of just whole enjoyment*" [v11, 259], which is not traditional of Asian culture. This prompted a shift in defining freedom as "pockets of enjoyment." This maintained priority in the problem space on freedom, but in a way that accommodated Asian values:

> *"Becomes a manifestation of great autonomy. The freedom-" maybe it should say 'that freedom of having pockets of enjoyment reflects a sense of achieve'-achievement towards a good life"* [11,21].

When the team discussed hard work and the Asian people's endurance, the idea of freedom as "pockets of enjoyment" was identified as an accurate assumption. Diligence is emphasized in the Asian culture, where diligence refers to the amount of effort people put toward reaching their goals, which requires self-respect and knowledge and emphasizes an individual's resilience toward challenges and difficult contexts (Zhang, 2011). Different views of the value of work and family affect how the team perceived the information and how it was incorporated into the problem space.

The way the team discussed the definition of freedom sometimes shifted back towards this individual freedom. At various points when these shifts were happening in the problem space, one of the external consultants directed emphasis back on Asian values of life, for example:

> *"I think some subconscious they want some freedom or some way of liberation but I don't think the way we have written it, may have been kind of extreme … not correct way to say"* [v14, 291].

The emphasis of freedom returns to the ideas of "*pockets of enjoyment*" after his interjection. [v14, 274]. Throughout the conversations, he helped shape this definition of freedom to be more in line with East Asian culture. The team felt solid in this final definition of freedom:

> *"It's good to… emphasize these pockets there, because what we kind of focused on in ASIAN CITY FROM PHASE 1 was the "okay, endure now", and that's from until you're fifty, and there is not these small pockets at all, it's just endurance. Hard work, and then: it's freedom and happy life."* [v11, 142].

Throughout the process, the interpretation of the Asian people and their freedom expression changed as the team better understood the collectivist nature. Although there were references to individualistic freedom at times, the team supported "pockets of enjoyment" as a final definition of freedom.

Culture and perception of norms had a significant effect on how the problem space was articulated, investigated and redefined. These perceptions especially impacted the team's understanding of three solution requirements in problem space: environment; status; and freedom. The design team's Western background focused more on the individualistic values, whereas participants' Asian background facilitated their interpretation of these three requirements from a collectivist perspective.

4.3 User data and its translation by the team

The way the team translated user data also impacted the problem space. For example, the team seemed to struggle to translate what participants said about *status*, as the data from the participants' contrast the way the team shaped the problem space in response. On the other hand, *trust* is an example where the translation of the user data aligned well with what the participants said in the co-creation sessions, which prompted a major shift in the team's understanding of the problem.

The emphasis of *status* in the problem space by the team was not reflected in the data from participants' discussions in the CC sessions. Status was frequently discussed and emphasized; however, the user data did not reflect that status was a priority for participants. For them, status was not a motivating factor for their actions, for example, one of them discussed his volunteer experiences in a poor area of Tibet and described his motivation for doing this as due to his belief in the holistic experience, not to show off or brag about it:

> *"I think they were thinking a little more broader like recycling or eco-friendliness for the sake of in itself and really like, truly believing in the whole experience thing and not showing off. And their aspirations were also going, not just into travel and to going to difficult places like Brian, okay he drove five thousand kilometers from ASIAN CITY to Tibet, but, like they were thinking about going to do volunteering: in like very poor places: and, I mean those were the type of things that they were looking at, which I think goes beyond really like to just- …"* [v7, 271].

In translating this to define status in the problem space, the team created a narrative for why customers do things, proposing that customers take action in order to gain social status for themselves. This narrative created by the design team contradicts the initial testimony of the CC participants.

> *"I'm sacrificing something over here, to gain something over here… I'm using my free time, which I worked too hard to get, to help out in a school over there, so that people will see me, hopefully see me, understand what I'm doing and place me in society here, which I wanna be.'* [v11, 367].

In the problem space, these insights on status turn into a product requirement where the final product or service must be "*brag-able*" [v11, 385]. Later in the design process, this interpretation of status as a user motivation manifests through the idea

of gamification as a key aspect to include. For example, the team suggested green environment as one thing that could be braggable to achieve status:

> *"You could compete if you … have a product like who are environmentally friendly drivers for instance and then you can share it and show it"* [v16, 191].

