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Describing and Understanding Team Integration in New Product Development: A Case Study

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Résumé

Étant donné que les problèmes en développement de produits sont de plus en plus complexes et difficiles à résoudre, le rôle des designers est en changement continu. Ils sont de plus en plus impliqués dans les équipes multi-disciplinaires dès le début d'un projet. Des compagnies adoptent une approche de travail d'équipe qui réunit plusieurs bases de connaissances (disciplines, expertises) différentes dans un seul groupe. Tandis que ces groupes donnent accès à plusieurs bases de connaissances différentes, les membres de l'équipe doivent surmonter le défi de communiquer, négocier et développer une compréhension partagée des objectifs à travers leurs raisonnements différents et parfois opposés.

En tant que designer junior, ces dynamiques peuvent intimider, puis faire le pont entre les points de vue différents peut paraître difficile. Afin d'améliorer l'intégration dans une équipe, une réflexion sur les dynamiques mêmes est nécessaire, mais il semble y avoir peu de moyens pour bien expliquer les interactions. Cette recherche se penche donc sur la question de comment décrire et mieux comprendre l'intégration dans une équipe en tant que designer nouvellement impliqué dans un projet et une équipe multi-disciplinaire.

Afin d'y répondre, cette recherche créé d'abord un cadre théorique centré sur l'implication d'un designer dans le processus, la gestion de la complexité, le travail en équipe, puis l'intégration efficace à travers le développement d'une compréhension partagée. Une étude de cas qualitative est menée par une approche nommée *Research-through-Design* (recherche par le design dans le contexte d'un projet) qui permet de jouer le double rôle de chercheur et designer. La collecte de données se fait surtout par journal de bord et observations participantes afin de documenter les actions et réflexions d'un designer qui s'implique dans une équipe multi-disciplinaire menant des projets de développement de nouveaux produits.

D'après les données recueillies, cette recherche tente décrire et mieux comprendre le cas en utilisant les catégorisations empiriques des facteurs qui influencent le développement d'une compréhension partagée proposées par Kleinsmann, Valkenburg et Buijs (2007). Grâce à ce cadre d'analyse, la description et réflexion sur l'intégration dans l'équipe furent un succès. Toutefois, cette recherche propose quelques précisions au cadre d'analyse ayant pour but d'y améliorer et faciliter l'observation, la description et la réflexion sur les dynamiques d'équipe pour des futurs designers juniors. Cette recherche espère donc proposer un appui aux designers pour développer leurs compétences à mieux travailler en équipes multi-disciplinaires.

Mots clés: Design de produit, Intégration, compréhension partagée, travail d'équipe, recherche par le design, collaboration

Abstract

As new product development continues to change, designers appear increasingly involved in multi-disciplinary teams from the outset of project inception. This is due to the progressively challenging, multifaceted, and complex problems design must resolve. After all, no single individual possesses the knowledge to create most new products. Companies depend on the teamwork of individuals with different knowledge bases who come together as a single design group. In breaking down silos and creating these integrated teams, overall effectiveness is threatened by their ability to communicate, negotiate, and develop a shared understanding of their goals and means of achieving them.

As a junior designer, team dynamics can be intimidating. Bridging different and sometimes conflicting individual views is challenging. Tougher still is reflecting on and describing dynamics as they happen in practice. Without the ability to explain dynamics, identifying and improving team integration seems nearly impossible. As such, this research aims to address these constraints by finding a way to describe and better understand team integration in action.

To accomplish this, a theoretical framework is developed to explore designer involvement, managing complexity, teamwork, and effective team integration. From this, a qualitative case study is conducted to reflect on teamwork in action using a Research-through-Design approach. This places design practice in the centre of research and allows the researcher to also play the role of a newly integrated designer. It relies extensively on journal entries and participative observations in order to create a story of designer involvement in new product development.

In interpreting the data through an empirical categorisation of factors that are said to influence the development of a shared understanding (Kleinsmann, Valkenburg, & Buijs, 2007), a working description and reflection of team integration was achieved. In addition, this research proposes some amendments that aim to improve the framework and enable other junior designers to better observe, describe, and reflect on team dynamics in the future. This research therefore hopes to contribute by supporting designers in improving their ability to work effectively within multi-disciplinary new product development teams.

Keywords: Product Design, Team integration, Teamwork, Team Dynamics, Research-through-Design, Collaboration

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List of Abbreviations

CAD	Computer-Aided Design
CPER	*Comité pluridisciplinaire d'éthique de la recherche*
GRAD	Groupe de Recherche en Aménagement et Design
MITACS	The Mathematics of Information Technology and Complex Systems MITACS is a national, not-for-profit organisation that has designed and delivered research and training programs in Canada.
NPD	New Product Development
POP (model)	Proof Of Principle (model)
RtD	Research-through-Design
R&D	Research and Development
3D (printing)	Three Dimension (printing) *also known as* Additive Manufacturing

If we ask 'What is the design?' at any time in that process my response would be following Durkheim[1]*, that it exists only in a collective sense. Its state is not in the possession of any one individual to describe or completely define, although participants have their own individual views, their own images and thoughts, their own sketches, lists, diagrams, analyses, precedents, pieces of hardware, and spread-sheets which they construe as the design.*

Bucciarelli, 1988, p. 161[2]

[1] Durkheim, E. (1950). *Les règles de la méthode sociologique* (11 ed.). Paris: PUF.

[2] Bucciarelli, L.L. (1988) An ethnographic perspective on engineering design. *Design Studies, 9*(3), pp. 159-168.

Introduction

This research is interested by designers working in a team with other professionals within a new product development setting. The inquiry is curious about teamwork and team integration, and focuses on these topics as a way to better describe and understand them as they manifest in design practice. This is motivated by experiences as a practicing junior designer trying to integrate and work effectively within a new design team. These experiences brought about challenges to bridging the often different expertises and perspectives that each team member embodied in the project. While this was easily sensed throughout the design process, it was difficult to describe or reflect on team dynamics.

Research on this topic is valuable to design practice as teamwork has become an increasingly popular approach to problem solving (Cross, Rebele, & Grant, 2016). There is a widely accepted view that problems in current new product development are increasingly complex (Dong, 2005). According to Kleinsmann, Buijs, & Valkenburg (2010), this complexity has to do with the fast occurring changes, and increasingly integrated needs at large: For instance, users want simple yet multipurpose objects, sophisticated technology yet a high product turnover, and both intuitive yet personalised functionalities. Industries that operate in new product development have reported on the positive impact of integrating multiple disciplines into a same team, and specifically involving (industrial and product) designers at the outset of a projects' inception (Gemser & Leender, 2001; Heskett, 2017). Working with others allows access to a variety of views, opinions, and knowledge-bases which team members can access through communication and negotiation (Stumpf & McDonnell, 2002). While this approach presents good opportunities, breaking down the disciplinary silos and working together in a single team is also risky and complicated (Schön, 1983). Views can differ and negotiations within the team can incur inefficiencies or even create hostile situations (Bucciarelli, 1994). To overcome these challenges, teams should adopt integrative practices like collaborative design and develop and maintain a shared understanding to enable effective teamwork (Chiocchio et al., 2011). Still, effective team integration and collaborative design are threatened by a broad variety of factors that are sometimes difficult to dissimulate. As this research tried to find ways to describe team integration, research on the enablers and barriers to shared understanding emerged: The article *Why do(n't) actors in collaborative design understand each other? An empirical study towards a better understanding of collaborative design* by

Kleinsmann, Valkenburg, and Buijs (2007) provides an empirical categorisation of factors that affect the development of shared understanding. Their findings became a central component to the strategies and methods to understanding, coding and interpreting research data.

To inquire about team integration in new product development, this research reports on a case study involving the addition of a designer in a multi-disciplinary[3] research and development team. Reporting on the case study through qualitative methods and a Research-through-Design approach created a chronological account of designer involvement and allowed for a dual role of designer and researcher to be used in reporting on team interactions, exchanges, and dynamics during a period of time. To achieve the goal of this research inquiry, the data collected was analysed and interpreted through factors from Kleinsmann et al. (2007). The chapters that follow provide a detailed account of (i) the theoretical framework used to form research boundaries, (ii) the methodology used to collect data, and the methodology design of this research, (iii) the results reported through a *restorying* approach (Creswell, 2007) similar to Bucciarelli (1994), and (iv) the data interpretation and analysis done through the theoretical framework broadly, and the factors from Kleinsmann et al. (2007) specifically. As a contribution to knowledge, this research will attempt, through the use of an empirical categorisation as analytical framework, to better describe and understand team integration as it happens in practice.

[3] The term ‘multi-disciplinary’ is used generally to explain that the team is formed of individuals from different disciplines (i.e. engineering, industrial design, or others). This specification is done to avoid debate about the distinctions between multi-disciplinary, inter-disciplinary and trans-disciplinary. For further details, see De Coninck (1996), or Leblanc (2009).

Chapter One: Theoretical Framework

The framework is formed of four sections: an exploration of (i) the designers' role within a product development team, (ii) the value of 'integrated design' in new product development for managing today's increasingly complex challenges, (iii) the importance and intricacies of working as a team, and (iv) working towards effective integration, or designing collaboratively.

1.1 Designers' Role Within a Team

This section looks into changes in new product development and their impact on the role of designers in teams. First, an understanding of design is needed: "To design is to devise courses of action aimed at changing existing situations into preferred ones" (Simon, 1969). According to Nigel Cross (2001), design maintains and improves the world we live in. Designing is a goal-oriented problem-solving activity (Archer, 1965), and creates precise characteristics for the blurry and multidimensional contexts (social, cultural, environmental, …) that surround a project (Boutinet, 1993). Next, it's noticed that these endeavours to improve the world we live in have - within the product design process - "shifted from an individual and rather unorganised activity to a systematic one performed in a multi-disciplinary team" (Hoegl et al. 2004 in Kleinsmann et al. 2007, p. 59). Team-based design practices are of interest in product development: Cross and Cross (1995, p. 143) express how "teamwork is of considerable importance in normal professional design, and is becoming of greater importance in product design as it becomes a more integrated activity". According to Kleinsmann and Valkenburg (2007, p. 59), "well-performed integrated product design processes may result in reduction in time to the market, higher-quality products that fit the market needs and the possibility of developing products with different functionalities".

Beyond the process, involving industrial and product designers specifically is said to be especially useful. Gemser & Leenders (2001) found that whether companies invested considerably or little to nothing in industrial design, it had an above all favourable impact on the firm, the products, customer satisfaction, and "can enhance a company's competitive position" (p. 30). According to Johnson (2016, p. 20) this is because "designers, [and] especially product designers, are typically experts in conceptualising problems and solving them—ideal skills for tackling a wide range of issues…". In using design to solve problems big and small, industrial designers are increasingly recognised as valuable assets to project development from inception (Heskett, 2017). Designers can aid in integrating knowledge from the outset of a project through their abilities to conceptualise and solve problems which helps companies in new product development gain a competitive advantage over others.

Kleinsmann and Valkenburg (2007, p. 59) call this *integrated product design*. The idea of integration is explained in *Design Integrations* (Poggepohl & Sato, 2009) as breaking down functional silos and working across units. More recently, Cross (Rob), Rebele & Grant (2016, p. 74) equally pointed out that companies have become increasingly cross-functional: "silos are breaking down, connectivity is increasing, and teamwork is seen as a key to organisational success". In the same respect, Chiocchio et al. (2011, p. 79) explain that Integrated Design "is a [multi-disciplinary] participatory process bringing together specialists and key stakeholders […] in order to collectively resolve multifaceted, ill-defined, and intertwined design […] problems". This allows for a holistic view amongst team members which "should build adaptability and flexibility into the design solutions" (Charnley et al., 2011, p. 172).

1.2 The Value of Integrated Design in New Product Development: Managing Complexity

The previous section denoted a shift towards more integrated design activities, wherein knowledge and expertise from different team members is combined from the beginning of problem inception. This section explores the need for integrated design approaches in new product development, namely due to more challenging design problems and their increased complexity.

Complexity can be defined according to Cambridge Dictionary (2019) as "the state of having many parts and being difficult to understand or find an answer to". In this way, new product development is increasingly complex, clouded, and intricate (Dong, 2005; Stempfle and Badke-Schaub, 2002; Luck, 2019). New product development is also likened to innovative product development, which is especially complex in light of fast occurring changes and the more integrated needs of society at large (Hey et al., 2007; Alves et al., 2007). According to Valkenburg and Sluijs (2012, p. 5), "innovative developments transcend existing boundaries, […] whether or not to innovate is not the issue. The challenge lies in whether we can innovate fast enough". New, or innovative product development must combine and manage complexity, ill-defined situations, and difficult to resolve problems as an integrated activity. This is apparent in the design of the telephone as explained by Bucciarelli (1994) and more recently by Kleinsmann & Valkenburg (2010, pp. 20-21):

> In the last 15 years, the product had changed in many ways. The switch from a shared house phone to a personal phone has had a significant impact on both the product appearance as well as product use. People do not use their personal phone only for calling, but also for taking pictures, making movies, playing games, listening to music and as an agenda. This has changed the consumer attitudes towards a phone. What once was a rather functional product has become a product that expresses one's personality. Therefore, customers required their phone to be modern, easy to use, and of good quality. In the meantime, they did not want the phone to be expensive, as they would like to buy a new one every 2 years. These customer needs reflect increasing customer demands and increasing product complexity, requiring a far-reaching integration of the different knowledge domains of the actors from different disciplines during collaborative new product development.

Here, Kleinsmann and Valkenburg explain that consumer needs are shaping the way objects are designed. By demanding simple yet multipurpose objects, rather high technology and quality turnovers, and needs that exceed usefulness to reflect personal preferences, new product development addresses an increasing number of complex and multifaceted parts of a single object. The authors suggest integrating knowledge from different disciplines and collaboration between people. In the same respect, Bucciarelli (1994) wrote in a section called *Do you know how your telephone works?* about the different needs and facets of using, making and understanding a telephone:

> Does anyone know how their telephone works? How about the designer of the device? Surely, he or she must know. I followed this line of thought for a while, but again, I found my footing less sure than I had anticipated. Indeed, from my own observations, I can claim fairly confidently that there is no single individual alone who knows how all the ingredients that constitute a telephone system work together to keep each of our phones functioning. There is no one 'maker'. Instead, inside each firm, there are different interests, perspectives, and responsibilities - corporate planning, engineering,

> research, production, marketing, servicing, managing - and consequently different ways in which the telephone 'works' (Bucciarelli, 1994, p. 3).

Bucciarelli points out that designing a telephone (almost 25 years ago), like many other products, concerns multiple complex, multifaceted, and fast changing problems. Valkenburg and Sluijs (2012) explain how problems are not only affected by economical, technological, user, and societal shifts, but also by the dizzyingly fast moving advancements and changes in each. These challenges can be referred to as *Wicked Problems* (Rittel & Webber, 1973). By wicked, they mean ill-defined and elusive problems that are often vicious and tricky. They explain that wicked problems are not simple or tame, and should not be treated as such. To understand wicked problems, ten distinguishing characteristics are proposed (Rittel & Webber, 1973):

1. There is no definitive formulation of a wicked problem.
2. Wicked problems have no stopping rule.
3. Solutions to wicked problems are not true-or-false, but good-or-bad.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a one-shot operation; because there is no opportunity to learn but trial-and-error, every attempt counts significantly.
6. Wicked problems do not have enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another problem.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
10. The planner has no right to be wrong.

Rittel & Webber (1973, p. 156) point out that "the information needed to understand [a wicked] problem depends upon one's idea for solving it", and there is no finite set of rules and procedures to determine the 'correct' explanation or combination of solutions, which are often dysfunctional and incompatible with one another anyway. These characteristics resonate in many ways with challenges found in new product development: each are difficult to formulate, unique, and have an innumerable set of solutions. They are also most often consequences from previous problems, and symptoms of further issues. The authors insist, "composed of members drawn from different functions, NPD [New Product Development] teams must integrate deep expertise in multiple areas to conceptualise, develop, and commercialise innovative products" (p. 124). Managing high degrees of uncertainty, ny, and ill-defined, even wicked problems calls for an integrated design process (Emondson & Nembhard, 2009).

1.3 Working as a Team

It is said that no single individual can effectively solve the multifaceted and complex design problems of today alone; Arias et al. (2000, p. 86) explained that "complex design problems require more knowledge than any single person possesses". Given the complexities, Détienne (2006, p. 2) proposes "that solving these problems often requires that multiple competencies be put together which happens between co-designers from various disciplines". Integrated design develops between multiple professionals from different backgrounds, disciplines, and practices (Chiocchio et al., 2011). In this way, Bucciarelli (1994, p. 23) explains that design is a social process: "Executive mandate, scientific law, marketplace needs - all are ingredients of the design process, but more fundamental are the norms and practices of the subculture of the firm". The subculture embodies different social dynamics, like shared and unshared values, interests, and rationales between team members. Working as a team is seen as a good way to overcome complex problems, but is challenged by the differences between team members. According to Zahedi (2011, p. V), "in complex design projects, problems typically arise when the design process is undertaken by multi-disciplinary groups of experts as well as non-experts because they do not share a common vision about the user's needs, do not have identical goals related to the task, and do not have a common language to have productive dialogues as the design process progresses". Zahedi brings to light some threats to effective team-based design driven by the different perspectives each person holds. Team members have different abilities to offer the project which reveals underlying factors to integration namely, according to Cross & Cross (1995), cognitive and social aspects of working as a team.

First, cognitive aspects can be understood as the matter of acquiring and understanding knowledge through thought, which is said to differ from one team member to the next (Cambridge, 2019). In design, a persons' cognition can be referred to as their *frame(s)*, which according to Hey et al. (2007, p. 81) is "shaped by an individual's unique combination of prior experiences and cultural backgrounds". According to Dong et al. (2013, p. 13) "framing is a moment-by-moment perception of specific units of information partially influenced by the manner of presentation of information". Framing, in new product development, can be seen as the way through which each person uses their existing knowledge, experiences and beliefs to perceive or understand a problem, task or piece of information. This notion is also illustrated by Bucciarelli as o*bject worlds:* In his book *Designing Engineers,* Bucciarelli (1994, p. 162) explains that object worlds are "worlds of technical specialisations, with their own dialects, systems of symbols, metaphors and models, instruments and craft sensitivities". For each person, these object worlds, or frames are furnished with methods, techniques, values, and perceptions that connect the "real" world to past experiences and knowledge.

Second, social aspects of working as a team can be understood as the matter of working with one another, where communication and negotiation are critical components to becoming more integrated. Gao & Kvan (2004, p. 123) in characterising good teamwork, explain that "communication is essential for designers to exchange and develop their ideas with colleagues and clients". Equally, Cardoso et al. (2016, p. 1) state that "communication is regarded as a key factor in design projects' success or failure". Communication is a matter of sending, receiving, and reciprocating information which, in design research, can be mediated through verbal communication as well as different forms of representation. Verbal communications are rich and ongoing externalisations of team members' thinking and reasoning (Wiltschnig et al., 2013, p. 524). Simply, they are the words and sentences we share with one another, and use to talk to each other. However, this is complicated because, as Zahedi (2011) highlighted, each person speaks a different language to a certain degree. This doesn't mean French or English, but rather as Bucciarelli (2002, p. 222) proposes, language rooted in different scientific paradigms that have specific "conventions and customs, often curious norms and forms of expression as well as tokens and grammar, jargon and idiom". It is said that different disciplines hold different specialised languages, and that discrepancies can happen even within professionals from the same discipline (Schön, 1983; Bucciarelli, 2002). Other forms of representation are communicated through artefacts like sketches, prototypes and mock-ups (Luck, 2019) and human-computer interactions (Button, 2000; Arias et al. 2000). These forms of communication embody, track or make visible aspects of the design and often represent the outcomes of design communication and negotiations (Oak, 2011). In light of communicative challenges to integrating different people into a single team, effective integrated designing is said to be underlined by the development of a common ground. Team members negotiate their frames to integrate the knowledge they collectively hold and create shared goals, objectives, and means of achieving them (Détienne, 2006). According to Valkenburg & Dorst (1998, p. 249), "for team designing to be effective we rely on team members to support each other [which lies] in synchronising their thoughts and activities."

