Exploring the Collaboration Between Industrial Designers and Engineering Designers in a Handover Situation

sharing the product concept's underpinning logic

Laursen, Esben Skov

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BY
ESBEN SKOV LAURSEN

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Esben Skov Laursen

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PhD supervisor: Associate Prof. Louise Møller,
Aalborg University

Assistant PhD supervisor: Associate Prof. Poul Henrik Kyvsgaard Hansen,
Aalborg University

Associate Prof. Christian Tollestrup,
Aalborg University

PhD committee: Professor MSO Nicola Morelli (Chairwoman)
Aalborg University

Associate Professor Birgitte Geert Jensen
Aarhus School of Architecture

Senior Researcher Anders Wikström
SICS Swedish ICT Västerås

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Summery

This study focuses on handover situations between industrial designers and engineering designers in product development projects, on a 'project level'. The handover situation creates a gap between the industrial designers and the engineering designers in the product development process which becomes evident in the processual transition from the product concept to the development of the product. During the conceptual phases, the industrial designers create an underpinning 'logic' in order to handle the ambiguity and complexity of the design problem and to guide the creation of the product concept. During the development phase the engineering designers create detailed solutions and/or make the needed changes to the product concept in order to finalize the development of the product. However, as they are unaware of the product concept's underpinning logic, the engineering designers potentially erode the originally intended design and thus weaken the integration and, consequently, the competitive and financial advantages of integrating industrial design in product development projects. It is, therefore, important for the industrial designers to explicitly emphasize the underpinning logic of the product concept to the engineering designer at the handover. Accordingly, it is an underlying assumption that maintaining the design intent proposed by the industrial designer in the final product, and/or ensuring that changes to the underpinning logic still is in 'alignment' with the perspectives is vital in the effort to ensure the competitive and financial advantages of integrating industrial design in product developing projects. Moreover, it is assumed that if the engineering designer has an understanding of the underpinning logic of a product concept during the development phases, it would potentially make it possible for the engineering designer to develop detailed solutions, or make changes to the product in line with the design intended by the industrial designer, or give the engineering designer an awareness of when the solutions or changes significantly changes the final product from the intended design.

The research design of the study is divided into two main parts. In the first part, the current situation is investigated based on of six case studies (containing 20 interviews). The analysis of the empirical material indicates that **the elements of the underpinning logic of a product concept that are most challenging to communicate and transfer in a handover situation are the elements which**

relate to the human perspective rather than the technology or business perspective. The elements that are most challenging to communicate are therefore beyond the functionality and technology of the product, containing e.g., emotional, symbolic, and social aspects. In the second part of the study, a 'support tool' based on Solution Frame-work to explicitly emphasize the underpinning logic of a product's concept in a handover situation is tested. The support tool is tested based on a 'Lab.-study' which consists of six student projects (that involve professional engineering designers). The analysis of the empirical material indicates that **explicitly emphasizing the underpinning logic seems to improve the engineering designer's ability to understand whether potential production changes are coherent with the product concept's underpinning logic.**

In order to recognize the impact of these findings, they should be connected with the positioning of engineering design and industrial design established in this study. The focus on the contribution of industrial design as primarily concerned with the meaning of the products and the result as both a product concept and the underpinning logic provides a different approach to understanding the challenges between industrial designers and engineering designers. The findings, therefore, open up a new research area in the relationship between industrial designers and engineering designers.

Resume
Dette studie beskæftiger sig med overleveringer i produktudviklingsprojekter mellem designere (industrial designers) og ingeniører (engineering designers), på 'projekt niveau'. Overleveringer i en produktudviklingsproces skaber et 'gap' mellem designere og ingeniører, som bliver særlig tydeligt i overgangen fra konceptfasen til selve konkretiseringen af produktet. I konceptfasen udvikler designeren en underliggende 'logik' for at kunne håndtere tvetydigheden og kompleksiteten, der er indbygget i et designproblem, samt for at kunne styre udviklingen af produktkonceptet. Under konkretiseringen af produktet udvikler ingeniøren detaljerede løsninger og/eller ændrer produktkonceptet. Men, fordi ingeniøren ikke er bekendt med produktkonceptets underliggende logik, er der risiko for at ingeniøren eroderer det oprindelige 'design intent' og derved svækker de konkurrencemæssige og økonomiske fordele, der er ved at integrere design i produktudviklingsprojekter. Det er derfor vigtigt at designere eksplicit understreger den underliggende logik for produktkonceptet til ingeniøren i en overlevering. Det en underliggende antagelse at bevarelsen af 'design intented' er nødvendigt, for at sikre de konkurrencemæssige og økonomiske fordele ved at integrere design i produktudviklingsprojekter. Ydermere er det en antagelse, at hvis ingeniøren har en forståelse af den underliggende logik for et produktkoncept under konstruktionen, vil det være muligt for ingeniøren at udvikle detaljerede løsninger, eller lave ændringer af produktet, der er afstemt med designet foreslået af designeren, eller, at ingeniøren vil blive opmærksomhed på, hvornår løsninger eller ændringer signifikant ændrer det endelige produkt fra det 'intented design'.
Undersøgelsesdesignet for dette studie indeholder to hoveddele. I den første del er den nuværende situation undersøgt på baggrund af på seks cases (indeholdende 20 interviews). Analysen af datamaterialet indikerer at **elementerne i den underliggende logik af et produktkoncept, der er mest udfordrende at kommunikere og overføre i en overleveringssituation, er de elementer, som er relateret til 'human' perspektivet fremfor det 'tekniske' og 'forretningsmæssige' perspektiv. De mest udfordrende elementer at kommunikere er således elementer som rækker udover funktionaliteten og teknologien i produktet, og som f.eks. indeholder følelsesmæssige, symbolske og social aspekter.** Den anden del af studiet er en test af et 'værktøj', baseret på

’Solution Frame-work’, til eksplicit at understrege et produktkoncepts underliggende logik i en overleveringssituation. Værktøjet er testet i et ’laboratoriestudie’ indeholdende seks studieprojekter (med professionelle ingeniører). Analysen af datamaterialet indikerer, **at en eksplicit præcisering af den underliggende logik ser ud til at forbedre ingeniørens mulighed for at forstå, om potentielle ændringer er i overensstemmelse med produktkonceptets underliggende logik.** For at forstå betydningen af disse konklusioner, skal de ses i sammenhæng med positioneringen af designere og ingeniører beskrevet i dette studie. Forståelsen af industrielt design som fokuseret på betydningen (meaning) af produkterne, og resultatet som både et produktkoncept og den underliggende logik, giver en anden tilgang til at forstå de udfordringer, der kan være mellem designere og ingeniører i en overleveringssituation. Resultaterne af dette studie åbner derfor et helt nyt forskningsområde i forholdet mellem designere og ingeniører.

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This dissertation marks the end of a journey that not only has expanded my knowledge and understanding of design and design research but has also given me valuable insights about myself. However, the journey has not been an individual process and many people deserve acknowledgement.

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Thank you,

Esben Skov Laursen

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1 Introduction

The increased complexity of products and the competitive environment which focus on cost, time-to-market, and quality have made the product development process[1)] a collective rather than an solitary activity (Kleinsmann 2006; Valkenburg 2000). Accordingly, product development is normally conducted in multidisciplinary teams in order to ensure the needed skills. An effective integration between professionals from different disciplines has been identified as one of the key drivers in ensuring a successful product development process (Griffin & Hauser 1996; Troy et al. 2008). Multidisciplinary integration in product development projects, also known as integrated product development (IPD), has therefore been heavily investigated during recent decades, making IPD the most dominant paradigm within the area today (Gerwin & Barrowman 2002). The primary concept of IPD focuses on upstream activities in the product development process in order to avoid downstream problems (Koufteros et al. 2001). The main elements in this effort are: (1) early and continues involvement of participants, (2) a process with overlapping and concurrent workflow of activities, and (3) the use of multidisciplinary project teams[2)] in order to ensure the collaboration between the team members (Smith 1997; Koufteros et al. 2001). However, situations in companies can be identified where 'best practice' of IPD is not applicable. This could for instance be the case when companies choose to use consultants, e.g., industrial design consultants in product development projects. The companies use industrial designers as consultants, e.g., because they lack the skills represented by the industrial designers, or because they lack resources/tasks for a full time employee, e.g., in small and medium-sized enterprises[3)] (SME). The use of industrial designers as consultants potentially results in: (1) separation of work activities between the industrial designers and the internal team members due to differences in skills, and/or (2) 'partial' or 'discontinued' involvement of the industrial designers in the product development process to limit the use of resources. Both aspects hamper the collaboration and consequently also the integration, resulting in a lack of shared understanding regarding both the process and the content of the project between the industrial designers and the rest of the team members (Kleinsmann 2006). As the rest of the team members are dependent on the results of work activities conducted by the industrial designers for fulfilling their own tasks (Stompff 2012), a 'handover situation' emerge. The situation is illustrated in figure 1.0.

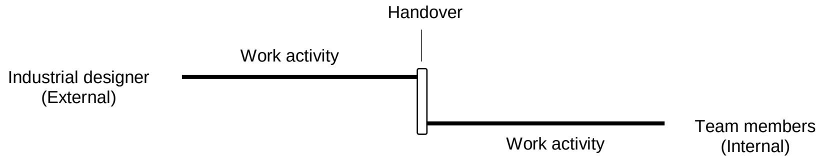

Figure 1.0 A handover situation in a product development project as a result of the work activities between the industrial designer (external) and the rest of the team members (internal) being separated, and a discontinued (or partial) involvement of the industrial designer in the product development process, after the handover.

A handover between an industrial designer and the rest of the team members in a product development project would typically be in the form of a project meeting, e.g., supported by a model of the intended product, a PowerPoint presentation, and a few additional documents. Accordingly, a handover situation can also be regarded as a situation of interdisciplinary communication, where the industrial designer must communicate and transfer the results and knowledge obtained through the separated work activities to the rest of the team members. The situation is stressed by limited time, difference between disciplines (e.g., focus and work methods), and limited possibilities for feedback. Accordingly, clearly communicating the results and knowledge (e.g. verbally) becomes of great importance in a handover situation.

As a means of investigation and a delimitation of the research focus, this study focuses on industrial designers as consultants in product development projects, on a 'project level'. Firstly, industrial designers are commonly used as consultants in product development projects. Secondly, there is a general interest in the integration of industrial design (ID) in product development projects, as the integration of ID has been identified as a way to ensure competitive (Kotler 2006; von Stamm 2010) and financial advantages (Gemser, Gerda; Leenders 2001; Hertenstein et al. 2005) in companies where the competition on the market also contains aspects beyond the functionality and technology of the products, e.g., the symbolic and social significance of products to the users. In a product development project, ID consultants potentially corporate with a wide range of different professionals. However, the focus in this study is on the relationship between the industrial designers and engineering designers. Firstly, the relationship is common within product development projects (involving industrial designers). Secondly, as it will be revealed later, the relationship is believed to be important in the effort to ensure the integration of ID in the product development process on a project level. Given the focus on the relationship between industrial designers and engineering designers, this study concentrates on the development of (physical) human centered products which contains technology, e.g., mobile phones, cars, power tools, and furniture, as these types of products are of relevance to both industrial designers and engineering designers.

When concentrating on human-centered products, which contain technology and are developed by companies (a commercial setting), three overall perspectives emerge naturally, a: human perspective, technology perspective, and business perspective (Brown 2009, p.15). Based on Brown (2009), the three perspectives can be described as, what is desired (by humans), what is (technical) feasible, and what is (commercial) viable. All three perspectives are common to both the industrial designers and engineering designers but they are emphasized differently by the two groups in the product development process. The different emphasis on the three perspectives relies on many aspects, e.g., the educational background of the industrial designers and engineering designers, previously experience in practice, the design task, the composition of the product development team, and the company. However, traditionally industrial designers have a strong focus on the human perspective, whereas engineering designers have a strong focus on the technology perspective (Ulrich 2011). The business perspective is regarded as a common perspective between industrial designers and engineering designers, although they tend to view it slightly different, as will be revealed later in chapter 2. Interpreting Brown (2009), the technology perspective contains considerations regarding, e.g., functionality, construction, performance, production, and (technical) quality of the product; the human perspective contains considerations regarding, e.g., usability, emotions, and meaning of products; and the business perspective contain considerations regarding, e.g., the cost and price of the product, the cash-flow of the project and business case, the supply-chain, and the possibilities and limitation on the market being targeted.

The differences in emphasis on the three perspectives create a 'gap' between the two groups of professionals which negatively stresses the handover situation. Besides creating a 'gap', the differences in emphasis on the three perspectives also imply that the industrial designers and engineering designers have different roles and responsibility in the product development process.

Given their strong focus on the technical aspects in the product development process, engineering designers are normally regarded as responsible for finalizing the product for production (Persson 2005). Engineering designers, therefore, tend to focus on the functionality and detailed construction of the product. The responsibility of having a fully functioning product at the end of the product development process makes the engineering designers focus predominately on taming the design task to make it operational (Ulrich & Eppinger 2012). On the other hand, industrial designers are focused on developing products with 'meaning' for the users, integrating the emotional and symbolic dimensions of products into the form and functionality of the product (Krippendorff 2006; Verganti 2009). However, meaning of products is ambiguous, complex and context depended (Krippendorff 2006). The industrial designer is therefore presented with inherent wicked design problems when they develop products (Krippendorff 2006). Accordingly, industrial designers and engineering designers tend to perceive design problems as predominantly wicked and tame, respectively. Consequently, industrial designers tend to focus on the creation of the product concept that ensures coherence between the emotional and symbolic dimensions which are integrated into the form and functionality of the product. The engineering designers, on the other hand, tend to focus on developing the product concept into a fully functioning product.

Regarding the product development process as a planning approach[4)], the transition between creating the product concept and developing it into a product can also be identified as a processual transition between the early conceptual phases and the later development phases. Accordingly, this processual transition in the product development process becomes a natural setting for the handover between industrial designers and engineering designers, given their different perspectives, roles, and responsibilities.

Consequently, the handover situation is regarded as both a processual transition, between the conceptual phases and development phases, and as a gap between two groups of professionals. The situation is illustrated in fig. 1.1.

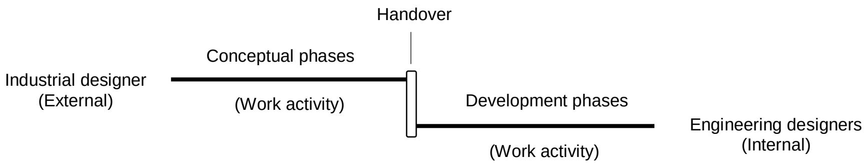

Figure 1.1 The handover situation as both a processual transition between phases and as a handover between two groups of professionals.

The separation of work activities and the difference in emphasis on perspectives and accordingly differences in roles, responsibilities, and how design problems are predominantly perceived create a gap between the industrial designers and the engineering designers. The gap becomes evident in the transition from the product concept to the development of the product. During the conceptual phases, the industrial designers gain insights into both the users and context by conducting, e.g., interviews, observations, and various forms of tests. Embedded in these work activities, the industrial designers create an underpinning 'logic' in order to handle the ambiguity and complexity of the design problem and to guide the creation of the product concept (Schön 1983; Dorst 2015; Møller & Tollestrup n.d.) The underpinning logic consists of mental constructs (frames) that help the industrial designer to make sense of an ambiguous and complex situation. The underpinning logic also makes it possible for the industrial designer to identify the limitations and options for the product, e.g., the nature of the product, the number of features to be implemented in it, materials, form and usability (Møller & Tollestrup n.d.; Schön 1983). Moreover, the industrial designer aims at constructing an underpinning logic with an 'alignment' between the different perspectives (Møller & Tollestrup n.d.). Brown (2009) describes 'alignment' as bringing the perspectives "*into a harmonious balance*" (p. 18). This differs from 'traditional' solution strategies looking for compromises or making one perspective superior (Dorst 2015).

The results of the conceptual phases regarded from the perspective of ID is accordingly not just the product concept, normally emphasized in a handover situation, but also the underpinning logic of the product concept.

During the development, after the handover, the engineering designers will create detailed solutions and/or make needed changes to the product concept in order to finalize the development of the product. This could, e.g., be changes to the materials due to cost, production method, or the needed physical strength of the parts, or changes to the form of the product as a consequent of the detailed development of, for instance, a hinge or a button. However, in a handover situation it is very important that the engineering designer understands the underpinning logic of the product concept. Being unaware of the underpinning logic, the engineering designer potentially erodes the originally intended design and thus weakens the integration and, consequently, the competitive and financial advantages of integrating ID in product development projects. It is therefore important that the industrial designer ensure that the underpinning logic of the product concept is communicated and transferred at the handover, in order for the logic to remain part of the considerations made during development. Accordingly, it is an underlying assumption in this study that maintaining the design intent proposed by the industrial designer in the final product, and/or ensuring that changes to the underpinning logic still are in 'alignment' with the perspectives are vital in the effort to ensure the competitive and financial advantages of integrating ID in product developing projects. Moreover, it is assumed that if the engineering designer has an understanding of the underpinning logic of a product concept during the development phases, it would potentially make it possible for the engineering designer to develop detailed solutions, or make changes to the product in line with the design intended by the industrial designer, or an awareness of when the solutions or changes significantly changes the final product from the intended design. It is therefore important for the industrial designers to communicate and transfer the underpinning logic of the product concept to the engineering designer at the handover in the effort to ensure the integration of ID into the final product, on a 'project level'. The situation in focus in this study is illustrated in figure 1.2

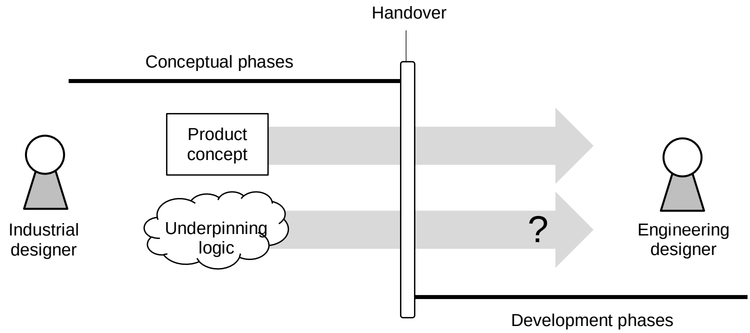

Figure 1.2 The handover situation as both a processual gap between phases and as a gap between disciplines (industrial designers and engineering designer), emphasizing the underpinning logic of the product concept.

1.1 Current Research on the Relationship between Industrial Designers and Engineering Designers in Product Development Projects

Several researchers have investigated the relationship between either industrial designers or engineering designers and other groups of professional, e.g., Beverland (2005), Griffin and Hauser (1992), Micheli et al. (2012), Veryzer (2005), and Zhang et al. (2011). Still, only a few researchers (Warell 2001; Persson 2005; Johansson & Holm 2008; Pei 2009; Rasoulifar 2014; Kim & Lee 2014) have investigated the relationship specifically between industrial designers and engineering designers. Warell (2001) has focused on a way to describe the product form in a normative way, Persson (2005) has investigated the collaborative aspects, Johansson and Holm (2008) have explored the characteristics of the collaboration, Pei (2009) has focused on the communication through design representations, Rasoulifar (2014) has focused on the communication of brand value (a marketing rather than ID based aspect) and the emotional response of consumers linked to products, and Kim and Lee (2014) have explored the reasons for conflicts.

1.1.1 The Challenges

The research which focuses on the relationship between industrial designers and engineering designers provides a good foundation for understanding the interaction between industrial designers and engineering designers, and the barriers that challenge the relationship. Both Persson (2002) and Pei (2009) have made a comprehensive analysis of the relationship between industrial designers and engineering designers identifying the barriers affecting the collaboration. Persson (2002) identified 17 influencing factors, e.g., contradictory roles, specification comprehension, inconsistent concept evaluation, different languages (terminology), product interpretations, differences in education and design problem approach, haphazardly accomplished project meetings, attitude and trust, and product representations, through a observational study in a large industrial company. Pei (2009) did a similar study (interviews and observations) and identified 19 problem areas in the collaboration between industrial designers and engineering designers. Despite their slightly different framework for categorizing the factors, Persson and Pei identified many of the same barriers. In summary, they mentioned the following factors:

- **Organizational factors:**
    - confidentiality and deliberate isolation of industrial designers, industrial designers as a minority, contradictory roles, reward systems and prestige issues, and haphazardly accomplished project meetings (Persson)
    - poor direction of project management, not having a common goal, and company bias on ID and engineering design (Pei)

- **Process factors:**
    - differences in functions and time plans, inconsistent concept evaluation, differences in internal collaboration, differences in design problem approach, and administrative media tools (Persson)
    - no formalized meetings, and not choosing the right tools and methods (Pei)

- **Tools:**
    - product representations (Persson)
    - inappropriate selection of design representation method, poor translation from 2D sketch to 3D CAD, and wrong implementation of design representations (Pei)

- **Human factors:**
    - differences in skills between novice and senior members, attitudes and trust, and vague design motivations (Persson)
    - conflicts in personal principles, poor communication skills, not understanding each other, fixed mindset, conflict of interest, inadequate experience, individual differences and attitude, and Western/Asian approach of working (Pei)

- **Educational factors:**
    - specification comprehension, different languages (terminology), product interpretations, and differences in education (Persson)
    - not having knowledge of the other field, and dissimilar educational background (Pei)

1.1.2 Approaches towards the Challenges

Several 'solutions' have been suggested to overcome some of the above mentioned factors. Warell (2001) suggests a common 'language' (*Design Syntactics*) between industrial designers and engineering designers by offering a way to describe the product form in a normative way, where the aesthetic and technical aspect of a product are interconnected. Thus, Warell aims at improving the collaboration by creating a 'common' language between industrial designers and engineering designers, indirectly improving the communication and interpretation of both specifications and product. However, Warell focuses on the 'output' (concept/product) of the design process, rather than the underpinning logic behind it. Rasoulifar (2014), focuses on the communication of brand value and the emotional response of consumers linked to products, suggesting three different tools (*annotations, word mappings and multiple-domain matrices*). In this effort, she adopts the engineering based principle Kansei Engineering which can be describes as an approach to translating 'customer´s psychological feelings and image into elements of a product' (Schütte 2005). Accordingly, Rasoulifar focuses on the engineering designer decoding the product concept and thus improving the communication. However, Rasoulifar only focuses on a limited part of the underpinning logic (brand value and the emotional response of consumers). Consequently, the understanding becomes scattered and detached. Pei (2009), focus on the differences in the perception and understanding of the various design representations normally used in a product development process. As a means to creating a common platform for the industrial designers and the engineering designers, he proposes a tool (ID Cards) that provides the industrial designers and engineering designers with a standardized overview of the different design representations. The 'ID Cards' provide the industrial designers and engineering designers with a common 'language', indirectly improving the communication. However, focus is on improving the communication in general, rather than on improving the communication of the underpinning logic. Persson (2005) focuses on the collaborative aspects and identifies the problems as being too little time and space provided for the disciplines to share their knowledge and experiences and he argues for the need of a ‘collaborative workspace’ which would create space and time to share knowledge and experiences. Thereby, Persson focuses on the more general organizational and processual factors rather than the communication of the ‘output’ and underpinning logic on a ‘project level’. Kim and Lee (2014) suggest a higher degree of collaboration between of industrial designers and engineering designers through their education as a means to avoid future conflicts. Consequently, Kim and Lee focus on a harmonious collaboration rather than communication of the ‘output’ or underpinning logic.

1.2 Gap of Knowledge

When examining the current literature which investigates the relationship between industrial designers and engineering designers, there is a lack of material which investigates the collaboration in the cases, where it is not possible to follow best practice of IPD due to a handover situation understood as both a gap between disciplines and as a processual transition in the product development process. Moreover, there is a lack of research that concentrates specifically on the underpinning logic of the product concept in the investigation of the relationship between industrial designers and engineering designers. Accordingly, there is a gap in the literature as no one focuses on the communication and transfer of the underpinning logic of a product concept within a handover situation between industrial designers and engineering designers in a product development project.

1.3 Research Aim

The overall aim of this study is to contribute to a deeper understanding of the integration of ID in product development projects by focusing on the relationship between industrial designers and engineering designers. Although the advantages of integrating ID in the development of human centered products is widely recognized (Sanders 2006), little is still known of how to ensure the integration of ID in product development projects. This study investigates those situations in practice where it is not possible to follow best practice of IPD. Overall, the study is divided into two parts; firstly, the situation (as-is) is investigated, as we try to understand the current situation and challenges, and secondly, the situation is improved (to-be). The research questions of this study are also framed within this specific empirical research setting which forms the platform for the study, and the answers to the research questions are therefore to be understood taken this context into account. Furthermore, it is assumed that by focusing on the underpinning logic of the product concept rather than just on the product concept, a better integration of ID in product development projects will be ensured.

1.3.1 Research Questions

RQ1: ***Which aspects of the underpinning logic of a product concept are challenging for the industrial designer to communicate and transfer to the engineering designer in a product development project in a handover situation?***

RQ2: ***To which extent does explicitly emphasizing the underpinning logic of a product concept affect the engineering designer's ability to understand whether potential production changes are coherent with the product concept´s underpinning logic?***

1.4 Summary

In this chapter, the study was motivated by and overall positioned as concerned with the integration of ID in product development projects by focusing on the relationship between industrial designers and engineering designers. Based on the literature review it was found that there is a lack of research which focuses on situations in practice where the relationship between industrial designers and engineering designer is hampered in a handover situation. A handover situation is in this study, understood as both a processual transition between the conceptual and development phases in a product development process, and as a gap between industrial designers and engineering designers, due to differences in emphasis on perspectives, roles, responsibilities and, predominantly perception of design problems. The aim of the study is to understand which elements of the underpinning logic of a product concept that are challenging for the industrial designer to communicate and transfer to the engineering designer in a product development project with a handover situation. Moreover, the aim is to investigate, if the communication and transfer of the underpinning logic from the industrial designer to the engineering designer can be improved by explicitly emphasizing on it in a handover situation, and how it affects the engineering designer's ability to decode the underpinning logic.