While status seems to be a more prominent driver as the team's work continues, the data from the co-creation session do not emphasize status or competition as motivating factors which suggests another transformation of the problem space.

Another design requirement emphasized was trust. Trust manifested itself as the conflict between the perceptions of customers of local versus foreign companies. Participants described this as believing that foreign companies produce high quality products, but at the same time them desiring a company to be producing locally:

> "*I need to have your company where your customers are"* [v15, 172].
>
> "*And also- then the other one started to say that it was also important that it was actually a local brand, a place in ASIAN CITY if the products were made for ASIAN CITY"* [v14, 135].

The team's response was that based on prior experience with low quality local goods an Asian customer may trust foreign quality better, but that he/she may not connect with or understand the foreign values. This leaves a market opportunity for the team to translate those foreign values to values that local customers can understand, potentially through a popular figure mediating this translation:

> *"… maybe a foreign brand has some values, but it's difficult to understand that value, because they're foreign values"* [v14, 156].
>
> "*How can we find the local counterpart of those values"* [v14, 156].

This understanding led the team to redefine aspects of the problem space and discussing the need to build customer trust through, for example, local manufacturing while also producing foreign quality. The team's translation of the user data was that in order to be successful in the Asian market, the customers have to both trust the quality of the product as well as trust in the values of the company. The team then explored redefining what "manufacturing locally" actually means to the customer in order to take advantage of the existing company structure:

> *"The other brands are not doing as well when they produce locally, but if you can differentiate by what type of manufacturing locally really means, then there' … trust and assurance of the final product, that it's not gonna lower the quality*" [v17, 154].

Ultimately, when recording the translation from participant data to the design decisions made by the team, we uncovered instances of alignment with user data that were also in our dataset as well as instances where the user data were not present or did not align with the evolved understanding of the solution requirements in the problem space. The user data impacted the process as did the team's translation of these data into their design problem descriptions.

5 DISCUSSION

Our analysis demonstrated how the problem space evolved through the co-creation sessions and the team's interpretations of the conversations. The team's understanding of the design problem and solution requirements shifted throughout discussions in their process, and as they got input from lead users. For example, the team's understanding of needing to address environment in their goals to get into the Asian market had large shifts from a green/sustainability definition to one that focused on a more holistic notion of environment. At the same time, this original definition of environment was incorporated into another criterion, the need to address the status of the potential user. The evolution of the problem space described in our work is consistent with Adams *et al.*'s (2017) discussion of co-inquiry as a framework for mapping changes in the team's understanding of the design problem.

We were also able to document evolutions in the team's understanding of the seven pillars they used to articulate the problem space. Within this documentation, we sometimes saw pathways that were linear and building on prior understandings, and other times, saw tensions between multiple views of the problem. This documentation highlights the iterative and complex nature of a design problem and how a team comes to understand the real needs that need to be addressed. Past research supports this finding as design experts simultaneously and iteratively explore a problem while searching for solutions (Dorst & Cross, 2001), and the problems are constantly envisaged, posed, formulated and created through a great deal of effort spent in restructuring to reach solutions (Getzels & Csikszentmihalyi, 1976; Restrepo & Christiaans, 2004).

Our analysis also revealed three specific factors that had a demonstrative impact on the evolution of the problem space: the structure of the co-creation sessions; cultural perceptions and norms; and user data translation. The team's decision to ground the co-creation sessions in the seven identified pillars developed from Phase 1 impacted the breadth of the discussion that likely ensued during the sessions. This is known in the psychology literature as "priming" (Bargh, Chen, & Burrows, 1996; Levin, Schneider, & Gaeth, 1998; Tversky & Kahneman, 1981) Priming can both preclude and promote certain discussion (Klein, 1993, 1997; Ramser, 1993).