Thus, working as an integrated team in new product development allows team members to access and collectively hold shared knowledge, shared goals, and a shared means of achieving them. However, integration is challenged by the potentially conflicting frames each person holds, which is further influenced by team members' abilities to communicate and negotiate with one another.

1.4 Working Towards Effective Integration, or Designing Collaboratively

Teamwork is denoted by potentially conflicting frames which on the one hand threaten team integration but on the other hand provide a possible means to observing and researching it in practice; According to Stumpf & McDonnell (2002, pp. 8-9), "the notion that individuals may hold conflicting frames neatly explains problematic team designing. It can hence be used as a normative measure to talk about when designing goes right and when it goes wrong". Under this premise, teamwork can be described and understood through the integration of team members' frames.

When talking about team integration, design research refers to (i) 'cognitive synchronisation', (ii) 'shared frames', (iii) and 'shared understanding'. According to Kim & Maher (2008), research has proven that cognitive synchronisation is essential to designing as a team, and is largely an argumentation process. Team members unify in the way they perceive the project, and think within it. Cognitive synchronisation provides order to a multi-disciplinary teams' overall design strategy which, if respected, allows them to work effectively (Macmillan et al., 2001). Similarly, shared frames are “discursively constructed during collaborative negotiation processes, include input of all team members, and thus encapsulate the knowledge shared by the team” (Kleinsmann et al., 2012, p. 487). This calls back to ‘individual frames’, which help construct shared frames. It was noted that individual frames evolve over time and shift based on peoples’ experiences and new knowledge. These frames are elusive and often implicit. Indeed, the same is said about shared frames, wherein teammates need to review, reconstruct, or make explicit shared frames for every interaction (meeting, discussion, negotiation) (Dong, 2005). For effective integration to happen, team members should be constantly aware of the knowledge available to the project and continually nurture these shared frames to maintain an integrated view of overall problems, solutions, objectives, and processes (Hey et al., 2007). Unifying different people and their respective views, frames, understandings, and perceptions is also described as shared understanding which, according to Kleinsmann & Valkenburg (2008, p. 371) allows team members “to be able to integrate and explore their knowledge and to achieve the larger common objective: the new product to be designed”. Lahti et al. (2004) value shared understanding for bridging design elements from each team member and for creating a shared design context. In creating a shared understanding, Arias et al. (2000, p. 84) propose that new insights, new ideas, and new artefacts emerge from bringing often controversial points together.

Shared understanding is a valuable part of effective integration. In fact, Dong (2005) correlates effectiveness and shared understanding, while Macmillan et al. (2001) refer to the following authors (Cross and Cross, 1995; Blessing, 1996; Minneman, 1991; Brereton et al., 1996) to advocate for its value in successful collaborative design: “researchers that have studied group design activity generally agree that shared understanding between the design team members can aid the decision making process and is the key to successful collaboration” (p. 170). Shared understanding is embedded in research about collaborative design which according to Mattesich and Monsey (1992, p. 39) is the most integrated form of teamwork:

> **Cooperation** is characterised by informal relationships that exist without any commonly defined mission, structure or planning effort. Information is shared as needed, and authority is retained by each organisation so there is virtually no risk. Resources are separate as are rewards.

> **Coordination** is characterised by more formal relationships and understanding of compatible missions. Some planning and division of roles are required, and communication channels are established. Authority still rests with the individual organisations, but there is some increased risk to all participants. Resources are available to participants and rewards are mutually acknowledged.
>
> **Collaboration** connotes a more durable and pervasive relationship. Collaborations bring previously separated organisations into a new structure with full commitment to a common mission. Such relationships require comprehensive planning and well defined communication channels operating on many levels. Authority is determined by the collaborative structure. Risk is much greater because each member of the collaboration contributes its own resources and reputation. Resources are pooled or jointly secured, and the products are shared.

Unlike collaboration, other forms of teamwork like cooperation and coordination are less integrated activities. Team members are more independent and work most often on their own, connecting at times but without strong relationships. They seem to maintain their own values and authorities which leave them rather unaccountable for others' issues. The distinction is important since these terms are often used interchangeably, which complicates and confuses the research landscape (Mattesich & Monsey, 1992). According to Kvan (2000 p. 410), "collaborative success can therefore be said to be achieved when we have accomplished something in a group which could not be accomplished by an individual". Moreover, Chiu (2002), explains that "collaboration implies a durable relationship and a strong commitment to a common goal" (p. 188), as well as a "deeper, more personal synergistic process, [which] involves negotiation, agreement, and compromise in order to achieve success" (p. 205).

Still, while collaboration infers well-integrated teams, processes, goals, and design outcomes, research highlights some caveats to its effectiveness. According Mattesich and Monsey (1992), greater integration presupposes higher risks to participants. Lahti et al. (2004, p. 352) point out that "collaboration may be time consuming and sometimes requires extensive efforts of community building; hence some researchers claim that it is only suited for very particular problems requiring close coupling of the design process and its participants". As well, Kokotovich & Dorst (2016, p. 14) observed that collaboration can adversely lead participants to conventional views of the problem, rather than innovative ones. Nevertheless, collaboration channels members into new organisational structures with shared objectives, operations, responsibilities, and outcomes. It weaves members' interests, expertise, responsibilities, and objectives to suggest a strong integrated relationship. According to Chiocchio et al. (2011, p. 79), "collaboration is a key mechanism to integrated design teams' effectiveness".

Within research on the effectiveness of collaborative design, Kleinsmann et al. (2007) provide a categorisation of factors that influence the development of shared understanding. They are drawn from empirical analyses on collaborative new product development in teams with multiple professionals and expertises. The factors are said to affect the development of shared understanding as both enablers or barriers —either positive or negative influences— and can happen on three organisational levels: the actor-level, the project-level, and the company-level.

The Actor-level is about collaborations or other interactions between actors. Four factors affecting this level are identified (p. 66):

1. *The ability of an actor to make a transformation of knowledge*. This factor concerns the knowledge exchange between two different disciplines. Since actors of different disciplines use different knowledge, a transformation of knowledge is always needed. The actors need to transform both the content of the knowledge and the representation of the knowledge.
2. *The similarity in language used between the actors*. The major issues concerning the similarity in language are the different jargon that the actors use (both in words as well as in drawings) and the different native languages that the actors use.
3. *The applicable experience of the actors*. Actors use their experience while they are designing. This influences their actions. The enablers within this factor deal with the experience that actors have with the regular tasks within the design project. They use their experience from earlier projects to do their current design task. The barriers deal with the innovative aspects of the design project because the actors lack experience upon these aspects. […]
4. *The empathy of actors about the interest of a task*. This factor deals with the understanding of the content and interest of one's task. In addition, it is about to what extend an actor is able to interrelate his tasks to other (interrelated) tasks. The barriers within this factor deal with:
    - Actors do not fulfil a task that is required because they are not aware of the interest of the task or they underestimate a task.
    - Actors perform a task and do not inform other actors, since they do not know that the information is important for the other actor.
      In order to prevent these two situations it helps when an actor has a clear understanding of the design process. By knowing the design process, an actor will see the task dependencies he has with other actors. This will provide him with a better understanding about the interest of his design task.

The Project-level is about managing the project. It takes into account actions such as planning, structuring, informing, and budgeting. Five factors (pp. 66-67) affecting this level are identified:

1. *The efficiency of information processing*. The most important barriers concerning the efficiency of information processing are: (1) the information arrives too late for the receiver, so he can not continue his task; (2) the status of the document is not known by the receiver; (3) the status of the documents are not sufficient; (4) the information is put in a database that the receiver cannot open; (5) the information flow is disturbed because an actor has no time to process it; (6) it is unclear what information is needed, etc. Enablers concerning the efficiency of information processing are: (1) the early involvement of another sub team, (2) the active approach of one sub team towards another sub team, (3) the efficient data management system, (4) the active use of the minutes of meeting.
2. *The quality of project documentation*. Problems with the quality of the documents are caused by, for example: ongoing changes in the documents, incomplete documents, new appointments about how to set up the document, for the actors it is unclear how to deal with certain documents or the interest is insecure, etc. Despite these quality problems, the engineers actively use the documents, such as minutes of meeting and action lists, in order to structure the complexity of the design project.
3. *The division of labour.* Problems with the division of labour often occur at the beginning and at the end of a design project, because people have to work on other design projects. [The authors' field study brought them to say that] Another aspect concerning the division of labour was that some actors had too much work during the project. Therefore they focused too much on one aspect of their task. In order to overcome capacity problems, suppliers were involved in the design processes of both cases.
4. *The rigour of project planning*. [Design projects with a tight schedule can lead to efficient decision-making, but] the risk of [a] tight schedule is that fewer alternatives than normal [are] generated and some decisions [are] taken on the base of little information.
5. *The controllability of product quality.* Quality problems concern the quality of the parts and the controllability of the quality of the parts. Also, the testing of both software and parts has been difficult in both design projects. Another problem that concerns product quality was validity of the quality procedures.

Finally, the company-level is about the way companies organise their product development projects and resources (human, material, and financial). Two factors (p. 67) affecting this level are identified :

1. *The organisation of resources*. From our study, it appeared that the organisation of resources has been difficult at the beginning and at the end of the design project. At the start of the project the resources needed to be allocated to the project. At the end of the design project, there have been also some issues concerning the organisation of resources, because many engineers went to new design projects.

2. *The allocation of tasks and responsibilities*. Problems with the allocation of tasks and responsibilities occurred if engineers could not connect their task to the other tasks. If this was the case, the engineers were not willing to be involved in aspects outside the scope of their own task. They only wanted to be involved in a particular task when this was formally arranged. This was because for the engineers it was difficult to foresee the consequence of getting involved in a task outside their direct scope. System engineers, or product architects, are responsible for integrating the tasks of all different actors. Therefore, a solution for this problem would be a well functioning system-engineering group (or product architecture group).

Kleinsmann et al.'s (2007) categorisations provide an examination of the factors at play in the development of shared understanding. The actor-level factors resonate with those discussed in the theoretical framework such as language, experience, and translating knowledge across disciplines and individual frames. The project and company levels also align with team integration and collaborative design in the way they channel members into new organisational structures with shared operations, responsibilities, and outcomes. Still, as their research relies on two case studies within specific contexts, they recommend further investigations and refinement to their proposed categorisations through more case studies about collaborative design, and shared understanding in a new product development setting.

The theoretical landscape proposes further recommendations and characteristics to designing that encourage team integration / effective collaboration. Namely, Rosen (2006) proposes 10 cultural elements that should appear in any good collaborative design setting, namely trust, sharing, goals, innovation, environment, collaborative chaos, constructive confrontation, communication, community, and values. Many of these aspects have already emerged in the theoretical framework, but trust and community have been less addressed, and deserve more attention. The notion of 'trust' resonates with observations from Leblanc & Gagnon (2016) and Mattesich & Monsey (1992) about collaborative design; there is a noticeable connection between trust and the idea that well integrated collaborators share in the risks and benefits of a project. Indeed, Chiocchio et al. (2011, p. 81) correlate the effectiveness of integrated teams with the trust between them, wherein "people are relying on someone with specialised training and knowledge, while lacking the expertise and information to understand their actions". The ideas behind trust and community also align with Bergema et al.'s (2015) notion of 'click'. They support 'trust' as an important aspect of reliable social relations and team climate and suggest that "the click between team members can heavily influence the collaboration" (Bergema et al., 2015, p. 5). Contextually, the authors infer that strong and positive interpersonal relationships between team members enables effective collaboration. They suggest ‘click’ fosters a willingness to help each other, thus reinforcing a sense of community.

1.5 Reflecting on the Theoretical Framework

The theoretical framework revealed that complex problems in new product development require more knowledge that any single person possesses, and that it seems working as team is a promising way to solve them. Through effective teamwork, team members can transcend disciplines, cultural backgrounds and expertise to create a greater body of available knowledge and a more holistic view of the problem by accessing each persons’ respective frames. However, doing so effectively involves some significant challenges that require team members to communicate, negotiate, and integrate. Collaborative design is said to best embody these needs as team members are called upon to develop a shared understanding. In this way, each person views the problems and solutions similarly, provides and accesses each others' knowledge, and shares in the goals, objectives, and means of achieving them. To do so effectively, some notable factors in designing as a team are said to influence the development of a shared understanding. These factors may serve as a framework to better describing and understanding effective team integration as it happens in practice. These findings have brought about questions that will hopefully aid in exploring team integration in a new product setting, namely:

- Can the factors outlined in the theoretical framework provide a means to describing and further understanding team integration?
- Do certain factors play larger roles in developing shared understanding?
- Are there other factors outside of those described that noticeably (empirically) influence development?

The following chapter explains the methodology of the research and methods used for collecting data to help answer these questions.

Chapter Two: Methodology

This research is motivated by an inquiry about *describing and understanding team integration in new product development*. The research objectives are to:

- Explore and document involvement as a junior designer in a new product development setting and multi-disciplinary team;
- Analyse and report on team integration;
- Understand factors to team integration during the design process.

This research went through an iterative process and back and forth between theory and practice to identify a suitable means of interpretation. Accordingly, the framework of analysis was refined while working through the collected data, after completing in-field research. Nevertheless, the inquiry remained guided by the intent to research through the practice of design, and began with a topic similar to team integration in multi-disciplinary teams, namely designer and scientist collaborations in new product development. An invitation to work within a new product development company was accepted and designer involvement was studied over a few months. As the project advanced, it became clearer that the context of designer and scientist more suitably served as a case study on teamwork broadly. The sections that follow will explain the use of qualitative inquiry and case study, the value of research embedded in the practice of design, the methods used to gather data, and some recommendations regarding its collection. Finally, the methodology design of this research is presented, including the proposed framework of analysis.

2.1 The Use of Qualitative Inquiry

Qualitative inquiry is used to understand and make sense of situations and experiences while also investigating the deeper meanings behind them. It is used as a form of inquiry to provide structure to explore a given subject when research is partial or incomplete (Creswell, 2007). Unlike quantitative inquiry used in validating or weighting existing theories, qualitative research explores and attempts to uncover, characterise, and understand social behaviour (Van der Maren, 1996). Additionally, it was later found that by using qualitative data from the field in the form of anecdotes and stories that research by Kleinsmann et al. (2007) could be used as a means of analysis.

2.2 The Use of Case Study

While it is clear that this research is qualitative, selecting the best approach according to Creswell's *Five Qualitative Approaches to Inquiry* (2007) - narrative, ethnographic, phenomenological, grounded theory and case study - seems less obvious. Mainly, while each approach is said to be suited to a research focus, type of problem, unit of analysis, data collection, and data analysis strategy, researching through the action of designing and reporting on designer's involvement points towards narrative, ethnographic and case study. In fact, Creswell (2007) and Yin (2014) explain how either approach is equally suitable, namely since they all share in the unit of analysis of an individual and their lived experience. Still, this research chooses case study for three reasons:

1. Yin (2014, p. 97) proposes the use of case study to "investigate a contemporary phenomenon within its real-life context", and according to Creswell (2007, p. 73), case study is used to "understand an issue or problem within a bounded system". Bounded systems are a setting or context within which a culture-sharing group performs their actions.

2. Creswell (2007, p. 76) explains how case study is best suited to "illustrate an issue [and] compile a detailed description of the setting of the case". For Yin (2014, p. 16), "you would do case study research because you want to understand a real-world case […] likely to involve important contextual conditions pertinent to your case".

3. Other design researchers, such as Bucciarelli (1988, 1994 & 2002), Cross (1992), Valkenburg (1998), and Dong (2005) engage with case study in their research based on similar inquiries like shared understanding, design in action, and team dynamics. Their contributions point towards the value of case study for the present research inquiry.

Considering the research context, intentions, theme, and precedent in design research, a qualitative form of inquiry using a case study approach is selected. To collect data, this research is inspired by Bucciarelli (1994) and Valkenburg (1998) who, in one way, presented their qualitative data through storying, or *restorying*. Restorying is a narrative approach that emphasises learning new content through personal understanding and story sharing with others (Slabon et al., 2014). This approach creates a chronological account of a field study through some main / key concepts; according to Creswell (2007, p. 56), "this framework may consist of gathering stories, analysing them for key elements of the story (e.g., time, place, plot, and scene), and then rewriting the stories to place them within a chronological sequence (Ollerenshaw & Creswell, 2000)". Restorying can be useful to create a causal narrative that explains the development of an idea, issue, or solution (Cortazzi, 1994).

2.3 Research Embedded in the Practice of Design

Looking into team dynamics through the practice of design aligns with views like Findeli (2004) who states that design research needs to happen in the action of designing. In this way, knowledge is created through the real interactions between people. Godin and Zahedi (2014, p. 4) state that "research in design is not concerned with the 'true', but with the 'real'". This proposes a relativist argument that separates design research from more formal concepts and modes in scientific research like positivism. Positivism, which creates theory from visible or verifiable facts sometimes fails to create knowledge in design since, as Kolko (2010, p. 15) explains, some design activities are made visible through artefacts (the object being designed), but some aspects of design are insular, "less obviously understood, or even completely hidden from view". This echoes Jones' (1970, p. 46) black box theory that argues "the most valuable part of the design process goes on inside the designer's head and partly out of reach of his conscious control". In both design research and practice, it is uncertain how people's actions and thinking directly lead to the final designs.