1.5 Structure of the thesis and overview of chapters

To provide a full overview of the thesis, each of the chapters is briefly summarized.

Chapter 1
Introduction

Chapter one commences with an overall positioning and motivation of the study. Moreover, the current literature focusing on the collaboration between industrial designers and engineering designers is reviewed, identifying a 'gap of knowledge'. This is followed by a presentation of the research questions, including the research aim.

Chapter 2
Theoretical framework

Chapter two presents the theoretical framework of this study. The chapter is divided into two main sections. In the first section, the handover is discussed as a gap between industrial designers and engineering designers, focusing on differences in emphasis on perspectives, roles, responsibilities, predominantly perception of design problems, and approaches towards them. In the second section, the handover is discussed as a processual transition embedded in the product development process. The focus is on the transition between the conceptual and development phases in the product development process as it is a natural transition for a handover between industrial designers and engineering designers. This is followed by a discussion of how the collaboration and communication is hampered by the handover situation.

Chapter 3
Research framework

Chapter three presents the research framework of this study. The research framework consists of a presentation and discussing of the overall philosophical position within pragmatism, the methodology based on Design Research Methodology, and the main elements of the research design, including the methods for gathering and analyzing data. The empirical material that forms the foundation of this study consists of six case studies (including 20 interviews) and a 'Lab.-study' consisting of six student projects.

Chapter 4
First descriptive study

Chapter four contains the first descriptive study. The study is an explorative investigation of the current situation (as is) primarily based on 20 interviews with mainly industrial designers and engineering designers divided between six cases (retrospective). The main implications are that the sub-frames embedded in the human perspective, seem the most challenging to communicate and transfer to the engineering designers. Moreover, it seems that especially the sub-frames (within the human perspective) containing emotional, symbolic, social, and cultural elements are particularly difficult to communicate and transfer.

Chapter 5
Prescriptive study

Chapter five contains the perspective study. The chapter commences with a discussion of the different types of support. Afterwards the chosen support is presented and discussed, including the considerations for choosing the type of support.

Chapter 6
Second descriptive study

Chapter six contains the second descriptive study. The study investigates whether explicitly emphasizing on the underpinning logic in a handover situation improves the communication and transfer of it from the industrial designer to the engineering designer. The main implications are that explicitly emphasizing on the underpinning logic in a handover situation does seem to improve the situation. This is indicated by the higher number of correct answers given to a series of questions answered by the engineering before and after being introduced to underpinning logic.

Chapter 7
Conclusion

Chapter seven commences with answering the research questions. This is followed by a discussion of the reliability of the study. Afterwards, the findings of the study are positioning within the existing knowledge in the field. Finally, future research within the area is suggested.

2.0 Theoretical Framework

Part of the theoretical framework has already been touched upon in the 'Introduction'. The aim of this chapter is to further describe and discuss the relevant theoretical areas, in the effort to position and frame the study. The theoretical framework provides the foundation on which this study stands and, moreover, the lenses through which this study should be seen.

2.1 The Structure of the Chapter

The chapter is divided into two overall sections, following the research focus. In the first section (chapter 2.2), the handover is seen as a 'gap' between disciplines focusing on the differences between industrial designers and engineering designers. In the second section (chapter 2.3), the handover is seen as a processual transition embedded in the product development process. The two sections are followed by an overall concluding summary.

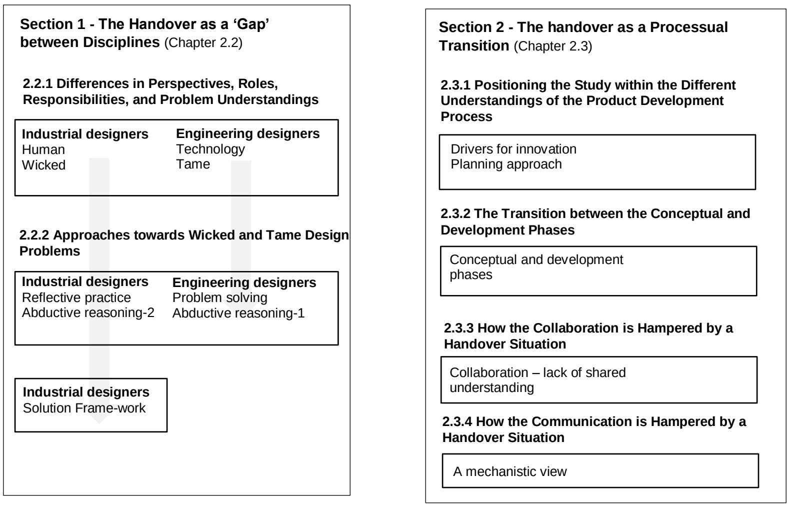

Figure 2.0 The structure and overall content of the chapter.

2.2 The Handover as a 'Gap' Between Disciplines

In this section, the handover is first explored as a gap between industrial designers and engineering designers. There exist several understandings of an 'industrial designer' and 'engineering designer' within the literature, many of which are contradictory or even conflicting. This is no surprise as both terms are social constructs, based on the context and the experience of the scholar. This study is no exception to this. The aim is therefore merely to provide the reader with an understanding of 'industrial designer' and 'engineering designer' as the two terms are understood in this study. Consequently, the description of industrial designers and engineering designers given in this chapter becomes a context related 'proposal' of how industrial designers and engineering designers should be understood, rather than a generally applicable definition.

2.2.1 Differences in Perspectives, Roles, Responsibilities, and Problem Understandings

This study approaches the differences between industrial designers and engineering designers as a matter of emphasis on perspectives, and accordingly differences in roles and responsibilities. It will be argued that the predominant perspective of respectively industrial designers and engineering designers, not only affects the roles and responsibilities given to the two groups of professionals, but also affects how design problems are predominantly perceived. At the end of the chapter, the differences will be discussed and summarized.

2.2.1.1 Human Perspective

The human perspective contains considerations regarding, e.g., usability, emotional, social, and cultural aspects, and meaning of products (Brown 2009). This is the predominant perspective for industrial designers (Krippendorff 2006; Brown 2009; Dorst 2015). The strong focus on users is what distinguishes industrial designers from others, e.g., engineering designers (Krippendorff 2006, p.48). Central to the human perspective and accordingly industrial designers is the 'meaning' of products (Krippendorff 2006, p.47). Krippendorff (2006) describes 'meaning' as mental constructs invoked by our senses, context dependent, and based on previous

experiences, emerging when interacting with the product (Krippendorff 2006). For instance, meaning of a product is how we perceive ourselves and how we believe others perceive us, e.g. when driving a Lamborghini (Krippendorff 2006). The industrial designers aim at ensuring the meaning of the product by focusing on creating a coherence between the emotional and symbolic dimensions of the product and the functionality and form of the product (Krippendorff 2006; Brown 2009).
When focusing on the meaning of products industrial designers are faced with a complex and ambiguous design problem (Rittel 1972; Dorst 2015). Firstly, meaning is individual and context dependent, making it challenging to ensure that the aspired meaning of a product make sense to most of the users (Krippendorff 2006). Secondly, industrial designers do not just need to obtain an understanding of what should be designed, the industrial designer needs to obtain a 'second-order understanding' (Krippendorff 2006). A second-order understanding is the industrial designers' understanding of the user's understanding of the product (Krippendorff 2006). The context dependency and accordingly 'wickedness' of design problems make industrial designers tend to focus on the conceptualizing of the product to ensure the coherence between the emotional and symbolic dimensions of the product and the functionality and form of the product in order to create meaningful products for the users (Lofthouse 2004).

Engineering designers also consider the users and accordingly the human perspective when they develop (human centered) products (Ulrich & Eppinger 2012; Andreasen et al. 2015). However, engineering designers tend to regard users from a more rational and functional perspective compared to the holistic view within industrial design (Ulrich 2011). Engineering designers seem to focus more on the rational and functional aspects of the human perspective often linked to the usability of the product, e.g., ergonomics and (functional) ease of use. The field of Human-Computer Interaction (HCI) is an example of this. Within the field of HCI a lot of attention has been given to, e.g., user cognition and user performance in regards to interaction with products, making the human interaction measurable, functional, and rational (Law et al. 2009). The more intangible aspects of the human perspective, e.g., the emotional and symbolic dimensions of products seem less emphasized within the field of engineering design, with exceptions. For instance, Kansei engineering, an engineering approach which aims at translating 'customer´s psychological feelings and image into elements of a product' (Schütte 2005). However, underlying the approach it seems to be a goal to create some general deterministic connections between human emotions and elements of the product. Accordingly, this approach differs from the context-depend human perspective within industrial design.

This predominantly functional, rational, and context independent view on users within engineering design seems to make it possible for engineering designers to apply some general values and principles, e.g., regarding the user´s cognitive capability, performance goal or the user's emotional responses. Accordingly, engineering designers do not tend to perceive the same degree of 'wickedness' in design problems as the industrial designers do.

2.2.1.2 Technology Perspective

The technology perspective is the predominant perspective within engineering design and it contains considerations regarding, e.g., the functionality, construction, performance, production, and (technical) quality of the product (Ulrich & Eppinger 2012; Brown 2009). The perspective is very broad and therefore engineering designers normally have their own areas of specialty, e.g., mechanics, software, hardware, or materials. These areas of specialty are, moreover, often further sub-divided due to the complexity embedded in them, e.g., the area of materials can for instance be further divided into: metals, polymers, ceramics, and composites, which again can be sub-divided. Accordingly, engineering designers can be characterized as 'specialist' (Lofthouse 2004). Depending on the (technological) complexity of the product, a number of engineering designers with different specialties can be required in a product development project team. Alone, the individual engineering designer only covers a limited area, but together the engineering designers cover all the technological aspects relevant to the product being developed. The knowledge and skills embedded in the technology perspective often make the engineering designers responsible for 'finalizing' the product development - having a fully functioning product (Persson & Warell 2003; Ulrich & Eppinger 2012). Finalizing a product could for instance contain activities such as: making detailed mechanical constructions, ensuring the functionality and performance of the product, constructing PCBs, and writing software. Accordingly, engineering designers predominantly focus on taming the design problem and making it operational (Persson 2005; Ulrich & Eppinger 2012). Embedded in the perspective emerging from 'technical rationality' underlying the perspective, there seems to be some general values, e.g., making it cheaper to produce, more efficient, faster (Krippendorff 2006; Schön 1983). However, these values are normally imposed by the engineering designers or their 'clients', and not necessarily based on an understanding of the users and context relevant to the specific design task in focus (Krippendorff 2006). Accordingly, the engineering designers are presented with a predominantly functional and rational design problem, rather than a complex and ambiguous design problem.

Industrial designers also consider the technology perspective when developing products. However, as the industrial designers do not have the same level of technical knowledge and skills as the engineering designers, they tend to focus on the 'effect' of the technology rather than on, e.g., the detailed construction or production of it (Brown 2009). Industrial designers are also sometimes referred to as 'brokers' of technology (Hargadon & Sutton 1997), indicating a broader (but less profound) view on technology (Stompff 2012). Therefore, industrial designers evaluate the challenges, opportunities, and possibilities connected to the technology with regard to the case dependent understanding of the users and context-of-use. This focus on the conceptualizing within the technology perspective, rather than detailed solutions resonate well with the role and responsibility of the industrial designer embedded in their predominately perspective - the human perspective.

2.2.1.3 Business Perspective

When working in the context of commercial companies, designers (industrial designers and engineering designers) need to take into consideration the commercial viability of the products they develop, e.g., the cost of the product, the sales price of the product, the cash-flow of the project and business case, the supply-chain, and the possibilities and limitation on the market being target (Brown 2009). The business perspective is not seen as a predominantly perspective, for neither the industrial designers nor the engineering designers. The role and importance of the business perspective for both the industrial designers and engineering designers can be seen as a prerequisite for both the industrial designers and engineering designers in the project. The business perspective is regarded as a shared perspective, although it seems that industrial designers and engineering designers tend to emphasize on different aspects of the perspective. Johansson and Holm (2008) have in a study reported that engineering designers tend to be more focused on keeping budgets and time schedules than the industrial designers, when they work together. This focus resonates well with the role and responsibilities of the engineering designers in the product development, taming and operationalizing the design problem, with the aim of having a fully functioning product at the end of the product development process. A 'working' product is in this context consequently also understood as something that is commercial viably. Industrial designers, on the other hand, tend to be more focused on the overall aspects of the business perspective, e.g., the possibilities and opportunities on the market and users being targeted (Brown 2009). This focus on the possibilities and opportunities within the business perspective corresponds well with the role and responsibilities of the industrial designers, who primarily focus on the conceptualizing of the product.

2.2.1.4 Discussing and Summarizing the Differences in Problem Understanding

When the human, technology, and business perspectives in relation to industrial designers and engineering designers are discussed several significant differences are revealed. The predominant perspective of *industrial designers* is the human perspective primary which focuses on ensuring the meaning of the products, from the perspective of the users. This is why the industrial designers tend to concentrate on the conceptualization of the product and creating coherence between the emotional and symbolic dimensions of the product and the functionality and form of the product. Therefore, the industrial designers think of the technology and the business perspective with focus on the challenges, opportunities and possibilities related to the meaning of the product, while they carefully try to balance the perspectives. The embedded complexity and ambiguity in the human perspective that ensures meaningful products from the perspective of the users, presents industrial designers with *wicked* design problems. Wicked design problems, introduced by Rittel and Webber (1973), can be described as complex, unique, subjectively and ill-defined. The understanding of wicked design problems and the solutions to them are subject to redefinitions without any 'stopping rule'. Moreover, there is no unambiguous way to test the validity of a solution to a wicked design problem (Buchanan 1992; Coyne 2005).

The technology perspective is predominate perspective of *engineering designers*. And as they have profound knowledge of the technology, the engineering designers are normally regarded as the ones responsible for finalizing the product and making sure it is fully functional and commercial viable. The engineering designers' focus on taming and operationalizing the design problem makes them emphasize on the end product. The functional and rational view embedded in the technology perspective influences the engineering designer's view of the other perspectives. Accordingly, engineering designers tend to see design problems as less 'wicked'. Applying general, context independent values embedded in engineering design also help the engineering designer in taming and operationalizing the design problem. Accordingly, engineering design focus on making design problems *tame*. Tame design problems are defined as opposite to wicked design problems. And so, tame design problems can be described as manageable, recognizable, objective, and well-defined, and in a stable context. Tame design problems can therefore be fully understood, defined, evaluated, and tested.

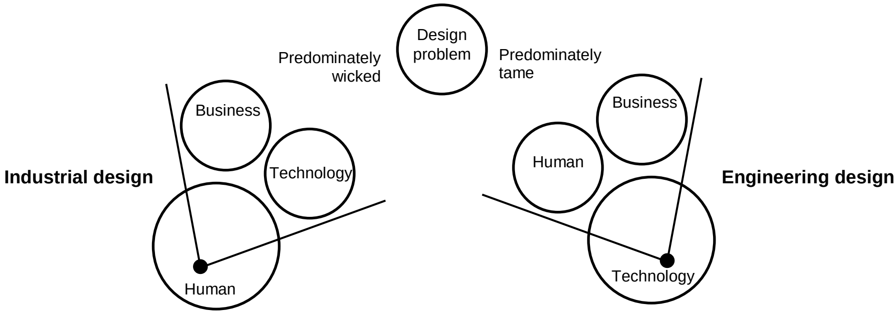

Figure 2.1 The figure illustrates how industrial design is predominately based within the human perspective, and 'look' at the business and technology perspective, and how engineering design is predominately based within the technology perspective and 'look' at the human and business perspective. Moreover, the differences in emphasis on perspectives as well as roles and responsibilities tend to make the industrial designers and engineering designer perceive design problems differently, that is as predominantly 'wicked' and 'tame', respectively.

This study proceeds by discussing the different approaches applied to the product development process by engineering designers and industrial designers respectively, given their predominant understanding of design problems.

2.2.2 Approaches towards Wicked and Tame Problems

As revealed in the previous chapter, industrial designers and engineering designers tend to perceive design problems differently. In this section, it will be argued that the differences in problem understanding require different approaches, 'problem solving' and 'reflective practice', and therefore also different reasoning processes. This chapter can, therefore, be regarded as a discussion of the predominate approaches and interconnected reasoning processes underlying industrial designers and engineering designers respectively, given their predominantly perception of design problems. The chapter commences with discussing the approach towards tame design problems (the right side of figure 2.1), normally applied by engineering designers.

2.2.2.1 Problem Solving

When design problems are perceived as tame, it is assumed that it is possible to achieve an understanding of the basic nature of the design problem before starting to solve the problem (Rittel 1972; Coyne 2005). Once the design problem has been exhaustively understood, a variety of possible solutions can be generated and afterwards evaluated (Coyne 2005). Based on these evaluations, the best possible solution is chosen. Given the inherent criteria of predictability, stability, and clarity, design problems can be isolated, kept static, and broken down into a hierarchy of (relatively) simple sub-problems, which then can be solved using an rational and analytical process (Dorst 2015; Rittel 1972). To understand the reasoning process underlying the problem solving approach, an understanding of both deduction and abduction is needed.

Traditionally, reasoning can be divided into *deduction*, *induction*, or *abduction*. The different reasoning processes emerge from the differences in what is known and what is unknown to the problem solver (when starting to solve the problem). Dorst (2011) describes deduction and induction by using the following general equation to identify what is known and what is unknown:

WHAT (thing) + **HOW** (working principle) leads to **RESULT** (observed)

Figure 2.2 The above illustration is based on Dorst (2011, p.523).

Within *deduction*, the 'thing' (WHAT) and the 'working principles' (HOW) of the 'thing' are known. This allows results to be predicted. This could, for instance, be the tensile strength of a round bar of aluminum, used in a product. If the diameter of the bar and the material properties of the aluminum used (WHAT) are known, and the mathematical equation needed to calculate the tensile strength (HOW) is known, then the tensile strength of the bar (RESULT) can be predicted through calculations.

WHAT (thing) **+ HOW** (working principle) **leads to ??**

Figure 2.3 The above illustration is based on Dorst (2011, p.523). Within deduction both the 'WHAT' and 'HOW' are known whereas the 'Result' is unknown.

Within *induction*, the 'thing' (WHAT) and the 'RESULT' are known, but not the 'working principles' (HOW). Consequently, a hypothesis is proposed (a creative process) and tested. This could, for instance, be to propose the mathematical equation (HOW) between the tensile strength of a round bar (RESULT) and its diameter (WHAT). Performing a series of tests would make it possible to confirm or deny the proposed mathematical equation (hypothesis).

WHAT (thing) **+ ?? leads to RESULT** (observed)

Figure 2.4 The above illustration is adopted based on Dorst (2011, p.523). Within induction both the 'WHAT' and 'RESULT' are known whereas the 'How' is unknown.

Abductive Reasoning-1

When focusing on design problems, abductive reasoning becomes the main reasoning process (Dorst 2011). When focusing on the act of designing, 'RESULT' is changed to 'VALUE' as the aim of design is to create value for others rather than just results (Cross 2006; Dorst 2011). Consequently, the equation is changed to:

WHAT (thing) **+ HOW** (working principle) **leads to VALUE** (aspired)

Figure 2.5 The above illustration is based on Dorst (2011, p.523).

Abductive reasoning comes in two forms (Dorst 2011) which are particularly interesting when focusing on how industrial designers and engineering designers handle wicked and tame design problems respectively. Adopting the adjusted equation of Dorst (2011), both the 'VALUE' and 'HOW' are known to the designer, in the first form of abduction (Abduction-1). The only unknown is the 'thing' (WHAT).

?? (thing) **+ HOW** (working principle) **leads to VALUE** (aspired)

Figure 2.6 The above illustration is based on Dorst (2011, p.524). In abduction-1 both the 'VALUE' and 'HOW' are known. Only the 'thing' (WHAT) is unknown.

In other words, the designer knows what value he or she wants to achieve and at least one way (working principle) of how this can be achieved. Consequently, the only element unknown is the 'thing' which is to be created. For instance, a PCB within a product needs cooling. Both the 'VALUE' (cool the PCB) and different principles of how to cool the PCB (HOW) are known, e.g., active cooling using a fan or water (closed system) or passive cooling using convection. The design task then becomes a matter of choosing a (known) principle and then designing the specific solution needed. The first logical step is to create the 'thing' based on a chosen 'working principle', as it is the only unknown in the equation. Then, having a full equation (WHAT, HOW and VALUE) the final step is to test (using deduction) if the 'thing' created leads to the aspired valued (Dorst 2011). Accordingly, induction and deduction are both embedded in abduction-1.

Product specification

The problem solving approach and the underlying abductive reasoning (abductive reasoning-1) make it possible for the engineering designer to build on the known working principles, which are believed to lead to the aspired value. In the effort to tame the design problem and as a consequence of the taming of the design problem the 'product specification' becomes central. A product specification contains goal formulation in terms of functional specifications and performance specifications of the product (Ulrich & Eppinger 2012; Andreasen et al. 2015). The project specification is the basis for choosing the relevant working principle and evaluating them, if there is more than one. A product specification is the foundation for the rational and structured exploration of the solution space and afterwards generating and evaluating potential solutions (Dorst 2011; Schön 1983; Krippendorff 2006). The functional and rational view on the perspectives embedded in engineering design as well as the focus on taming and operationalizing the problem make the engineering designer apply generic, rather than context dependent solutions (principles). This resonates well with the understanding of a 'closed' solution space, which builds on a product specification and known principles. This thesis will proceed with discussing the approach towards wicked design problems (the left side of figure 2.1), normally applied by industrial designers.

2.2.2.2 Reflective Practice

This chapter focuses on the approach applied to design problems predominantly perceived as wicked. When perceiving design problems as wicked, they are regarded as ambiguous and complex, with no possibility to achieve an understanding of the basic nature of the design problem before starting to solve the problem (Rittel 1972). When solving wicked design problems, the designer *"…seeks both to understand the situation and to change it*" (Dorst 2015, p.134). This means that designers learn about the problem as a result of trying out the solution, co-developing an understanding of the problem along with the creation of the solution (Dorst & Cross 2001; Lawson 2006). Wicked problems can consequently not be solved following a series of logical steps, building on top of each other (Rittel 1972; Dorst 2015; Buchanan 1992). From a problem solving perspective, the designer must make sense of a situation that initially does not make any sense. The designer must construct the situation by applying a different type of abductive reasoning, abductive reasoning-2. (See section below)

Abduction 2

Following the earlier mentioned description of induction, deduction and abduction-1 in relation to 'problem solving', the second form of abduction (abduction-2), and the underlying reflective practice, is more complex. The only element known to the designer is the (aspired) 'VALUE'. Both the 'thing (WHAT) and the 'working principle(s)' (HOW) are unknown to the problem solver.

?? (thing) + **??** (working principle) leads to **VALUE** (aspired)

└── **FRAME** ──┘

Figure 2.7 The above illustration is based on Dorst (2011, p.524). In abduction-2, both the 'WHAT and 'HOW' is unknown to the designer.

Consequently, the 'thing' (WHAT) and 'working principle(s)' (HOW) need to be developed in parallel. For instance, this could be a case when a product with a high degree of technical complexity is developed for a group of users who are 'afraid' of 'technology'. In such cases there are no known solutions to and/or principle for how to overcome this unique (context dependent) 'paradox'[5)]. Accordingly, the designer must co-develop an understanding of the problem and the solution to solving the problem (Dorst 2011). In order to do this, the designers develop or adopt a 'frame' (Dorst 2011). A frame "*is the general implication that by applying a certain working principle we will create a specific value*" (Dorst 2011, p.524). When only the 'VALUE' is known, the most logical step is to work backwards to propose a 'working principle' that is believed to lead to the aspired value, which can also be seen as an act of *induction* (Dorst 2011). The next step is then to create the 'thing' based on the proposed 'working principle', which can be regarded as an act of the first form of abductive reasoning (Dorst 2011). Then, when the equation is complete (WHAT, HOW and VALUE), the final step is to test whether the 'thing' created leads to aspired valued (Dorst 2011). Accordingly, induction and deduction are both embedded in abduction-2.

Framing and the Underpinning Logic

Within reflective practice, the concept of framing is adopted as a way to handle the complexity and ambiguity of wicked design problems. Schön (1983) describes this process as 'framing' and 'reframing' the problem settings - "*the process by which we define the decision to be made, the ends to be achieved, and the means which may be chosen*" (p. 40). Based on Schön (1983), the act of framing is identified as containing four steps: *naming*, *framing*, *moving* and *reflecting*. Schön originally named the last step 'evaluating' but it was later suggested changed to 'reflecting' by Valkenburg and Dorst (1998) to emphasize the reflective nature of framing. The four steps will be described briefly below:

Naming: "…*we name the things to which we will attend*…" (Schön 1983, p.40). By naming the things which he or she will attend to, the designer shows which elements of the problem setting she believes to be important. Moreover, the way the things are named shows how they are perceived by the designer. In other words, the way a situation is described also indicates how the situation is perceived.

Framing: Schön (1983) does not offer a clear definition of this step. However, based on Schön (1983), framing is described as suggestion an understanding of the problem settings and/or solution that is believed to make sense to the users (Valkenburg & Dorst 1998).

Moving: This is where the designing takes place. The frame created is tested through various moves depending on the frame/context. Schön (1983) describes moving as: "*Each move is a local experiment that contributes to the global experiment of reframing the problem*…" (p. 94).

Reflecting: During reflection, the designer evaluates the frame and the outcome of the move to see if it makes sense to the context.