Cultural perceptions and norms of the design team and the co-creation participants played a critical role in shaping the problem space. The different perspectives of the two groups meant that the design team had to understand their own norms, of which they might not readily be aware, and develop a deep enough understanding of another culture's realm to be able to interpret what co-creation participants were saying. Other literature has documented that knowledge of the culture influences solution characteristics (Felgen *et al.*, 2004); in this work, we additionally highlighted impacts it can have on problem characteristics. Designers are often given the role of a cultural interpreter (Kimbell, 2011), collecting insights from different cultures and translating this information. Understanding these cultural variations has been shown to have significant impact on creating relevant products and solving the right problems (Gautam & Blessing, 2007). In this study, differences in Asian and Western cultures were challenging for the team to understand, and they spent much of their discussions navigating how their own culture influenced their understandings of the problem. This navigation played a role in how they approached their design process, consistent with

how Clemmensen *et al.* (2017) describe design thinking as a "culturally situated practice." Other work has demonstrated dramatic differences in the nature of Asian and European thought processes (Nisbett, 2003). According to Nisbett's findings, Asians are more holistic in the way they perceive the world whereas Westerners approach it from an analytic perspective. Asians focus on the context and situation and the relationships among objects and people. On the other hand, Westerners try to categorize the objects with labels they create in their perceptions, and treat the world as static and governed by rules. Asians' are more interdependent, considering self as a part of a larger whole, while Westerns thinking more independently, seeing self a unitary free agent. These values and tensions were evident throughout the evolution of the features of the problem space.

User data gathered also informed modifications to the problem space. In our comparisons, at times these data translated directly from what participants said, and at other times, these data and their translation seemed to be in conflict. Literature has documented struggles in this translation of user data to solution requirements (Mohedas, Daly, & Sienko, 2014; Mohedas, Sabet-Sarvestani, Daly, & Sienko, 2015). However, in the translation of user data to design decisions, designers also incorporate their own lenses and expertise (Cross, 2004; Daly, 2008), thus everything a user says is not automatically incorporated or incorporated at all into a design decision. The designer has a broader perspective on the problem, the market, and other aspects that will impact the success of the design. In cases where the data were not directly translated, we do not know why this was so from the data we had. For example, the definition of environment as being focused on sustainability was not lost in the problem statement, but incorporated into status. Perhaps the team had insights on the way the auto industry is moving and regulations of the industry to know this had to be maintained as part of the problem even if users were not emphasizing it.

The factors of Cultural Perceptions and Norms and User Data Translation are likely related. However, as discussed by Gray and Boling (2017), in many cases cross-cultural design practices and user-centred design practices have not yet converged to a common approach. Translating user data is by nature, cross-cultural, so long as the designer is not also the user (Cooper, 2004). While cultural perceptions and norms were explored as part of an explanation for why there were inconsistencies in what users said in the sessions and the ways it was translated to design decisions by the team, there were likely other reasons for why there was not a one-to-one match in what users said and how the team defined the problem, including the expertise of the team in knowing what would make the project successful, company priorities, and the ways the team leveraged user-centred design tools.

Several implications for research and pedagogy emerged from our work. One research implication is to explore additional factors that might impact problem space exploration in a diverse range of problem contexts. A related pedagogical implication is that design instructors can be more explicit on how and when to explore a problem space, perhaps even using examples from studies such as these representing how what might seem like a simple choice or an easy interpretation has implications for the way the design problem is understood. In many cases, designers take the design problem as it is rather than fully iterating on it (Cross, 2001). Specifically, intentional instructions on the need to explore the problem and how various factors may be influencing an understanding of the problem can support more reflective practice.

As discussed by Valgeirsdottir and Onarheim (2017), process awareness can support better understandings of the problem space.

6 CONCLUSIONS

From our analysis of the evolution of a design problem throughout a team's work, we revealed three factors that prompted shifts in the design team's understanding of the real needs and solution requirements. The problem space evolved due to the nature of the co-creation sessions, including their setup and structure, designers' perceptions of other cultures, and their interpretation of the data gathered from the users. These results highlight areas in which a design team can focus, allowing them to be more aware of the ways their problem understanding is being impacted, and strategize different choices or interpretations they might consider as they define their current understanding of the design problem. While much emphasis has been given to exploring solutions in design to achieve quality design outcomes, exploring multiple perspectives from which to view the design problem can also significantly support design success. Recognizing ways these perspectives are shaped is an important step to leveraging them intentionally in a design process.

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