To report on the practice of design, some research methods have been developed, namely constructive design methods, action-research, and Research-through-Design (RtD). These different practice-based design research approaches share in the idea that design knowledge can happen through the action of designing and equally share in an overarching principle that puts design practice in the middle of the research. First, Rendell (2013, p. 117) explains how in constructive design methods, "instead of posing research questions and then finding answers, in much design research the process operates through generative modes, producing works at the outset that may then be reflected upon later". According to Koskinen et al. (2011) constructive design research is described as an umbrella-term for action-research and RtD which all allow for more flexible and experimental methodologies centred around constructing things like artefacts, spaces, and systems as a key means of building knowledge. Second, according to Jonas (2007), action-research proposes building theory based on observations of making and remaking, which Zimmerman et al. (2010, p. 311) sums up as a "sequence of iteratively planning, acting, observing, and then reflecting". The process closely links the creation of knowledge to observations and reflections on design practice. These reflections are used to plan and test new scenarios that are again observed and reflected upon, evolving theory through recursive acts of designing. Third, Research-through-Design (RtD), according to Findeli (2004) likens the design aspect of creation to research, and can be considered the closest thing to actual design practice. In this way, Jonas (2007, p. 34) also proposes that RtD "denotes a genuinely designerly process of knowledge generation". In RtD, the researcher detaches from positivist thinking and fully embraces a constructivist approach: "When designers work as facilitators rather than detached observers, the last remnants of the idea that researchers ought to be detached, impartial observers — "flies on the wall" — disappear. What comes about is the idea that design is supposed to be an exploration people do together, and the design process should reflect that" (Koskinen, 2011, p. 84). The researcher participates in the design process, playing the dual role of designer and researcher. Godin and Zahedi (2014) refer to the researcher as designer/ researcher. In RtD, the role of researcher and designer are exclusive, but embodied by the same person. *The researcher is the designer, is the researcher.*

RtD allows knowledge to emerge from different parts of design activity, namely through the actions of individuals and the artefacts they create throughout the design process. RtD weaves these two aspects (action and artefact) together. In one way, artefacts are the tangible outcomes of design actions, like sketches, plans or final prototypes and designed objects. But, these artefacts are also relevant to RtD research as carriers of knowledge (Frayling, 1993) who can embody the rationales, objectives and values of the people involved, or as Zimmerman et al. (2007, p. 42) explains, "codify their own understanding of a particular situation and provide a concrete framing of the problem and a description of a proposed, preferred state". Bucciarelli (2002, p. 228) adds to the idea of artefacts in design to say that "it is important to realise that the object of design is not a real object". Artefacts, in a team setting, represent the negotiations and communications —or the trade-off of different object-worlds / frames— between team members. Bucciarelli (2002, p. 231) highlights that they "provide a milieu for inquisition and exploration of the whole and its interfaces within, as well serving to illustrate hard technical features or function when deployed by participants from different object worlds". In this way, artefacts enable team dynamics and design actions, support negotiations as a physical placeholder for design objectives, and as Bowers (2012) explains, help reveal the heterogenous thoughts at play. Based on these explanations, the RtD approach was selected as it aligns with the exploratory inquiry of the present research.

2.4 Methods

To report on qualitative inquiries, Creswell (2007) and Yin (2014) propose the use of multiple data collection methods to gain a broad and multifaceted view of the context. Yin (2014) proposes six forms of data collection: documentation, archival records, interviews, direct observations, participant observations, and artefacts, which are each explained below:

2.4.1 Documentation

Documentation can take many forms such as journals, checklists, e-mail correspondences, studies, administrative documents, and searches (internet or otherwise) done during or prior to field research. Yin (2014) underlines that these should be 'stable' and 'exact' with 'broad coverage', meaning they should be continually available, easy to read, and well organised by date, event, and setting. Documentation is especially helpful to corroborate information and record evidence of statements, discussions, or theories.

2.4.2 Archival Records

Archival records refer to documents like public use files or budget reports. They may be quantitative, and are often published. Yin (2014, p. 106) explains how "most archival records were produced for a specific purpose and a specific audience other than the case study investigation, and these conditions must be fully appreciated in interpreting the usefulness and accuracy of the records".

2.4.3 Interviews

According to Yin (2014), interviews are a guided conversation with a consistent line of inquiry but are often fluid without a rigid structure. This allows the researcher to hold a conversation with the participant and adapt questions in order to target other topics during the interview. This also helps the researcher refine their questions from one interview to the next. Questions should be reviewed to ensure objectivity and impartiality, either by another researcher or a board of ethics. Researchers should take notes in a journal and consider audio recording for accurate referencing. Yin (2014) highlights three forms of interview: in-depth, focused and survey-like. In-depth interviews look into participants' insights, sometimes over multiple sessions[4]. Focused interviews are less exploratory and usually used

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[4] Multiple interviews with the same person can make them a 'key informant'. While this can be very useful, researchers should be "cautious about becoming overly dependent on a key informant, especially because of the interpersonal influence -frequently subtle- that the informant may have over [them]" (Yin, 2014, p. 107).

to corroborate a hypothesis. While they remain open-conversations, the questions likely follow a protocol and provide qualitative answers, like in-depth interviews. Survey-like interviews use focused, rigid questions to yield quantitative results (example: ‘yes or no answers’, or ‘on a scale of 1 to 10’).

2.4.4 Direct Observations

Case studies should take place in field, or “in the natural setting of the ‘case’” (Yin, 2014, p. 109). The researcher observes participants during meetings, activities, or while performing their tasks to record information about the topic of the study. The researcher is a fly on the wall, they do not interfere or interact with participants. A direct observer may, for example, sit in the corner during a meeting, making sure not to influence the situation in any way. This lets the researcher document participants in action without biasing data. Sometimes, observational instruments like grids, tables or checklists are developed to “assess the occurrence of certain behaviours during certain periods of time” (Yin, 2014, p. 109). Audio and video recordings, and journal entries can be used to document direct observations.

2.4.5 Participant Observations

Similar to direct observations, participant observations immerse the researcher in the field to study participants in their setting. In addition, the researcher can assume “a variety of roles in the case study situation and may actively participate in the events being studied” (Yin, 2014, p. 111). Unlike the fly on the wall, the researcher contributes actively to the situation, impacting the dynamics, and likely influencing outcomes. While this can be considered to bias results and research credibility (Becker, 1958), Yin (2014, p. 112) explains how interventions by the researcher (or in this case, the designer) “can produce a greater variety of situations for the purposes of collecting data.” and can be invaluable in some case studies. Documenting participant observations is the same as direct observations.

2.4.6 Artefacts

Yin (2014, p. 113) explains artefacts as “a physical or cultural artefact: a technological device, a tool or instrument, a work of art, or some other physical evidence”. Artefacts vary in shape and size depending on the context and object of study: from a knife in a kitchen, to a water cooler in an office. Artefacts can already exist in the environment or be created during the case study. According to Bucciarelli (2002), the artefacts developed during a design process –such as mock-ups, sketches and prototypes– serve many essential functions: they physically represent the design process and illustrate design negotiations between team members.

2.5 Recommendations for Data Collection

The use of Research-through-Design as a design research inquiry can help further understand team integration in action. However, the constructive approach comes with some caveats to data collection. A main criticism in RtD, as Godin & Zahedi (2014) point out, is in *reproducibility*, or "that which can be regularly reproduced by anyone who carries out the appropriate experiment in the way prescribed" (Popper, 1959, p. 23). Zimmerman et al. (2007, p. 499) explains that "[t]here can be no expectations that two designers given the same problem, or even given the same problem framing, will produce identical or even similar artefacts". To overcome criticisms on its theoretical grounding, RtD, uses Action-Research's practice of data *recoverability,* instead of *reproducibility*. According to McNiff (2013, p. 18) *recoverability* means the designer/researcher must make sure that "the process is recoverable by anyone interested in subjecting the research to critical scrutiny". Godin and Zahedi (2014, p. 6) help RtD researchers by proposing Pedgley's recommendations for *recoverability*:

> Owain Pedgley (2007) provides a list of best practice that could help ensure recoverability of the project. These best practices should then be used in RtD (all from Pedgley, 2007, p. 473): **Chronology**: "Describe work in the same sequence that it occurred, ideally as bullet-points"; **Clarity**: "Keep entries intelligible, insightful and honest"; **Focus**: "Keep entries succinct: they should not be a crafted essay"; **Record images**: "Record still and moving images of developing and completed physical models"; **Out of hours**: "Account for instances of 'out of hours' designing in the next day's diary"; **Diary admin**: "Ensure that all diary sheets are numbered and dated"; **Modelling admin**: "Ensure that all modelling outputs are numbered and dated to aid cross-referencing (e.g. 'LB1:22' refers to log book 1, page 22)".

Godin & Zahedi (2014) also present Pedgley's (2007) recommendations for good documentation, namely (i) solo effort, (ii) endurance, (iii) subject delimitation, and (iv) mobility. First, solo effort recognises that much of the documenting will undoubtedly be done alone. After all, while the research happens in practice and involves everyone in the product development team, the research inquiry is independently managed by the researcher. As such, the designer / researcher has the lone task of data collection. On that note, Pedgley's second recommendation, endurance, incites the stamina and attention needed to report on the whole field study, sometimes lasting months or years. Reporting /

journal entries should happen at least daily, should report on as much as possible, and should annex documents and artefacts like sketches or presentations. Using multiple sources and reporting on as much as possible is important to *recoverability*, but there are obvious limitations which Pedgley amends in the third recommendation: subject delimitation. To prevent data overflow, Pedgley proposes that a focused area of inquiry or research subject be defined. Finally, documenting should be mobile, since "the design process does not necessarily stop when the designer / researcher leaves the studio" (Pedgley, 2007 in Godin & Zahedi, 2014, p. 10). In fact, this follows in the recommendation to record out-of-hours, during social events or after-work activities. This also aligns with the notion of 'click' (Bergema et al., 2015), wherein team integration is influenced by social camaraderie and activities.

2.6 Methodology Design of This Research

As the methodological section leads to understand, this research uses a qualitative case study approach and Research-through-Design (RtD) to conduct the inquiry and collect data. Using this methodological combination has the benefit of looking into the lived experiences and social dynamics of team members by playing the role of both researcher and designer (team participant) in a new product development team. To prepare and conduct the case study, the following 8 guidelines are presented[5]:

1. The project should centre around an industrial product with multiple functionalities and contain innovative aspects (i.e. novel design, uses, or functionalities). In addition, the team should comprise willing team members from different knowledge bases (i.e. disciplines) with different responsibilities who carry out interdependent tasks. These conditions align with the in-field research plan as presented to MITACS for funding (annex 1), and to the Ethics Committee for approval (annex 2). They equally answer to the research recommendations from Kleinsmann et al.'s (2007) paper which, as presented later on, serves as an important reference for this study.

2. As it has been pointed out that the role of designer has shifted to the early phases of product inception and development, the research will start at or near the beginning of a project.

[5] Although some of these guidelines were not clearly addressed and documented before starting the field study, it seems important to list them here, namely to help recognise the limits of the inquiry.

3. The case study should allow for sufficient time to collect data about the development of team dynamics (i.e. their actions throughout the new product development process). Sanders and Stappers (2008) point out that actions can have long-range consequences throughout the design process and Arias et al. (2000, p. 86) explain how for complex problems, "heterogeneous groups work together on projects over long periods of time". According to the company involved in the new product development, design involvement would be useful if the case study lasts about 12 weeks.

4. This research will conduct a single case study rather than multiple. According to Creswell (2007, p. 74), single case studies "focus on an issue or concern, and then select one bounded case to illustrate this issue" which here reports on team integration through shared understanding in a collaborative design team. In addition, it can also be viewed as a continuation of Kleinsmann et al.'s (2007) investigations and serve as one of multiple case studies as it relies and reflects on their results.

5. The researcher will follow in an RtD research approach to collect data by playing the role of both intern-designer and researcher. Doing so acknowledges tensions in the designer / researcher role, and a need to distinguish data collected from one and the other. This is because, as Findeli et al. (2008, p. 74) explain, their intentions differ since "researchers' community is interested in 'fundamental' or 'theoretical' knowledge, [and] the practitioners' community in 'applied' and 'useful' knowledge". To create division, Zahedi's (2011) journal entries method is used: Her PhD journal entries were organised to hold designers' notes on the left side page of the journal (verso), while the right side (recto) was allocated to researchers' notes. This should create contrast and division between the notes from either role.

6. Multiple methods will be used to collect data and ensure *recoverability*: (i) journal entries taken by designer and researcher roles during direct and participant observations in meetings, out-of-hours, and during work sessions, (ii) interviews with other participants reflecting on different moments or events during the case study[6], (iii) and by collecting artefacts such as sketches,

[6] See Annex 3 for Interview Structure, approved by CPER Ethics Committee

prototypes, and mock-ups which are said to embody the design process. In addition, to prevent data overflow, the inquiry will be delimited to team dynamics during and about design activities.

7. The data will be presented chronologically through the *restorying* approach and guided by Bucciarelli's book *Designing Engineers* (1994), where he describes his experiences and team dynamics while involved with different new product development companies as a participating design engineer. The presented data will provide a week-by-week account of the design process / tasks, as well as examples / anecdotes that embody different proposed factors to the development of shared understanding (Kleinsmann et al., 2007) that week.

8. The data will be interpreted using Kleinsmann et al.'s (2007) factors to the development of shared understanding by organising different events / moments / anecdotes into instances. Instances are moments recorded throughout the day, varying from longer and more dynamic interactions like a group meeting, to shorter and more reflective ones like a quick conversation in the hallway, or observations about design objectives. The instances are analysed to see which factors emerge as either enablers or barriers and, to better visualise the overall development, are organised into a table.

While this research presents a clear methodology design, the decision to use categorisations from Kleinsmann et al. (2007) was done after conducting the case study. Figure 1 below illustrates the main stages of the research to better explain the iterative cycle between theory and results which led to using the categorisations as a framework:

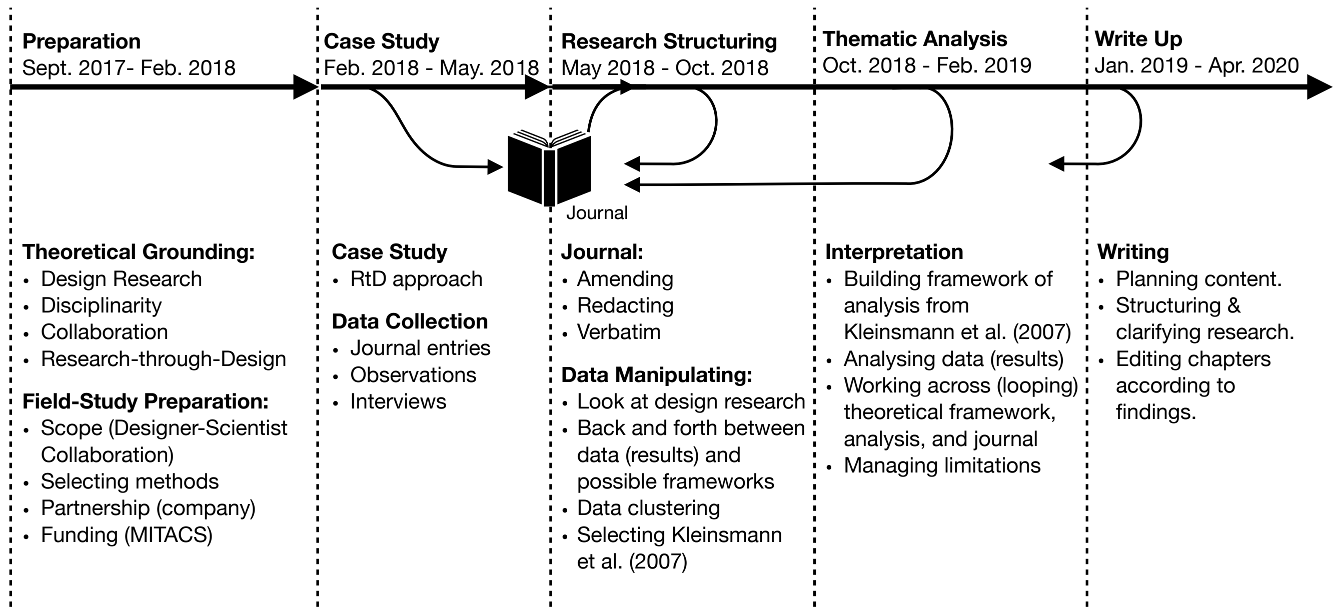

Figure 1: Methodology Design of the Research

Overall, this study began with a few months of preparation; understanding design research and the use of practice-based research approaches and methods. This was done through courses on design methodology, and exploratory literature reviews on the subject of collaboration in new product development. The review lead to the subject of collaboration between designers and scientists from researchers like Pullin (2015, p. 1): “How [the device] looked would be part of how someone perceived them and part of how the person perceived themselves; part of their identity, in some ways. Yet as engineers and clinicians, the people working on the project, we didn’t have any way of addressing those issues or even thinking about them very deeply”. Such observations revealed an opportunity to look into multidisciplinary integrated teams in product development settings. This exploratory investigation seemed to blend well with practice-based research and qualitative inquiries. Submissions to the University Ethics Committee, funding from MITACS, and an invitation to a willing research partner in industry were quickly drawn up on the topic of observing designer-scientist collaborations. The research preparation phase was cut short as the company provided a date that was sooner than expected. While research methods and a broad subject delimitation of collaboration between disciplines were defined, a theoretical framework, design methodology, and data analysis method were not yet completed. The case study was conducted over about three months, collecting data primarily through participant observations and interviews recorded in a journal. The journal —generated during the case study — was amended with some editing after the fact to create a more complete account of the case from collected data.

Next, it was believed that manipulating the data and analysing thematically to create data clusters would help construct the main research chapters and determine a framework of analysis. According to Creswell (2007, p. 61), data clustering is when significant statements and themes are used:

> The researcher develops ***clusters of meaning*** from significant statements into themes. These significant statements and themes and then used to write a description of what the participants experienced (***textural description***) [and] to write a description of the context or setting that influenced how the participants experienced the phenomenon, called ***imaginative variation*** or ***structural description***. Moustakas (1994) adds a further step: Researchers also write about their own experiences and the context and situations that have influenced their experiences".

A few months were spent manipulating the data and working back and forth between the journal and literature to find theories that resonated with case study findings. In working this way, Kleinsmann et al. (2007) presented a categorisation that tied in well with the data and the case. It was mobilised into a framework and tested on journal results, which worked well; each proposed factor from their research could be found in the data and contributed in better understanding the instances across the case study. From there, the research focused more specifically on collaboration, team integration, and the effectiveness of teams through their shared understanding in new product development settings. A first write up was done from January 2019 to August 2019, with further refinement and clarification from November 2019 to April 2020. Writing up consisted of drawing up a plan, writing the chapters, and mending each to explain findings coherently and provide a good flow from one chapter, and finding, to the next. The chapter that follows presents the case study results that served as the crux to this practice-based research project.

Chapter Three: Field Study

This chapter presents the data collected during the case study. The first section describes the context of the case study and how it respects the methodology design of this research (Section 2.6). The second section tells the story of designer involvement and team integration through a chronological account of the case. This provides a broad idea of day-to-day activities.

3.1 The Context

The company involved in the case study design and manufacture mobility assisting products that support rehabilitation and are used to aid in mobility issues throughout a person's everyday life. The director of R&D at the company was contacted by this research's supervisor who obtained agreement for research. The R&D team were enthusiastic to experiment with an industrial designers' involvement in their projects for a few months. The company did not have any notable problems with their products or designs; Indeed, they had been recently awarded multiple international awards for their new products, but they wanted to try blending design and engineering further. The ethics disclaimer reflected this idea by proposing research about designer-scientist collaborations and the repercussions of their working together (see annex 4). The company was looking to innovate and use multi-disciplinary collaboration to further improve their products. Designer involvement was to last about 12 weeks, during which I (researcher / interning junior-designer) would work on three projects, although one was not funded in time. The two projects, called *Element* and *Freedom*[7], had already started, but were still described as rather nascent projects. The projects were about industrial products with multiple functionalities, designed with many innovative elements. The projects also involved task interdependencies and varying responsibilities between team members from different engineering fields (such as materials, electrical, bio-mechanical and computer engineering), different organisations (like affiliated clinics, manufacturing contractors, and university research partners), as well as different expertises (like clinicians and medical device specialists who provide maintenance services to users in clinics across the country). A list of team members and other staff involved, as well as their roles in the case study are as follows (others were involved but not given names such as Researcher 1 and 2, or Asset manager as they appear only once):

[7] The names of products, and research participants / team members (including names and genders) were changed for anonymity.