Seen from the outside, framing can be seen as an almost randomly process where proposals are made to a design problem. Initially the designer must frame the settings of the situation as design problems do not present themselves to the designer Schön (1983). In this process of framing/reframing the problem settings, the designer 'names' the elements of interest and 'frames' the perspective through which they will be valued[6)] (Schön 1983). The constructed frame is then tested, proposing a solution to see if it captures the complexity of the situation. This is also described by Schön (1983) as a 'reflective conversation' with the situation where the situation talks back to the designer. If the tested frame fails to capture the complexity of the situation the settings must be reframed. Schön (1983) describes reframing as the construction of a new understanding of the problem setting if the designer "*finds himself stuck in a problematic situation which he cannot readily convert to a manageable problem*" (p. 63). Buchannan (1992) describes the situation of reframing well with this short example:

'Traditional graphic design yielded larger signs but no apparent improvement in navigation – the larger the sign, the more likely people were to ignore it. Finally, a design consultant suggested that the problem should be studied from the perspective of the flow of the costumer experience. After a period of observing shoppers walking through stores, the consultant concluded that people often navigate among different sections of a store by looking for the most familiar and representative examples of a particular type of product. This led to a change in display strategy, placing the products that people are most likely to identify in prominent positions' (Buchanan 1992, p. 12).

In this process of testing the reframed situation, new discoveries will be revealed which again will call for new refection-in-action (Schön 1983). Through the process, the designer develops an 'underpinning logic', based on the 'frames' (Schön 1983) of both the situation and the product concept. The product frames guide the designer and make it possible for the designer to identify the limitations and options for the product. Consequently, the underpinning logic of a product concept, understood as product frames, becomes of vital importance in a product development project with a handover situation between industrial designers and engineering designers.

2.2.2.3 Problem Frames and Solution Frames

The description of framing by Schön does not give any clear understanding of what a frame is, expect: 'an understanding of the problem settings and/or solution that is believed to make sense to the users' (Schön 1983). Dorst (2011) offers a more detailed description of frames, when he describes a *frame* as the connection between the deep insights into the users and the context connected with the working principles of the product. Moreover, Dorst (2015) emphasizes the novelty embedded in frames and try to demystify the 'creativity' often connected with design. Frames offer "…*a novel standpoint from which a problem can be solved*…" (Dorst 2015, p.55). In other words, frames create a novel understanding of the problem as well as a novel way of handling it.

By using the equation used to describe abductive reasoning, a frame can be described as the connection between the HOW (how the different elements are interconnected and acts) and the VALUE (aspired).

WHAT + **HOW** leads to **VALUE**
(thing) (working principle) (aspired)
└── **FRAME** ──┘

Figure 2.8 The figure is based on the work by Dorst (2011, p.524).

This understanding presents frames as 'problem frames' – "*that is the designer's ability to see the problem in a new or redefined perspective and therefore present a direction for a radical new solution*" (Møller & Tollestrup n.d., p.1). However, based on insights from practice Møller and Tollestrup (n.d.) find that when designers solve wicked design problems, they develop and refine a number of frames, rather than just one overall 'problem frame' (Møller & Tollestrup n.d., p.5). These additional frames handle different (important) perspectives and aspects of the design problems, not necessarily included in the overall problem frame. These additional frames are named 'solution frames' (Møller & Tollestrup n.d.). In contrast to the overall problem frame(s), the solution frames provide a detailed direction for developing the product (Møller & Tollestrup n.d.). Together, problem frame(s) and solution frames are named 'Solution Frame-Work' (Møller & Tollestrup n.d.). The solution framework "*provides an understanding of what the product can and cannot do as well as how the different frames, that create the products solution space, are aligned with each other*" (Møller & Tollestrup n.d., p.17). The 'wickedness' is reduced and the design problem tamed as the 'logic' underpinning the situation and product is developed and refined. In other words, the underpinning logic embedded in the solution framework contains the framing of a product (product framing). Adopted from Møller and Tollestrup (n.d.) the solution framework can be visualized as:

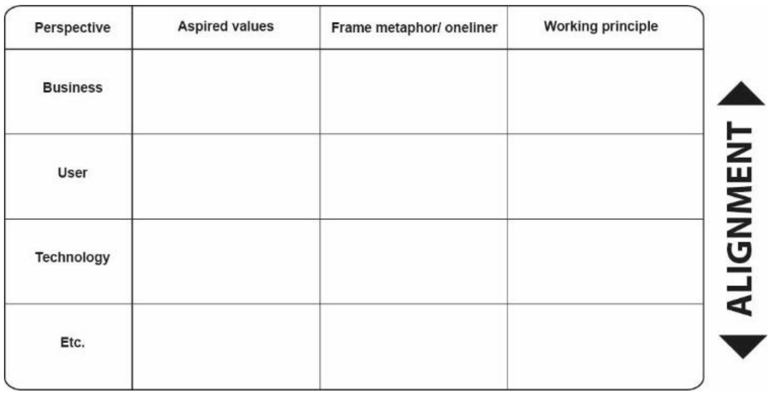

Figure 2.9 The solution framework. The figure is adopted with permission from Møller and Tollestrup (n.d.).

Each sub-frame (either a problem or solution frame) in the solution framework can be regarded as a 'line of logic'. These lines of logic connect and unfold insights, e.g., about the users and the 'aspired value', that derive from this. Theses insights/values are then connected to a 'working principle', which decides how they should be experience by the users and 'crafted' into the product (Møller & Tollestrup n.d.). Each sub-frame can contain perspectives and/or aspects of importance to the product. In this study, the 'elements' of the solution framework are understood as the insights/values, working principles, the sub-frames, or the perspectives. The one-liners/metaphors for each sub-frame are to be regarded as headlines, summarizing the content of the frame (Møller & Tollestrup n.d.). The three perspectives mentioned earlier: business, technology, and human are used as a general categories of the sub-frames.

In the process of creating the underpinning logic, the industrial designers do not just create individual 'lines of logic'. The industrial designers also ensure that the sub-frames are aligned. This means that the values contained in each of the sub-frames are aligned, not going against each other, and the working principles are aligned, not going against each other, or any of the sub-frames (Møller & Tollestrup n.d.).

In summary, this study is based on the assumption that it is vital to communicate and transfer a product's underpinning logic in a handover situation, as it becomes the foundation for understanding the proposed product concept, and moreover makes the product frames more operational to the engineering designers during the later phases of development.

2.2.4 Discussing and Summarizing Section one – the Handover as a 'Gap' between Disciplines

In this section, the differences between industrial designers and engineering designers have been approached as a matter of differences in the emphasis on perspectives (human, technology, and business) and the corresponding differences in roles, responsibilities, and the predominant perception of design problems. Moreover, it has been discussed how the differences in the understanding of design problems imply different approaches to design problems. Accordingly, the predominant approach underlying industrial design can be described as 'reflective practice', whereas the predominant approach underlying engineering design can be described as 'problem solving'.

Focusing on the interaction between industrial designers and engineering design in a product development project, the perception of design problems as wicked can be challenging. The industrial designers solve the design problem by proposing a solution (product concept) based on a specific set of product frames, developed and refined through the process. The product frames are consequently the foundation to fully understand both the design problem and the product concept. If the engineering designer is only presented with the working principles embodied in the solution (e.g., a model) and not the underlying logic in form of the solution framework, the engineering designer is left with a fragmented understanding. Later changes or corrections made to the product concept by the engineering designer will potentially be detached from the underpinning logic, and will possibly erode the originally intended design, and the alignment between the perspectives and sub-frames.

Accordingly, it is therefore assumed that the communicating and transferring of the underpinning logic from the industrial designer to the engineering designer is vital when focusing on ensuring the integration of industrial design into the final product.

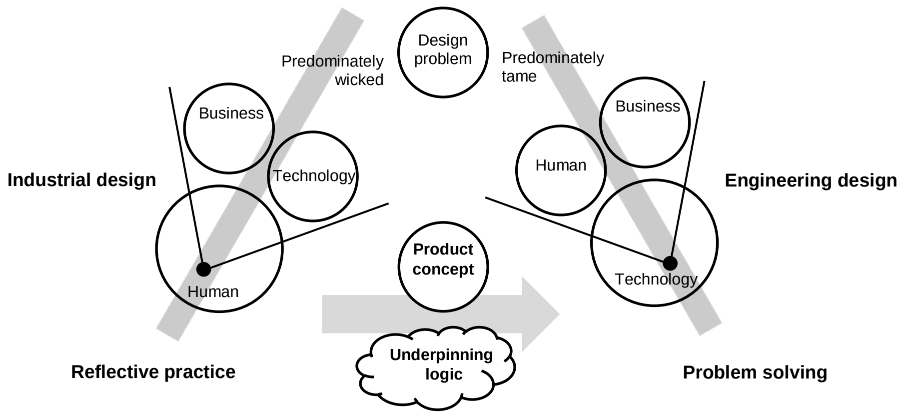

Figure 2.10 The figure illustrates the underpinning logic underlying the product concept, implying an embedded 'wickedness' in the design problem. The arrow indicates that both the product concept and the underpinning logic must be communicated and transferred, between the industrial designer and engineering designer in a handover situation.

2.3 The Handover as a Processual Transition

In the first section, the handover between industrial designers and engineering designers has been discussed as a gap between disciplines. In this section, the handover is further stressed by also regarding it as part of a processual transition embedded in the product development process. The chapter commences with a discussion of the different understandings of the product development process. This is followed by a discussion of the positioning of the processual transition in the product development process, relevant to this study. Finally, it is discussed how the processual transition hampers the collaboration and communication between the two groups of professionals. The section ends with an overall summary.

2.3.1 Positioning the Study within the Different Understandings of the Product Development Process

Traditionally, drivers for innovation within product development have been divided into market 'push' or market 'pull' (Liem & Brangier 2012). Within market push, technology and knowledge (embedded in the company) have been regarded as the main drivers for innovation, whereas a profound understanding of the users and context have been regarded as the main drivers for innovation within market pull innovation (Andreasen et al. 2015). Recently, this understanding has been expanded with 'design driven' and 'market driven' innovation, respectively, expanding the 'push' and 'pull' side of innovation (Liem & Brangier 2012). In design driven innovation, the main driver for innovation is the internal 'knowledge-building' within companies and among stakeholders and interpreters, aiming at discovering hidden needs on the market (Verganti 2009). In market driven innovation, the main driver for innovation is the user's participating in the product development process (Sanders & Stappers 2008). In market driven innovation, the users are seen as participants in the product development process facilitated by the designer, whereas the users are regarded as objects for observations and investigations in traditionally user driven innovation (Sanders & Stappers 2008). This division between the different direction within innovation divided into an push or pull understanding, and how they are interconnected is illustrated by Liem and Brangier (2012). See figure 2.11

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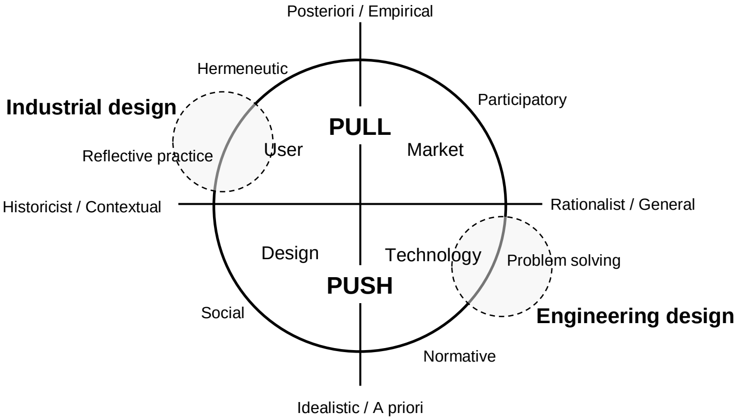

Figure 2.11 The figure is based on Liem and Brangier (Liem & Brangier 2012, p.5247). Industrial designers and engineering designers are positioned within 'user-pull' and 'technology-push', respectively, given their predominantly underlying reasoning processes.

These different understandings of drivers for innovation are underpinned by different reasoning processes or approaches and accordingly understandings of the product development process. According to Liem and Brangier (2012), six types of 'design reasoning' can be identified:

- **Problem solving**, underlying 'user-pull' (closer to 'Rationalist / General').
- **Hermeneutic**, underlying 'user-pull' (closer to 'Posteriori / Empirical').
- **Reflective practice**, underlying 'user-pull' (closer to 'Historicist / Contextual').
- **Participatory**, underlying 'market-pull'.
- **Social**, underlying 'design-push'.
- **Normative**, underlying 'user-pull' (closer to 'Idealistic / A priori').

Particularly interesting to this study is reflective practice and problem solving, in accordance with the earlier description of the industrial designers and engineering designers and their approaches towards design problems. Accordingly, the focus in this study is on 'user-pull' based on reflective practice, and 'technology-push' based on problem solving, representing industrial designers and engineering designers, respectively (see figure 2.11). The differences in the underlying reasoning also imply different understandings of the product developing process.

The problem solving approach based on an understanding of the design problem as tame implies a predominantly ‘planned’ understanding of the product development process. The planning approach can be describe a linear, rational, systematic, and sequential process, with occasional feedback build on an assumption that the context is predominantly stable and predictable (Kopecka et al. 2012; Andreasen et al. 2015) . The reflective practice approach based on an understanding of the design problem as wicked implies a predominantly situated and ‘agile’ understanding of the product development process. The agile approaches emphasize the changeability of the context, the need for reflection, and that the understanding of the problem and solution is co-developed (Kopecka et al. 2012).

This study takes a predominantly ‘planned’ stand towards the product development process. Firstly, the research focus is on situations in practice where a handover situation occurs, based on a sequential and phase divided understanding of the product development process. Secondly, this study focuses on industrial designers involved in the product development process as consultants. The product development projects are consequently ‘owned’ by the companies, including the product development process. The industrial designers, therefore, need to adapt their understanding of the product development process to fit that of the company, which will typically by influenced by the engineering designers’ reasoning and understanding of the product development process, and the natural influence they have on the product development process. Consequently, an understanding of the product development process as predominately planned seems to best describe the situation in practice, which is investigated in this study.

2.3.2 The Transition between the Conceptual and Development Phases

Several planning approaches exist within the literature, e.g., Cooper (1994; 2014), Roozenburg & Eekels (1995), and Ulrich & Eppinger (2012). A simplified model can be found in the PDMA Handbook, where the product development process is divided into three overall phases: the Fuzzy Front End (FFE); the New Product Development (NPD); and Commercialization. Andreasen et al. (2015) have a corresponding model but offer a more detailed description of the process in practice. They describe the product development process as a sequence of activities: exploration, concept synthesis, product synthesis, product development, and product life synthesis. These activities result in a series of design outcomes: task (exploration), concept (concept synthesis), design (product synthesis), business (product development), and use (product life synthesis), see figure 2.12.

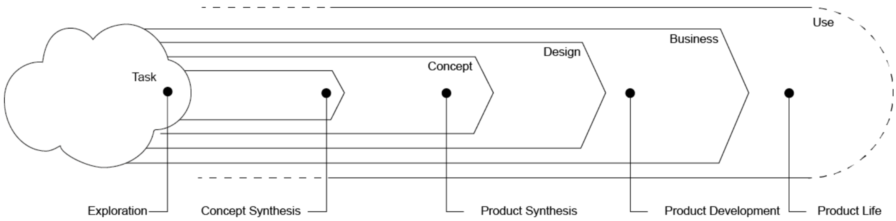

Figure 2.12 An simplified version of the Encapsulation Design Model based on Andreasen et al. (2015, p. 4).

Accordingly, the product development process can be seen as a process of conceptualizing, gradually concretizing the values and needs identified (Andreasen et al. 2015). In this process, the focus changes from creating a product concept to transforming it into a product specification, and finally to turning it into the (physical) product (Andreasen et al. 2015; Ulrich & Eppinger 2012). Adopting the phase description by Andersen et al. (2015), the three outcomes (product concept, product specification, and (final) product) relates to the following three phases in the Encapsulation Design Model: concept synthesis, product synthesis, and product development. During concept synthesis, the values and needs identified are transformed into a product concept, meeting the needs and clarifying the intention of the product (Andreasen et al. 2015). The product synthesis leads to a definition of how the product will be materialized, e.g., sub-parts and their composition, and materials. The end result of product synthesis is an unambiguous definition of the product's composition, which provides the foundation for the next phase which is development (Andreasen et al. 2015). During the development phase, the product concept is materialized based on the product specification. The product is finalized for production, ensuring the functionality and quality of the product.

Relating the above understanding of the product development process to the description of industrial designers and engineering designers given earlier in this chapter, the transition between the conceptual and development phases becomes a natural setting for the handover between industrial designers and engineering designers. The focus on the meaning of the products and the lack of knowledge and skills related to the technical area (compared to the engineering designers) make the industrial designers tend to concentrate on the conceptualizing of the product. The industrial designers' focus on synthesizing and balancing the insights from the different perspectives is used to produce a product concept, which conceptualizes the knowledge. On the other hand, the profound knowledge within the technology perspective makes the engineering designers focus on embodying the product concept in order to ensure a fully functional and commercial viably product.

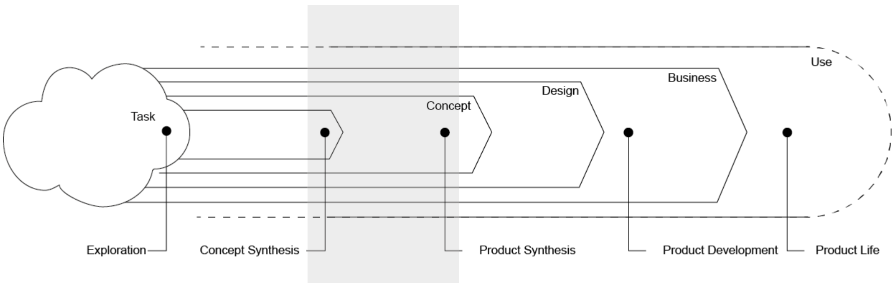

Figure 2.13 The model is based on Andreasen et al. (2015, p. 4). The gray area marks the transition from the conceptual phases to the development phases.

Adopting the phase description by Andersen et al. (2015), the processual transition in focus in this study is rather loosely positioned as taking place between 'concept syntheses' and 'development' (marked with gray on figure 2.13). The vagueness emerges due to the difference in perspective between industrial designers and engineering designers and the situated understanding of the product development process which is influenced by, e.g., the type of product being developed and the conditions (e.g. time and resources). This vagueness can also be found in the understanding of the term 'concept'. For instance, a concept does not mean the same to different types of designers, as they emphasize on different aspects (Kleinsmann 2006). Consequently, several definitions of the term 'concept' exist in the literature, but common to the definitions of concepts are that they all are rather vague and general, e.g., Pahl and Beitz (2007), Roozenburg and Eekels (1996), and Ulrich and Eppinger (2012), and do not describe the specific content (e.g. number and types of drawings or other documentation) normally used to document a concept. Given the broad focus on 'human centered products that contain technology', this study adopts a broad definition of the term 'concept' in order to cover the variety embedded in this 'category' (human centered products containing technology). Adopted from Andreasen et al. (2015) a concept is understood as: "…*a proposal for a product's composition and issues that is detailed enough to justify it as a good answer to the task and intention…" (p. 31).*

In summary, because of the research focus and practice of this study, it is positioned within an understanding of the product development process as a predominantly planned approach. Within an understanding of the product development process divided into overall phases, the transition between the conceptual and development phases is regarded as a natural setting for the handover between industrial designers and engineering designers. However, the detailed positioning of the transition is situational and can, accordingly, not be generally determined

2.3.3 How the collaboration is hampered by a handover situation

The study proceeds with exploring how the collaboration is hampered in a handover situation between industrial designers and engineering designers. In other words, what are the consequences of a handover situation?

As mentioned earlier, the integration between disciplines, normally referred to as IPD is a vast area of research. The concept and research of IPD covers the entire product development process, including "*consideration of the product life cycle, human thinking and working methods, teamwork, holistic organization methods, application of innovative technologies as* *well as expanded forms of communication and information*" (Vajna & Burchardt 1998, p. 3). The vast number of aspects can generally speaking be divided into *organizational* aspects (e.g., procedures, methods, planning, organization, and technical support), and *collaborative* aspects (e.g., teamwork, parallelization of activities, knowledge profile, and skills) (Kleinsmann 2006). The organizational aspects have been heavily investigated, whereas less attention has been given to the collaborative aspects (Kleinsmann 2006). However, research have shown that while the organizational aspects create a common platform between the team members for interaction, they do not necessary ensure integration (Kahn 1996). In order to obtain integration between disciplines, collaboration is needed (Kahn 1996). Kahn summarizes that: "*interaction may be necessary, but not sufficient, component of product development success; collaboration makes the difference between success and nonsuccess*" (Kahn 1996, p.144). In other words, while the organizational aspects create a foundation for interaction, the collaborative aspect ensures the integration.

Adopted from Kleinsmann (2006), based on Kahn (1996), interaction becomes collaboration if the team members create a shared understanding of both the content and the process of design. Kleinsmann (2006) defines a shared understanding as a "*…similarity in the individual perceptions of actors about either how the design content is conceptualized (content) or how the transactive memory system*[7)] *works*" (Kleinsmann 2006, p. 67). The main drivers for establishing a shared understanding of the process and content ensuring integration between disciples are accordingly the collaborative aspects. Especially continuous interaction and communication throughout the project period are seen as important with regard to obtaining a shared understanding and accordingly integration between disciplines (Kleinsmann 2006). Continuous interaction and communication throughout the project period is not possible in a handover situation. Consequently, the integration of especially the collaborative aspects will be negatively affected in a handover situation, due to the discontinued or only partial involvement of the industrial designers and the separation of work activities. This impairs the establishment of a shared understanding of both the process and the content of the design (Kleinsmann 2006). In other words, it is not possible to obtain real integration in a handover situation as the collaborative aspects are stunted.

A handover situation can, however, have different 'levels' depending on the level of interaction between the team members and/or the level of alignment between team member, departments, or organizations. Accordingly, the level can be regarded as a continuum between full and continues involvement (ideal of IPD) with full alignment between the organizational and collaborative aspects, to a 'over the wall' handover with no interaction and no alignment between the organizational and collaborative aspects. Between these two extremes the situation can be described as a degree of 'handover'. The situation is illustrated in figure 2.14.

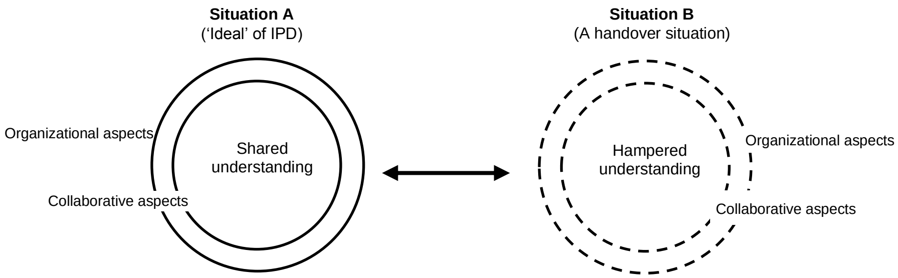

Figure 2.14 The figure illustrates the two situations described above.

In summary, the integration between professionals from different disciplines is multidimensional as it contains both organizational and collaborative aspects. Accordingly, a handover situation hampers both the organizational and collaborative aspect, which results in a lack of shared understanding regarding both the process and the content of the project (Kleinsmann 2006).

2.3.4 How the Communication is Hampered by a Handover Situation

The study proceeds by exploring how the communication is hampered in a handover situation. As reviewed in the previous chapter, communication is the vehicle for establishing a shared understanding, collaboration, and consequently integration between disciples. Despite the collaboration being hampered, the communication is still of vital importance, and it should be focused on when transferring the underpinning logic in a handover situation.

Communication is both a cognitive and social process, which implies a *systemic* understanding of communication (Maier et al. 2005). A systemic understanding does not only focus on the 'content' but also on the 'relationship' (Maier et al. 2005; Watzlawick et al. 2000). The content is what is being communicated, while the relationship is how it is said (Maier et al. 2005; Watzlawick et al. 2000). Accordingly, a systemic view takes into account the individual cognitive processes which creates meaning, previously experiences, assumptions, interaction, relationships, and the social context in which the message is communicated (Maier et al. 2005). However, the separation of the work activities creates a handover situation where the results and knowledge obtained by the industrial designer in the conceptual phases must be communicated and transferred to the engineering designers, e.g., typically during a (handover) meeting. The handover situation can, accordingly, be characterized by limited time (interaction) and limited possibility for feedback between the industrial designer and engineering designer. A handover situation between the industrial designers and the engineering designer therefore entails a predominantly mechanistic view of the communication. Accordingly, this study takes a predominantly *mechanistic* stand and will focus on the content of the communication rather than on the cognitive and social aspects related to communication.

Consequently, inherent in the handover situation is a mechanistic, one way view, focusing on the sender (industrial designer) and the message (product concept and underpinning logic) (Maier et al. 2005). In other words, the situation in terms of communication is based upon a systemic view but the understanding embedded by the research focus and the empirical setup entails a predominantly mechanistic view.

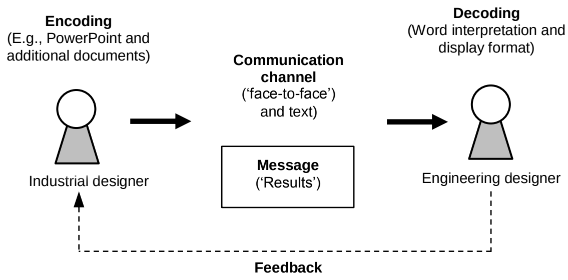

Figure 2.15 The handover situation as a situation of interpersonal communication between the industrial designers and engineering designer. The illustration is a simplified and case modified representation of the model originally proposed by Claude Elwood Shannon (1949).