Table 1: (Main) Actors in the Case Study

Sara	Director	All Projects
Paul	Project Champion + Engineer	Element (Pro. Champ.) + Freedom (Engineer)
Ian	(Young) Engineer	Element
Peter	Orthotist	Element
Jim	Project Champion + Engineer	Freedom (Pro. Champ.) + Element (Engineer)
Larson	Prosthetist	Freedom
Tyler	Engineer	Element and Freedom
Nancy	Engineer	Other Projects
Amy	(Young) Engineer	Other Projects
Dave	Engineer	Other Projects
Kyle	Engineer	Other Projects
Oren	Engineer	Other Projects
Vicky	(Young) Engineer	Other Projects
Ben	Director	Outsourced Company
Aaron	Engineer	Outsourced Company
Taylor	Engineer	Outsourced Company
Miranda	Engineer	Outsourced Company
Jeff	Design Engineer	Outsourced Company
Max	Designer + Researcher	Researcher of this study (Author)

The company was recently relocated from the city centre to an industrial park in a nearby smaller town. Most team members commuted for about an hour and carpooled into the office. The company took over a rather large building split over two floors. The ground floor was split into five sections; the R&D department occupying about half of the floor, test labs for products and materials, a small clinic to meet with patients, a manufacturing line for specialised products in their catalogue, and a restricted area for their specialised inventory. Most of my time was spent on the ground floor in the open plan office space working at my desk or in the test labs, apart from some meetings on the floor above (mostly reserved for administrative and support teams). Desks were messy and filled with prototypes of different projects, documentation about the projects, and books on design and manufacturing processes or specific topics related to their projects. There was also a whiteboard with the names, objectives, and tasks of every project against a wall near the middle of the office. On Mondays, the team would gather around the board and discuss progress. These 'Monday morning meetings' were used to inform others on any tasks or tests to try and avoid conflicts in the labs during the week. There was also a canteen where team members were often found filling up on tea or instant coffee provided by the company.

On the first day, the director presented the company's design process during a staff meeting. She illustrated their process using Newman's (2002) Design Squiggle:

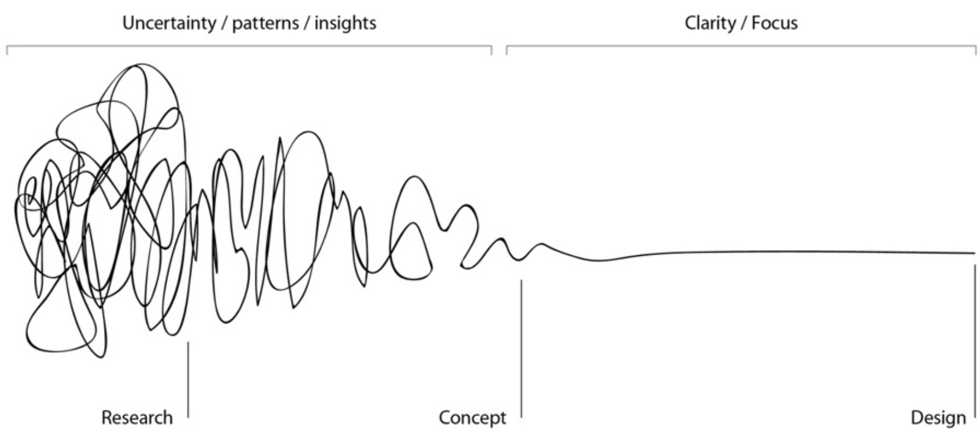

Figure 2: Newman's Design Squiggle

She explained that the process is messy and there is a significant amount of back and forth in the early stages. She then explained that this photo was taken from the Cambridge University Engineering portfolio, and "if we're using the same as them, then we must be doing something right". Later in the case study, around the fifth week, a project champion presented me with the process they use in projects: a three-step process of POP model, Alpha design, and Beta design. According to them, the POP model is a Proof Of Principle to demonstrate that the concept is technically feasible. The POP model relies almost purely on scientific principles and can take many years to test and develop into a functional product. Once the POP model is achieved, the team moves into the Alpha stage to optimise any major issues in the POP model such as weight or ergonomics. By the end of the Alpha design stage, the product shouldn't see any other significant changes ('freezing'). Next, the team enters Beta design where adjustments are made according to cost effectiveness, durability, manufacturing, and aesthetics. The Beta model is finally sent to marketing before entering production. The project champion explained how products almost never loop back into previous stages since (i) the POP model is validated and works, (ii) the Alpha model relies on the valid POP model principles and improves components or materials, and (iii) the Beta design addresses final issues that should be easy to resolve. The projects (*Element* and *Freedom)* were both in the final stages of Alpha design when designer involvement started.

3.2 The Story

This section provides a chronological account of the case study. It creates an overview through weekly highlights (i.e. main events, concerns, or affairs), and provides examples of significant instances that occurred during the week. It also mentions the means of data collection for each instance, and sometimes provides examples of the raw data from which the instances were taken. In total, 119 instances were recorded through journal entries on participant observations, direct observations, interviews, and audio and video recordings.

The instances highlighted were chosen for a few reasons: (i) They embody a variety of factors from Kleinsmann et al. (2007) and demonstrate the breadth of the findings, (ii) they often guide the story by following the development of team integration between more active or involved team members and the designer, or (iii) they were significant in some way to the designer —denoting a noticeable impact to team dynamics.

3.2.1 Week 1

The first week included meetings with new team members, skill-sharing sessions, settling into the office, catching up on the two projects, and starting ideation for them. The director provided an introduction on the first day and asked Ian, a younger engineer in the firm to give a tour of the facilities. Over the next few days, work began on the two projects, mainly understanding them, their progress, meeting some of those involved (who were available) and beginning on the projects by drafting to-do lists, finding materials, setting up my desk and sorting out company registration (i.e.

computer logons and ID badge). Friday was spent at a research clinic with some team members to meet a patient wearing an *Element* prototype.

Significant Instances Include:

- **Skill-share session**

  [Journal entry from direct observation]

  On the first day, I attended a Skill-share session; the Research & Development (R&D) department met for lunch, and a few fellow members shared new skills and knowledge from their project and practice. Jen presented on Bluetooth data exchanging, and held a question period. Sara, the R&D director, seemed to carry the session and gave feedback on most comments (ideas / questions). She seemed quite important to the session and team dynamics overall. She was light-hearted and joked with staff while still providing constructive criticism about projects, ideas, and staff members in the department. There was a good flow of questions, some of which unresolved and others explored in more detail. A single question could be discussed between multiple people, not just Jen, Sara and the inquirer.

- **Meeting *Element's* project champion**

  [Journal entry from participant observation]

  Paul, the project champion on *Element* seemed really busy and overwhelmed with another project, but took the time to talk about *Element* briefly, and how they were at the Alpha model. We walked around the office looking and talking about different pieces, and manufacturing processes for *Element.* During the talk, Paul shared some design objectives for the project:

  - 3 settings
  - 2 buttons
  - A computer chip board
  - Perhaps an OFF / ON function?
  - Magnet for a sensor along a main component
  - Neat packaging, with access to 5 AAA batteries

  We then went to my desk. When he noticed that there was no computer, he said he would request one with I.T., and asked if I knew how to work a CAD modelling program. I said yes, and he went on to say that the models were in a shared cloud vault. Then he asked what I should need in order to work on the project; I said I would start exploring the concepts a bit on my own, and if I could have the model physically and work on things through sketch. He agreed and left to work on his other projects while bringing different prototypes of *Element* from around the office throughout the day.

- **Finding materials for sketches and prototypes**
  [Journal entry from participant observation]
  Some time was wasted in the first days to find materials for sketching and model-making. The stationary cupboard was said to have any office materials needed, but didn't carry some design basics like pencils, sketchbooks, scissors, and tape. A few hours over the next days were spent asking different staff in the building where materials could be found. Finally, after looking in trash bins, in the storage mezzanine, in the plastics lab, and the presentation cupboards in the main lobby, I salvaged cardboard, modelling putty, and different types of meshing.

Figure 3: Example of Materials

- **Discussing with clinician in the car to see patient**
  [Journal entry from participant observation and verbatim]
  On the first day of the week, Jim asked me what I did. When I told him I was an industrial designer, he guessed that I was here to help them make the project look good. I light-heartedly disagreed and said some comments about optimising, user perception, and balancing technology, viability, and desirability. We then worked together on a few occasions throughout the week. When we arrived at a clinic Friday with Paul to meet a patient and get his feedback on the *Element* project, we met with the project's clinician, Peter.

  Jim: *Hey Peter, this is Max. He's doing the industrial design part, looking at placement of components, optimising space in Element and getting an understanding of the user, ergonomics, and packaging.*

  Peter: *Ok, great, so Max you're looking at the aesthetics, making sure it looks good?*

  Before I could answer, Paul and Jim responded:

  Paul: *He wants to see that the user is happy with it, things like sitting right, being satisfied with it.*

  Jim*: We need to reach the emotional part of the brain, rather than just the rational parts of design. We need to show stakeholders more on user satisfaction, and that's why Max is useful.*

3.2.2 Week 2

Over the second week, making prototypes had started for both projects, and all effort was put to bringing new ideas. During the week, Jim, the *Freedom* project champion asked for some sketches of innovative ideas for a quarterly presentation, and Sara wanted a presentation the next week on my progress with a few proposals of new *Element* designs. The week was fast paced, working on my own on the projects with intermittent feedback from both Project Champions on most days, and advice from others in the department.

Significant instances include:

- **Meeting with Jim**

  [Journal entry from participant observation and verbatim]

  Jim came to my desk and talked about his needs for the quarterly presentation. He wanted to have some sketches vectorised. At first I didn't understand what he meant by 'vectorised' and assumed he wanted to turn the sketch into a 3D model with CAD modelling. I thought this a bit of a waste of time if he just wanted general ideas.

  Jim: *Can you vectorise them? It's the easy part, sketching is the hard part since you need to actually know how to draw.*

  Max: *See, for me its the opposite, sketching is easy but vectorising is hard.*

  Jim: *It's easy because you just get to put some music on and trace out the lines…*

  Then I understood what he meant by vectorising, not in a CAD model, but just an illustration.

  Max: *Oh! I see what you mean, sorry I thought you wanted a fully formed 3D model.*

  Jim: *Just the contours in a clear view: Bolder lines outside, thinner lines inside. Start there, and we can see about things like shading to make it realistic.*

  Max: *Oh yeah, I can do that. I've done a full bike like that before, take a look.*

  Jim: *Maybe not realism yet, but help it look good as a concept. You're bike reminds of generative design actually, do you know it?*

  Max: *Not sure, do you mean those slimmed down models?*

  Jim: *Take a look on google, see something like that:*

Figure 4: Example of Generative Design

  Jim: *See, generative design takes a design, it calculates design optimisations based on the input and produces something that usually looks organic.*

  Max: *Ok, I see what you mean. I'll do some designs that keep this in mind. I'll look at biomechanics to find the strains and pulls.*

- **Conversation over morning coffee**

  [Journal Entry from participant observation and verbatim]

  I walked into the canteen to get a coffee about mid-morning. Dave, an engineer working with *Element* was there and started a conversation. We discussed some developments over the past week, and generating ideas.

  > Dave: *I think as long as you make it less bulky than the competitor, we've already won.*
  >
  > Max: *I've done some of that, but I'm presenting a sort of far-out concept as 'ideal' for the first quarter that changes up the whole concept but I think could really work!*
  >
  > *Dave: If it's presented, it needs to get a good reaction from Marketing. Marketing is happy if they can directly compare it to the competitor and show improvements against it.*

- **Talk with Larson:**

  [Journal Entry from participant observation / audio recording]

  Larson is the in-house clinician helping with the *Element* project. He had great advice, but younger engineers often struggled with him because of what they called 'generational gaps' about feminism, gender identity, and sexuality. I had questions about the relationship between users' body and the product and went to find him in the test lab. We discussed multiple topics. He shook my hand when I asked about one of the solutions: *"I completely agree but try getting that across in the technical design"*. We continued to talk and he advised me on limitations to the design. He also told an anecdote about one idea I proposed: *"I had resolved that problem ten years ago on another project, and when they made the new design, they didn't think of that or involve me on the project. It was quite frustrating as they didn't make use of the knowledge I had on the issue and it came back to cause problems in the design. They didn't ask as they were way behind on the development and, at a meeting when I brought it up they said 'this is the design we're doing'. They wound up with a problem we already solved 10 years ago.*

- **Inverting the module**

  [Journal entry from participant observation]

  Paul came to my desk for our planned update on ideas for *Element* and to talk about the presentation for next week. When I proposed one idea, he challenged it, but I had resolved every problem he brought up by chasing after answers from nearly everyone in the project over the week. By the end, he really liked the idea: *"I don't know why we never thought of that, it would be much safer… sometimes it just takes a new perspective"*. It was really validating to get positive feedback on the concept that others challenged me on over the week: Problem after problem had been finally resolved and challenged. Paul took the concept with him at the end of the meeting, and over the course of the day, most senior engineers had come to my desk to congratulate me on the concept. It was really motivating, and I felt the presumption that I was just here to make it look pretty was long gone. I felt like part of the team.

3.2.3 Week 3

Week three began with lots of energy, and pressure to complete the presentation due Thursday. The concepts for *Freedom* were done by Monday for their quarterly meeting, and the presentation for *Element* wrapped up Tuesday. Finishing on time was important since I was absent the following week for a conference, and Sara was leaving for the month before my return. Her feedback in person could only happen this week. Problematically, there were weather conditions that closed the offices from Wednesday to Friday. I sent an email to Sara and Paul with a PDF of the presentation Friday when we saw the offices would stay closed. Otherwise, it was business as usual with meetings on Monday and Tuesday.

Significant instances include:

- **Monday morning meetings**

  [Journal entry from participant observation]

  Every Monday, the R&D department met to discuss ongoing projects, look at task allocations, and clarify different material, testing, and manufacturing needs for projects to avoid overlap and optimise work flow across the department. In a project outside of this research scope (i.e. *Freedom*, and *Element*), an asset manager, project champion, and engineer were involved in the final steps of prototyping:

  Asset manager: *We're working with someone to validate the material.*

  Project Champion: *Do we have the updated material on the CAD model yet?*

  Asset manager: *No, not yet…not until the material is finalised.*

  Engineer*: Can we go into user testing with this one in the meantime, is it similar enough?*

  Asset manager: *I don't think so.*

  Project Champion: *Have we even gone into testing with this new material? Can't we start testing at least for other parts of the project?*

  Asset manager: *No…not yet.*

  At this point, the engineer and project champion turn to look at Sara, expecting an answer.

  Asset manager: *We have to go through project auditing first, but there's some big delays and we don't really know why. We put it in quite some time ago.*

  Sara: *Yes, well the company we normally used is no longer with us so senior management is looking at new ways to audit for now.*

- **Meeting about Monday morning meetings**

  [Journal entry from participant observation and audio recording]

  Tuesday, a few younger engineers were selected by Sara to have a somewhat secretive meeting about Monday morning meetings and how to improve them. This one was led by a younger project champion, Amy, who was mandated to relay ideas back to management. As a new team member, I had only assisted a few meetings, and asked for more information before we started.

> Amy: [Monday morning] *meetings only happened with like the heads of department in a small room, and then there were some minutes that would get distributed. But then we decided that we would do a stand-up thing, because it used to last like an hour and a half every Monday, and it was a waste of time. And then everyone would get like secondhand information. And the whole point of making it shorter was because no one wants to… it's not necessary to everyone to debrief what's been happening with the project. The whole point is 'this is what we're gonna do this week and this is what is going to stop us'. So then Sara or a counterpart will try to find a solution. So the conflict that may happen will get solved straight away. That's the whole point, but we're obviously not achieving that, are we?*
>
> Max: *I think we saw that yesterday between the asset manager about auditing the prototype, then the project champion responded, then it bounced back and eventually went to Sara. I don't really know if it was resolved by the end of it because I didn't really understand what was going on with the whole auditing thing.*
>
> Ana: *Haha, no exactly, it didn't actually.*
>
> Max: *Aha, ok so it didn't get resolved, but it seemed to be going somewhere. But maybe like you're saying, everyone is agreeing on something but it's not going anywhere.*
>
> Ana: *Yep. So that's the whole point why we're here. You may all have different opinions. The decision of that format was made with a group of senior staff, but perhaps we can propose other changes.*

The meeting was filled with ideas on the format, on the aftermath, etc… There were loads of barriers, and things we agreed on and things we negotiated. We pulled out some stronger ideas but there was a common *'whatever'* that highlighted how we all didn't quite know how to give a fully-formed and improved format.

3.2.4 Week 4

After a week away in conference, I returned to the office and met with both project champions for *Element* and *Freedom*. I hadn't received feedback on the presentation, and the quarterly meeting had been delayed. It seemed both project champions were preoccupied with other projects that week. I felt lost and didn't know where to go with either project. There was also talk of going to an outsourced company that were helping with *Element* and *Freedom,* but it had yet to be formalised. As Sara was away, and unavailable for the rest of the month, most people were working from home. I had very little to do, and worked on personal research for three days.

Significant instances include:

- **Meeting with both project champions**

  [Journal entry from participant observation]

  Had a quick meeting with Paul this morning, but it felt a lot like 'ok' talk: I would talk about ideas, and he acknowledged them. Another engineer came to talk to him and ended our meeting. He went to work on other projects in a lab the rest of the day. I didn't have the chance to prompt for next steps, and didn't really know where to go from there. Still, I tried to generate some ideas (taken from notebook): *Possible next steps: Maybe look at how to install it, but only nuts and bolts since the dimensions haven't been set yet…maybe do some really wacky designs again… If I were an engineer what would the next step be? I don't know! That's pretty frustrating…*

  I intercepted Jim after a meeting. He mentioned going to the outsourced company, but has yet to talk to their director about it… he showed the quarterly presentation draft and where he planned to put my designs. We discussed the design a bit, but it felt like the talk I had with Paul just before. I wanted to get a head- start and direction this time. When prompted, he said we had to wait a bit longer until the alpha design was set (a more formalised prototype nearing final design). Maybe that was an indication for me: time to start looking at optimisations, maybe try to find off-the-shelf solutions, but I didn't jump on it. Was that my chance? I didn't jump on it because I doubted I knew enough and would disappoint them or fail, causing more grief or wasted energy.

- **Testing *Freedom* with academic researchers**

  [Journal entry from participant observation, verbatim, and video recordings]

  I was invited to watch *Freedom* tests with a user. They were trying out new programs for the automated functions that researchers from a University were hired to develop. I took the opportunity to interview the user to gain insight on how he conducts his day with and without mobility-assisting products, and met with the researchers:

  Max: *Hi there, I'm an industrial designer involved on Freedom for a few months.*

  Researcher 1: *What are you doing as an industrial designer on the project?*

  Researcher 2: *He's gonna make our stuff pretty.*

  Max: *Hopefully, I'll be able to do little more than that, but it is one part of the project.*

  Researcher 1: *There's more to that in industrial design.*

  I felt that there was tension between us in the start of the meeting. One researcher seemed frustrated if I asked the user to conduct moves that they hadn't anticipated.