The handover situation can, therefore, be described as a case of interpersonal communication, based on the original model by Claude Elwood Shannon (1949). In the communication process the results and knowledge obtained through the separated work activities must be communicated and transferred to the engineering designers. The results and knowledge, understood as both the product concept and the underlying product framing, are encoded into a message, e.g., a model (product representation) and a verbal presentation supported by a PowerPoint presentation. Especially the encoding of the product framing can be challenging. Firstly, the product framing contains intangible aspects in terms of, e.g., emotions, social, cultural, and symbolic aspects. It is well known that these more abstract aspects can be difficult to encode and communicate. Secondly, the creation of frames is partly a personal process as it builds up on personal experiences (Schön 1983) and a situated understanding of the context. Both aspects can be intensively challenging to encode, communicate, and transfer. Thirdly, despite the product framing being crafted into a representation of the product concept, the product framing underpinning the product concept is not necessary explicit in the mind of the designer. After the message has been encoded it is communicated to the engineering designer, e.g. verbally at a 'face-to-face' project meeting. Ideally the message is received and perceived by the receiver (engineering designer), as intended by the sender (industrial designer). However, the receiver does not necessary interpret the message as meaningful (Maier et al. 2005). As the feedback is limited, the sender is in practice left without any real confirmation of whether the message has been received in the desired way or not. The only 'conformation' is the detailed solutions or the changes made to the originally proposed product concept by the engineering designers through the development phases.

In summary, the handover situation creates a situation where the message (the product concept and underpinning logic) must be communicated within limited time (interaction) and limited possibility for feedback between the industrial designer and engineering designer. This entails a predominantly mechanistic view of the communication between the industrial designers and the engineering designers. Accordingly, focus is on the encoding and transfer of the message (the product concept and underpinning logic) rather than the cogitative and social processes. Moreover, the encoding of the message, especially of the underpinning logic can be challenging.

2.3.5 Summary of Section Two – the Handover as a Processual Transition between Phases

In this section the handover situation has been explored as a processual transition embedded in the product development process. The study has been positioned within an understanding of the product development process as predominantly planned, given the research focus. By focusing on the interaction between industrial designers and engineering designers, the transition between the conceptual and development phases is identified as a natural setting for the handover in the product development process. The transition between the conceptual and development phases becomes vaguely defined due to the differences in perspective between industrial designers and engineering designers and the situated understanding of the product development process. It is therefore not possible to generally determine a specific point in the product development process where the transition takes place. The transition is therefore regarded as happening somewhere within the conceptual and development phases (see figure 2.13). Furthermore, regarding the handover as a processual transition hampers both the collaboration and communication between the industrial designers and engineering designers. As integration between the disciplines is multidimensional, both the organizational and collaborative aspects are hampered in a handover situation, resulting in a lack of shared understanding regarding both the process and the content of the project. Moreover, the handover situation entails a predominantly mechanistic view of the communication between the industrial designers and the engineering designers. Accordingly, focus is on the encoding and transfers of the message (the product concept and underpinning logic) rather than on the cogitative and social processes.

Accordingly, regarding a handover situation as a processual transition between phases in a product development process further hampers the collaboration and communication, between the industrial designers and engineering designers in a handover situation.

2.4 Chapter Summary

In this chapter the handover situation has been explored as both a gap between disciplines and as a processual transition in the product development process.

In this study, the handover situation is regarded as a general gap between industrial designers and engineering designers, understood as differences in the emphasis on perspectives (human, technology, and business) and accordingly differences in roles, responsibilities, and the predominate perception of design problems. Moreover, the differences in the understanding of design problems imply different approaches underlying industrial design and engineering design, 'reflective practice' and 'problem solving', respectively. Accordingly, the industrial designers solve the design problem by proposing a solution (product concept) based on a specific set of frames (solution framework), which have been developed and refined through the process. The product frames are consequently the foundation for fully understanding both the design problem and the solution, and therefore of vital importance in a handover situation.

This general gap between the disciplines is further stressed by also focusing on the handover situation as a processual transition between the conceptual and development phases in the product development process. The separation of work activities between the industrial designers and engineering designers and the change in focus from the concept to the development creates a handover situation which can be characterized by limited time and limited possibility of feedback. This hampers both the organizational and collaborative aspects and results in a lack of shared understanding regarding both the process and the content of the project, between the industrial designers and engineering designers.

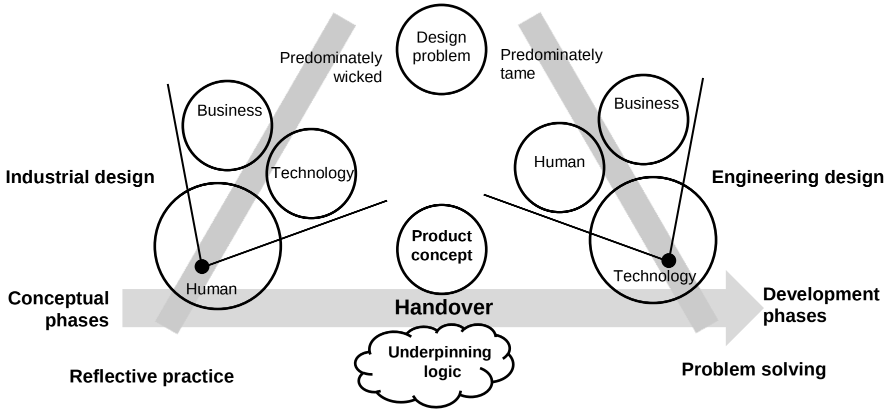

Figure 2.16 The situation and element in focus in this study.

3 Research Framework

In this chapter, the research framework underlying this study will be presented and discussed. The chapter contains a presentation and discussion of: the overall philosophical position of the study in terms of pragmatism, the methodology based on Design Research Methodology, and the main elements of the research design, including the methods for gathering and analyzing data. Figure 3.0 illustrates the different elements of the research framework and how they are interconnected.

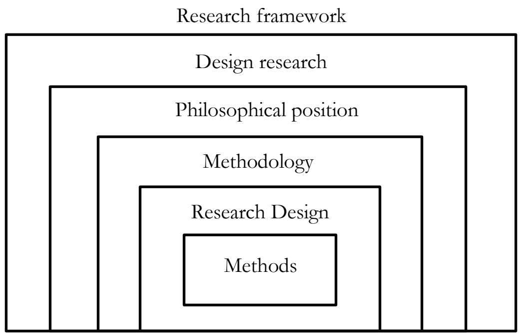

Figure 3.0 The main elements of the research framework and how they are related.

The chapter commence with an overall discussion of 'design research'.

3.1 Design Research

This study is part of the vast field of design research. Design research is the study of design that investigates the principles, practices, and procedures of design by using scientific methods with the aim of improving our understanding of the field of design (Cross 2006). The aim of design research is to improve the conditions for practice through providing new ways to understand reality (Cross 2006; Blessing & Chakrabarti 2009). However, beneath this overall and general description, the picture becomes multifaceted. Design research covers many different directions within practice, e.g. graphical design, industrial design, product design, engineering design. These different directions build on similar, overlapping, and contradicting philosophical foundations and use mixed methods and approaches, making the picture complex (Blessing & Chakrabarti 2009). Furthermore, fields "outside" design, e.g. psychology, management and marketing have investigated design, and so have contributed to the field but also added to the complexity of the core content of 'design research'. By adopting the concept of paradigms[8)] described by Kuhn (1970), design research, can be described as being in a 'pre- paradigmatic' period where several paradigms co-exist (Dorst 2006; Verganti 2009; Melles 2008). The need for a philosophical positioning of the studies within design research is therefore clearly important. The focus on the philosophical positioning within the field of design research is, therefore, not just important in the case of the specific study but also as a means to further develop the understanding of design research.

Design research differs from other fields within science. Design research does not merely aim at understanding the situation, it also aims at changing (improving) the situation (Blessing & Chakrabarti 2009). Consequently, design research is an act of designing in itself, as it requires "*the creation and evaluation of a model or theory of the desired situation and of the support*" (Blessing & Chakrabarti 2009, p.9). Cross (2006) describes design as focused on and interested in: practicality, ingenuity, empathy, and a concern for 'appropriateness' when solving problems. Consequently, these values also underlie design research, which differ from the values of both *natural* [author] sciences (objectivity, rationality, neutrality, and a concern for 'truth') and the humanities (subjectivity, imagination, commitment, and a concern for 'justice') (Cross 2006). When interpreting the values of design research and comparing them to those of natural science and the humanities, it appears that design research balances the ideals of the others rather than being in contrast to them.
With this understanding and overall positioning of design research in mind, as well as the research focus as presented in chapter 1, the philosophical positioning of the study will be discussed.

3.2 Philosophical Position

This study could have been viewed as entirely within the ideals of either - natural science or the humanities rather than design. However, viewing the study entirely from the perspective of natural science, the results could potentially have been more 'objective' and 'neutral', but could also have been less related to the 'practicality' of the situation. In other words, there could be elements relevant to the situation, which are difficult to measure objectively and neutrally, e.g. the engineering designer's understanding (a cognitive process) of the underpinning logic. On the other hand, viewing the study entirely from the perspectives of the humanities would potentially ensure a 'practicality' related to the specific situation but not necessarily an understanding that could be expanded beyond that one. Consequently, this study is positioned within design, where it draws on aspects from both natural science and the humanities, as it aims at understanding the situation at hand, which makes it possible to expand this understanding to other similar situations. From a philosophical point of view this study is positioned within *pragmatism*, drawing on both the quantitative positivistic paradigm and the quantitative (social) constructivist paradigm, with regards to the ontologically and methodologically aspects of this study. Accordingly, the study takes on a multiple philosophical position with pragmatism at the core. As there exist several (different) directions within pragmatism, it is important to note that the description of pragmatism given in this study is primary inspired by the work of classical pragmatist John Dewey (1859-1952).

Dewey's understanding of pragmatism can be seen as a combination of Charles Sanders Peirce's[9)] (1839–1914) scientific foundation and William James' (1842–1910) more humanistic thrust and focus on embodied experience (Rylander 2012). In general, pragmatism can be described as the focus on practice and the knowledge that emerges through observing practice (Melles 2008). Focus is on ideas and knowledge useful to practice rather than knowledge simply representing reality (positivism) or knowledge obtained through consensus (social constructivism) (Rylander 2012). Consequently, theories are not regarded as objective understandings of reality or social constructed facts, but tools proved useful in reality having an *instrumental* view on theories (Brinkmann 2006; Bacon 2012). Knowledge is produced within and through interaction with the world and creates experiences. Experiences are both the means and the ends of inquiries, and they emerge when: "*…the individual is constantly reacting to and reflecting on the consequences of its interactions with the environment*" (Rylander 2012, p.23). Knowledge within pragmatism is therefore regarded as dynamic and situated rather than the universal truth or social constructed facts independent of reality, which is in clear contrast to both positivism and social constructivism. Thus, pragmatism provides an approach that resonates well with both the practice of design and design research. The focus on understanding practice and accepting several "truths" are key elements of pragmatism relevant to this study. Other important elements are the focus on experiences obtained through continued experiments and reflections as well as the search for context dependent knowledge with the aim of applying value to users in practice. Hence, pragmatism fits well with the values of design and the ideals of design research (practicality, ingenuity, empathy, and a concern for 'appropriateness´ (Cross 2006)).

Having presented the core of pragmatism and established it as generally relevant to design research and this study, the focus will be turned toward the dualism embedded in pragmatism (particular to Dewey's understanding of pragmatism). Within pragmatism, the object and subject are not regarded as separate, which is in contrast to both positivism and social constructivism. In pragmatism, knowledge is regarded as constructed based on our perception of reality combined with our previous experience and beliefs, which also is the case in social constructivism (Rylander 2012). However, these constructions are limited by the situation (reality); hence it should be possible to identify the constructions in practice which also is the case in positivism (Rylander 2012).

The dualistic point of view contained in pragmatism can also be identified in the research questions underlying this study. Accordingly, this study seeks to both understand the situation by identifying the aspects of the underpinning logic of a product concept that are challenging for the industrial designer to communicate and transfer to the engineering designer, and also to improve the situation by explicitly communicating the product framing underpinning the product concept. The understanding of the situation (first research questions) can, consequently, be regarded as a social construction based on the perception of reality, whereas the aim of improving the situation can be regarded as taking the constructed understanding and applying it to a new situation in order to verify if it holds any general value, which would indicate a more general and objective understanding of the situation. In other words, knowledge as a purely social construction or knowledge without any meaning in practice is not valuable to a pragmatist (Brinkmann 2006). Accordingly, this study seeks to combine the dualistic point of view regarding subject and object, respectively which exist within positivism and social constructivism. Consequently, knowledge is limited and not claimed to be a universal truth (Bacon 2012).

Having positioned the study within pragmatism the methodology will be discussed. Moreover, it will be revealed how the pragmatic stand point of this study is linked to the methodology and methods used.

3.3 Methodology

Since there are no common methodologies grounded within pragmatism, a situational methodology needs to be established (Stompff 2012; Blessing & Chakrabarti 2009). The overall methodology of this research design is inspired by 'Design Research Methodology' (DRM) described by Blessing and Chakrabarti (2009). DRM is specifically aimed at design research, which suggests a common approach including methods and tools is used to investigate the design field. Since the aim of design research, as mentioned earlier, is both understanding and improving the situation, DRM consists of two main strands: 1) developing an understanding of the existing situation, and 2) developing a support to improve the existing situation (Blessing & Chakrabarti 2009). This requires the researcher to formulate a description of the existing situation, a description of the desired situation, and a proposal of the support that is likely to turn the existing situation into the desired situation, and maintain this (Blessing & Chakrabarti 2009). These 'outputs' are 'translated' into four phases. The four phases are:

Research Clarification (RC): The main aim of the first phase is to clarify the research goal and to create the foundation for the formulation of the research question(s). The output of this phase, besides the research questions, also contains an initial description of both the situation 'as-is' and (desired) 'to-be'.

First descriptive study (DS I): The aim is to further specify the initial description of the 'as-is' situation, as a foundation for the development of the support. This can be done both through further literature reviews but also by the conduction of empirical studies.

Prescriptive study (PS): The aim of the prescriptive study is to develop the support by taking into account the results found in the first descriptive study. Developing the support can be regarded as a design task, including initial tests of the support.

Second descriptive study (DS II): The second descriptive study has two aims. The first aim is to evaluate the suitability and applicability of the support developed. The second aim is to understand the impact of the support. Thus, the analyst attempts to answer the question "Does the support create the desired situation?"

Blessing and Chakrabarti (2009) operate with different emphases on the phases which can be applied to a study depending in its research focus and resources. They operate with three different 'levels' of emphasis which are: a research-based study, a comprehensive study, and an initial study. A research-based study contains a literature review, whereas a comprehensive study contains a literature review and an empirical study or the development and/or evaluation of a support. An initial study aims at terminating the project and providing indications rather than proof of the consequences of the results obtained. Moreover, the aim of an initial study is to prepare the results for future investigation by other scholars. According to Blessing and Chakrabarti (2009) the research clarification can normally only be approached as a research based study which contains a literature review, whereas the first descriptive study both can be approached as research based or a comprehensive study, depending on whether the literature review provides sufficient knowledge for the researchers to understand the current situation, or indicates whether additional knowledge is needed. The prescriptive study can be approached as both: a research based study (choosing between existing support), a comprehensive study (developing the support), or an initial study (merely suggesting how the findings of the first descriptive study could improve the situation). The second descriptive study can be approached as an initial study (merely providing indications of the support´s suitability, applicability, and impact on the situation) or as a comprehensive study (firmly evaluating the support´s suitability, applicability, and impact on the situation). The general connection between the phases and approaches is illustrated below:

Phase	Research Clarification	First Descriptive Study	Prescriptive Study	Second Descriptive Study
Approach	Review based	Review based or comprehensive	Review based, comprehensive, or initial.	Initial or Comprehensive.

Figure 3.1 An overview of phases and approaches.

A comprehensive study within the first descriptive study should normally be followed by as a minimum an initial study in the next phase (the perspective study) in order to suggest how the findings could improve the situation (Blessing & Chakrabarti 2009). A comprehensive study developing the support (prescriptive study) should normally be followed by as a minimum an initial study providing indications of the support´s suitability, applicability, and impact on the situation (Blessing & Chakrabarti 2009).
Following all the phases, DRM is a comprehensive methodology. Therefore, as pointed out by Blessing and Chakrabarti (2009), the methodology should not necessary be followed rigidly but merely serve as inspiration for the process, which also has been the case in this study. Moreover, given the complexity of design research which covers several different disciplines, the DRM is also very inclusive in its description of methods and tools. Accordingly, a situational research design must be established.

3.3 Research Design

The research design consists of four main elements: research questions, theories, methods, and data (Tollestrup et al. 2011). All four elements are related, as they set the frames for the study and consequently the results. The research questions and main theories will only be referred to in this chapter as they already have been presented in chapter 1 and 2, respectively.

Given the research questions, aligned with the philosophical position with pragmatism and the methodology inspired by DRM, this study covers all four phases of the DRM. The 'level' of emphasis on the phases and the methods applied to the phases has emerged through the research project. For instance, the literature review on the relationship between industrial designers and engineering designers in product development projects with a handover situation revealed an area of little knowledge.

The literature review was then supplemented with an empirical explorative case study to gain more knowledge about the current situation (as-is). However, if the literature review had revealed a well investigated area and a deep understanding of the situation, the research focus could had been moved to the later phases, developing an altogether new support to improve the situation. Since the emphasis of this study is on the first descriptive study understanding the situation, the later phases developing and evaluation the support has been less emphasized in the project.

The illustration below provides an overview of research design as a combination of the phases of DRM, the aim(s) of each of the phases and the chosen methods for gathering and analyzing data.

Phase	Research Clarification	First Descriptive Study	Prescriptive Study	Second Descriptive Study
Research questions		**First research question** Which aspects of the underpinning logic of a product concept are challenging for the industrial designer to communicate and transfer to the engineering designer in a product development project in a handover situation?		**Second research question** To which extent does explicit emphasizing the underpinning logic of a product concept affect the engineering designer's ability to understand whether potential production changes are coherent with the product concept´s underpinning logic?
Aim	**Clarifying** (Identifying 'gap of knowledge' and formulate research questions).	**Exploring** (Understanding the situation 'as-is').	**Selecting** (Selecting the design support to help improve the situation – 'to-be').	**Evaluating** (Provide indications of the design support´s suitability, applicability and, moreover, impact).
Emphasis	**Review based**	**Comprehensive**	**Review based**	**Initial**
Methods	**Literature review** (systematic and citation based)	**Literature review** (systematic and citation based) **Case study** (information-oriented) **Interviews** (Semi-structured) **Solution Frame-work** (analysis)	**Literature analysis** (systematic and citation based) **Interviews** (Semi-structured) **Reasoning**	**Lab.-study** (comparative) **'Think aloud'** (Semi-structured) **Solution Frame-work** (analysis)

Figure 3.2 The main elements of the research design connected to the methodology of the study.

In the following section, each of the methods for gathering or analyzing the data will be described and discussed. The order in which the methods are presented in the next chapter follows the order they are used in the study (see figure 3.2).

3.3.1 Methods, Data and Analysis

In the following, each of the methods used in the study will be presented including a discussion of the motivation for choosing them.

3.3.1.1 Literature Review and Analysis

The literature review and analysis were mainly been used in the clarification of the research (RC) and the first descriptive study (DS I). Minor reviews of the literature were also conducted in relation to the prescriptive study (PS). The literature reviews were conducted using two approaches: 1) a systematic literature review using key words, and 2) a review using citations and references. The main part of the articles that were considered relevant was identified using the reference and citation based approach. Only a few references were found through the systematic review using key words. This implies a scattered and 'immature' research area without a generally accepted terminology.

In order to ensure a broad, comprehensive, and updated review both peer-reviewed journal papers (including Ph.D.-theses) and conference papers were included for both approaches. The identified articles were selected through a series of steps, inspired by Blessing and Chakrabarti (2009). Firstly, the articles were selected or deselected based on the relevance of their title/sub-title, secondly the remaining articles were selected or deselected based on the relevance of the abstract, and thirdly the remaining articles were selected or deselected based on the relevance of the full paper. As the full paper versions of all the articles were not read, there is a risk that relevant articles were deselected in the process. However, in cases of any doubt the articles were included in the next step to minimize this negative side effect of this approach. The comprehensive selection approach of articles were only used in the research clarification and not for the minor reviews done in the study.

3.3.1.2 Case Studies

Because of the explorative nature of the first descriptive study (understanding the situation), a case study approach was chosen to ensure focus on practice. Moreover, the case study approach resonates well with the pragmatic philosophical position underlying the entire study. Yin (2009) defines a case study as: "…*an empirical enquiry* *that investigates a contemporary phenomenon in depth and within real-life context…*" (p. 14). The case study provides an in-depth approach, which allows the researchers to gain a holistic and meaningful understanding of complex situations (Yin 2009). The case-study method has been widely criticized as a scientific method, especially in terms of generalizing (Flyvbjerg 2006). However, the purpose of the first descriptive study is to *learn* about the situation and not to *prove* anything. Flyvbjerg (2006) argues that: "*Context-dependent knowledge and experience are at the very heart of expert activity"* (p. 222), and accordingly vital when focusing on *learning*.

Another important aspect also to consider when using case studies is the strategy for selecting the cases. In this chapter, the overall consideration and parameters for selecting a case will be discussed, whereas the detailed and operational parameters for selecting the case are described in chapter 4.

Depending on the purpose of the study, the strategy can be 'random selection' or 'information-oriented selection' of cases (Flyvbjerg 2006). When the focus is on learning and gathering as much information as possible about a situation, an 'extreme' (untypical) case will often offer more information about the situation in focus, than a randomly selected 'representative' (typical) case (Flyvbjerg 2006). The representative cases will often only reveal 'average' or 'typical' information about the situation. Given this study's overall focus on cases containing a handover situation between industrial designers and engineering designers understood as both a 'gap' between disciplines and as a transition between phases, which results in a hampered collaboration between the two groups of professionals, the overall focus when selecting cases can be described as 'extreme'. However, within this selected sub-group, cases have been selected ensuring a variety in terms of: business area, company size, and the product being developed, making it possible to better generalize within the sub-group.

All the cases in the first descriptive study are retrospective. A retrospective case study in this investigation is understood as the gathering of data taking place after the events of interest have happened. The use of retrospective case studies are widely criticized mainly due to the timespan between when the events actually happening and when the data is gathered (Blessing & Chakrabarti 2009). Accordingly, the data gathering relies upon the memory of the respondents, and the available documentation, which may be very sparse and selective in both instances. There is also a risk that the respondents (intendedly or unintendedly) will post-rationalize and give a constructed understanding of the situation, which may not be a true representation of the actual situation. This critique is also applicable to this study. However, besides holding some practical advantages (see chapter 4), the use of retrospective cases also holds some advantages in regards to the data being gathered. It is assumed that the engineering designers have a better understanding of the project goals at the end of the project or after it is finished. A gap in the understanding of the underpinning product framing therefore indicates that it have not been shared during the project.

3.3.1.4 Interviews

In order to gather data from a case study, a method needs to be applied. A wide variety of methods can be used to collect data in a case study – both quantitative and qualitative methods. In this study, the main method for gathering data for the case studies has been in-deep (qualitative) semi-structured interviews. Adopted from Kvale (2008), the purpose of the qualitative interview is to get a deep understanding (lived world and meaning of interpretations) of the described phenomena. This resonates well with the explorative purpose of the case study. The semi-structured interview requires openness to changes both in the order and the formulation of the questions in order to follow up on the answers given by the interviewee (Kvale 2008).

The interviews were audio recorded and notes where taken during the interview. The notes were primarily used to help keep track during the interview, but also used to note any emerging questions (for later investigations either during or after the interview). Based on the interviews, the product framing for each of the products/cases where documented by the researchers[10)] using the concept of Solution Frame-work presented in chapter 2. The template of the solution framework used for documenting the product framing is a simplified version of the original template. The distinction between problem frames and solution frames made in the original concept behind solution framework is not relevant in this study as the focus is on the entire solution framework. Focus is on the sub-frames understood as the insights/values connected with the working principles. The frame metaphor/one-liners is disregarded as it is regarded as primary an industrial design support to understand and categories the sub-frames. This is therefore disregarded in the template. The product framing was documented, by interpreting the answers given by the respondents and searching for the 'meaning', and/or e.g., looking for similarities in words, examples or even sentences. Accordingly, the product framing for each of the cases can be regarded as a social construct. The documented product framing were afterwards showed to the interviewee in order to get the understanding verified. The product framing for each of the cases where then used to analyze the answers given by the respondents looking for correspondence or lack of correspondence in their understanding of the underpinning logic. Afterwards, the results of the individually cases where compared and analyzed across cases, looking for patterns.

3.3.1.5 'Lab-study'

The aim of the second descriptive study (DS II) was to evaluate the 'support' proposed. For practical as well as well as for research related reasons the test was conducted as a 'lab-study'. A 'lab-study' is in this study understood as study within a controlled context, mirroring practice or a fraction of practice. Testing the support in practice would clearly result in some practical challenges in terms of time and resources. Using test results from practice would, moreover, make it difficult to make a comparative study and test the hypothesis (see chapter 6). The aim of the research setup was to simulate a handover situation of a product concept between industrial designers and engineering designers, where the engineering designers are afterwards presented with a number of questions (representing dilemmas) related to the product concept. The questions simulate the situation where changes to the original product concept are needed, e.g., due to the cost of the product, production related issues, or new technology being available. Data based on the questions were gathered both as quantitative and qualitative data. The questions could all be answered with a 'yes' or 'no'. However, not knowing the reasoning behind the answer the respondents could potentially give a correct answer based on the wrong reasoning. The respondents were therefore also asked to think aloud (the method will be described in the next section).

The cases used in this study were projects conducted by students but done in collaboration with various companies, to simulate practice as best possible.

3.3.1.7 ‘Think Aloud’

As part of the second descriptive study the respondent were asked to ‘think aloud’ when answering the ‘dilemmas’ revealing the reasoning behind their answers. The ‘think aloud protocol’ is for instance widely used in usability testing to gain insight into the respondents cognitive processes (Krahmer & Ummelen 2004). The engineering designers were encouraged to ‘think aloud’ as they were answering the questions (see chapter 6). As some of the respondents had difficulties either explaining their reasoning and/or describing it simply, the researcher also asked questions to start the process in order to clarify or elaborate. The interviews were afterwards analyzed comparing the answers to the product framing documented for each case.

3.4 Summary

This chapter included a presentation of the overall philosophical position of the study in terms of pragmatism, as it was found that it had many overlaps with design research. Moreover, the methodology based on Design Research Methodology, which contains all four phases was reviewed and discussed. Finally, this chapter presented the methods used for gathering and analyzing data.

4.0 Descriptive Study I

This chapter identifies the situation 'as-is' – the first descriptive study[11)] (DS I). The aim of the chapter is to identify which elements of a product concept's underpinning logic that are challenging for the industrial designer to communicate and transfer to the engineering designer in a product development project setting with a handover situation (research question one). This chapter holds, within the limits given by the agreement of anonymity signed with the companies, a detailed description and analysis of the six cases representing the empirical material used in this investigation (DS I). At the end of the chapter the findings are summarized, setting a direction for the second part of the study (chapter 5 and 6), changing the situation.

4.1 Selection of Cases

The overall strategy behind the selection of cases has already been described in chapter 3, which focuses on 'information-oriented´ cases. The purpose of this section is therefore to describe the detailed and operational selection of cases. Given the research aim of this first descriptive study, all the cases stem from practice and are carried out by experienced designers[12)]. All the cases are retrospective and limited to a Danish context due to availability and practicality (resources and time). The Danish context is not presumed to be unique, nor vital to the results of this study, and the findings are therefore believed to be generally applicable to the research area. The use of retrospective cases affects the reliability of the study as already discussed in chapter 3. However, product development projects normally run for months or even years, and their time schedules often change, making it difficult (if not impossible) to have included ongoing projects in the research design. Moreover, the use of retrospective cases also hold some advantages, as it is possible to verify a priori whether the cases have met the research related criteria before the data collection starts. This will be further discussed in the following paragraph.

The research related criteria have emerged based on the research aim and have been used in the selection of the cases. The main research related criteria are:

1. The cases should contain collaboration between industrial designers and engineering designers.
2. The cases should cover a product development project with a handover situation of the product concept between the industrial designer and engineering designers.
3. The industrial designers should play an 'integrative' role in the product development process.
4. The projects should be 'successful' (from the companies' points of view).
5. The cases should represent a 'variety'.

The first criterion, 'collaboration between industrial designers and engineering designers', is directly related to the overall research focus of this study, and was therefore a prerequisite for all the cases. All the cases considered were examined to determine whether the understanding of industrial design and engineering design underlying the cases predominately corresponded with the understandings underpinning this study. The limitation of the case material to a Danish context eased the task considerably as all the industrial designers and engineering designers, except two[13)] were educated in Denmark, and therefore represented a rather homogeneous understanding of the two terms. The second criterion, 'a handover situation' was also a prerequisite for all the cases. It was found that cases where industrial designers were involved in the design process as consultants were most likely to contain a handover situation. However, despite the focus on cases with industrial designers participating as consultants, the cases represented a variety in the 'level' of the handover situation. A detailed description of the level of handover is given in connection to the presentation of the cases in the following section. The description will focus on the level of interaction rather than organizational aspects as these were found to be less relevant when describing the level of handover in the various cases.

Finding cases where the industrial designers played an integrative role in the design process proved to be difficult. Based on preliminary interviews with managers, project managers, engineering designers and industrial designers in the effort to identify useful cases, it became clear that many of the industrial designers were doing product styling - adding a 'beautiful' form to an already developed (technical and functional) solution, rather than playing an integrative role in the process. However, the use of retrospective cases made it possible to immediately evaluate the role of the industrial designers, ensuring that only cases where the industrial designer played an integrative role were chosen.

The remaining three criteria (*'successful', retrospective*, and *'variety'*) emerged as a result of overall considerations regarding the validity of the investigation, practicability, and general applicability. This study focuses on situations where the collaboration between industrial designers and engineering designers is hampered due to the discontinued or partial involvement of the industrial designers in the product development process, and the separation of the work activities between industrial designers and engineering designers. However, the collaboration between the industrial designers and engineering designs can be hampered for several other reasons, e.g., personal conflicts, unclear goals, poor project management, etc. (Holland et al. 2000). These aspects could potentially also (negatively) affect the communication and transfer of the underpinning logic of the product concept from the industrial designer to the engineering designers. In order to limit the effect of these aspects, the companies involved were asked to suggest what they believed to be 'successful' projects. Successful projects are here understood as projects where: the team was empowered and felt that the project was both interesting and important, and the leadership, roles, and responsibility were clear. Moreover, there was an organizational supportive climate towards the team and constructive, rather than personal conflicts among the participants. Furthermore, there were a mutual respect and thrust between the participants, and a willingness and openness to learn (Holland et al. 2000). The evaluation of the projects in regards to their 'successfulness' was done in collaboration with the companies and was in practice only possible due to the use of retrospective cases. Lastly, in order to ensure a better generalization of the findings, the cases chosen represented a variety in terms of business area, company size, and the type of product being developed. For details regarding the variety of the cases, please see table 4.0 below.

4.2 Overview of Cases

The table below gives an overview of the six cases of this study. The third column ('Company') is primarily included to show the variety of the cases, and thus it is not part of the following analysis. The variety of the business area can be seen in the second column ('Business Area').

Table 4.0 *– an overview of the cases.*

Case	Business Area	Company[1)] (main)	Companies	Interviewees	Project documentation made available
1.	**Well-fare (W)**	Main (W) develops, manufactures, and sells (international) a variety of products for disabled and other mobility impaired persons. Young company - just above 10 years old. Small company - below 50 employees.	*(Main (W))* *(Design1 (W))* *(Design2 (W))*	3 Engineering designers (ED1, 2 and 3) 1 Industrial designers (ID1) 1 Industrial designers (ID2)	Prototype PowerPoint presentation 3D model and drawings Additional project documents
2.	**Production (P)**	Main (P) develops, manufactures, and sells (international) products used within welding, e.g. when building a ship. Mature company – just below 50 years old. Small company – just below 300 employees.	*(Main (P))* *(Design (P))* *(Engineering (P))*	1 Project manager (PM1)[3)] 1 Marketing consultant (MC1)[3)] 1 Industrial designer (ID1) 1 Engineering designer (ED1)	PowerPoint presentation 3D model and drawings Additional project documents
3.	**Service (S)**	Main (S) develops, manufactures, and sells (international) a variety of products, e.g., for clearing floor areas (washing and vacuum cleaning). Mature company – above 100 years old. Major company[2)] – above 5.000 employees.	*(Main (S))* *(Design (S))*	1 Engineering designer (ED1) 1 Product manager (PM1) 1 Industrial designer (ID1)	Prototype PowerPoint presentation 3D model and drawings Additional project documents
4.	**Interior (I)**	Main (I) develops, manufactures, and sells (international) a variety of lighting fixtures. Young company – just above 10 years old. Small company - below 50 employees.	*(Main (I))* *(Design (I))*	1 Engineering designer (ED1) 1 Industrial designer (ID1)	PowerPoint presentation 3D model and drawings

5.	**Offices (O)**	Main (O) develops, manufactures, and sells (international) a variety of chairs, e.g., for professional use users sitting at an assembly line). Mature company – above 50 years old. Small company – below 100 employees.	*(Main (O))* *(Design (O))* *(Engineering (O))*	1 Product manager (PM1)[4)] 1 Industrial designer (ID1) 1 Engineering designer (ED1)	PowerPoint presentation Additional project documents
6.	**Energy (E)**	Main (E) develops, manufactures, and sells (international) a variety of 'intelligent' solutions for measuring energy and water. Mature company – above 50 years old. Major company – above 1.000 employees.	*(Main (E))* *(Design (E))*	1 Engineering designer (ED1)[5)] 1 Product manager (PM1)[5)] 1 Industrial designer (ID1)	PowerPoint presentation 3D model and drawings Additional project documents

Notes:
1) The years of age and numbers of employees are approximately. The evaluation of the company size is based on employees and, moreover, seen in a Danish context as all the firms would be regarded as small or medium from an international perspective.
2) The company is divided into several divisions. The 5.000 employees are the total number of employees for all the divisions.
3) 'PM1' and 'MC1' were interviewed together.
4) The interview with PM1 (O) was not audio recorded.
5) 'ED1' and 'PM1' were interviewed together.

4.2.1 Data and Method

The vehicle for this investigation is 20 interviews primarily conducted with industrial designers and engineering designers. In some of the cases (2, 3, 5, and 6), product managers, project managers, and people from marketing, relevant to the cases were also interviewed. Besides the interviews, additional project documentation (e.g., product specifications, project plans, PowerPoint presentations, and prototypes) was also made available[14)]. The level and type of additional project material varied across the cases. For an overview please see table 4.0.

All the interviews were conducted on the locations of the companies except for five[15)] interviews, which were done over the phone. In most of the cases, the PowerPoint presentation used at the originally handover meeting was used during the interview with the industrial designer, reconstructing the handover situation of the product concept between the industrial designer and engineering designers. The additional project documentation was used to confirm statements and/or to reconstruct details about the process during the interviews. The product framing in each of the cases was documented by the researchers[16)] based on the data collected in the interviews. The results were shown to the industrial designers and engineering designers afterwards for verification. Moreover, they were used to analyze the interviews, making it possible to compare the understanding of the underpinning logic between the industrial designers and engineering designers.

4.3 Unfolding the Cases, Handover Situations, and Product Framing

In this section the cases and underpinning logic of the product concept are described in details. Each case description will commence with a short description of the settings, the product, and the handover situation, followed by an overview of the product framing identified in the case.

4.3.1 Case 1 – Welfare (W)

The core setup in this case consists of the main company (Main (W)) owning the project, and the design consultancy firm, Design1 (W), originally initiating the idea. Main (W) develops, manufactures, and sells a variety of products for disabled and other mobility impaired persons on an internal market. Design1 (W) solves various design tasks for other companies, but also develops its own product concepts, which are sold to other companies, as in this case. A second design consultancy firm, Design2 (W), was brought in to assist Main (W) with the development during and after the handover. The second design consultancy firm is in this study, however, regarded as part of the 'engineering design perspective', as they belong to the recipients of the original product concept. The product developed in this case is intended to assist healthcare personnel, such as assistants or nurses, when elderly people have fallen and they cannot get up by themselves.
Some of the main challenges connected with the development of the product were: laws and regulations, limited space, safety and usability.

4.3.1.1 The Handover Situation

The originally product concept was developed by ID1 (W) prior to the handover. The main handover of the product concept took place at a project meeting where primarily a working prototype supported by a PowerPoint presentation was used as means of communication.

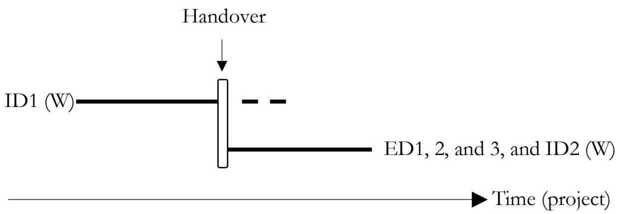

Figure 4.0 The figure shows an illustration of the handover situation in case 1 (W).

Moreover, different project documentation, e.g., technical drawings, specifications, and test results, was handed over as well. The handover was later followed up by a few additional meetings and communication by mail and phone, but the communication and collaboration between ID1 (W) and the rest of the team was limited after the handover (indicated by the dotted and short line for ID1 (W)).

4.3.1.2 Product Framing

The product framing described below is the original sub-frames intended by ID1 (W) to support the product concept and the sub-frames that emerged later through the development.

Table 4.1 *– The product framing*

Perspectives/ sub-frames	Insights / aspired values	Working principles	Correspondence (+)/ lack of correspondence (-)
Business *(1) Lower cost*	Today, two people are needed to lift an elderly person fallen on the floor (determined by Danish regulations, regulating the work environment for healthcare personnel). This is both costly and time consuming.	A "chair" that lifts the fallen person off the floor makes it possible for one person to manage the job and saves both time and resources.	(+) The industrial designer and engineering designers expressed the same understanding of the insights and working principle during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained into the final product.

Human *(2) Elderly*	The elderly feel vulnerable and are afraid of falling again while getting up.	The look of the product as a "chair" is familiar to the elderly (and healthcare personnel). The "legs" of the "chair" is 'oversized' to give a reliable expression to the product.	(-) The industrial designer and engineering designers expressed the same understanding of the elderly people being afraid of falling again. However, the engineering designers emphasize the 'functional' aspect of the insight – addressed by ensuring the stability and strength of the product, whereas the industrial designer also emphasizes the emotional aspect – 'feeling vulnerable', addressed by making the product look familiar (a chair) and giving it a 'robust' look (oversized "legs"). The lack of correspondence in the understanding of the sub-frame indicates that it was only partly shared. The indications of a partly shared sub-frame are moreover supported by the final product. The familiar look of the product as a "chair" was kept but the "legs" were changed considerably ('downsized') mainly due to technical considerations. This indicates that part of the insight (the emotional and psychological aspects) was not shared during the development.
(3) Healthcare personnel	The healthcare personnel have a general high barrier towards (new) technology.	The product is designed as one piece to ease the use of the product (minimizing assembly).	(-) The industrial designer and engineering designers expressed the same understanding of the healthcare personnel's' high barrier towards (new) technology. However, the working principle of the product being in one piece is in contrast to the working principle of sub-frame 6, which became governing for final product. This indicates that the working principle of this frame either not was shared and/or given a lower priority than sub-frame 6.
(4) Elderly	The elderly feel insecure, afraid and humiliated when they fall and are unable to get up again by themselves.	The product "embraces" the person who falls almost as two persons would by kneeling on each side and gently lifting the person up again.	(-) The industrial designer addresses the insights with a working principle expressed as the product "embracing" the elderly (emotional and functional perspective), whereas the engineering designers (especially ED1) addresses the insights with a functional perspective (focus on getting the person up fast). The lack of correspondence in the understanding of the insights, and consequently also the working principle indicates that the insights only were partly shared, or given a lower priority.

(5) Context	The product must be able to operate in wet areas, e.g., a toilet/bath. Moreover, the elderly can accidently have peed in their pants.	The materials and surfaces of the product are easy to clean and the electronics are covered.	(+) The industrial designer and engineering designers, all expressed the same insight and working principle during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained into the final product and the sub-frame becomes governing for the decisions made regarding material and surfaces of the product, together with general considerations regarding cost and production.
Technology *(6) Regulations*	The weight of the product must not exceed 7 kg, due to regulations.	The product was separated into seven parts, allowing the parts to be grouped into two units each below the weight of 7 kg.	(+) This sub-frame emerged during the development and the working principle became governing for the direction of the development of the product. The industrial designer was at that point only partly involved in the process (see figure 4.0). However, the industrial designer recognized the working principle. Consequently, the sub-frame is regarded as shared.

4.3.2 Case 2 – Production (P)

The core setup in this case consists of the main company (Main (P)) who owns and initiated the project, and the design consultancy firm, Design (P). Main (P) develops, manufactures, and sells (internationally) products used for welding, e.g., when building a ship. Design (P) solves various design tasks for other companies. A second design consultancy firm, Engineering (P), within plastic molding was brought in to assist Main (P) with the development during and after the handover. The industrial designer from the second design consultancy firm in this study is regarded as part of the 'engineering design perspective', as he belongs to the receivers of the originally product concept. The product developed in this case is a welding torch used for more demanding welding task (focus on precision and quality). Main (P) wanted to differentiate the product through a focus on the users, context, and product quality. Some of the main challenges connected with the development of the product were: size of the product (small), usability, and modularity.

4.3.2.1 The Handover Situation

The product concept was developed by ID1 (P) based on a comprehensive field study. Prior to the handover, elements and drafts of the product concept and underpinning logic were "tested" with the rest of the project group at project meetings, as indicated with the dotted line. The main handover of the product concept took place at a project meeting where primarily a PowerPoint presentation supported by a 3D model was used as a means for communication.

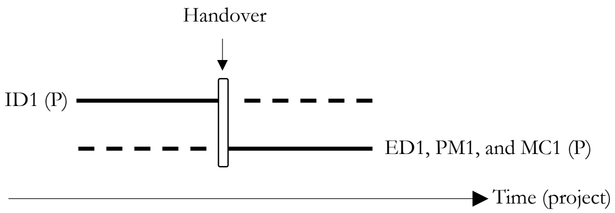

Figure 4.1 The figure illustrates the handover situation in case 2 (P).

The handover was followed up by several meetings and communication by mail and phone through the development of the product. The collaboration and communication after the handover were, however, not continued as indicated by the dotted line (ID1 (P)). This case, together with case 3, represents one of the most integrative collaborations between the industrial designer and engineering designers in the empirical material of this investigation.

4.3.2.2 Product Framing

The sub-frames described below are the original sub-frames intended by ID1 (P) to support the product concept.

***Table 4.2** –the product framing*

Perspectives/ sub-frames	**Insights / aspired values**	**Working principles**	**Correspondence (+)/ lack of correspondence (-)**
Business *(1) Differentiating*	The product should stand out (differentiating strategy) due to features and product quality (compared to the price).	Differentiating the product through a focus on the user and context, and product quality.	(+) The industrial designer and engineering designers expressed the same understanding of the insight and working principle during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained into the final product. However, the later sub-frames representing the focus on the user and context were not necessary shared.
Human *(2) Users*	The users of the product are dedicated and focused on quality and efficiency of both the work carried out and the product used to do it. The product should therefore, e.g., be easy to maneuver and operate. Moreover, shape and coloring can be used to create a certain expression.	The product is made as small as possible (physical) to make it more maneuverable. Moreover, the shape and coloring of the product helps underline the small size of the product and ease the interaction.	(-) The industrial designer and engineering designers expressed the same understanding of the focus on the size of the product (seems to be a generally known demand within the area). However, an understanding of shape and coloring used to underline the small size could not be found in the interviews with the engineering designers. They expressed an understanding of the coloring (shape was not mentioned) as a marketing aspect (styling), rather than a design element. The lack of correspondence in the understanding of the sub-frame (working principle) indicates that it was only partly shared. The indication of a partly shared sub-frame is moreover supported by another example. After the finalization of case 2 Main (P) has (internally) developed and designed a variant of the product based on the original version. However, it is difficult to find the same 'logic' in the product, except from the colors being the same.
(3) Users	The product is intended for more demanding welding task. The welders who use this product are regarded as experts.	The product expresses 'professionalism' - looking almost like a tool used at a laboratory.	(-) The industrial designer and engineering designers expressed the same understanding of the insight. However, the engineering designers did not express any understanding of the working principle during the interviews. The lack of correspondence in the understanding of the working principle indicates that the sub-frame was only partly shared.

(4) Users	A welding torch is the primary tool for a welder. The welders therefore focus on the ergonomics of the product.	Emphasis has been put on the ergonomics and the general usability of the product.	(+) The industrial designer and engineering designers all expressed the same insight and working principle during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained in the final product.
(5) *Context*	The product should limit the stressful position of the user's wrist often needed due to narrow spaces.	A new patented solution was developed allowing the handle of the welding torch to turn instead of the hoses (water and gas) inside the handle.	(+) The industrial designer and engineering designers, all expressed the same insight and working principle during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the sub-frame became governing for the product (part of ensuring the differentiation (sub-frame 1))
Technology (6) Flexibility	Main (P) wanted a modular product in order to make small production series.	Different versions of the products can easily be created by adding/removing a few parts (changing the functionality).	(+) The industrial designer and engineering designers, all expressed the same insight and working principle during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained in the final product.

4.3.3 Case 3 – Service (S)

The core setup in this case consisted of the main company (Main (S)) initiating and owning the project, and the design consultancy firm, Design (S). Main (S) develops, manufactures, and sells (internationally) a variety of products mainly for clearing floor areas (washing and vacuum cleaning). The context for the products is very broad and covers domestic areas, office areas, and manufacturing and building construction areas. Main (S) wanted to differentiate their product (vacuum cleaner) through a focus on the user and the context. The vacuum cleaner in this case is primarily intended for the rough environment of construction sites or industrial production sites. Some of the main challenges connected with the development of the product were: size and weight of the product (should be kept small), usability, and price (the market is very competitive).

4.3.3.1 The Handover Situation

The product concept was developed by ID1 (S) based on a comprehensive field study. Prior to the handover, drafts of the product concept and underpinning logic were "tested" with the rest of the project group at project meetings, indicated by the dotted line. The main handover of the product concept took place at a project meeting where a PowerPoint presentation supported by a 3D model was primarily used as means for communication.

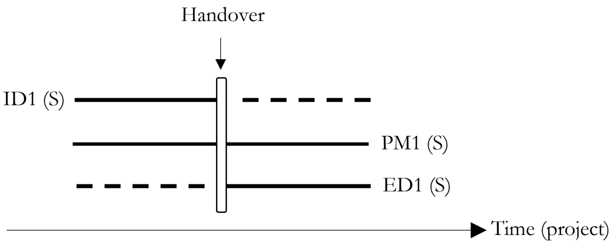

Figure 4.2 The figure shows an illustration of the handover situation in ca

The handover was followed up by several meetings and communication by mail and phone throughout the development of the product. The collaboration and communication were not continued as indicated by the dotted line. However, the product manager (PM1) from Main (S) was involved in the project both before and after the handover. He was, therefore, able to act as an internal (in Main (S)) ´product champion´ (Chakrabarti 1974) through the development of the product and to support the implementation of the product framing of the product concept. Together with case 2, this case represents one of the most integrative collaborations between the industrial designer and engineering designers in the empirical material of this investigation.

4.3.3.2 Product Framing

The sub-frames described below are the original sub-frames intended by ID1 (S) to support the product concept.

***Table 4.3** – the product framing*

Perspectives/ sub-frames	**Insights / aspired values**	**Working principles**	**Correspondence (+)/ lack of correspondence (-)**
Business *(1) Differentiating*	The product should stand out (differentiating strategy) due to features and product quality (compared to the price).	Differentiating the product through a focus on the user and context, and product quality.	(+) The industrial designer and engineering designers expressed the same understanding of the insight and working principle during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained into the final product. However, the later sub-frames which represent the focus on the users and context were not necessary shared.
Human *(2)* Users	The product is not the user's primary tool. It is a secondary product assisting the user while cleaning (not the primary work task).	The product is regarded as an 'assistant' to the user, standing in the background ready to assist when needed. To emphasize the 'assistance role' the product has a flat surface on the top for the user to place the primary tool (e.g. a drill) while using the product. Moreover, the product is given a 'dynamic' (slightly titled backwards) look to support the impression of an assistant, always ready.	(-) The industrial designer and engineering designers expressed the same understanding of the product as not being the user's primary product. In the following a division needs to be made between ED1 and PM1, as PM1 expressed the same understanding of the working principle as ID1. The same understanding of the working principle could, however, not be found in the interview with ED1. The lack of correspondence in the understanding of the working principle indicates that it was only partly shared.
(3) Users	Ergonomics and usability is regarded as important parameters in the effort to differentiate the product.	The functionality of the product is "simple", e.g. no automated cord winder as dust would damage the mechanics. Moreover, the focus on the usability of the product ensures a product that supports the uses, e.g. the bucket[1)] inside the vacuum cleaner has a handle to easy the emptying.	(+) The industrial designer and engineering designers expressed the same understanding of the insights and working principles during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained in the final product.

(4) *Context*	The product should be used in rough environments, e.g. a building site.	Vital functions such as the on/off button were placed and protected to limit the risk of them getting damaged or even broken. Moreover, the product was given a 'robust' look, e.g., adding a bumper and large wheels.	(-) The industrial designer and engineering designers expressed the same understanding of the insights (rough environment) and the functional accepts of the working principle (protected button and large wheels). In the following, a division needs to be made between ED1 and PM1, as PM1 expressed the same understanding regarding the working principle as ID1. However, the emotional aspects (e.g. looking robust) were not expressed by the engineering designers during the interviews. The lack of correspondence in the understanding of the sub-frame (working principle) indicates that it was only partly shared.
Technology (5) Parts	The 'technical' product concept was primary built on known technology. Consequently most of the ('technical') parts were known.	The functionality, size, and placement of vital ('technical') parts were given beforehand, as former concepts/knowledge was reused.	(+) The industrial designer and engineering designers expressed the same understanding of the insights and working principle during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained in the final product.

Notes:
1) Instead of a bag, which is used in vacuum cleaners for domestic use, this vacuum cleaner has a bucket where all the dirt is collected. When full the bucket is emptied and the vacuum cleaner is ready for use again.

4.3.4 Case 4 – Interior (I)

The core setup in this case consists of the main company (Main (I)) who owns the project and the design consultancy firm, Design (I), who initiated the project. Main (I) develops, manufactures, and sells (internationally) a variety of lighting fixtures. The context for the products is very broad and covers domestic areas, office areas, and public buildings (e.g., schools or universities). The lighting fixture developed in this case is intended for larger spaces to cast Omni light on its surroundings. Some of the main challenges met during the development of the product were: the detailed construction, the technology used (bulb), and the material and production methods. Compared to the other cases, the product developed in this case is significantly less complex (from a technological perspective).

4.3.4.1 The Handover Situation

The product concept was developed by ID1 (I) who focused on the technology (light bulb) and material (production method). The main handover of the product concept took place at a project meeting where a 3D model was used as the primary means for communication.