  Jim: *Great, can you walk a bit faster and turn quickly. That works, Max what are you thinking?*

  Max: *Could you try tripping up a bit, like if you didn't notice there was a ledge to the sidewalk. Try to catch yourself .*

  User: *Like this?*

Researcher 2: *That isn't set in the program. Freedom should be set into stair mode if he's going down a ledge.*
Max: *Sure, but accidents might happen.*

- **Meeting with Paul**
  [Journal entry from participant observation]
  I came into work Friday after only doing half-days before since Jim and Paul were working on other projects from home and Sara was still away. I emailed Paul in the morning about looking at some of the papers, or research and products they published and developed in the past - giving myself something to do. Instead, Paul sent me new developments for the structure he'd been working on for *Element*. He called me and we discussed dimensions, positioning, manufacturing, and costs. He introduced a new constraint about accessing one of the components. We discussed some ideas about abrasion, and I eventually proposed that we wrap the components in a rubber casing that moulds itself to the body. This way, we could send into testing and report on where it was most damaged to better design the final concept. We both agreed and he went online to order materials, but administrative issues made it difficult to release money to order the casing, and once cleared, delivery would set us too far back.

3.2.5 Week 5

This week was also relaxed with little to do. Both project champions were preoccupied with other projects and working from home most days. Most younger engineers were working in the office a few days a week, but also working from home. There was a common consensus between us that there was little to do and we were spending our days reading up on research online and waiting for tasks from others. I wanted research to move forward and collect data so I decided to organise a brainstorm session with two younger engineers on the general idea of energy storage for the products (batteries, charging ports, …).

Significant instances include:

- **Interview with Vicky and Ian after the brainstorm session**
  [Journal entry from interview with audio recording]
  The interviews were individual and lasted about 30 minutes each. Questions were centred on what was expected out of the session, and on the flow of the session. To try and amend objectivity, I often reminded them to separate myself in two: *"During the brainstorm, I was a designer, but now I'm a researcher who wants to know more on team dynamics with the hopes of improving teamwork. So feel free to talk about things that 'Max'* [myself as the designer] *did that you think hindered the flow, or made it more difficult for you to participate or be effective".* Vicky and Ian are both electrical engineers involved in *Element* but working on different areas of the project.

Vicky started to understand what was asked of the brainstorm after I (the designer) provided some examples. It was close to what she thought was expected, but - in terms of innovating - thought that much of the brainstorm was inefficient since the ideas were too outlandish. Still, she said "*it was interesting to have a different conversation to what I'm used to and talking about other things. I don't know what they all have to do with each other, but I'm guessing that's part of what was expected our of your style of brainstorm. For myself, if it isn't feasible, it isn't useful, and sort of naive to think about".*

Ian said his expectation of a brainstorm was very close to what I seemed to want: "*It was quite similar to what actually happened, in the sense that a group of us throw ideas out and have a discussion a people start bouncing ideas off of each other. Someone says something that triggers something in your mind to say something else and just a whole bunch of ideas —maybe not feasible— come to mind. It escalates and you sometimes come back to the focal point and choose things that are eventually feasible".* He was surprised that the brainstorm drifted into other topics that left the core subject, but ultimately saw value in them: *"I didn't expect it to be so 'out there', which is like the purpose of a brainstorm but I wasn't expecting so…I expected it to be more on the topics of design […] but I guess that's how we can get so innovative, by being carried away by the discussion even if what we're talking about isn't feasible".*

- **Meeting with Jim and the director of the outsourced manufacturer**
  [Journal entry from participant observation]
  On the last day of the week, Ben —director of the outsourced manufacturer working with *Element* and *Freedom*— visited our office and Jim introduced us. We talked about my working from their offices for a few days. He asked about my priorities in the project, and what I did in order to plan meetings in advance with key members in his team. When he asked about the tools I would need, I brought him to my desk to show him the process. We then discussed my involvement at his office:

  > Max: *I'd like to sit with engineers involved in the two projects and see what they're doing, how they're thinking about the projects. My goal is to use this to reflect on how we can change the products to better adapt to the users' perspective, not just technology or economic needs.*
  > Ben: *Great, ok. We've never had anything like this before so I don't really know…I need an idea to go back with on how we can involve you.*
  > Jim: *Your company works on the tech, and we work on taking it to the market. We need to get increasingly involved with clinicians and manufacturers, people working from their knowledge bases. Max is working outside of [our objectives] to address problems from a bigger context.*
  > Max: *Exactly! In that way, I want to have a general understanding of everything to find the best compromises…well not compromises, but negotiated outcomes between everyone involved.*

We mutually agreed and Jim and Ben continued to discuss the project. However, I couldn't understand them as they spoke through the hardware and manufacturing methods too quickly. It really felt like a missed opportunity to participate with them.

3.2.6 Week 6

An email came in over the weekend from Ben at our outsourced company inviting me to work in their office (a few hours away) from Tuesday until the end of the week. Monday, I worked with Paul on some details for *Element* that would be useful to share with Ben and his team. I also prepared an information sheet for the team: guidelines for my involvement, my research, and my design objectives (see annex 5). The week was spent working with them on both *Element* and *Freedom,* and learning about their manufacturing process.

Significant instances include:

- **Talking with Aaron**
  [Journal entry from participant observation]
  Aaron was a younger engineer at the outsourced company working on *Freedom* creating a printable 3D model using additive manufacturing. Beforehand, Ben sat with me for about an hour teaching me how to design based on the constraints of using additive manufacturing. I sat down with Aaron and asked him to explain the whole system of the product to me. We went through everything, and I needed him to repeat and explain lots of components more than once. One component took a while to explain, we used one of his diagrams to clarify, but I struggled to understand it at first. I asked him to talk me through it as I drew my own diagram of what he was explaining. By the time we finished, we saw my diagram was actually almost identical to his, apart from a few symbols. From there we both understood each other really well. We started to be able to talk at the same level and negotiate the design. We were looking at a cut view of the product in a CAD model. He printed it out and we started playing with the components. After nearly 2 hours he looked at the final design we made, sighed and looked at me: *"This is going to be a lot of work"*. I apologised knowing the work ahead and he responded: "*No it's fine, it's a really good improvement, it's just going to derail my workload but we should really put this into the design".* We sent the final improvements to Jim and Ben for approval.

- **Talking with Miranda**
  [Journal entry from participant observation]
  I went to talk to Miranda, a member of Ben's team who worked directly on *Freedom* developing new ideas to optimise the design. Her job was similar to mine in many ways: she was a general problem solver for the company. She presented a design that thought to solve one of our problems with weight distribution and managing the power storage. When I saw her design, it reminded me of an idea I had

a few weeks prior that was rejected. I explained to her why it couldn't work and she was a bit frustrated that no one had told her those limitations : *"we wasted all this money and time on something that could never work"* she said. However, I really thought her idea was interesting. We sat down together and tried to imitate her principle and turn it into a viable solution. [Note: By the end of the case study, the idea we built together based on her idea was implemented into one of the final proposed designs of the product].

- **Talking with Ben about design and engineering**
  [Journal entry from participant observation]
  Since I was only with the outsourced company for a few days, they did not provide a swipe card to access every area. This was fine since, once in the main office I could access most areas needed. However, the design of the building meant that I couldn't access the bathrooms near my office without a card and had to use the executive bathrooms upstairs, crossing the glass windows of company directors including Ben. This turned out great because every time I passed back in front of their offices, Ben called me into his office and we talked about different ideas or progress as emails from others arrived in his inbox. One afternoon, three younger engineers were tasked with optimising some of the components for a different project using additive manufacturing principles. I helped them out and they gave me credit in their email to Ben. When I passed by his office from the bathroom later that day, he invited me in and we talked about design and engineering.

  He explained that for a long time in his industry, designers and engineers were opposites. It was always a challenge to negotiate with a designer. He explained, pointing to opposite sides of the room with both his arms that "*design is in this corner making products lighter and better, but we engineers pushed for the cheapest option. Sometimes there were arguments to make changes now, but we always went for the cheapest option, usually something off-the-shelf, mass-produced somewhere else. But now, with advancements like additive manufacturing, the complex forms we can make are cheaper, lighter and better. I think engineering and design can finally speak the same language".*

3.2.7 Week 7

After completing the week at the outsourced manufacturer, I came back with lots of notes and changes made to the designs. We talked with Jim and Paul on the phone over that previous week, but there was still a debrief to have with them both, although Paul was still very preoccupied with another project for the week. The week was otherwise spent building off of feedback from the debriefs.

Significant instances include:

- **Debrief with Jim**

  [Journal entry from participant observation]

  We sat down in the afternoon of the first day back to talk about my time in the other company. I was expecting a discussion based on the notes I had taken and the design drafts that were made up. I prepared a checklist of everything I wanted to talk about. His first question was *"what did you get out go your time with them"*. The question threw me off, I found it was more about what we accomplished together there, not what I 'got out of it', though I could have misunderstood what he meant. I shuffled through the papers and started explaining some of the new designs and new developments thanks to their manufacturing process. After making these points, he said: *Okay, and what did you learn"*. I think he wanted specific details but I wanted to address the broader concepts first before perhaps getting lost in the specifics. I moved into some specifics, looking at the conflicting understandings between everyone involved. I mentioned that everyone, Ben, Aaron, Miranda, Jim (himself), and myself had different visions of the final design, and working with our own views. Jim seemed frustrated as I was explaining concepts, shuffling through sketches, mock-ups, and my journal. Eventually he said that our company gave the design, and their job was to deliver on it. Since my time at the company (case study) was coming to an end, he proposed I take my notes and provide a reference book that they could give to another designer they often hired for the final design. I tried presenting another concept that Ben liked and could potentially significantly reduce costs. Jim was interested and wanted me to ask Ben for some numbers: *"If cost effectiveness and manufacturing are intertwined, there must be numbers to calculate this.".* I agreed that there could be numbers but I didn't see the worth in asking if we didn't have a final design yet. It seemed he didn't want to work on our 'hunch' without proof.

- **Talk with Kyle**

  [Journal entry from participant observation]

  I was writing up the reference booklet for *Freedom* a few days after my meeting with Jim. I got to a section about one component and it sparked an idea I thought was worth exploring. I wanted to ask Jim but he was away, as was Larson the clinician. Instead, I went to another senior Engineer, Kyle. I walked up to his desk with the *Freedom* prototype at hand and some quick sketches of my idea. He provided me with information about how this component worked with the users' body. He said this new idea could solve some of the problems we had with the product, but not before mentioning, and reminding me before I left his desk, that the way it is designed now has been tried and tested; There would need to be a good reason to change it, and making the change required solid evidence that it was worthwhile.

3.2.8 Week 8

Sara returned in week 7 but was busy with meetings all day since arrival. Monday, she came to my desk and asked about my progress. We talked together for about an hour. We agreed that I was almost done with my involvement and she proposed I hold a skill-share session about both projects and my design process next week. After the meeting, I spent most of the week working on the presentation and finishing up the reference booklet for *Freedom*.

Significant instances include:

- **Talk with Sara**
  [Journal entry from participant observation]
  Sara pulled up a chair to my desk and inquired about my progress. We went through different prototypes and referred to the presentation from week 3 (she admittedly had not reviewed). She proposed I make a presentation on my design process, some of the differences I found between theirs and mine, and present some concepts with my reasoning for the changes from one prototype to the next. We also talked about making more innovative concepts before I left. She proposed a concept she already mentioned in week 2. It prompted me to show some of my more 'radical' designs. But, it became quickly frustrating since she focused on whether they were feasible with today's technology and knowledge. At that moment, I felt trapped between everyone's reasoning and expectations (Sara, Jim, Paul, and my own). I sensed contradictions and couldn't find how to strike a suitable balance.

- **Working on the presentation**
  [Journal entry from participant observation]
  I worked on the presentation from home Tuesday and Wednesday. We all worked from home often when we needed to search on the internet or create presentations since the computers were quite slow and crashed often. The Internet connection was very poor, especially in the afternoon because they shared large loads of data with their overseas company which was prioritised over staff work-stations. I arrived in the office Thursday and two younger engineers near my work-station welcomed me back jokingly. Our area of the office was far from anyone else and the other desks near us were used by staff that were rarely present. I came into the office almost as a courtesy to the project champions who ended up working from home that day anyway. By lunch, I returned home to finish drawing up some concepts, working on the reference booklet, and building the skill-share presentation.

3.2.9 Week 9

This week was much more energised and busy. I presented Tuesday afternoon and from there, my willingness to work on the project resurged. Project champions were more available and opinionated. It was a great week for debate, discussion and rethinking Research and Development.

Significant instances include:

- **Presentation at Skill-share session**

  [Journal entry from participant observation and audio recording]

  The presentation started around 13:30. I began with a few slides on the term 'Design Process' and the many definitions and methods used within it. I referred to the article by Kim & Lee (2010) on design and engineering in product design which argues that engineering is concerned with 'Product working functionality', while design focuses on 'Human using functionality'. I presented the company design process (Pop, Alpha and Beta Design) and then explained my own broadly (see figure 5 which shows the rather messy, non-linear process and main design stages), then specifically for both *Element* and *Freedom.*

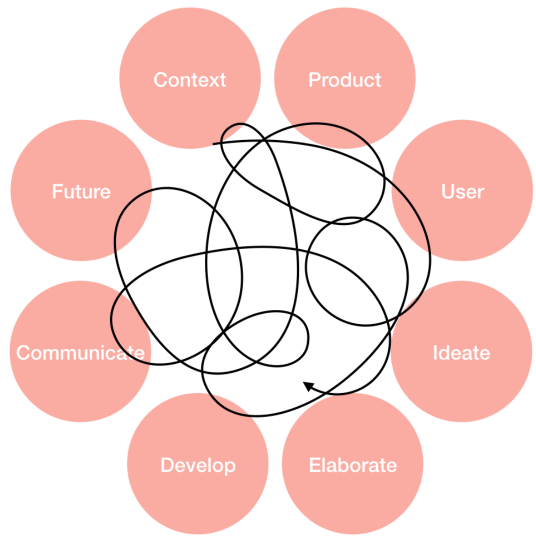

Figure 5: Proposed Designer Process

  The presentation was followed by a question period that saw team members asking about various topics that really seemed to bridge their understanding of designing and mine. They asked questions like: *"What categories of question should we ask early on in the design process to anyone other than the engineers. What should we be asking to the users, the clinicians, or the support teams to help us improve the design"*. They also questioned the relationship between theory and practice*: "To what point do you rely on theory, research that already exists on topics like ergonomics for buttons and position, and practically testing an idea with users?"*. They also had observations like*: "It's true that in the summer, no one wants to wear those ugly pink compression stockings. There's likely truth in saying that looking at trends, not just in our target group, is a successful means to a good product; clever companies are standing out by relying more on fashion"*.

- **Talk with Paul, Tyler and Oren**

  [Journal entry from participant and direct observations and audio recording]

  After the presentation, there seemed to be a lull in productivity that afternoon, but an electricity across the department as people seemed to debate their work based on some of the proposals, methods, and ideas from the presentation. When I pointed this out to Ian, he agreed and added that *"It's provocative and sparks conversation because it's not fact but it still works"*. I walked into the electronics lab where Paul, Tyler and Oren were talking about design and innovation. Paul said that "*we need more sessions like this to remind us that we're doing this for the user"*. [Note: It felt really validating; I wrote in my journal in bold caps that *"I FEEL ALIVE",* meaning the afternoon gave me a boost of energy and willingness to work more on the projects and with the team]. There was also debate about innovating:

Oren: *We need a market takeover, invest like Dyson and more radical products.*

Tyler: *But we're not that kind of company.*

Paul: *We've got a lot of talented people in this company and we can do a lot with nothing. Maybe we're just not motivated.*

Oren: *I wouldn't know where to put it in my time sheet…we've got no costs for time allocated to R&D, only ongoing projects at the moment…*

3.2.10 Week 10

Most of the time during the final week of case study was put into working on *Element* designs and the reference booklet for *Freedom.* There were multiple work sessions with Paul, and most of my time was spent in the test labs and at my desk drawing up new ideas. I also worked more with Ian on developing 3D models of the sketches as he was much more efficient than I for building complex forms in the modelling software, and wasn't busy with other projects.

Significant instances include:

- **Lights with Paul and Tyler**

  [Journal entry from participant observation]

  I went to Paul's desk to talk about *Element*. We had previously agreed on a single lighting system that used multiple LED lights that refracted off a piece of frosted plastic, but his new prototype had multiple lights side by side. I questioned him on this and he explained that Tyler said it would be impossible. I wanted more information, and asked to discuss together further with Tyler.

  Max: *Why is it unfeasible, I thought we resolved that?*

  Paul: *I'm not sure, Tyler said it wouldn't be possible.*

  Max: *Did he explain why?*

  Paul: *No, not really I suppose.*

  Max: *Can we go ask him?*

  Paul: *Sure.*

  We went to the electronics lab to find Tyler, who explained that given the multiple functions, the system would require multiple lights. I agreed with him, but explained that the different coloured lights would accomplish that, and smaller lights would likely make it difficult to dissimulate from one to another. We started debating the problem until we realised that no one quite knew how many functions the system would have; or how many lighting indicators the product would need. All three of us continued to debate the number of functions and lights needed. The conversation finally hit a sort of breakthrough:

Tyler: *"If there are five functions then, as a user, I would want 5 lights.*
Max: *Wait, ok that's your opinion on it then, your personal preferences. That's fine, but it's no longer a matter of technology or feasibility, just perception and preference. Personally, I want a single block of light because I think it would look much better in the final design, and I think I would only need a single light as a user. My choice is quite minimal, I know that, but 5 lights seems overwhelming and confusing to me; What if we look at the functions you want and see if we can't meet somewhere in the middle? That might make it both readable for me, and clear enough for you.*

We both agreed and came to the conclusion of three light blocks side by side. One indicating battery power with two colours (Full or Low / Empty), one for the main function (passive or active), and another for the two specialised movements.

- **Nancy, pencils**
[Journal entry from participant observation]
On the last day, I began to clear my desk: archiving sketches, returning prototypes to Jim, Paul and different test labs, and packing away my personal items. When I found out in Week 1 that their stationary didn't have pencils, I had asked administration to order some but they told me it required a form (which I couldn't access) and would take about 6 weeks. Instead, I went to a store and purchased my own; two 3H, HB, and 6B pencils, a sharpener, and an eraser. As I put things away, Nancy, an engineer who worked beside me, came to ask for the pencils and sharpener. She admitted to using them when I was away and really liked the feel of a pencil more than the company pens. I gladly gave them to her and suggested she ask Sara to order some. She suspected that administration wouldn't clear the costs for them and accepted to buy her own out of pocket when the time came. I suggested where to buy them and explained pencil hardness and softness to her so she could pick the best ones for her.

Chapter Four: Data Interpretation and Limitations

This chapter, over four sections, interprets the data collected from the case study on team integration in a new product development setting and provides some limitations to the overall research. The first section shows two examples on how the instances are analysed, followed by a table that presents an analysis of the instances against the 'factors and levels' proposed by Kleinsmann et al. (2007) (see section 1.3). The second section relies on the case study data and the analysis table to describe and better understand team integration. It also reflects on the use of Kleinsmann et al.'s categorisations model: Reporting on what it does well, its shortcomings, and some proposed amendments to improve it. The third section seeks to further describe and understand team integration through different perspectives taken from remaining concepts of the theoretical framework. Finally, the fourth section presents limitations on the research regarding the case study, the results, and the analysis, respectively.