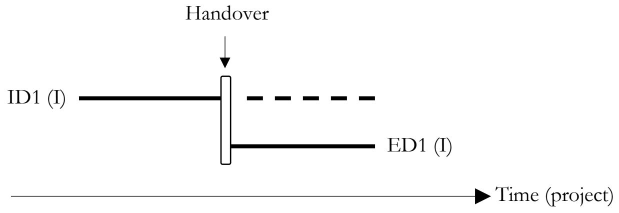

Figure 4.3 The figure shows an illustration of the handover situation in case 4 (I).

The handover was followed up by several meetings and communication by mail and phone throughout the development of the product. The collaboration and communication was, however, not continued as indicated by the dotted line.

4.3.4.2 The Product Framing

The sub-frames described below are the original sub-frames intended by ID1 (I) to support the product concept.

Table 4.4 *– The product framing*

Perspectives/ sub-frames	Insights / aspired values	Working principles	Correspondence (+)/ lack of correspondence (-)
Business *(1) Differentiating*	The fixture should stand out and be unique (differentiating strategy).	The product is given a visual 'direction' (physical), which combined with the material and light distribution makes it unique.	(+) The industrial designer and engineering designers expressed the same understanding of the insight and working principle during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained in the final product.

Human *(2) Spectators*	Despite the size of the fixture (large) it should give the spectators an impression of a flying object, e.g. an airship, when it has been installed. 'Flying' is understood as a 'hoovering' and having a 'direction'.	The form of the fixture sets a horizontal direction and the (two) wires make it possible to raise or lower one end of the product to give the product a vertical direction. Moreover, the (thin) wires give an impression of an object flying.	(+) The industrial designer and engineering designers all expressed the same insight and working principle during the interviews. Both the industrial designer and engineering designers emphasizes the details of the construction, supporting the aspired experience. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained in the final product.
(3) Spectators	The fixture should give an even Omni light (seen as an indicator of quality).	Emphasis has been on both the production methods and material (cannot be revealed in details).	(+) The industrial designer and engineering designers all expressed the same insight and working principle during the interviews. Both give the same example of finding the right position for the bulb inside the fixture as a key element in this effort. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained in the final product.
(4) Context	The product should give multiple options for placing the product either alone or as part of an installation with several fixtures.	The flexible suspension system (two wires) allows for multiple options.	(+) The industrial designer and engineering designers all expressed the same insight and working principle during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained in the final product.
Technology *(5) Size/cost*	The product is based on an insight regarding rotational molding and the possibility to make large plastic parts at a low cost.	The overall form and the detailed construction of the fixture support the product method.	(+) The industrial designer and engineering designers all expressed the same insight and working principle during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained in the final product.

4.3.5 Case 5 – Office (O)

The core setup in this case consists of the main company, Main (O), who owns and initiated the project, and the design consultancy firm, Design (O). Main (O) develops, manufactures, and sells (internationally) a variety of chairs, e.g., for professional use, i.e., users sitting at an assembly line). Design (O) solves various design tasks for other companies. A second design consultancy firm, Engineering (O), was brought in to assist Main (P) with the development, after the handover. The second design consultancy firm is regarded as part of the 'engineering design' perspective, as they belong to the receivers of the original product concept. The basic idea behind the product was to create a chair with 'dynamic seating' (slowly moving the seat and back rest of the chair), making sitting less stressful for the body (siting still on a chair for longer periods of time (e.g. one hour) is not healthy for our bodies). Some of the main challenges that arose in the development of the product were: ergonomics, the detailed construction, and the technology used. The project was stopped before it was put in production due to a recalculation of the business case.

4.3.5.1 The Handover Situation

The original product concept was developed by ID1 (O) who focused on integrating the main idea of a 'dynamic seating' in the design of a chair suitable for multiple situations. The main handover (1) of the product concept took place at a project meeting where a PowerPoint presentation was used as the primary means of communication.

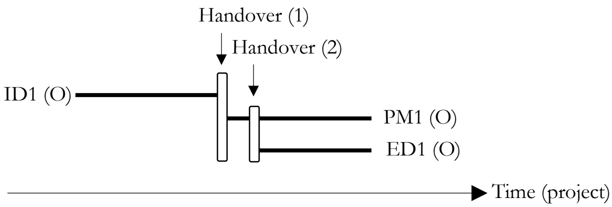

Figure 4.4 The figure illustrates the handover situation in case 5 (O).

The main handover (1) was not followed up by any additional meetings. Therefore, the second handover (2) was without any involvement from ID1 (O). Consequently, this case represents the least integrative collaboration between the industrial designer and engineering designers in the empirical material of this investigation.

4.3.5.2 The Product Framing

The sub-frames described below are the original sub-frames intended by ID1 (O) to support the product concept and the sub-frames which emerged later through the development.

***Table 4.5** - The product framing*

Perspectives/ sub-frames	Insights / aspired values	Working principles	Correspondence (+)/ lack of correspondence (-)
Business *(1) Differentiating*	The chair has unique 'dynamic seating' that ensures blood circulation while seated.	The seat and back rest can move (gently) which activates the muscles (creating blood circulation).	(+) The industrial designer and engineering designers expressed the same understanding of the insight and working principle during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained in the final product.
(2) Integrated	The functionality and technology should be integrated into the product.	The different elements of the design should be integrated and interconnected in a product (chair).	(+) The industrial designer and engineering designers expressed the same understanding of insights and working principle. However, the working principle was regarded as too difficult to achieve and the aim of the project was consequently changed (see sub-frame 3).
(3) Unit	The functionality and technology should be developed into a separate unit which could be sold separately (to other manufactures) or build into various products (chairs).	The technology and chair was seen as two separate units, which were assembled separately rather than integrated.	(-) This sub-frame emerged during the development of the working principle and became governing for the direction of the development of the product. The industrial designer was not involved in the process at that point (see figure 4.4).
Human *(4) Understanding the product*	The 'dynamics' of the chair should be recognizable in the design.	The different elements (batteries, motors and etc.) were used as form elements (visible in the design).	(-) The engineering designers did not express any understanding of the sub-frame during the interviews. The lack of correspondence in the understanding of the sub-frame indicates that it was not shared or that it was given a lower priority than sub-frame 3.

4.3.6 Case 6 – Energy (E)

The core setup in this case consists of the main company, Main (E), who owns and initiated the project and the design consultancy firm, Design (E). Main (E) develops, manufactures, and sells (internationally) a variety of 'intelligent' solutions for measuring energy and water consumption. Main (E) wanted to differentiate their product (energy meter) by focusing on the users and the context. Some of the main challenges connected with the development of the product were: size of the product (small), usability, and quality.

4.3.6.1 The Handover Situation

The product concept was developed by ID1 (E) with focus on the users and the context. The main handover of the product concept took place at a project meeting where a PowerPoint presentation was used as the primary means of communication.

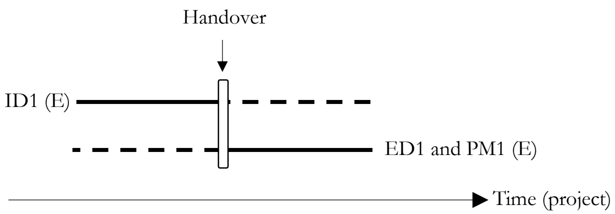

Figure 4.5 The figure illustrates the handover situation in case 6 (E).

The handover was followed up by several meetings and communication by mail and phone throughout the development of the product. The collaboration and communication was, however, not continued as indicated by the dotted line.

4.3.6.2 The Product Framing

The sub-frames described below are the original sub-frames intended by ID1 (E) to support the product concept.

Table 4.6 *– The product framing*

Perspectives/ sub-frames	Insights / aspired values	Working principles	Correspondence (+)/ lack of correspondence (-)
Business *(1) Cost*	The installation cost (time) of the product is a competitive aspect (the time used should be as little as possible.	The product is divided into two parts which makes it easy (faster) to fit and mount in narrow places (cabinets).	(+) The industrial designer and engineering designers expressed the same understanding of the insight and working principle during the interviews. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained in the final product.
Human *(2) Users*	The product should signal 'thrust' and 'reliability, as the measurements are used to calculate the cost of the energy used during a year (can be a considerable amount).	The product is shaped by using simple geometric forms (square and circle). The main colors used are gray and black (almost 'dressed' like an accountant underlining the serious aspect of the product).	(-) In the following a division needs to be done between ED1 and PM1, as PM1 expressed the same understanding regarding the sub-frame as ID1. The same understanding of the sub-frame cannot be found in the interview with ED1. The lack of correspondence in the understanding of the sub-frame indicates that it was shared, or only partly shared.
(3) Users (professionals)	The product measure the energy used through a year. Reading the data is consequently one of the main functionalities of the product.	The product is divided into two parts allowing the part with the display to rotate into the desired angle. This allows for a flexible installation.	(+) The industrial designer and engineering designers expressed the same understanding of the insight and working principle during the interviews. They all give the same example of the product being separated into two parts and the rotating principle. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained in the final product.
(4) Context	The product must be able to fit in narrow spaces as it is installed in cabinets with not much room.	The size of the product is minimized using the principle of a circle as the main form for the product instead of the principle a square.	(+) The industrial designer and engineering designers expressed the same understanding of the insight and working principle during the interviews. They all give the same example of the circle as governing principle for the form of the product. The correspondence in the understanding of the sub-frame indicates that it was shared. Moreover, the working principle is maintained in the final product.

4.4 Analysis and Discussion

In this analysis, the main focus is on the sub-frames with the aim of identifying which perspectives and/or elements of the product framing that is challenging for the industrial designer to communicate and transfer to the engineering designer. Additional findings, relevant to the study, is presented and discussed at the end of the chapter.

4.4.1 Perspectives

The initial focus of this analysis is on the three perspectives (business, human, and technology) within the product frames identified. The first step is to investigate if any of the perspectives seem particularly challenging for the industrial designer to communicate and transfer to the engineering designers. The identified sub-frames across the cases are separated into categories based on the three perspectives. Moreover, each sub-frame is marked based on to whether any correspondence was found in the description given by the industrial designers and engineering designers (see table 4.7). The indication of 'correspondence' or 'lack of correspondence' for each of the sub-frames can be found in the comments of the Correspondence / Lack of correspondence-column in each of the tables that show the underpinning logic of the frames of each case, e.g., see table 4.1).

Table 4.7 *– The identified sub-frames across the cases separated into perspectives and marked with regards to 'correspondence' or 'lack of correspondence'.*

Perspective	Case/sub-frame	Correspondence	Lack of correspondence	Notes
Business	*Case 1/sub-frame 1*	*X*		
	Case 2/sub-frame 1	*X*		
	Case 3/sub-frame 1	*X*		
	Case 4/sub-frame 1	*X*		
	Case 5/sub-frame 1	*X*		
	Case 5/sub-frame 2	*X*		
	Case 5/sub-frame 3		*X*	*The industrial designer was not involved in the project when the sub-frame emerged.*
	Case 6/sub-frame 1	*X*		
Human	*Case 1/sub-frame 2*		*X*	*The insights/values were only partly shared.*
	Case 1/sub-frame 3		*X*	*The working principle was not shared (another understanding of the insight was applied).*
	Case 1/sub-frame 4		*X*	*The functional but not the emotional aspect of the insights was shared.*
	Case 1/sub-frame 5	*X*		*The sub-frame contains functional/rational insights and working principle.*
	Case 2/sub-frame 2		*X*	*The insights (shape and coloring as design elements) were not shared.*
	Case 2/sub-frame 3		*X*	*The working principle (product expression) was not shared.*
	Case 2/sub-frame 4	*X*		*The sub-frame contains functional (ergonomic) insight and working principle.*
	Case 2/sub-frame 5	*X*		*The sub-frame contains functional insight and working principle.*
	Case 3/sub-frame 2		*X*	*The working principles seem not shared (with ED1).*
	Case 3/sub-frame 3	*X*		*The sub-frame contains functional insight and working principle.*
	Case 3/sub-frame 4		*X*	*The functional but not emotional aspect of the working principle seemed shared.*
	Case 4/sub-frame 2	*X*		*Despite the emotional aspects, the insights and the sub-frame were shared.*
	Case 4/sub-frame 3	*X*		*The sub-frame contains functional insight and working principle.*
	Case 4/sub-frame 4	*X*		*The sub-frame contains functional insight and working principle.*
	Case 5/sub-frame 4		*X*	*The sub-frame was not shared.*
	Case 6/sub-frame 2		*X*	*The sub-frame was not shared.*
	Case 6/sub-frame 3	*X*		*The sub-frame contains functional insight and working principle.*
	Case 6/sub-frame 4	*X*		*The sub-frame contains functional insight and working principle.*
Technology	*Case 2/sub-frame 6*	*X*		
	Case 3/sub-frame 5	*X*		
	Case 4/sub-frame 5	*X*		
	Case 1/sub-frame 6	*X*		*The sub-frames emerged during development*

When examining table 4.7, it becomes immediately clear that the sub-frames within the human perspectives seem to be the most challenging to communicate and transfer whereas both the business and technology perspective seem significantly easier to share (only one sub-frame within the business perspective seems to have not been shared). In the following, each of the perspectives will be analyzed in details in order to get a deeper of understanding why the human perspectives seem to be the most challenging to communicate and transfer. The analysis will commence with the business and technology perspectives as both of these perspectives generally seem to be shared between the industrial designers and engineering designers. Understanding these perspectives potentially provides some insight into why they are shared, which again might be helpful when trying to understand why some of the sub-frames within the human perspective seem more challenging to communicate and transfer.

4.4.2.1 The Business and Technology Perspectives

The sub-frames of both the business perspective and the technology perspective all (expect one) seemed to have been shared (see table 4.7). The only sub-frame within those perspectives that was not shared belongs to case 5 (offices – chair), sub-frame 3 (insight: 'The functionality and technology should be developed into a separate unit…'). However, the sub-frame emerged after handover 1, when ID1 was no longer involved in the project (see figure 4.4). It is therefore natural that the sub-frame is not expressed in the interview with ID1. When analyzing the interviews, the rest of the sub-frames seem to have been shared, as both the industrial designers and engineering designers describe the same insights/values and working principles as well as emphasize the same aspects within the business and technology perspective. For instance, they use identical examples to explain the main idea behind the product or the main technical challenges of the project, and they use many of the same words and in some of the cases almost the same sentences to explain the perspectives. The correspondence in the description of the sub-frames within both the business and technology perspective, given by the industrial designers and engineering designers, indicates that the sub-frames have been communicated and transferred.

The correspondence in the understanding of the sub-frames within the business and technology perspective resonates well with both industrial designer's and engineering designers' needs to take the commercial and technical viability into consideration when developing products (see chapter 2). Despite their focus on different aspects within the two perspectives, they still have the same expectations and understand the perspectives in a common way, which makes the communication and transfer less challenging.

Furthermore, the sub-frames within the business and technology perspective also represent what can either be described as a prerequisite for all the cases or at least key aspects in understanding the cases, as all the projects have a commercial focus and technological content. In having selected what are regarded as ‘successful’ cases (see 4.1 Selection of cases), the sharing of these key aspects are also strengthened. Part of ensuring that a project is ‘successful’ is ensuring that the goal of the project is clear to all the team members (Holland et al. 2000). Lastly, the correspondence in the understanding of the sub-frames within both the business and technology perspective is most likely also (positively) influenced by the fact that all the cases are retrospective. The team members will normally have a better overview of the project, including the key elements such at the main business idea, at the end of the process.

4.4.2.2 The Human Perspective

Studying the sub-frames within the human perspective, it is immediately clear (see table 4.7) that this perspective is more challenging for the industrial designers to communicate and transfer to the engineering designers than the two other perspectives. In total, 18 sub-frames were identified within the human perspective across the cases. In this paragraph, focus will be on the nine sub-frames that seem to have been communicated and transferred from the industrial designers to the engineering designers. The remaining nine sub-frames will be commented separately in the following paragraph. The nine frames that seem to have been shared are listed in table 4.8 (extracted from table 4.7).

***Table 4.8**- the sub-frames within the 'human-perspective' shared (extracted from table 4.7).*

Perspective	Cases/sub-frames	Correspondence	Lack of correspondence	Comments
Human	*Case 1/sub-frame 5*	*X*		*The sub-frame contains functional/rational insights and working principle.*
	Case 2/sub-frame 4	*X*		*The sub-frame contains functional (ergonomic) insight and working principle.*
	Case 2/sub-frame 5	*X*		*The sub-frame contains functional insight and working principle.*
	Case 3/sub-frame 3	*X*		*The sub-frame contains functional insight and working principle.*
	Case 4/sub-frame 2	*X*		*Despite the emotional aspects the insights and the sub-frame were shared.*
	Case 4/sub-frame 3	*X*		*The sub-frame contains functional insight and working principle.*
	Case 4/sub-frame 4	*X*		*The sub-frame contains functional insight and working principle.*
	Case 6/sub-frame 3	*X*		*The sub-frame contains functional insight and working principle.*
	Case 6/sub-frame 4	*X*		*The sub-frame contains functional insight and working principle.*

Within the nine frames, correspondence was found in regards to the examples used to explain the situation and the words used to describe either the aspired values and/or working principles. For instance, both the industrial designer and engineering designers in case 1 (welfare – 'chair') emphasized the importance of the product being able to operate in wet areas, e.g., a toilet/bath and. And in case 2 (production – welding torch) both the industrial designer and engineering designers emphasized the importance of the ergonomic of the product giving similar examples of difficult working situations (sub-frame 4). The correspondence in the description of the sub-frames given by the industrial designers and engineering designers indicates that the sub-frames have been shared. When examining the sub-frames, it seems that all of them (expect one) contains what can be described as 'rational and functional insights/values and/or working principle' (See table 4.8 – 'Comments'). In other words, when thrust of the sub-frames within the human perspective are on rational and functional aspects it seems that they are less challenging for the industrial designer to communicate and transfer to the engineering designers, which fits well with the rational and functional focus of the engineers (see chapter 2). As for the sub-frames within the business and technology perspective, the findings are most likely (positively) influenced by the fact that all the cases are retrospective.

4.4.2.3 Summary

Having analyzed the sub-frames across the perspectives that seem communicated and transferred between the industrial designers and engineering designers, the following have been revealed:

- Sub-frames belonging to the business or technology perspective seem less challenging to communicate and transfer.
- Sub-frames within the human perspective, where thrust of the sub-frames contains rational and functional values/insights and/or working principles seem less challenging to communicate and transfer.

Generally it seems as if the rational and functional aspects of the perspectives are less challenging to communicate and transfer. It also appears that the results are most likely (positively) influenced by the fact that all the cases are retrospective and 'successful', as sub-frames that represent prerequisites for or at least key aspects in understanding the cases seem less challenging to communicate and transfer.

4.4.3 Three Situations

After having examined the sub-frames within the three perspectives that seem shared, the focus will now turn to the sub-frames (within the human perspective) that seem to have not been shared. When analyzing these sub-frames (see table 4.9 - extracted from table 4.7), the picture becomes more complicated. However, the identified sub-frames can be covered by three main situations happening.

In the first situation, only the rational and functional aspects of the underpinning logic are adopted by the engineering designers in the handover situation. In the second situation, the insights/values and working principles of the underpinning logic seem to have been communicated and transferred, but the connection (frame) between them has not been shared or transferred. In the third situation, none of the sub-frames of the underpinning logic seems to have been communicated and/or transferred. Each of the situations will be described in further details in the following three paragraphs, including argumentation and examples.

Table 4.9 *– The sub-frames within the 'human-perspective' not communicated and/or transferred. The ones marked with an 'O' are the ones where the interconnection between the values and working principles seems to have not been shared (extracted from table 4.7).*

Perspective	Cases/sub-frames	Lack of correspondence	Entire sub-frame	Insights/ values	Working principle	Comments
Human	*Case 1/sub-frame 2*	*X*		*X*		*The insights/values were only partly shared.*
	Case 1/sub-frame 3	*X*		*O*	*O*	*The working principle was not shared (another understanding of the insight was applied).*
	Case 1/sub-frame 4	*X*		*X*		*The functional but not emotional aspect of the insights was shared.*
	Case 2/sub-frame 2	*X*		*X*		*The insights (shape and coloring as design elements) were not shared.*
	Case 2/sub-frame 3	*X*		*O*	*O*	*The working principle (product expression) was not shared.*
	Case 3/sub-frame 2	*X*		*O*	*O*	*The working principles were not shared (with ED1).*
	Case 3/sub-frame 4	*X*		*O*	*O*	*The functional but not emotional aspect of the working principle was shared.*
	Case 5/sub-frame 4	*X*	*X*			*The sub-frame was not shared.*
	Case 6/sub-frame 2	*X*	*X*			*The sub-frame was not shared.*

4.4.3.1 Situation 1 - The Values and Insights Only Partly Adopted by the Engineering Designers

This category covers situations where the values and insights are only partly adopted by the engineering designers. When analyzing the interviews, it seems as if only the rational and functional aspects of the underpinning logic are adopted by the engineering designers in the handover situation. The emotional aspects of the insights are either valued differently or not emphasized by the engineering designers. Regardless of the reason for this, the engineering designers seem to create their own 'logic' based on the fragmented understanding of the insights/values. Consequently, the engineering designer forms an alternative underpinning logic less connected to the context by connecting the partly adopted insights and values with the working principles predominately driven by (generic) engineering design values, rather than case related values. The situation is illustrated in figure 4.6

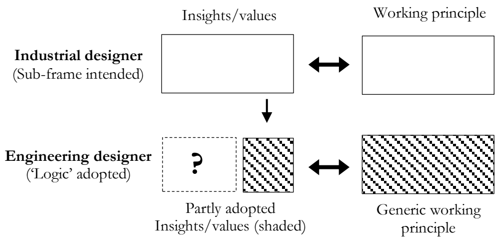

Figure 4.6 The figure illustrates situation 1, where the insights/values are only partly adopted by the engineering designers, and an alternative logic is created by the engineering designer.

Example

In case 1 concerning the development of a chair to assist the healthcare personnel when elderly people fall, sub-frame 4 offers an example of insights/values which are only partly shared between the industrial designer and the engineering designers. When the industrial designers describes the insights/values of the sub-frame, their focus is on both the functional and rational aspects (stopping the situation – getting the person up again), but also on the more emotional aspects (the elderly person feeling insecure, afraid and humiliated), whereas the engineering designer emphasizes the rational and functional aspects. The difference in the understanding of the insights/values consequently leads to two very different working principles. The engineering designer addresses the insights with a functional working principle, metaphorically speaking, by describing a football player who has fallen on the field and one of his teammates, who reaches his arm out to help him up again. The working principle builds on a generic value of 'efficiency' (getting the elderly person up fast – stopping the situation). The industrial designer, however, addresses the insights with a working principle expressed as the product "embracing" the elderly person, metaphorically speaking as two persons, kneeling on each side and gently lifting the elderly person up again. The focus can be described as getting the elderly person up in a controlled and secure manner, which is faster than the present solution (seen from the perspective of both the elderly person and the healthcare personnel). Source: *Case 1, sub-frame 4*.

4.4.3.2 Situation 2 - The Values and Working Principle are not interconnected

This category covers situations where the values and working principle of the underpinning logic are not interconnected by the engineering designer in the handover situation. When analyzing the interviews, it seems as if the insights/values and working principles are communicated and transferred, but that the connection between them – the frame – is not. Consequently, the engineering designer is left with insights and values about a situation and context which is experienced as detached from the product concept. On the other hand, the engineering designers are also presented with a product concept where the working principles are 'crafted' into the product, but detached from the underpinning logic (values/insight). Consequently, the engineering designer is left with what seems to be fragmented knowledge about insights/values, detached from the product concept, and working principles embodied in the product concept, without understanding of the logic behind the principles/solutions chosen. The situation is illustrated in figure 4.7.

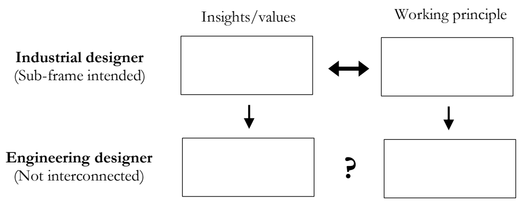

Figure 4.7 The figure illustrates situation 2, where the insights/values and working principle seem to be communicated and transferred, but the interconnection between them seems not to be.

Example

In case 3 concerning the development of a vacuum cleaner, sub-frame 2 offers an example of the working principle not being interconnected to the insights/values. Sub-frame 2 contains insights about the product not being the user's primary tool. ID1 describes a working principle where the product is seen as a maid. He also refers to the product as a 'buddy' or 'guardian' but chooses the term 'maid': "…one that does what it is expected to do. It just works…." (Interview: case 3, ID1, 12.48 min.). The product is, e.g., given a 'dynamic' (slightly titled backwards) look to support the impression of an assistant, always ready to help. ED1 describes the tilted form as 'smart'. When asked about how the form might affect the users, the explanation is marketing driven, rather than design driven - ED1: "If one can create a design that is unique and easy to recognize…and that positively influences the business, it is worth going for" (Interview: case 3, ED1, 13.4min.). In other words, the reason behind the form (slightly titled backwards) is not interconnected to the insights/value identified by the industrial designer. Source: *Case 3, sub-frame 2*.

4.4.3.3 Situation 3 – The Insights / Values and Working Principles not shared

This category covers situations where the entire sub-frame seems to be not shared. This situation is difficult to exemplify, as the sub-frames are not found through analyzing the interviews with the engineering designers. However, instead of the context related sub-frames (initiated by the industrial designer), it seemed as the engineering designers created generic sub-frames, based on engineering based values, which became governing for their understanding of the product framing. For instance, focus on keeping the time schedule, performance of the product, e.g. speed or strength, or efficiency. The situation is illustrated in figure 4.8.