4.1 Data Interpretation Through the 'Factors and Levels' to the Development of Shared Understanding

Different events, actions, and reactions within each of the 119 instances embody different proposed factors in the form of either enablers or barriers (see section 1.4). This research also adds the option of 'overcome barrier': a challenge / barrier that members resolved or overcame which then positively influenced the development of shared understanding. Before presenting the table, two examples of instances - taken from Chapter 3 - are analysed to explain how factors and levels were identified:

Example 1: Talking with Aaron (Week 6)

Aaron was a younger engineer at the outsourced company working on *Freedom* creating a printable 3D model using additive manufacturing. Beforehand, Ben sat with me for about an hour teaching me how to <u>design based on the constraints of using additive manufacturing.</u> I sat down with Aaron and asked him to explain the whole system of the product to me. We went through everything<u>, and I needed him to repeat and explain lots of components more than once</u>. One component took a while to explain, we used one of his diagrams to clarify, but I struggled to understand it at first. I asked him to talk me through it as I drew my own diagram of what he was explaining. By the time we finished<u>, we saw my diagram was actually almost identical to his, apart from a few symbols. From there we both understood each other really well.</u> We started to be able to talk at the same level and negotiate the design. We were looking at a cut view of the product in a CAD model. He printed it out and we started playing with the components. <u>After nearly 2 hours he looked at the final design we made, sighed and looked at me: *"This is going to be a lot of work"*. I apologised knowing the work ahead and he responded: "*No it's fine, it's a really good improvement, it's just going to derail my workload but we should really put this into the design".*</u> <u>We sent the final improvements to Jim and Ben for approval.</u>

In this instance, three factors were reported:

1. **The applicable experience of actors, as an enabler**
    - Thanks to a prior understanding of additive manufacturing and experience with the product *Freedom*, we understood one another, our approach to designing, and our objectives. As Kleinsmann et al. (2007, p. 56) explain "the enablers within this factor deal with the experience that actors have with the regular tasks within the design project. They use their experience from earlier projects to do their current design task".
2. **The similarity in language, as an overcome barrier**
    - At first, there was a misunderstanding between myself and Aaron. I could not understand his way of communication (i.e. the diagram). However, after taking time to explain and work on a new diagram together, I started to understand his way of presenting the system and his terminology. I noticed that his explanations were easier for me to understand. Afterwards, there was an ability to exchange ideas.
3. **The interest in a task, as an enabler**
    - Both team members were motivated to resolve the problem. Nearly 2 hours were spent working on the project, and while tired and a bit discouraged by the work ahead, both were interested in not only completing the task, but sharing the results with others involved in the project.

Example 2 : Working on the presentation (Week 8)
I worked on the presentation from home Tuesday and Wednesday. We all worked from home often when we needed to search on the internet or create presentations since the computers were quite slow and crashed often. <u>The Internet connection was very poor, especially in the afternoon because they shared large loads of data with their overseas company which was prioritised over staff work-stations.</u> I arrived in the office Thursday and two younger engineers near my work-station welcomed me back jokingly. Our area of the office was far from anyone else and the other desks near us were used by staff that were rarely present. I came into the office <u>almost as a courtesy to the project champions</u> who ended up <u>working from home that day anyway.</u> By lunch, I returned home to finish drawing up some concepts, working on the reference booklet, and building the skill-share presentation.

In this instance, three factors were reported:

1. **The organisation of resources, as a barrier**
   - Internet quality and computer issues were continually described by many staff members as a longstanding issue that hindered efficiency. The problem was not resolved during the case study.
2. **The interest of a task, as a barrier**
   - ‘a courtesy’ implies that attendance had little to do with the tasks to fulfil in the project. The designer did not know of tasks (or their interrelations) in the project.
3. **The rigour of project planning, as a barrier**
   - As team members stayed at home or returned home early, the project lacked planning from the designer’s perspective. While the designer came into the office, his co-workers did not. Still, had they arrived during the afternoon, the designer had already left.

The examples presented above illustrate the reasoning used throughout the analysis to identify factors to the development of shared understanding. The table that follows presents the identified enablers, barriers, and overcome barriers for each recorded instance (Note: Interpretation of the table will follow in section 4.2). The enablers are represented by a green square with the letter ‘ E ’, barriers are represented by a red square with the letter ‘ B ’, and overcome barriers are represented by a blue square with the letters ‘ OB '. The factors are referred to as follows:

- **Actor level**
  - TK**:** Transformation of knowledge
  - SL : Similarity in language
  - EX : Applicable experience of actors
  - EI : Actors’ empathy about the interest of a task
- **Project level**
  - IP : Efficiency of Information Processing
  - QD : Quality of project documentation
  - DL : Division of labour
  - PP : The rigour of project planning
  - PQ : Controllability of product quality
- **Company level**
  - OR**:** Organisation of ressources
  - ATR: Allocation of tasks and responsibilities

Table 2: Factors to the Development of Shared Understanding by Instance

Date	Instance	Actor Level Factors				Project Level Factors					Company Level Factors		Notes/Special
		TK	SL	EX	EI	IP	QD	DL	PP	PQ	OR	ATR	
12.21	Confirmation Email				E								
1.30	Email Date				E								
2.12	Skillshare 1	E			B			E					
2.12	Presentation Design Thinking R&D director							E					
2.12	First meeting	E			B								
2.13	Paul: needs	E			E			B					
2.13	To do List								E				Solo
2.13	Components with Tyler and Paul	B	OB										Substantiation
2.13	Jim meeting 1							E					
2.13	Starting point: what do you need with Jim	E	E		E		E						
2.13	Desk Allocation										OB		
2.14	Sara intro to Ian gives Tour				E						E		Click
2.14	Tables at Lunch										OB		
2.13	Stationery Closet										B		Substantiation +/-
2.14	Jim Meeting 2	B	OB	E									
2.14	Design Priorities								E				Solo
2.14	Lunch Sara comes to get me										OB		
2.15	Low info (Paul)							B					Substantiation
2.15	Explorations Sketching + Prototypes		E								B		Solo
2.15	User 1 Interview Questions			E									Solo
2.15	I.T Installs Computer										B		
2.16	Paul and I discuss Ians ideas		E		E								
2.16	Charging method			E			E						Implicit Knowledge
2.16	Leg Bag Sewing			E									
2.16	Peter in Car	E		OB	E								Designer Involvement
2.16	Hypothetical Thermodynamics				E								Click
2.16	Our Values - Company		E		E								
2.16	Interview with User 1			E									
2.16	Train Ride separate										B		
2.16	Ugly Box for Product			E									Click
2.19	Presentation Vectors		OB										
2.19	Generative Design		E	E									
2.19	3D Printing		E								E		
2.20	Sketching and Models		E				B						Solo
2.20	Amy Materials + Plastercine			E		B	E						Implicit Knowledge
2.21	Sketch + Plan views	E											Solo
2.21	Sara Presentation								E				
2.21	Director Ideas			E	E								
2.21	Dave Morning Coffee						OB						Substantiation
2.20	Vicky Jealous (CAD modelling)				E			OB					
2.20	Cello Tape and Scissors				B						B		
2.20	Printing - Showing how to use										E*		*Enabler and Barrier
2.22	Planning Presentation		E	E									Solo
2.22	Photos and Presentation			E									Solo
2.22	Talk with Larson (Product)			E									
2.22	Talk with Larson (Involvement)			E	B	B	B						
2.23	Inverting the Module	E		E									
2.23	Doubting Introspection				B								Solo
2.23	Foot Design Views	E											Solo
2.26	Monday Morning Meeting 1							E	E				Solo
2.26	Drawings for Ankle	E	E				E						Solo
2.26	Materials Auditing					B					B		Lack of reasoning
2.26	Monday Morning Meeting 2					B			OB				
2.27	Meeting about Monday Morning Meetings			E	E	E	B	B	B		B	B	
2.26	CAD model saving (vault)				E			B	B		B		
2.27	Drawings for presentation (with Ian)		E	E									
2.27	Systems Engineering	OB	OB										
2.28	Plan workload					B		E					Solo
3.1	No presentation								B				
3.1	Presentation email sent					E	E						Solo

Date	Instance	Actor Level Factors				Project Level Factors					Company Level Factors		Notes/Special
		TK	SL	EX	EI	IP	QD	DL	PP	PQ	OR	ATR	
3.12	Monday Morning Meeting 3								E				
3.12	Research Students		OB		OB			OB					Designer Involvement
3.12	User Testing			E	E								
3.12	Mention Manufacturer visit			E					B				
3.12	Paul meeting	B			B			B					Loss of Self
3.12	Jim Meeting 3	B			B			B					Loss of Self
3.15	How to Work with them?	B			B			B					Loss of Self
3.15	New Design Constraints			E	B		OB						Implicit Knowledge
3.15	Rubber Personalising			B									
3.15	Plan workload			E	E			B					Solo
3.15	Organising Product Flow (Scénario d'usage)			E	E			B					Solo
3.15	Packaging Ideas			E	E			B					Solo
3.16	Absent 1				B								
3.19	Brainstorm with Ian and Vicky	OB	OB		B			E					Click
3.19	Meeting Ben		B			E		E	E			E	
3.19	Jim and Ben		B	B	B								
3.22	Role in Office							B				B	Loss of Self
3.22	Substantiation		OB										
3.22	Casing Materials	E			E								
3.22	Pogo Stick Idea			B			B						Substantiation
3.23	Blue Peter Email			B									Designer Involvement
3.26	Prep Design sheet (sensemaking)	E	E										
3.26	Feeling Proactive							E					
3.26	Discussion with Paul over phone				E		E						
3.26	As effective as possible plan				E								
3.27	Aaron Valve Plan		OB	E	E								
3.27	Lunch meet		E	E		E					E		
3.27	ISO Spool			E			OB						Implicit Knowledge
3.27	Heat Control		E		E								
3.28	Manufacturing Process Meeting				E	E	OB			E			Implicit Knowledge
3.28	Optimisation Relics			E	E	B	OB						Implicit Knowledge
3.28	Battery Idea with Miranda			E			OB						
3.28	Build Direction			E	E								
3.28	Sean: pumps	E	OB	E	E	B	B						Implicit Knowledge
3.29	Designer Engineer Comparison		E	E	E						E	E	
3.29	Office Setup										B		
3.29	Bathroom Pass		E								OB		
3.29	Furniture										B		
3.29	Jeff Meeting		OB	E									Designer Involvement
4.3	Jim Meeting 4		B	B			B						This is a strange one…
4.4	Kyle Talk			B	OB						B	B	Substantiation
4.5	Expenses MOOG										B		
4.5	Sara Ideas			B	E		B	E					Implicit Knowledge
4.5	Amy Presentation (timeslot and Info)					B							
4.7	Deliberations	B							B				Solo
4.7	Involvement							B	B				Solo
4.9	Finances Drama										B	B	
4.9	Skillshare 2		E				E						
4.9	Monday Morning Meeting 4				E						E	E	
4.10	Absent 2							B	B				
4.12	Leave Early				B			B	B		B		
4.17	Presentation	E	E	E	E						B		
4.17	Afternoon Electricity			E	E								
4.17	Paul, Oren & Tyler	E	E	B	B			B	B		B	B	
4.17	Talk With Ian	E											Substantiation
4.18	Light Idea with Paul	E		E									
4.25	Lights with Paul and Tyler	E		E		OB	OB		B	E			
4.25	SW model with Ian	OB	OB	E	E								Click
4.26	Nancy Pencils	E									B		

4.2 Describing and Understanding Team integration

This section describes team integration through the results table, stories, instances, and factors reported in the case study through (i) the actor-level, (ii) the project-level, and (iii) the company-level as well as (iv) a reflection on the use of factors (and levels) as a means of analysis.

4.2.1 Actor Level

Overall, actor-level dynamics were helpful, and mostly enabled team integration. For instance, the table shows almost only enablers to the development of shared understanding between team members over a three-week period, from February 12 to 27. Overall, it is visibly obvious that the volume of enablers outweighs the other two forms. Team members discussed challenges in the project and explored solutions from their respective interpretations, but also communicated with one another, shared their views, and often developed a state of connectedness (Nonaka, 1994 in Dong et al., 2013). They developed a shared mental model of the project and objectives, although there were sometimes significant and problematic differences between team members. This was the case in talking to Miranda and Jim about the different knowledge each person in the team possessed regarding specific design limits. Still, most enablers and some overcome barriers widened design boundaries and helped team members build ideas individually and with another. As they became more integrated, their ideas were "not just shared, but shared and multiplied" (Latch Craig & Zimring, 2000, p. 190). This was also the case in the conversation between the designer and project champion about 'vectorising', and generative design.

While many team members could share their understandings about some topics, they failed to synchronise around other topics, creating frustrating situations and an unwillingness to work together. This can be seen in the meeting with an academic researcher who struggled to find value in using industrial design (the designer) while conducting tests with the patient. Moreover, motivation dropped and confusion instilled when the designer returned from a conference and did not know which next steps to take, even after meeting with both project champions. According to Schön (1983, p. 21), team members "construct meanings on the basis of [their] own, distinctive repertoires of thoughts, feelings and perceptions", and while some of their repertoire was synchronised, not all their understandings were mutual.

When communicating, team members sometimes sensed discomforts. Tensions rose between the designer, Tyler, and Paul when negotiating the lights on *Element.* Schön (1983) explains how discomfort and misunderstandings are intrinsic to communicating. When they understood the different reasonings and perceptions at play, Tyler, Paul, and Max (myself) successfully overcame their differences and jointly agreed on design objectives, they respected one another and were more willing to work together. They improved their relationship, and viewed one another as more reliable and trustworthy, an important aspect to good teamwork (Badke-Schaub & Frankenberger, 1999; Charnley et al., 2011; Valkenburg et al., 2015). They 'clicked' which helped develop a shared understanding and a willingness to work together in future projects (Bergema et al., 2015).

While collaborative design research affirms the benefits of social camaraderie, or 'click' between team members, sometimes strong relationships between a few members of a larger team were problematic. These very synchronised team members communicated very well together and worked across problems quickly. They may have even developed their own specific jargon and mental models. However, this made it difficult for others to contribute. A mixture of very synchronised and unsynchronised team members left some feeling segregated. This was the case when introduced to Ben, the director of the outsourced company; As Jim and Ben discussed designer involvement between one another, the designer failed to understand them or contribute to the discussion (about his own involvement). Rather than negotiating as a team, the 'outsider' struggled to be heard. Bucciarelli (1994) recognised the 'outsider' struggle in his observations on engineering subcultures:

> What makes the corporate activity of designing a subculture is that those engaged in the activity, in going about their work, espouse a common goal and share particular priorities, beliefs, and values: they call upon jargon-laden, instrumental language; they interact both within the firm and with others on the outside in distinct ways; and their identity and survival depend, in large measure, upon the viability of the group and its productions. In this sense, they are not like you and me. They, as a community working up their projects, speaking their own language, on their own turf, are different from outsiders. (Bucciarelli, 1994, p. 23)

Close relationships between team members were helpful in the design process, but an 'outsider' saw a greater challenge in integrating their own knowledge and contributing to the team.

Still, language appeared mostly unproblematic, with very few barriers reported in the table. Team members were most often willing to discuss or ask about their interpretations, clarify their intentions or terminology, and work together. At the outsourced company, communication between the designer and Aaron was enabled by knowledge about the product and manufacturing process. Although they struggled in some ways, they eventually overcame the misunderstandings using multiple forms of communication, like mock-ups and prototypes. While there are many positive and obvious examples, language was also deceptive. For example, during a brainstorm activity with Vicky and Ian, team members reacted differently to proposed ideas while both advocating for innovative ones. To innovate, one believed outlandish ideas were vital, while another perceived them as roadblocks or distractions. This affected the flow of ideas during the activity with one member proposing outlandish ideas, while the other tried to avoid them. This issue was eventually resolved and clarified for later activities, but only after interviewing them individually. Therefore, the extent of language barriers is unclear since the team may not know how their underlying differences influence teamwork and team dynamics.

4.2.2 Project Level

Project-level factors had a mixed impact, meaning there seemed to be about equal parts enablers and barriers to the development of an integrated team. The results overall are heterogenous, and it would be impossible to compare quantitatively for this level as different instances have more or less impact on the overall development of shared understanding over others. Still, it can be said that most enablers are found in the beginning of the case study. The data indicates clear objectives were shared between the team members. Project champions initially provided clear deadlines and their expected deliverables; Sara asked for a presentation on progress, Paul asked about the materials needed, and Jim often presented new developments or prototypes and asked for concepts for a quarterly meeting. This was motivational, which in turn made staying up-to-date and creating / negotiating ideas easier since there was a willingness to participate, work, and inquire about the projects.

As the table shows, most barriers began in the middle of the case study (as of week 4) and are attributed to project planning and documentation. They began following the week away at a conference during the meetings with both project champions which left the next steps blurry and unknown to the designer. Project development, documentation and objectives appeared clear to project champions, but other team members were not always informed. While project champions were assigned the responsibility to keep team members aware, they seemed overworked and less available, failing to maintain up to date documentation. For instance, when questions on design came up, Paul was often in a test lab working on another product. This delayed progress as a key team member was unable to help with design issues and tasks. Some team members - especially senior staff and project champions - were given many responsibilities and some preferred to work alone. Instead of sharing the workload, they attributed junior team members, mainly younger engineers, smaller tasks such as printing prototypes or measuring dimensions. Motivation dropped and younger engineers spent their time waiting or reading up on research, which hindered effective teamwork / integration. When project champions and other team members worked alone, many lost sight of overall project development. This was the case when team members worked from home, and when Miranda developed a product without knowing all the limitations. Divided workloads and working from home were especially problematic as some team members worked on objectives that overlapped those of others. Reunited, they were no longer an integrated team.

When work was redundant or unused, it discouraged team members, leaving them less interested in the project and unwilling to contribute without clear, up-to-date documentation. This was seen with the designer and the presentation on *Element.* A divided project blinded team members of one another's developments, and uncontrolled planning left them discouraged to explore further.

The team seemed to fall between both forms of collaboration proposed by Simoff & Maher (2000): single task and multiple task collaboration. Single task collaboration requires continued attempts to maintain integration between team members. They must engage actively together in the design tasks (Brandt et al. 2008). Single task collaboration is a continued engagement of all members around an evolving understanding, but team members mostly worked alone on their tasks. Multiple task collaboration is cooperative work in a collaborative design space (for example the CAD model folders could be considered a design space). The team members worked independently on their tasks, but documentation was rarely up-to-date, or readily available. The team could not achieve either form of Simoff and Maher's (2000) collaboration fully.