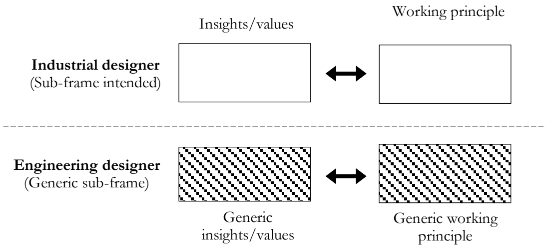

Figure 4.8 An illustration of situation 3, where the engineering designer creates generic sub-frames rather than context related ones.

Example

In case 2 concerning the development of a welding torch, sub-frame 3 offers an example of the entire frame not being shared. Sub-frame 2 contains insights about how the product should express 'professionalism' by looking almost like a tool used in a laboratory. ID1 describes the product associating it with values such as 'modern' and 'professional' (e.g. advanced productions). ID1 describes the working principle for the product as a transformation: "…from tool shop… It might be a bit exaggerated…. from tool shop to "laboratory" (Case 2, ID1, 9.32 min.). The term 'laboratory' is described later on in the interview as reminiscent of modern and advanced production facilities of for instance the auto or yacht (high end) industry. However, it is not possible to find the same understanding in the interview with ED1. On the contrary, ED1 describes the product framing by referring to a general set of values/insights and working principles (e.g. easy, cheap, fast, and effective) and thus creates generic frames, rather than context depend sub-frames. Source: *Case 2, sub-frame 3*.

4.4.3.4 Discussion

Common for the sub-frames which are not shared between the industrial designers and engineering designers is that thrust of values and/or working principles are more related to emotional, symbolic, social and/or cultural aspects than rational and functional aspects. For instance, the working principle for sub-frame 4 described in case 1 (welfare- 'chair'): *"…almost as two persons, kneeling on each side and gently lifting the person up again"*. The human perspective is recognized by the engineering designers (see chapter 2), but the engineering designers focus is on the rational and functional aspects of the human perspective, rather than on the emotional, social and cultural aspects. In other words, the lack of a common understanding of the human perspective seems to be part of the reason why some elements of the sub-frames within the human perspective are more challenging to communicate and transfer between the industrial designers and engineering designers. Moreover, the engineering designers tend to create context independent sub-frames based on generic values and principles embedded in the technology perspective.

The fact that there were unshared sub-frames between the industrial destines and engineering designers does, however, not mean that the underpinning logic from an ID perspective was not implemented and maintained into the final products. In four out of the six cases (case 2, 3, 4, and 5), the industrial designers found that the underpinning logic from an ID perspective were mostly implemented and maintained in the final product (it was not possible to make the evaluation in case 1 and 6). When examining these four cases, it seems that they succeeded in implementing and maintaining the framing because the industrial designers still was involved in the development after the 'handover', e.g., case 2 and 3. In case 3 (service – vacuum cleaner), the product manager (PM1), moreover, acted as a 'product champion' (for the product framing) which further ensured a successful implementation of the underpinning logic in the final product. In other words, the underpinning logic was not shared; it was primary ensured by the continuous involvement of the industrial designers or a representative.

4.4.4 Additional Implications

Having analyzed the sub-frames in relation to the perspectives, focus will now turn to the cases. Comparing the cases where the industrial designer was significantly involved after the handover, case 2 (production - welding torch) and case 3 (service - vacuum cleaner), with the cases were the industrial designer were not involved or only very limited involved after the handover, case 1 (Welfare – 'chair') and case 5 (office - chair), it seems that the cases were the industrial designer was involved after the handover have less conflicting sub-frames. In both case 1 and case 5 conflicting sub-frames could be identified, e.g., in case 1, sub-frame 6 (regulations requires the weight to be below 7 kg. is interconnected with the product being divided into seven pieces) is conflicting with sub-frame 3 (healthcare personnel having high barriers against new technology is interconnected with the product being in one pieces (minimum assembly)). In both cases (1 and 5) it seems that the solution to the dilemma (conflicting sub-frames) was to compromise or suppress one of the sub-frames in favor of the other, rather than to create an 'alignment' between them (e.g. by reframing). However, in the cases (2 and 3) where the industrial designers were involved in the process after the handover an 'alignment' was created between the different sub-frames rather than a compromise or suppression of one or more of the sub-frames, as was the case is case 1 and 5. This finding fits well with the description given by Møller and Tollestrup (n.d.) of alignment between sub-frames in the solution framework.

Case 4 (interior – light fixture) is particular interesting as it is the only case where all the sub-frames were shared between the industrial designer and engineering designer. When comparing case 4 with the rest of the cases, a number of things stand out, which could potentially be part of the explanation of why all the sub-frames were shared. Main (I) is very experienced working with industrial designers as it is company strategy that all projects are developed in close connection with industrial designers. Moreover, ED1 is trained as an industrial designer, which most likely makes him better understand and adopt the perspective of ID. Furthermore, by focusing on the product, it appears to be less complex (few parts and simple and known[17)] technologically). In other words, the project including the product framing is, all else equal, easier to overview and understand, which makes the sharing less challenging. Also the product framing contains a higher degree of freedom with fewer and less interconnected 'interfaces' between ID and ED, reducing the risk of conflicting sub-frames. Based on the very limited empirical material, it is not possible to conclude whether it is the organizational aspects or the product related aspects that affect the sharing of the product framing between the industrial designers and engineering designers, in this case. However, it could seem as if the organizational or product related aspects have an influence on the sharing of the sub-frames between industrial designers and engineering designers.

The lack of shared frames between the industrial designers and engineering designers seems to cause (unnecessary) iterations between the industrial designers and engineering designers. Moreover, the lack of shared frames also seems to affect some of the engineering designers slightly negatively, e.g., ED1 from case 2 (production – welding torch) explains how he prefers to show the solutions before too many details are added, as especially PM1 often have changes. In other words, the engineering designer is trying to solve a task without knowing when he is right or wrong.

4.5 Conclusion of the First Descriptive Study

The results and analysis of the first descriptive study indicated that:

- Sub-frames belonging to either the business or technology perspective are less challenging to communicate and transfer between industrial designers and engineering designers in a handover situation.
- Sub-frames (within the human perspective) containing what can be described as 'rational and functional values and working principles' are less challenging to communicate and transfer between industrial designers and engineering designers in a handover situation.
- Sub-frames (within the human perspective) where thrusts of the values and/or working principles are on emotional, symbolic, social and/or cultural aspects are more challenge to communicate and transfer.
- Unshared sub-frames can occur in three main situations; (1) the values are not shared or only partly shared, (2) the values and working principles are shared but not the interconnection between them, and (3) neither the insights/values or the working principles are shared.

Generally, it seems that the perspectives expected and understood by both the industrial designers and engineering designers are less challenging to share. And it seems that the results most likely are (positively) influenced by the fact that all the cases are retrospective and 'successful', as sub-frames that represents what can either be described as a prerequisite for the cases or at least key aspects in understanding the cases seem less challenging to share.

5.0 Prescriptive Study

The aim of the prescriptive study is to identify the 'design support' that can remedy the challenges in the handover situation between industrial designers and engineering designers. The goal of the design support is to ensure that as many sub-frames are shared as possible, in particular the sub-frames within the human perspective containing, e.g., emotional, social, and cultural aspects. The chapter commence with a discussion of the level and type of 'design support' and description of the current situation as a foundation for understanding the considerations made in relation to the design support.

5.1 The Level and Type of the Design Support

The limitation of this study, which focuses on the integration of industrial design in product development projects, indirectly sets a direction for the level and type of design support needed. According to Blessing & Chakrabarti (2009), there are different types and levels of design support. Based on the literature covering design research, Blessing and Chakrabarti (2009) define four common types and levels of design support: (1) design support as a *design approach* or *methodology*, which contains the overall framework, e.g., VDI 2221 (VDI 1993), (2) design support as *design methods*, understood as the sequences of activities to be followed, e.g., analysis, synthesis, simulation, and evaluation (Roozenburg & Eekels 1995), (3) design support as *guidelines* (rules, principles or heuristics), e.g. the many 'design-for-X' (e.g. Design-for-Manufacturing, Design-for-Cost or Design-for-Environment), and (4) design support as *design tools*, e.g., CAD tools, Product Data Management tools, Finite Element tools, and requirement capture tools. The two first levels of design support, design support as a design approach or methodology and design methods (Blessing & Chakrabarti 2009), are considered to be outside the scope of this study, as they focus on the entire process or underpinning methodology. Also the third level, design support as guidelines, is considered to be outside the scope of this study, as this study focuses on specific design objectives at a certain design stage rather than on more general guideline to the design process. The aim of the design support is to ensure a more effective and efficient use of the current approaches, methods, or guidelines through the development of a supportive tool, rather than changing the approach, methods, or guidelines.

5.2 The Current Situation

Recapturing the situation described in chapter 2, focus is on handover situations in the product development process between industrial designers and engineering designers. The handover situation is regarded as a general gap between industrial designers and engineering designers, understood as differences in the emphasis on perspectives (human, technology, and business) and, accordingly, differences in roles, responsibilities, and the predominate perception of design problems. Moreover, the situation is further stressed by also focusing on the handover situation as a processual transition between the conceptual and development phases in the product development process. The separation of work activities between the industrial designers and engineering designers and the change in focus from the concept to the development creates a handover situation which is characterized by limited time and limited possibility of feedback, hampering both the organizational and collaborative aspects of the design process.

Indicated by the findings in the first descriptive study, it seems that the sub-frames belonging to the human perspective which predominantly contain emotional, social, and cultural aspects are particular challenging to share with the engineering designers. The situation can be compared to communicating and transferring the result of a complicated math calculation. If only the end result of the calculation is communicated and transferred, the receiver has no foundation for understanding the conditions and calculations behind the result. In other words, the underpinning logic is the foundation for fully understanding both the design problem and the product concept. If the underpinning logic not is shared, the engineering designers are left with a fragmented understanding of the foundation for the product concept, which makes it difficult to understand when changes to the originally product concept are 'within' or 'outside' the product framing, as described in chapter 2. Accordingly, the aim of the design support is to: (1) make the product framing explicit to both the industrial designer and the engineering designer, and (2) make the product framing 'operational' to the engineering designers. Operational should here be understood as reducing the gap between the perspective of industrial design and engineering design to leave less room for interpretation by the engineering designer of the intended design. In other words, the criterion of success is not to present a design support that fully closes the gap, e.g., translating the qualitative aspects contained in a product framing into quantitative targets that will be directly useful for the engineering designers, as this is regarded as unrealistic. The criterion of success is a design support that reduces the gap, rather than closes it, by providing a higher degree of transparency in the logic underpinning the product concept.

5.3 Considerations and the Design Support

This chapter presents the considerations connected to the design support. The process underpinning the prescriptive study can be compared to a design process. The aim of this chapter is, therefore, neither to present the considerations in the order they emerged nor all the considerations that emerged during the process. The description below is a condensed summary presenting the foundation for the choice made.

Despite the positive indications of: (1) additional involvement of the industrial designers after the handover, and (2) the use of 'product champions' (see chapter 4) could help close the gap, these approaches are not considered in this study. Continues involvement of the industrial designer after the handover is regarded outside the scope of this study, as this approach is regarded as part of IPD. Moreover, continues involvement of the industrial designer is regarded as a comprehensive solution, which also is the case for the use of 'product champions' (Maidique 1980). The implementation of 'product champions' in companies is also regarded as significantly more complicated in regards to implementation of a design support-tool.

5.3.1 The Role of Design Representations in Design Communication

Design representations (e.g. sketches, drawings, models, and prototypes) are normally used throughout the development process for varies purposes including communication (Pei 2009). The use of design representations is often regarded as a way to design, visualize, and communicate the intended design in a project team (Cross 2006). Accordingly, design representation often plays an important role in showing the results of the connections between the different insights/values and working principles, by embodying the embedded knowledge. Industrial designers often communicate by using various forms of design representations as their main means of communication (Cross 2006). When using design representations, e.g., models in the product development process, the result emerges in a process of trial and error, or a 'reflection-in-action', as described by Schön (1983). However, the models do not explicitly show the underpinning logic developed through the reflection-in-action that create the model (Cross 2006). This knowledge remains tacit in the mind of the industrial designer. In other words, if the product framing is not explicit in the mind of the industrial designer, it becomes difficult to highlight and/or communicate via a design representation in a way that the engineering designer can understand.

5.3.2 The Importance of 'Naming' the Framing

Revisiting the four steps of framing, described by Schöns (1983), the first step was 'naming'. In other words, naming is a prerequisite for framing. The naming does not just show what is regarded as important, it also show how it is perceived (Schön 1983). Explicitly naming the sub-frames embedded in the product framing, consequently, becomes of great importance. However, the findings of the first descriptive study showed that the industrial designers had difficulties explicitly explaining the underpinning sub-frames. Being able to name the sub-frames is vital when trying to ensure that the product framing is explicit to both the industrial designer and engineering designer. Explicitly naming the product framing will show which elements of the insights/values are important and how they are interconnected to the working principles. To turn this in to a means of communication (and also documentation), the product framing should not just be verbally expressed during a handover it should be documented as well.

5.3.3 The Support

The support 'tool' proposed is a template based on the conceptual understanding of solution framework by Møller and Tollestrup (n.d.). See chapter 2 for a detailed description of the solution framework. The template of the solution framework is adopted in a simplified version, which primarily focuses on the sub-frames understood as the insights/values connected with the working principles. The frame metaphor/one-liner is disregarded, as it is regarded primarily a support for industrial designers to understand and categorize the sub-frames (see the visual representation of the Solution Framework (table) in chapter 2). Moreover, the sub-frames are divided into the three main perspectives underpinning human-centered products; human, technology, and business, which are in focus in this study. The distinction between problem frames and solution frames made in the original concept behind solution framework is not relevant in this study, as the focus of this study is on the entire solution framework with both types of sub-frames included. This is therefore disregarded in the template.

Perspectives/ sub-frames	Insights / aspired values	Working principles
Business *XX*	XX	XX
Human *XX*	XX	XX
Technology *XX*	XX	XX

Figure 5.0 The design support based on the template presented in Møller and Tollestrup (n.d., p.15).

5.3.4 Reflections

Trying to improve the communication and transfer of the underpinning logic by documenting it in writing can seem illogical and unfruitful. It is well known that expressing the intangible qualities of a product, e.g., the emotional, social and cultural aspects, is challenging (Maier et al. 2005). It would most likely have been regarded as more logical to use a kind of visual design representation as a 'means' to support the communication. However, using design representations does not necessary ensure the engineering designers' ability to operationalize the product framing. Documenting the underpinning logic in writing can be regarded as a way to make it explicit to both the engineering designer but also the industrial designers. Moreover, documenting the product framing in writing requires the industrial designers to reflect and formalize the wording (naming) of the insights/values and working principles. Formalizing the communication can be helpful in a handover situation (Eckert et al. 2013) and can create the foundation for using design representations as support for the communication.

The design support suggested in this study can therefore be regarded as the first step out of several in developing the design support. Firstly, the development of the design support can be regarded as a product development project solving a wicked design problem. Consequently, the support must be developed co-developing an understanding of the situation by taking small steps forward (Rittel & Webber 1973; Schön 1983; Dorst 2011). Accordingly, the suggested design support can be regarded as a 'minimum variable product' following the terminology of 'The Lean Startup' by Eric Ries (2011). Moreover, the simplicity of the design support suggested also makes it more straightforward to implement in practice.
Secondly, from a scientific point of view, the steps should be separated to limit the number of parameters tested at the time.

6.0 Descriptive Study II

The aim of this second descriptive study[18)] is to investigate whether explicit emphasis on a product concept´s underpinning logic improves the engineering designer´s ability to understand whether potential changes are coherent with the underpinning logic. The chapter commences with a detailed description of the research setup for the investigation (DS II). This is followed by a presentation of the empirical material that lies behind the investigation. At the end of the chapter, the results are presented, analyzed, discussed, and summarized in order to answer the second research question.

6.1 The Research Setup

The aim of the research setup is to simulate a handover situation of a product concept between industrial designers and engineering designers, where the engineering designers afterwards are presented with a number of questions (dilemmas) related to the product concept. The questions represent fictional dilemmas that simulate a situation where changes to the original product concept are needed, e.g., due to the cost of the product, production related issues, or new technology being available. The hypothesis is that by explicitly explaining and communicating the product framing in a handover situation, the understanding of the foundation for the product concept will be improved.

6.1.1 The Method

The hypothesis is tested in a constructed test environment involving industrial design students and professional engineering designers. The study is conducted as a comparative study between two situations, A and B. In situation A, the engineering designers are presented with the product concept and afterwards given six questions (dilemmas) related to the case. In situation B, the engineering designers are presented with both the product concept and the underpinning product framing as well as the product framing. Afterwards, the engineering designers are given the same six questions (dilemmas) as in situation A. The answers to questions given in the two situations are then compared to see if explicit explanation and communication of the product framing improves the transfer, and the engineering designers' ability to decode and operationalize the product framing. Each engineering designer is presented with one to six projects. All the presentations of the product concepts are given by students. The presentations are given verbally and are supported mainly by a PowerPoint, and in some of the cases also models and drawings. For practical reasons the presentations are video recorded and the recording is then presented to the engineering designers afterwards. Besides the practical advantages, the use of recorded presentations also ensures an identical presentation of the projects each time. Each presentation takes approximately 10-15 minutes, and in the cases where the engineering designers were also were presented with the product framing (situation B), they were given time to read the filled in solution framework document carefully. Moreover, the documentation of the product framing was available to them when they were answering the dilemmas. A visualization of the setup can be found below, see figure 6.0.

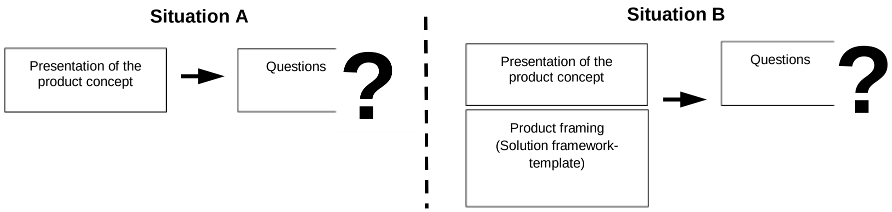

Figure 6.0 An illustration of the two situations.

6.1.2 The Empirical Material

The documented product framing and questions (dilemmas) are based on six projects done by industrial design student at Aalborg University. The projects were done in collaboration with various companies to simulate practice as best possible. The projects have been selected among 32 student projects[19)], and the projects with the best communicated and aligned product framing (evaluated by the supervisions) were chosen. A framing is strong when the different sub-frames/perspectives are aligned and recognizable in the product concept. However, this does not mean that the product framing necessarily has been fully understood by the student. According to Dorst (2015), framing normally requires experienced designers. Consequently, the final formulation and documentation of the product framing has been reviewed by the supervisors[20)] as they are considered to be experienced designers. In order to review the framing, the supervisors have carefully followed the students during the semester and given them a deep understanding of the product concepts and underpinning product framing. All the engineering designers that participate in the investigation are professionals with a minimum of three years of experience. They represent different areas of business and have different professional backgrounds within engineering design mostly within mechanical engineering.

6.1.3 The Dilemmas

The dilemmas have been constructed by the researchers[21)] based on input from the students, insights into the projects, and dilemmas generally known (by experience) from practice. Each case has six dilemmas. In three of the dilemmas, the suggestion is considered in alignment with (inside) the product framing and in other three of the dilemmas, the suggestion is considered not to be in alignment (outside) with the product framing (evaluated by the supervisors). An answer to a dilemma considered inside the product framing will be regarded as correct if the engineering designers also consider the proposal to be inside the product framing, and vice versa. A correct answer is given the value one (1) and an incorrect answer is given the value zero (0). As there are eight respondents in total, four (4) is the maximum point, and zero (0) is the lowest number of points a dilemma can obtain in each situation (A and B).

Given the findings in the first descriptive study, the focus in this descriptive study is on sub-frames containing emotional, symbolic, social and cultural aspects. In order to emphasize to the engineering designers that these intangible aspects do not affect, e.g. the functionality, cost, or performance (see the chapter 6.2 – the dilemmas related to each case), as this could affect their reasoning when answering the dilemmas, this fact is stressed in the background information related to most of the dilemmas. Moreover, it is stressed that the dilemmas should be regarded as independent of each other, and the information provided in the background information related to the dilemmas should be regarded as valid.

6.2 Case Description, Product Framing and Questions

In the following, each of the six student projects is presented to provide insight into the empirical material behind this study. The projects are presented by describing the situation and the main problem of the project, the proposed solution (product concept), and the related product framing. The questions (dilemmas) posed to the engineering designers after the project presentations (and product framing) are also presented for each of the projects. Each of the dilemmas are marked whether they are considered to be inside, or outside the product framing.

6.2.1 Case 1 - ZOO

6.2.1.1 Case 1, ZOO - Problem and Solution (Overview)

This case is about the zookeepers who watch the pygmy hippopotamus. The zookeepers feel that they spend too much time cleaning the facilities (mainly removing algae from the concrete floor) compared to the time they spent with the animals trying and stimulate them. Today, the floor is cleaned using a pressure washer which is very time-consuming (1m^2 takes 30 min.). Moreover, it erodes the surface of the floor over time, making it increasingly harder to clean (a rough surface makes it easier for the algae to grow). Based on experiments, the problem is solved by using steam instead of high pressured water. Tests conducted by the students indicate that the method is more effective (faster and the floor remains free of algae for longer time) and more gentle on the floor. The product developed can be seen below. As the steam leaves no immediate visual imprint on the floor (as with a pressure washer), a position system has been built into the product allowing the zookeepers to keep track of where he/she already has cleaned.

Figure 6.1 The three pictures above respectively show: (1) the entire product, (2) the interface (handle and screen), and (3) the articulated joint (principle known from, e.g., a wet mop) between the product and handle ensure an agile product.

6.2.1.2 Case 1, ZOO – Product Framing

Table 6.0

Perspectives/ sub-frames	Insights/values	Working principles
Business (1) Management/ zookeepers	The cleaning process of the concrete floor consumes too many resources (1 m^2 takes 30 min. to clean – the total area of the facilities is 148 m^2 - making it a 74 hour job). The current method erodes the floor, making the problem of algae worse (a rough surface gives the algae better conditions for growing).	The entire area (148 m^2) can be cleaned in 45 min. using steam instead of high pressure water. This significantly reduces the time used (with approximately 99 %) – freeing a lot of resources. The technology is also more gentle on the floor (keeping it "smooth"), reducing the algae problem over time.
Human (2) Zookeepers	The cleaning process of the concrete floor creates an imbalance between the time used on cleaning and the time spent with the animals (the animals are outside, away from the zookeepers, during the cleaning process). Moreover, the current solution gives the zookeepers a feeling that this battle they can never win, because once they have finished cleaning the floor, they can start all over again.	The significantly reduced time used on cleaning allows for a much better balance between the time used on cleaning and the time spend with the animals. The screen on the handle allows the zookeepers to monitor the animals while cleaning (the screen shows the outside facilities where the animals are). Moreover, it allows the zookeepers to (mental and physical) win the battle against the algae.
(3) Zookeepers	The zookeepers want to be in control of the situation as part of ensuring the well-being of the animals (endangered species), e.g., ensuring that there no waste is lying around on the floor in the facilities, as eating waste could potentially kill the animals).	The cleaning process is manual operated by the zookeepers allowing them to inspect the process and area.

(4) Zookeepers	The zookeepers want to be in control of the cleaning process while operating the product. Moreover, they want a reliable product that performs well and works when needed.	The product is operated by pressing a bar beneath the handle upwards. The principle is known from other similar products (e.g., a lawnmower) familiar to the zookeepers. The recognizable principle and the "bulky" bar/handle give the zookeeper an immediate sense of control. Moreover, the overall robust look (bumper, oversized wheels, and protective shells) supports impression that this is a reliable product.
(5) Zookeepers	The zookeepers are forced into a physically stressful position when they use the current solution (a pressure washer) due to the non-ergonomic positions (angle of neck and arm held up high) they are forced to use while using the current solution. Moreover, the product is noisy and the zookeepers are forced wearing earmuffs.	The product's wheels sit on the floor and the (limited) size, weight, and articulated joint (principle known from, e.g., a wet mop) between the product and the handle ensure an agile product.
(6) Context	The environment is dirty, warm and moist. The surface of the floor is bumpy and rough, and the layout of the floor is organic in shape and full of small "caves", where the product must be able to go into.	The product is covered, protected (has a bumper), and has large (oversized) wheels (at the back). The product is agile and easy to maneuver ensured by the pivotally front wheel and articulated joint between the product and handle.
Technology (7) Tracking	The steam technology does not give an immediate result as with a pressure washer. It is therefore not possible to track of where they already have cleaned.	A tracking system tells the zookeepers where they have already cleaned.

6.2.1.3 Case 1, ZOO - Dilemmas

Table 6.1

Question 1: (Outside)	*Background:* One of the engineering designers suggested automating the product (like it is known from vacuum cleaners) as research has shown that it is technically and economically possible to implement the technology needed in the product. *Question:* Do you support adding this feature?
Question 2: (Inside)	*Background:* The main shells that conceal and protect the product (see figure 6.1 - product picture 1) are currently produced in plastic. Research has shown that the material of the shells could be changed to deep drawing (metal) to reduce the cost of the shells. Changing the shells to metal will not significantly change the functionality (robustness to the environment, weight, etc.) of the shells. *Question:* Do you support changing the shells to metal?

Question 3: (Outside)	*Background:* One of the engineering designers suggests changing the bar beneath the handle (see figure 6.1 - product picture 2) into a button, because research has showed that it would reduce the cost. The button could be placed on the frame around the screen. Moreover, the current solution with the bar needs to be activated (pressed up) all the time. The engineering designer suggests changing the functionality, so that the steam is activated when the button is activated (released) and stopped again when the button is deactivated. *Question:* Do you support this suggestion?
Question 4: (Inside)	*Background:* One of the engineering designers found the current articulated joint (see figure 6.1 - product picture 3) between the product and handle to be too weak and wants to adjust it by oversizing it (same working principles). He is afraid that the joint will prove weak over time. *Question:* Do you support this change?
Question 5: (Outside)	*Background:* One of the engineering designers suggests that the screen on the handle (showing: (1) the animals while the product is operated, and (2) which areas have been covered) is removed to reduce the cost. *Question:* Do you support this change?
Question 6: (Inside)	*Background:* One of the engineering designers suggests making it possible to adjust the height of the handle. Research has shown that this can be done without significantly changing the price or robustness of the handle/product. *Question:* Do you support this change?