It seemed the team lacked a boundary spanning role, or gate keeper (Allen, 1971; Sonnenwald, 1996; Katz & Tushman, 1981) to continually plan, organise, and update the project. This may have to do with bad timing as Sara, the director was away for a few weeks which left team members to work on their projects without a clear leader. Poor documentation, information processing, and project planning were often reported in the table as project-level barriers to a shared understanding: this leads to believe that the team was divided and unsynchronised in their shared understanding of the project. It seemed that no one, or no single document was created that kept a project up to date. This caused confusion and made access to ongoing projects difficult. While Monday morning meetings were useful to stay informed on some project progress, they couldn't reflect changes made during the week. Kleinsmann et al. (2007) also mentions how some team members could become insecure in the documentation. This was especially true in CAD modelling as team members did not remember how to save files properly and preferred to keep their files on their computers instead of a shared server, to avoid disciplinary action. When searching project folders or the CAD model library, it was difficult to find recent updates or explorations done by other team members. Kleinsmann et al. also describe this barrier in *information processing: "*the information is put in a database that the receiver cannot open". Frequent communication is important to synchronising understandings and maintaining a motivated and united team (see Valkenburg et al., 2015). While communication between team members on an actor-level appeared positive, and mostly an enabler to shared understanding, it could be that the insufficient amount of information communicated on a project-level, and perhaps the company-level allocation of task and responsibilities left team members less interested in participating. This may have negatively influenced their ability and desire to maintain an integrated team (although this may be limited by the role and responsibilities of an intern-designer, further explained in section 4.4).

4.2.3 Company Level

Company-level factors were mostly problematic from the designer / researcher perspective, with most barriers attributed to a lack of resources. Although significantly less instances are recorded — when compared to the volume of actor-level factors — the table shows an overall higher number of barriers than enablers or overcome barriers. The first days were spent reorganising office spaces, finding materials, leaving the office to purchase other materials, and waiting for computer installations or updates. The table shows that some problems persisted throughout the 10-week involvement, with issues like team members trying to access a limited number a CAD model licenses, and poor Wifi connections due to server sharing. Here, delays in the project could be caused by differing approaches and adapting to company resources.

Some obstacles were conquered by adapting the situations, and eventually enabled team integration. For example, interpersonal relationships seemed hindered by the cafeteria floor plans that used small round tables. Moreover, many R&D staff ate their lunches at their desks. By re-organising the space and creating a bigger table in the nicer area of the room (near the bright windows), R&D team members began sitting together in a larger group and discussing personal and professional topics over lunch. This improved relationships between team members. In another example, the nearest bathrooms were inaccessible due to key card issues at the outsourced company. However, walking to the other floor to use the bathrooms enabled and sparked multiple useful conversations with Ben, their director.

Task allocation was also problematic, and mostly a barrier in the analysis table. As mentioned in the project-level, it was difficult for project champions to fulfil their roles and responsibilities. They seemed to often fail in creating an integrated team. Providing a boundary spanning role, or fulfilling Sara's role when away would likely improve the situation, which is considered a company-level responsibility.

R&D members managed their own time, budgets, and schedules. They submitted their hours to specific funds for projects, but this information seemed mainly used for financial purposes. During a weekly meeting, the R&D director explained the importance of developing new ideas and proposals, but did not seem to allocate these tasks to team members. Working on new ideas was also not an available option in weekly schedules. These circumstances created a confusing situation. It was difficult for team members to make time for new ideas when this wasn't an available option in their time sheets. During the conversation after the designer's presentation, Oren admitted that he couldn't see how to work on new ideas when they were not an available task in his schedule.

Company-level factors were most often barriers to the development of a shared understanding. Some notable factors include a lack of resources for designing, and time management issues. Many issues seem to be attributed to overwhelmed project champions, whose tasks and responsibilities hindered shared understanding not only on the company-level, but also complicated development on the actor and project levels.

4.2.4 Reflections on the Use of Kleinsmann et al. (2007) Model

The use of factors and levels to the development of shared understanding —proposed by Kleinsmann et al., (2007)— as a means of analysis provided a frame to help describe and better understand team integration in new product development. It allowed an overview of team integration to emerge by providing insight on the positive and negative impacts of different factors and levels.

Overall, the **applicable experience of actors** and their **interest in a task** were the most frequently observed factors in the case study, and useful indicators to team integration. The data showed how experience influenced the actions and contributions of people. As enablers, experience and interest accelerated the design process and, as barriers, made negotiations between team members more challenging. Unshared experiences required empathy and patience to work through misunderstandings and divergent outlooks. Next, team members' interest in a task was significant to shared understanding. Shared interests enabled team members to work together and exchange about the projects at hand. By knowing their efforts were not in a 'vacuum' (i.e. their efforts were connected), they were motivated and interested which also fostered a sense of value. As a barrier, a lack of interest in a task often meant that team members did not know how to contribute; They were misaligned with the project, underestimated their tasks, and lost sight of a shared goal.

Next, interconnections between the different levels and factors were noticed. For example, when poor project planning hindered shared understanding, it also had a negative effect on people's interest in a task and their motivation. Similarly, a successfully shared language enabled higher quality documentation. Thus, factors on one level were partly responsible for impacting factors on other levels. This indicates that the factors are not independent, but rather interconnected. It made the analysis more challenging as it was sometimes unclear which factor was most appropriate. Although, this aligns with the challenge of complexity and 'wickedness', wherein problems / actions are often symptoms and consequences of other problems (Rittel & Webber, 1973).

Since Kleinsmann et al.'s (2007) factors were based on two case studies, they suggest further investigation is needed, which may allow for new factors to emerge. This case study saw the recurrent influence of 'substantiation' where team members conflicted over providing proof or evidence for their ideas. This led to creating a new actor-level factor called *forms of reasoning.* A form of reasoning can be described as the way actors logically think. Design research suggests three forms of reasoning: deductive, inductive, and abductive (Dorst & Cross, 2001; Kolko, 2010; Bowen et al., 2016). Deductive and inductive reasoning are often referred to and associated with social sciences (inductive) and pure sciences (deductive). Some design researchers propose that designers think abductively, where they develop ideas and conduct research with fragments of information (Kolko, 2010). The designers' process works around unknown variables and partial understandings. Given these differences, the varying *forms of reasoning* that manifested in the case study influenced communication, negotiation, and the development of an integrated team. This factor can be briefly described as follows:

> New proposals are discussed between team members. As they explore an idea, there is a joint effort of understanding the proposal, its value, and benefits. When negotiating new ideas, team members often refer to proof or evidence to defend a proposal. When two opposing forms of proof are used, it's difficult to communicate how each form of reasoning is valid. For example, an actor relying on bio-mechanical principles may doubt a user's lived experience as reasonable proof.

4.3 Describing and Understanding Team Integration Through the Theoretical Framework

This section equally describes team integration through the case study and results, but uses some other concepts from the theoretical framework. This is done to widen the scope, and interpret and understand team integration in new product development in more ways.

Before the case study even began, team integration was enabled by the participating company's interest in involving a designer. A positive view of multi-disciplinary teamwork was denoted by their willingness to not only involve the designer, but to contribute resources to the research. According to Bergema et al. (2015), this suggests an initial 'click' between the researcher and director (Sara) who respectively endorsed design involvement early on in the development process.

There were also signs of team integration throughout the case study. This is based on the observation that designer input was used across the development process, as designer ideas found themselves in the final prototypes, mock-ups and presentations (like the designers' *Freedom* drawings used in the quarterly meeting). Integration was sometimes easy: Similar to Bucciarelli's (1994) view on 'subcultures', team members sometimes shared in the same views, objectives, or language. This was maintained by activities like Skill-share sessions and Monday morning meetings where team members became familiar with new knowledge and developments in the different projects. Other times, integration was more difficult and took negotiating and compromise. This was obvious in the discussion between the designer, Paul, and Tyler on the number of lights for *Element.*

As Cross and Cross (1995) proposed, this research saw team integration influenced by both cognitive and social aspects of working as a team. Cognitive aspects, like the different understandings of 'innovation' during the brainstorm challenged team integration. This also shows that team members held different individual frames. But, with respect to Kleinsmann et al. (2012) and Dong (2005), frames were seen to evolve throughout designer involvement. They were indeed moment-by-moment perceptions that changed over time. For example, Jim's view on industrial design changed noticeably in the first week. His understanding, after working with the designer shifted from *making it look good* to *the cognitive, financial, and market value of design involvement*.

Some tasks during the case study failed, but nevertheless enabled team integration. For example, the meeting on Monday morning meetings failed to achieve its result of a proposed improved format. Although there were no task-related outcomes from the meeting, the group gained a stronger sense of team integration, similar to Bucciarelli's (1994, p. 157) 'disaster meeting'. Through the design activity, team members worked closer together and gained insight on their shared views of the problem. The failure in this instance likely has less to do with team integration, and more to do with the wicked nature of the task itself (Rittel & Webber, 1973). The problem was ill-defined, lacked a clear formulation, and was unique to the company. There was little knowledge about the extent of possible changes and this kind of meeting / task was a first to those involved.

Next, it was difficult to further describe or understand team integration through Rosen's cultural elements of collaborative design. While it was easy to identify some elements like sharing, innovation, constructive confrontation, or communication, their correlations with team integration were not intuitive. For example, while more trust between members could correlate to more effectiveness, the same could not be said about more collaborative chaos in the group. Worst still, as Kokotovich & Dorst (2016) proposed, more trust between team members could adversely lead to more conventional solutions rather than innovative ones. This was the case with Miranda who created an innovative and successful idea without the same limitations that the designer had already accepted and integrated into his approach. Here, the designers' integration with project champions hindered innovation.

Other aspects that influenced team integration align with Mattesich and Monsey's (1992) views on collaboration. As a designer involved for a short time, team members did not equally share in the risks of the projects. The designer was a temporary addition to the project, rather than the partner of a "durable and pervasive relationship […] with a full commitment to a common goal" (Mattesich and Monsey, 1992, p. 39). In this way, teamwork was not always collaborative and stifled the development of a shared understanding.

4.4 Limitations

This inquiry on describing and understanding team integration in new product development relied on research that formed a theoretical framework, a methodology, and a means of data interpretation and analysis. Within this inquiry, there are limitations on the outcomes. These limitations are described below and address the case study, the results yielded, and the analysis.

4.4.1 Limitations on the Case Study

This research presents four limitations to the case study. First, team integration is influenced by the designers' involvement and role in the team. Roles and responsibilities differ between designers, engineers, project champions, and directors. As a result, this limits the results to the perception of team integration only through the role of an intern-designer. Second, the theoretical framework explained the value of design involvement at the outset of product inception (see Heskett, 2017). The director proposed projects that were in their early stages of the design process, but appeared further along than anticipated. Both projects already had clear design objectives, and multiple iterations / prototypes. This highlights different understandings of 'the beginning of a project' between the company involved and the researcher. Third, as Sanders and Stappers (2008, p. 9) explained, actions can have long-range consequences throughout the design process. This case study was limited to 10 weeks within a much longer project. It captures only a moment in the new product development process. Fourth, as Bucciarelli (1994) expressed, object worlds create an infinite number of possible outcomes. The individual team members, context, and projects created a unique situation that is not readily generalisable.

4.4.2 Limitations on the Results

This research presents four limitations to the results. First, Pedgley (2007) recommends subject delimitation to prevent data overflow. As mentioned, this case study was conducted with an initial inquiry that continued to evolve and change after designer involvement. Further research lead to using Kleinsmann et al. (2007) as a framework, but the original results were not specifically targeted to their proposed factors. Results are therefore limited by the initial exploratory subject of teamwork in new product development, not the development of shared understanding specifically. Second, by playing the dual role of designer and researcher, this research recognises the possibility of blurred lines between subjective and objective journal entries (see annex 6 for reflections on journal entries). Third, there were sometimes gaps in the journal as playing the dual role made reporting on interactions sometimes difficult. There were limits to stamina or endurance during data collection (Godin and Zahedi, 2014). This limits results to the recorded data, not the overall design involvement. Fourth, due to non-disclosure-agreements with the participating companies, many results, especially related to prototypes and specific product developments are limited. This is an intrinsic limit to working on a product destined for a competitive commercial market.

4.4.3 Limitations on the Analysis

This research presents two limitations to the analysis. First, while Kleinsmann et al. (2007) define each factor in their article, it was not originally made to be used as a framework of analysis. Although they sometimes provided definitions and examples of enablers and barriers from their own observations, some factors like 'the empathy of actors about the interest of a task' are only explained through barriers. This led to inferring or deducing definitions and examples of enablers, which risked misunderstandings. Moreover, this research pointed out that people often hold different definitions, languages, and understandings. Thus, the analysis may be contaminated by different understandings of the factors between myself and Kleinsmann, Valkenburg, & Buijs (2007). Second, this research identified a noticeably larger portion of actor-level factors, over the project and company levels. These results may be biased by the research approach which studied team dynamics through a participant of the design process, not through project managers or company directors.

Conclusion

This research was fuelled by an interest to describe and better understand team integration during the early stages of new product development. It was motivated by experiences in practice and becoming a better designer in multi-disciplinary teams, bridging different and sometimes conflicting views each team member holds. A review of literature helped by presenting the changing role of designers in new product development, their value at the beginning of a project, and the increased complexity design teams often face today. It also outlined the challenges and benefits to working as a team. While teamwork provides access to more knowledge than any single person possesses, it paradoxically creates more complexity by the need to synchronise peoples' individual frames into a shared one (an integrated team). The benefits of teamwork are especially accessible when team members develop and maintain a shared understanding.

Once this was understood and observed throughout the case study, this research tried to find a way to describe and report on the development of shared understanding as it happens in practice. Kleinsmann, Valkenburg & Buijs' (2007) categorisations from their article *Why do(n't) actors in collaborative design understand each other? An empirical study towards a better understanding of collaborative design* became a viable option used to analyse a case study on product development and designer involvement. Using Research-through-Design allowed me to participate in the design process and report through the role of both researcher and junior designer to gain a deeper insight into team dynamics. This method was a success and multiple sources of data collection created a multifaceted and *recoverable* account of the case. Still, the data was limited by the unique nature of the context, of the team members involved, of the role of a young, new and temporary designer, and the blurred lines of objective and subjective data reporting.

Nevertheless, the proposed factors and levels allowed for a better understanding of, and way to describe team integration. Overall, the actor-level dynamics most often enabled shared understanding, while project and company levels were mixed. Team members were willing to share their interests and knowledge about the projects. Organised activities like Monday morning meetings and Skill-share sessions created a space for open exchange and discussion during office hours, while social activities and ad hoc conversations were equally helpful to team integration. The greatest challenges were seen at the project-level as team members failed to inform one another about project planning or maintain a shared database of the projects. This hindered communication, and team members lost interest in the projects when they weren't updated. Although, this may be limited by the perspective of junior designer (with little knowledge on the company, or ability to change the process from the top-down).

Using the factors as a framework of analysis also allowed team integration to be observed over time. It revealed the highs and lows of team integration over the course of designer involvement. The analysis found a very integrated team in the beginning, but their shared understanding withered in the middle. This is likely due to the combination of a week-long departure for a conference, a director needed abroad, project champions increasingly working from home, a shuffle in project priorities, and the delay or cancellation of presentations and meetings. From the perspective of designer involvement, team integration was lost by a lack of teamwork, workload, and motivation. But, there was a reboot in the final weeks, largely due to the director's return, the final presentation, and wrapping up projects under a tight deadline. Confidence to stay up-to-date, communicate, and negotiate improved the sense of shared understanding.

Kleinsmann et al.'s (2007) factors helped in describing the case study, but some limitations and amendments are proposed. First, to be better used as a framework of analysis, some factors would benefit from more exhaustive descriptions that present the factors and provide examples of both enablers and barriers. Second, the analysis was sometimes challenged by overlapping factors: multiple factors applied to the same action for similar reasons. While it's easy to suggest that the categorisations become more insular, this would likely be an impossible task given the complexity of shared understanding. As Rittel & Webber (1973) explained, there is not a set of enumerable solutions, and actions are most often 'symptoms' of others. Actions are deeply intertwined and influence or emerge at different times and manifest in different ways throughout the product development process. Third, a new factor was proposed. This aligns with Kleinsmann et al.'s observations that further refinements to the categorisations are likely. *Forms of reasoning,* or the way actors logically think was seen to noticeably impact team members' ability to negotiate designs and understand one another.

Finally, this research could be significant to other junior designers as a potentially useful framework to making teamwork and team integration more observable, understandable, describable, and easier to reflect upon. It may also be helpful for improving teams with their own new product development process(es), their design context(s), and the social dynamics between team members.

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Annex 1: MITACS Funding

Mitacs

13 mars 2018

Réf. de la demande : IT10566
Réf. de la demande de financement : FR25230
Réf. de la facture : IN1718-20334
Dossier Mitacs : **QC – ISDE**

International Office
Université de Montréal
C.P. 6128, Succursale Centre-Ville Montréal, Quebec H3C 3J7
À L'ATTENTION DE : : Dr. Yves Guay, Direction des relations internationales

AVIS D'OCTROI DE SUBVENTION
Bourse de partenariat Mitacs Globalink :

Objet :	**« Evolving mobility-assisting devices through the study and better understanding of designer-scientist collaboration dynamics »**
Superviseur universitaire :	**Mithra Zahedi**
Étudiant :	**Maxim Lamirande**
Département, établissement :	**Design, Université de Montréal**
Organisme partenaire (nom et pays) :	**Chas A Blatchford & Sons, Angleterre**
Comptes :	**Veuillez ouvrir UN compte au nom du superviseur. Tous les fonds peuvent être déposés dans le même compte.**

La somme de **15 000 $** vous a été accordée pour le projet cité ci-dessus. Le compte(s) peut rester ouvert du **le 1 février 2018 – 15 août 2018** pour couvrir les dépenses liées directement aux frais de recherche engagés au cours de cette période. *La date de fermeture du compte comprend une période additionnelle pour dépenser la partie de la subvention prévue pour le matériel et la recherche.* Veuillez prendre note que tout versement ultérieur peut être modifié.

Veuillez attribuer les fonds octroyés selon les détails du stage et les montants prévus pour les allocations et les salaires, tel qu'il est indiqué à l'**annexe A**. Les conditions se rattachant à ce stage sont décrites à l'**annexe B**. Veuillez aviser Mitacs en cas d'un changement apporté aux dates de stage ou à l'identité du stagiaire.

Une certification ou une approbation appropriée du comité d'éthique de la recherche de l'université est requise pour poursuivre les activités de recherche prévues dans la proposition de recherche, conformément aux exigences des organismes subventionnaires fédéraux. *Mitacs pourrait exiger une copie du rapport pour s'assurer de sa conformité.*

Mitacs tient à remercier le gouvernement du Canada ainsi que le gouvernement du Québec via le Ministère de l'Économie, de la Science et de l'Innovation (MESI) de leur soutien continu accordé au programme Globalink.

Veuillez vous assurer de communiquer avec Rani Cruz à l'adresse rcruz@mitacs.ca ou au 514-840-1235 poste 7987 pour de plus amples renseignements.

Cordialement,

A. Batura

Arija Batura
Directrice, gestion des subventions

Montréal, QC
405, avenue Ogilvy,
bureau 101
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Université de la Colombie-Britannique
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Vancouver (BC) V6T 1Z3

Annex 2: *CPER* Ethics Committee Approval

Université de Montréal

Comité plurifacultaire d'éthique de la recherche

2 février 2018

Monsieur Maxim Lamirande
Candidat à la maitrise
Design - Faculté de l'aménagement

OBJET : Approbation éthique

M. Maxim Lamirande,

Le *Comité plurifacultaire d'éthique de la recherche (CPER)* a étudié le projet de recherche intitulé « Évoluer la conception de produits qui assistent à la mobilité par une meilleure compréhension des dynamiques de collaboration entre designers et scientifiques » et a délivré le certificat d'éthique demandé suite à la satisfaction des exigences précédemment émises.

Notez qu'il y apparaît une mention relative à un suivi annuel et que le certificat comporte une date de fin de validité. En effet, afin de répondre aux exigences éthiques en vigueur au Canada et à l'Université de Montréal, nous devons exercer un suivi annuel auprès des chercheurs et étudiants-chercheurs.

De manière à rendre ce processus le plus simple possible et afin d'en tirer pour tous le plus grand profit, nous avons élaboré un court questionnaire qui vous permettra à la fois de satisfaire aux exigences du suivi et de nous faire part de vos commentaires et de vos besoins en matière d'éthique en cours de recherche. Ce questionnaire de suivi devra être rempli annuellement jusqu'à la fin du projet et pourra nous être retourné par courriel. La validité de l'approbation éthique est conditionnelle à ce suivi. Sur réception du dernier rapport de suivi en fin de projet, votre dossier sera clos.

Il est entendu que cela ne modifie en rien l'obligation pour le chercheur, tel qu'indiqué sur le certificat d'éthique, de signaler au CPER tout incident grave dès qu'il survient ou de lui faire part de tout changement anticipé au protocole de recherche.

Nous vous prions d'agréer, Monsieur, l'expression de nos sentiments les meilleurs,

Jean Poupart, Président
Comité plurifacultaire d'éthique de la recherche (CPER)
Université de Montréal

JP/ RS/ rs
c.c. Gestion des certificats, BRDV
Mithra Zahedi, professeure agrégée, Design - Faculté de l'aménagement
Geneviève Bédard
p.j. Certificat CPER-17-130-D

adresse postale
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cper@umontreal.ca
Téléphone : 514-343-6111 poste 1896

www.cper.umontreal.ca

Annex 3: Interview Structure

Interview Synopsis : January 2018

Disclaimer: Given the semi-structured nature of the work, and how little referential literature is available on the matter, the first interviews will aid in directing specific questions and conversational directions relevant to the researcher.

Before beginning: Ensure that the participant has signed the consent form and ask if they have any questions.

Put forward that this interview is conducted from the RESEARCHER standpoint, not from the point of view of the designer. It is not to confront the perceptions amongst designers' and scientists' involvement, but to rally the information objectively from the standpoint of an outsider.

Start by warming up the conversation, discussing about them, their position, work, motivations. Encourage scientists to express any prior experiences working with designers. Compare prior experiences and those conducted in this study (across this project or the period observed). If no experience, ask them nonetheless on this particular event exclusively. They can discuss the nature of the work, how they worked together, barriers and enablers.

The purpose, in part, is to understand how scientists feel about the dynamics of introducing a designer in the beginning of the product development phase.

During the interview:

- Discuss effective communication and the tools that seemed to affect collaboration between designers and scientists.
- Explore how different tools from participants' disciplinary fields contributed to the situation (using examples if necessary). If there were any that coincide, overlap/overarch, clash, between participants
- Explore the impact on teamwork and collaborative design of prior experiences in other situations, with different agents or agents they had already worked with.
- Ask them to discuss the general approaches of each participant; this can open towards talking about scientific and philosophical methodologies. Ask them about their perspective on *metaphysical/intangible/non-physical* criteria.

Outside of the interviews, one-on-one discussions may occur, and spark conversations within or outside the workplace between the student and partners from the organization. These should be treated as the DESIGNERS expression and documented as so unless the other party affirms or specifies that their information should be treated as "researcher information". Any information retained must nonetheless respect the privacy and anonymity of the participants.

These perspectives and approach are in part taken from:

Gauthier, B. (2003). *Recherche Sociale: De la problématique à la collecte de données*. Québec, Canada: Presse de l'Université du Québec.

Creswell, J. W. (2007). Five Qualitative Approaches to Inquiry *Qualitative Inquiry and Research design: Choosing among five approaches* (pp. 53-84). London, England: Sage Publications.

Findeli, A., & Brouillet, D. (2008). *Research Through Design and Transdisciplinarity: A Tentative Contribution to the Methodology of Design Research*. Paper presented at the Swiss Design Network Symposium 2008, Mount Gurten, Berne, Switzerland.

Bucciarelli, L. L. (1988). An ethnographic perspective on engineering design. *Design Studies, 9*(3), 159-168.

Driver, A., Peralta, C., & Moultrie, J. (2010). Exploring How Industrial Designers Can Contribute to Scientific Research. *International Journal of Design, 5*(1), 17-28.

Peralta, C., & Moultrie, J. (2010). COLLABORATION BETWEEN DESIGNERS AND SCIENTISTS IN THE CONTEXT OF SCIENTIFIC RESEARCH: A LITERATURE REVIEW. *International Design Conference, Design Information and Knowledge*.

Annex 4: Participant Consent Form (*CPER* Ethics Disclaimer): 1 of 2

Consent Form

Université de Montréal

Title of the Reseach Project

Evolving mobility-assisting-devices through the study and better understanding of designer-scientist collaborations

Research Student
Maxim Lamirande, Ba Ind.
Masters candidate of Applied Sciences
Faculty of Environmental Design, University of Montréal

Project Directed by :
Mithra Zahedi, PhD
Associate Professor
Faculty of Environmental Design, University of Montréal

Project description

The 2016 issue of *University Affairs* journal highlighted how design is changing the way we approach problems. The article discusses "why researchers in various disciplines are using the principles of design to solve problems big and small" and points out "designers, especially product designers, are typically experts in conceptualizing problems and solving them—ideal skills for tackling a wide range of issues..." (Johnson 2016). In existing studies, reports express "the expected contribution of designers to supporting commercialisation of technology, [...] [demonstrating] the potential for industrial design to have an impact on research itself" (Driver, Peralta et al. 2010). Classically, fields of study involving the development of highly technological products introduces the designer at the end of the product development phase as a means of "styling" (Ulrich 2012). Considering how little research has been conducted on designer-scientist collaborations, those elaborated under this proposal would aim to contribute to findings on the outcomes of such interactions (Rust 2004, Peralta et al. 2010). Questions on the matter emerge, such as: What are the repercussions that can be seen and documented from collaborations between scientists and designers when the approach is shifted to integrate the designer at the beginning of the development process? Ultimately, this research will document the impacts that come from integrating the designer in the beginning of the development process

Nature of the participation

The study is conducted across two months working within a private research and development organization. Participation is not mandatory and a refusal will have no impact on their work/employment. Those who refuse will not be subject to analysis in the participative observations and will not be obliged to conduct an interview. The study will consist of participative observations with the R&D group and potential users, semi-structured interviews (within working hours, lasting approximately 30 minutes within a private environment to ensure the participant feels comfortable expressing themselves) are conducted with participants to understand and explore their perspectives on this new integration. Reflections on previous interactions with designers as well as the new interactions will help highlight the intricacies of designer-scientist collaborations.

Advantages

As a participant in this research, you will contribute in the evolution of the development process of high-technology products. These contributions will help define new approaches or confirm exiting methods to the development process of mobility-assisting devices.

Inconveniences

The researcher is aware of you time and will ensure that the interviews be conducted efficiently as to avoid any inconveniences to the participant.

Confidentiality

In order to fully appreciate the collected data, some interactions may be recorded as audio or in notebooks for future reference, and photos may be taken during collaborations. These recordings are only for research purposes and will not be published. The data will be kept on an external hard drive and destroyed after the allowed time (7 years). Information on your title or expertise may be published pending your personal approval as well as the approval of the organisation participating in the research (Chas A Blatchford and Sons). If preferred, no information will be divulged allowing to identify you in the publications of the research. Before any publications on the matter, the published data will be shared and confirmed with the organization to ensure that the published information will not cause any incoveniences to the participants or to the company.

Results Publication

Results on the study will be communicated with you upon publication of works (scientific articles, conferences or thesis. These publications allow the diffusion and promotion of the results.

Compensation

No compensation is anticipated for your participation in these interviews.

Voluntary Participation and Refusal

You are not obligated to participate in the interviews. You are allowed to refuse or decide against participating at any time during the interview. All the while, information supplied before that moment will be considered valuable to the researcher and will not be destroyed if they put the scientific nature of the project in peril.

Version 2 30/01/2018 1 of 2

Annex 4: Participant Consent Form (*CPER* Ethics Disclaimer): 2 of 2

Consent Form

Ressource

For any questions, communicate with :

Maxim Lamirande, researcher
Email : maxim.lamirande@umontreal.ca
Téléphone : TBD upon arrival in UK

Mithra Zahedi, Associate Professor
Emaill : mithra.zahedi@umontreal.ca
Téléphone:514.343.7576

Participant Consent

I, ____(Print letters)
Declare that I am fully aware of the information described above and have received answers to any and all questions I may have on the nature of the project. I consent to participate in the research and unders-tand that I refuse or cease participating at any moment through written or verbal communication without consequence.

I accept that visuals (photos) be used in publications (acticles, conferences, thesis).	I accept to be cited and identified as a participant in the publications of this research.	I accept that information pertaining to my title in the company and expertise be divulged in the publications of this research.	I consent that the data collected for this study be used in various publications within the research project pending your ethical approval and in the same respect to your confidentiality as this research.
YES NO	YES NO	YES NO	YES NO

Signature of the participant : _____________________________________
Date:_____________________

Email : ____
Telephone : ________________

Reseacher consent

I certify that I have a) explained to the participant the terms of this consent form : b) have answered any questions the participant may have in this regard ; c) indicated to the participant that they can end their participation in the research at any moment ; and d) that they will receive a copy of this form signed and dated.

Maxim Lamirande, Masters candidate of Applied Sciences, Faculty of Environmental Design, University of Montréal

Signature :____ Date : ____________________

For any questions or concerns on your rights and responsibilities or the responsibilities of the resear-cher, please contact the ethics committee of the University of *Montréal (Comité plurifacultaire en éthique de la recherche (CPÉR))* at cper@umontreal.ca or 514-343-6111, extension 1896, or consult the web-site: http://recherche.umontreal.ca/participants. For any complaints related to your participation or that of the researcher, contact ombudsman@umontreal.ca or (514) 343-2100 (ombudsman accepts toll-free calls)

Reminder : A signed and dated copy of this form must be given to the participant.

Version 2 30/01/2018 2 of 2

Annex 5: Designer Information Sheet: 1 of 2

Objective

- Gather **information** on functionality, interrelationships between components
- **Review** existing model
- Design priorities for **testing** (next checkpoint mid-april)

Involvement

- **Conceptualizing**, visualizing problems and solving them
- Standing **outside of** a specific **expertise**/specialisation or discipline
- Using a design process that **navigates** problem spaces that have **gaps** or "**unknowns**"

Sensemaking

Seeing Glasses to *Eyewear*

Assistive Technology to *Legwear*

Design Process (Cyclical)

1.Research Foundation ↔ **2.Ideation** ↔ **3.Refinement**

1.Research Foundation

- Historical background
- Reverse engineering
- Articles and publications
- User interviews
- Existing mandates
- Contexts
- Project Targets
- Developing Criteria

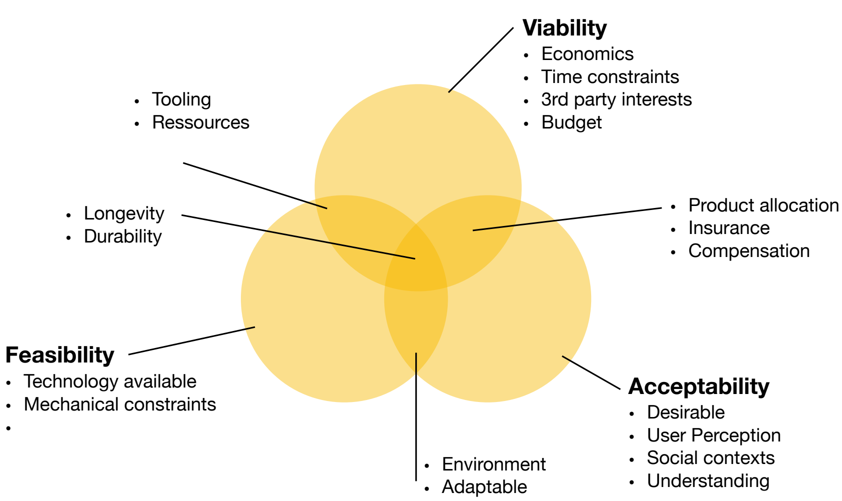
2.Ideation

- Mind mapping
- Photos
- Simulations
- Drawings
- 2D models
- 3D models

3.Refinement

- Validations
- Optimizing
- User testing
- Prints and production

Designing Considerations



Annex 5: Designer Information Sheet: 2 of 2

Research Priorities

Interdisciplinary collaboration dynamics between designers and engineers in new product development

- What happens when an industrial designer is involved at the outset of a project?
- What are the barriers and enablers to collaborating?
- What are the perceptions of each actor, their role, their impact?

Annex 6: Reflections on Journal Entries: 1 of 2

The journal contains the core data of this research. The journal illustrates the events and creates a chronological timeline of the 10-week involvement. It is crucial to data recoverability and was used to perform the analysis. Each entry into the journal was dated and time stamped, and includes the actors involved in each recorded interaction. I kept a journal on interactions with others, reflections on team dynamics and, project development. Sketches, prototypes (as photos), observations (direct and participant), documents, and discussions (either written, or recorded and redacted) were later added into the journal. Following Pedgley's (2007) recommendations, out-of-hour events, such as social activities like weekly sports and monthly dinners were also recorded.

To distinguish between designer and researcher, the entries were divided in two. On the left side, the designer would write down observations, participations, and discussions as they happened. To the right, the researcher would organise and annotate the entries. For example, see the figure below:

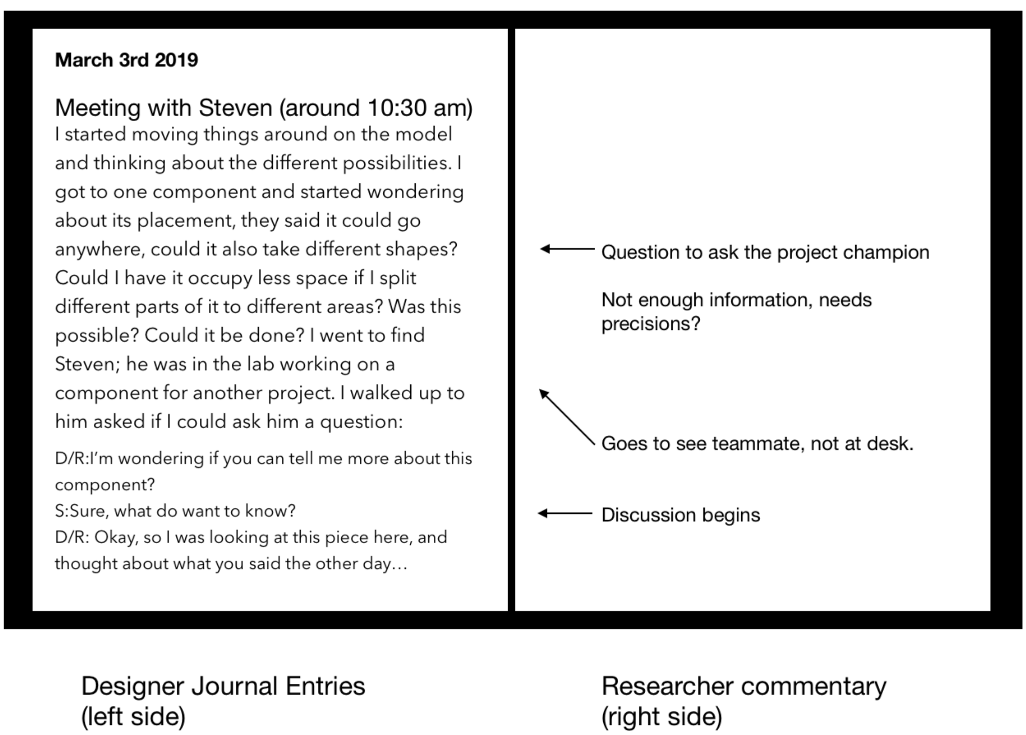


Figure 6: Example of Journal Entries 1

Annex 6: Reflections on Journal Entries: 2 of 2

In another example, the designer would write down what happened but added comments that seemed influenced by emotion. This resulted in a mixture of objective and subjective entries that were sometimes difficult to dissimulate. For example, the storyline would include the designers joy or frustration in the dynamics between team members and assumptions about behaviours. This could make some designer entries unreliable in accurately retelling the discussion.

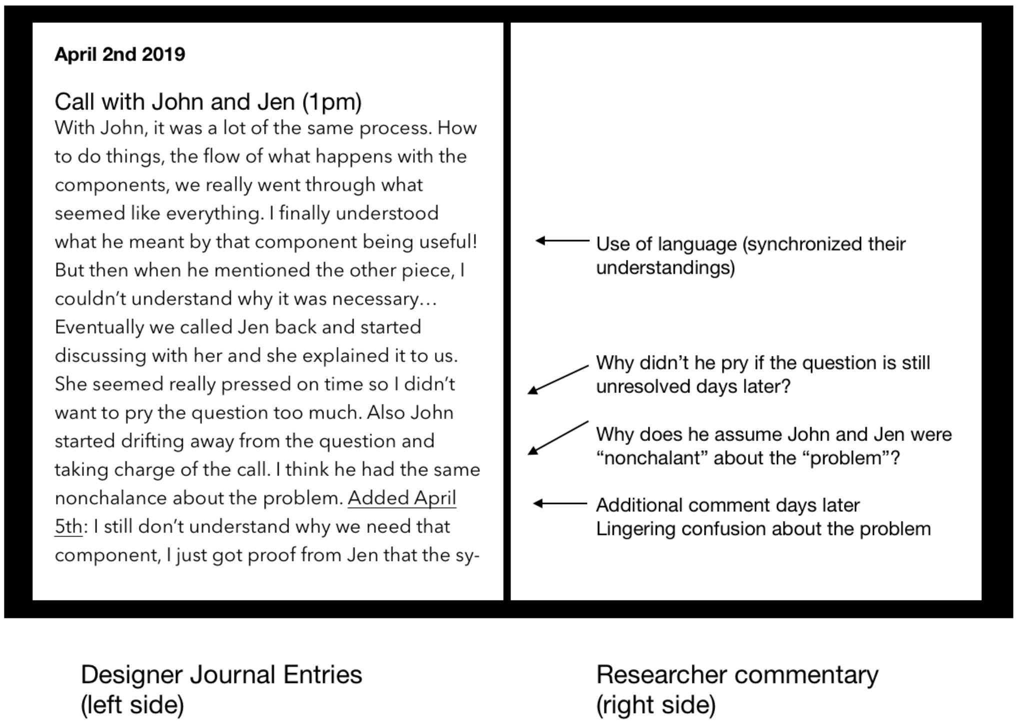


Figure 7: Example of Journal Entries 2

The designer could bias the data or content of a discussion by emphasising events that affirm their feelings and forgetting about others. In order to amend some entries and regain objectivity verbatim transcripts of audio recordings were added into the journal by date. In addition, the researcher could enter comments later on in the right-hand page to rectify or challenge the designer. While these designer entries could lack objectivity, their subjectivity was very useful; They deepened the understanding of dynamics between team members and the undiscussed or otherwise unrevealed logic of the designer.