6.2.2 Case 2 – Rust Protection

6.2.2.1 Case 2, Rust Protection - Problem and Solution (Overview)

This case focuses on the process of rust protection of cars. The process of rust protection is divided into seven steps. Through a study of observation and interviews, step 5 has been identified as particularly interesting, as this step is the least attractive position among the users because of the tough conditions (feeling hot and dirty and operating heavy equipment in a toxic environment). This is in contrast to the importance of this step. Step 5 is where the fluid that will protect the car against rust is sprayed up on the car, and, consequently, this is the most important step in the process. There are some clear problems with the usability of the current system, besides the unattractive work conditions. The users complain that the hose supplying the fluid is difficult to maneuver, as it gets in the way, and they have to hold a flashlight in one hand while spraying with the other. The suggested solution consists of a hose holder with rewind (similar to a cord rewind in a vacuum cleaner), a mask, and two gloves, one with the syringe and one with a flashlight. The product system can be seen below.

Figure 6.2 The four pictures above show (from the left): (1) the entire product system, (2) the hose holder, (3) the glove with the syringe, and the glove with the flashlight.

6.2.2.2 Case 2, Rust protection - Product Framing

Table 6.2

Perspectives/ sub-frames	Insights/values	Working principles
Business (1) Management/ users	The unattractive (physical) work environment makes it difficult to attract users and, moreover, to maintain them, which potentially affects the quality of the work negatively.	The improved usability of the equipment and the visual expression of the product signals that it is something important - like the equipment worn by special forces soldiers – makes the work more attractive (both physically and emotionally) to the users.
Human (2) Users	The users find the work (step 5) unattractive because of to the rough physical work conditions (warm, dirty and toxic). Moreover, the ill-suited equipment makes the situation unnecessarily hard. The users do not feel empowered.	The improved usability – the equipment is attached to the body and becomes 'a part of the users – e.g., the 'gloves' are fasten to the arms with a buckle (described as a buckle on a pair of roller skaters) keeping them tight. The visual expression of the product gives a sense of something important and professional, like the equipment worn by special forces soldiers, which makes the work more attractive and empowers the users.
(3) Users	Today, the hose is rolled out and lies on the floor before the work starts. This means that it gets in the way and that the user needs to keep an eye on the hose in order to not fall. This draws attention away from the work and slows down the process.	The hose holder is attached to the belt of the user and it has a built-in rewind keeping the hose at the right length at all times (see product picture 1), so that it does not get in the way of the user. The solution principle ensures a better mobility for the user.

(4) Users	The light fixtures mounted in the work area easily get dirty, which reduces their effect. The users must therefore carry a flash light in the one hand and the syringe in the other keeping both hands occupied.	A flashlight is attached to the arm (see product picture 1 and 4) which still allows the user to use the hand. Moreover, the mask has a built in Omni light.
(5) Context	The environment is dirty and toxic (they use oil products during the process). The equipment easily looks dirty and worn down.	The color of the product is dark (black), allowing the product to become dirty without looking dirty. The materials are selected to withstand the toxic environment.
(6) Hose holder	The hose is long and heavy.	In order to avoid the hose lying on the floor and getting in the way, the distance between the hose holder and the user needs to be small. If the distance is too great, the force that keeps the hose off the floor (at the right length) will be too great for the user to withstand. Therefore, the hose holder needs to be mobile to reduce the length between the hose holder and the user. Moreover, the user needs to trust that the hose holder can withstand the pull and keep the hose at the right length.

6.2.2.3 Case 2, Rust Protection - Questions

Table 6.3

Question 1: *(Outside)*	*Background:* One of the engineering designers suggests removing the hose rewind (making it manual as today) to reduce the cost of the product. *Question:* Do you support this change?
Question 2: *(Inside)*	*Background:* Currently, the shape of the different parts is highlighted with a thin red line. Marketing suggests changing the color of the line to orange or yellow. *Question:* Do you support this change?
Question 3: *(Outside)*	*Background:* One of the engineering designers suggests changing the way the syringe is fastened to the arm as the current solution with a glove and buckles is too expensive. He suggests replacing the buckles with two straps of Velcro. *Question:* Do you support this suggestion?

Question 4: *(Inside)*	*Background:* One of the engineering designers suggests a <u>slight</u> reduction in the dimensions of the 'legs' of the hose holder as it would make it possible to use standard dimensions, which would reduce the cost significantly. *Question:* Do you support this suggestion?
Questions 5: *(Outside)*	*Background:* One of the engineering designers suggests changing the form of the 'legs' of the hose holder from a 'Z-form' (angled) to a 'L' shape (straight up and down). It is a condition, that the functionality (stability) of the hose holder is maintained with the new suggestion. *Question:* Do you support this suggestion?
Question 6: *(Inside)*	*Background:* The shells of the hose holder (see figure 6.2 – product picture 2) are currently produced in metal. Research has shown that the material of the shells could be changed to plastic (vacuum forming) without significantly changing the functionality (including the ability to withstand the toxic environment) of the shells. It would however reduce the cost of the shells. *Question:* Do you support this change?

6.2.3 Case 3 – Breast Pump

6.2.3.1 Case 3, Breast Pump - Problem and Solution (Overview)

This case is about new mothers who use breast pumps. The focus is on the mothers who use a breast pump either because they produce too much milk or because they produce too little milk and need simulation to produce more. The current solutions are stigmatizing (noisy and industrial looking), time consuming, expose the breast, fixate the mother, and keep her away from her baby. Especially the cleaning process takes time (for the current, automated breast pumps) which means time away from the baby. The solution suggested uses a different suction system (water instead of air) which is less noisy. It also mimics the suction of a baby which is better for stimulating the breasts, if the mother is producing too little milk. Moreover, the suction system is a 'closed' system and the time used cleaning the system is therefore considerably reduced compared to existing, automated breast pumps that use air. The suggested solution allows the mother to conceal her breast while breast feeding or pumping milk out. Moreover, the pillow allows the mother to keep the baby close while pumping milk out. The product developed can be seen below.

Figure 6.3 The two pictures above show (1) the entire system (pillow, cups (placed on the breast) and breast pump) and (2) the system in context.

6.2.3.2 Case 3, Breast Pump - Product Framing

Table 6.4

Perspectives/ sub-frames	Insights/values	Working principles
Human (1) Mother	The current breast pumps are functionally oriented and industrial looking which make the mother feel like a cow when she uses the breast pump.	The suggested solution imitates the natural breast-feeding situation between a mother and a baby, as the pillow allows the baby to be close and a part of the situation while the pump is being used. The familiar look of the product allows it to blend in with the rest of artefacts in a (Scandinavian) home.
(2) Mother	With the existing products, the mother is fixed to one position, as she cannot lie down or move around freely (e.g., go from the living room to the nursery, if the baby cries). The mother feels vulnerable and helpless.	The pump and pillow are meant to be portable, e.g., the pump has a shoulder strap. And the pillow makes it possible for the mother to rest in various positions while using the breast pump. Overall, the solution allows the mother to feel in control of the situation.
(3) Mother/people	With the current systems, the breasts are more or less exposed to the surroundings while the pump is used, which can be intimidating to both the mother and to others. Moreover, the milk what runs in the tubes from the breast to the milk bottles is visible to others which also can be intimidating to both the mother and others, as breast milk is to most people something intimate and personal.	The system allows the breast to be concealed, as the cup attached to the breast is placed inside the bra, and the tubes are frosted, so the milk is not visible in the tubes as it runs from the cups to the milk bottle.
(4) Context	With the current systems, the mothers have a hard time keeping the babies close while using the breast pump, as the product (cups, tubes, and pump) is in the way. It can be stressful for the mother to be "separated' from her baby, especially during the first days of motherhood.	The design of the cups/tubes allows them to be placed underneath the clothes (e.g., a shirt) and ensures that they do not get in the way. The pillow offers a possibility to have the baby close while using the pump.

Technology (5) Pump system	The current breast pumps (except one) all use air to create suction in an 'open' system (the air and milk runs in the same tube). This makes it necessary to clean the entire system, which takes a long time (10-20 min.).	The solution suggested uses water in a closed system to create the suction. This significantly reduces the complexity for the users. And as it is a concealed system, the time needed for cleaning it is significantly reduced.
(6) Pump system	The current systems are noisy which makes the mothers feel like (industrial) milking cows.	The water based suction system used is considerably less noisy, which limits the problem.

6.2.3.3 Case 3, Breast Pump - Questions

Table 6.5

Question 1: *(Outside)*	*Background:* The fabric covering the breast pump is vulnerable to stains and marks. The fabric is suggested replaced with plastic (as the rest of the housing of the pump) to make it more resistant to stains and marks. Moreover, it reduces the cost of the product. *Question:* Do you support this suggestion?
Question 2: *(Inside)*	*Background:* Currently the color of the fabric is light gray. One of the engineering designers suggests making it white (to match the rest of the product). *Question:* Do you support this suggestion?
Question 3: *(Outside)*	*Background:* Research has shown that a clear tube is significantly less expensive than a frosted tube. It is therefore suggested to change the tube that runs from the cup to the breast pump in order to reduce the cost of the product. *Question:* Do you support this suggestion?
Question 4: *(Inside)*	*Background:* One of the engineering designers suggests adding a rewind for the tubes to the breast pump (as known from the wires of vacuum cleaners). *Question:* Do you support this change?
Question 5: *(Outside)*	*Background:* Research has shown that it is possible to build the technology needed to cool the milk into the breast pump without significantly changing the size or cost prize of the product. *Question:* Do you support this suggestion?
Question 6: *(Inside)*	*Background:* Currently the color of the fabric only comes in one color (light gray). Marketing would like a series of pastel colors. *Question:* Do you support this change?

6.2.4 Case 4 – Bath

6.2.4.1 Case 4, Bath - Problem and Solution

This case is about people with Parkinson's disease who experience many challenges in everyday life. One of the challenges people with Parkinson's meet is to take a shower, which they often need more often than usual as they generally sweat a lot. The main challenges are: reaching all areas of the body which can be challenging due to muscle rigidity, low fine motor control, keeping the balance, and squeezing soap out of a soap dispenser. The solution suggested is a specialized rotating shower head and a fixture mounted on the wall. The product developed can be seen below. The showerhead is angled to ease the task of reaching all areas of the body and different type of sponges (e.g., one for the body and another for the hair) can be attached to the shower head. The fixture on the wall holds the shampoo and has an integrated and hidden handle. The showerhead and fixture can be mounted as an ordinary showerhead/fixture, and can be used by other people (without Parkinson's) as well.

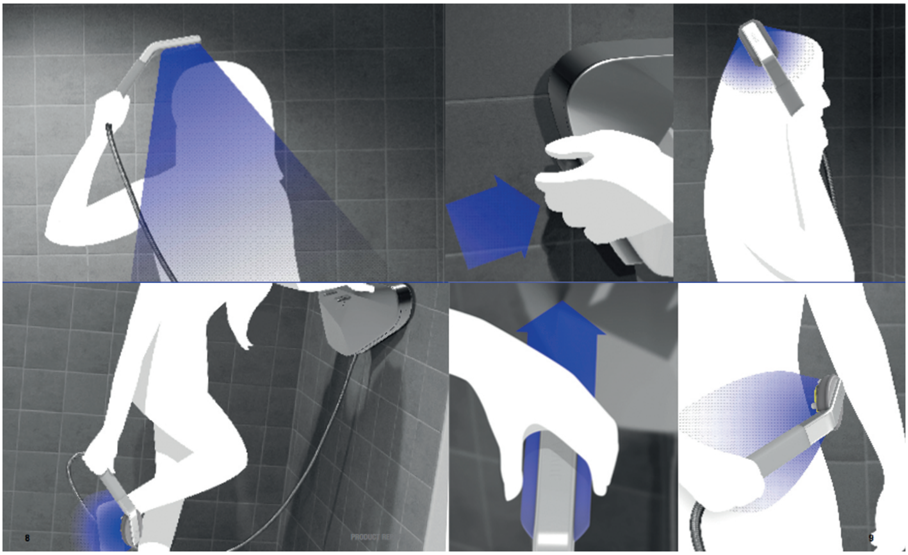

Figure 6.4 The pictures above show the product in use.

6.2.4.2 Case 4, Bath - Product Framing

Table 6.6

Perspectives/ sub-frames	Insights/values	Working principles
Business (1) The municipality	People with Parkinson's need assistance, e.g., when taking a bath, which is costly.	The product makes it possible for people with PD to take a shower on their own, which reduces the resources needed for caretaking.
Human (2) People with PD[1)] and helpers	Needing assistance when taking a bath is intimidating to both the people with PD and the caretakers (professionals or relatives).	The product makes it possible for people with PD to take a shower on their own, which empowers them. Moreover, it ensures a more balanced relationship between the people with PD and the caregivers – especially when the caregivers are relatives.
(3) People with PD	The existing products are stigmatizing, as they look like products used in hospitals or nursing homes.	The product has a modern and high end look which makes visually blend in with ordinary (high-end) showerheads. Moreover, the showerhead can be used by everybody – also people without PD.
(4) People with PD	Due to muscle rigidity people with PD have problems keeping the balance and raising their arms, e.g., reaching the back of the head.	A handle is integrated into the fixture - not immediately visible, making it less stigmatizing. The showerhead is angled (see product picture 6.4) - making is easier to reach all areas of the body, e.g., the back of the head or the back. This is also an advantage to people without PD.
(5) People with PD	People with PD have problems with low fine motor control and coordinating movements, e.g., making it difficult to distribute soap onto their bodies.	A rotating sponge is attached to the showerhead. Different sponges can be attached depending on the task, e.g., washing hair or washing the body.
(6) People with PD	The problems with the balance, low fine motor control, and coordinating movements make it difficult to pick up a soap bottle and to get the soap out it.	The soap bottles are places in the fixtures and soap can be released directly into the water by pressing a button when needed.
Technology (7) Rotating mechanism	Due to the wet conditions in a shower, the electrical power should be low voltage and preferably integrated into the product.	The water is used to propel a small turbine inside the showerhead supplying the power needed to drive the rotating mechanism (known principle from other showerheads with light integrated).

Notes:
1) Parkinson's disease (PD).

6.2.4.3 Case 4, Bath - Questions

Table 6.7

Question 1: *(Outside)*	*Background:* In order to lower the cost of the product, one of the engineering designers suggests making the fixture smaller. Consequently, the integrated handle will be mounted separately on the wall next to the fixture. *Question:* Do you support this suggestion?
Question 2: *(Inside)*	*Background:* In order to allow for more room for the rotating mechanics inside the showerhead, one of the engineering designers suggests making the showerhead larger (5% in each dimension). *Question:* Do you support this suggestion?
Question 3: *(Outside)*	*Background:* Research has showed that the integration the soap significantly increases the cost of the product. It is, therefore, suggested to remove the feature from the product. *Question:* Do you support this suggestion?
Question 4: *(Inside)*	*Background:* In order to lower the cost of the product, one of the engineering designers suggests making the showerhead in plastic (with a metal finish, e.g. chrome) instead of metal. *Question:* Do you support this suggestion?
Question 5: *(Outside)*	*Background:* Currently the fixture and showerhead has a metal look (surface). One of the engineering designers suggests making them both white. *Question:* Do you support this suggestion
***Question 6**:* *(Inside)*	*Background:* Currently the different sponges have the same color. One of the engineering designers suggests making the sponges in different colors so it is easier to identify them (so that there are different colored sponges for, e.g., for washing the body or the hair). *Question:* Do you support the suggestion?

6.2.5 Case 5 – Flight Case

6.2.5.1 Case 5, Flight Case - Problem and Solution

This case focuses on the logistics of taking down a light show after a concert. It often gets chaotic when the stage and light equipment are taken down after a show. Equipment is often lost in the undertaking, which is expensive, or it is not packed into the right flight cases[22)], which is time consuming, as it needs to be repacked later. Today, the registration of the contents of the flight cases is done in writing on plastic labels and on paper check lists. However, there is no guarantee that the equipment is packed or gets into the right flight cases. The solution suggested is a system that consists of a scanner (using RFID tags mounted on the various parts, e.g., light fixtures, cable, or microphones) and an 'E-tour label' (see fig. 6.5) which is mounted on each flight cases. An app provides the light technician with various possibilities to: get an overview, get control, and organize the equipment before and after the show. The system developed can be seen below. The scanner in each flight case automatically registers if there are, e.g., any light fixtures in the flight case, and if it is the correct ones (not just the type but also the specific light fixture). The light technician can get an immediately overview of the content of a flight case by using the app. By using the app, the light technician can also make the 'E-tour labels' mounted on each of the flight boxes light up in different colors, e.g., to group flight cases or ease the communication with the stage-hands[23)].

Figure 6.5 The picture shows: the app, E-tour label, and the E-tour label mounted on a series of flight cases.

6.2.5.2 Case 5, Flight Case - Product Framing

Table 6.8

Perspectives/ sub-frames	Insights/values	Working principles
Business (1) Event companies	There is an increasing demand for better quality (sound, light and stage effects) and more expensive equipment. It is costly for the event companies when any of this equipment is lost.	The system allows the event technician to keep a detailed overview of where the different equipment is, when it is taking down from the stage.
(2) Event companies	Any mistakes, e.g., leaving equipment on a site, bringing the wrong equipment to a site, or needing equipment at another site can be very costly for the event companies.	The system ensures the right equipment is packed, saving time and ensuring the quality of the job.
Human (3) Event technician	There is a lot of pressure on the light technician, as any mistakes made in preparation of and during the show (e.g., a light fixture that does not work) might be noticed by everyone – including the performer.	The system ensures the event technician is in control during the entire process (before and after the show) – making him feel confident that everything is perfect. The details of the location of the different equipment give the event technician the same feeling of being in control when taking down the stage as when executing a show.
(4) Event technician	The complexity and difficulties in communicating the different tasks to the stage-hands who set up or take down the stage make the event technician feel insecure and not on top of the situation. Even from a short distance, the flight cases all look the same which makes it difficult to identify any particular flight case.	The different colors of the 'E-tour label' help ease the communication between the event technician and the stage-hands, as it easy to identify a specific flight case or a group of flight cases.

6.2.5.3 Case 5, Flight Case - Questions

Table 6.9

Question 1: *(Outside)*	*Background:* Currently the flight cases for cables, microphones and etc. have long range scanners installed. The long-range scanner is, however, significantly more expensive than the short-range scanners that will be used in the flight cases with light fixtures. One of the engineering designers suggests changing the long-range scanner to a short range scanner to save cost. This will however mean that the stage-hands have to move the cable, microphones and etc. close to the scanner (mounted in the lid) before dropping it into the flight case. *Question:* Do you support the suggestion?
Question 2: *(Inside)*	*Background:* The product manager suggests changing the concept to allow for the stage-hands to run the app on their phones as well, so that they become being able to scan equipment to see where it should go. Their accessibilities to the app should, however, be restricted. *Question:* Do you support this suggestion?
Question 3: *(Outside)*	*Background:* One of the engineering designers suggests removing the display of the E-tour label to save cost *Question:* Do you support this suggestion?
Question 4: *(Inside)*	*Background:* One of the engineering designers suggests adding a feature to the app so which will make it possible to see if any of the flight cases have been tampered with before setting up the stage. *Question:* *Do you support adding this feature to the system?*
Question 5: *(Outside)*	*Background:* In order to save cost, one of the other engineering designers suggests having only one LED (visible when looking at the front of E-tour label) instead of LEDs on all four sides of the E-tour label. *Question:* Do you support this change?
Question 6: *(Inside)*	*Background:* The current display installed in the E-tour label has no back light, which makes it difficult to see the information on the screen in the dark. One of the engineering designers suggests changing the display to a different type with backlight. The change does not change the power consumption (batteries) or cost price significantly. *Question:* Do you support this suggestion?

6.2.6 Case 6 – Light Fixture

6.2.6.1 Case 6, Light Fixture - Problem and Solution

This case is about the light settings of a classroom in an elementary school which will help to ensure a good and stimulating working environment. The current light fixtures (fluorescent) have limited options for adjustments, e.g., the focus of the light, the intensity of the light, or the color of the light. However, all these parameters are today known to affect, e.g., our mood, level of energy, and ability to focus. The current fluorescent light fixture is also known to have a poor power consumption compared to LED fixtures. The solution suggested is a system that consists of a number of LED light fixtures that feature down-light and up-light and an app for controlling the fixtures. Besides making it possible to control the individual fixture (e.g. the color, intensity, and focus), the app can also be used to create various scenarios that support the focus and the means of the lecturing. Pictures of the fixture can be seen below.

Figure 6.6 The picture shows the light fixture and a tablet with the interface (app).

6.2.6.2 Case 6, Light Fixture - Product Framing

Table 6.10

Perspectives/ sub-frames	Insights/values	Workings principle
Business (1) Management	The current light fixtures (fluorescent) have high running cost (high power consumption and frequent replacement of fluorescent tubes).	The suggested solution has an expected lifetime around 20.000 h (≈ 20 years) for the power supply and above 50.000 h (≈50 years) for the LEDs. And LED fixtures have low power consumption.
(2) Management	Management is obligated to ensure that current regulations are followed, including the level of light in the classroom. However, the low flexibility of the current light fixtures makes it difficult to fulfill these obligations completely.	The suggested solution makes it possible to adjust not just the intensity, but also the color and focus of the light, e.g., dimming the light in a part of the class room to avoid overexposure.
Human (3) Teachers	The current light fixtures "dictate" the (light environment) settings, as there is little flexibility. This is contrary to how important the lighting conditions are to the work environment and to the effort expected to prepare for a lecture.	The suggested solution allows the teachers to adjust the light in order to support the means of teaching, by adjusting the intensity, focus and color of the light. Moreover, scenarios can be created which will ease the control during a lecture.
(4) Kids	The pupils are left with few options to create their own work environment, given them a feeling of being 'powerless'.	Within limitations (set by the teacher), the pupils are able to adjust the light individually to ensure the best work conditions for them. This also gives them a sense of being valued and empowered.

6.2.6.3 Case 6, Light Fixture - Questions

Table 6.11

Question 1: *(Outside)*	*Background:* The fixture is slightly bent to better reach a larger area of the classroom. The process of bending the housing of the fixtures is expensive. One of the engineering designers suggests just making the housing straight. *Question:* *Do you support the suggestion?*
Question 2: *(Inside)*	*Background:* Currently the fixture only comes in one color (aluminum). Marketing suggests also making a white version (anodized). *Question:* Do you support this suggestion?
Question 3: *(Outside)*	*Background:* The LED used in the fixture is expensive. However, white LEDs are significantly less expensive. It is therefore suggested to use white LEDs to save cost. Consequently, the color of the light cannot be adjusted (the intensity, temperature, and focus can still be adjusted). *Question:* Do you support this suggestion?
Question 4: *(Inside)*	*Background:* One of the engineering designers suggests using four wires instead of just two to make the wires slightly thinner). *Question:* Do you support this feature?
Question 5: *(Outside)*	*Background:* Management suggests reducing the flexibility of the system and to only make it possible to run pre-designed scenarios. *Question:* Do you support this change?
Question 6: *(Inside)*	*Background* The product manager suggests that the teachers could have their own profile in the system, e.g., allowing them to have a personal setting in the interface. *Question:* Do you support this change?

6.3 Results

Briefly recapturing the research design, the investigation consisted of two situations: situation A (onwards named 'A'), where the engineering designers are presented only with the product concept before answering the questions (dilemmas), and situation B (onwards named 'B'), where the engineering designers are presented with both the product concept and the underpinning product framing before answering the questions (dilemmas). Each case has six dilemmas, three of which are considered 'inside' the product framing and three of which are considered 'outside' the product framing. An answer to a dilemma inside the product framing will accordingly be regarded as correct if the engineering designers also consider the proposal to be inside the product framing, and vice versa. A correct answer is given the value one (1) and an incorrect answer is given the value zero (0).

Table 6.12 The results of the cases coded with one (1) for a correct answer and zero (0) for an incorrect answer.

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
Case 1											
Question 1 (outside)	0	0	0	0	0	1			0		0
Question 2 (inside)	0	1	1	1	1	1			1		1
Question 3 (outside)	1	1	1	1	1	1			1		1
Question 4 (inside)	1	1	1	1	1	1			1		1
Question 5 (outside)	0	1	0	1	1	0			1		0
Question 6 (inside)	1	1	1	1	1	1			1		1
Case 2											
Question 1 (outside)	0	1	1	1	1	1	0	1			
Question 2 (inside)	0	1	1	1	1	1	0	1			
Question 3 (outside)	0	0	0	0	1	0	0	0			
Question 4 (inside)	1	1	1	0	1	0	1	1			
Question 5 (outside)	0	1	1	1	1	0	0	1			
Question 6 (inside)	0	1	1	1	1	1	1	1			
Case 3											
Question 1 (outside)	0	1	1	1	1	1	0	1			
Question 2 (inside)	0	0	0	1	0	1	0	1			
Question 3 (outside)	1	1	0	1	1	1	0	1			
Question 4 (inside)	1	1	1	1	1	1	1	1			
Question 5 (outside)	0	0	0	1	0	1	1	0			
Question 6 (inside)	1	1	1	1	1	1	1	1			
Case 4											
Question 1 (outside)	0	1	1	0			1	1	0	1	
Question 2 (inside)	1	1	1	1			1	1	1	1	
Question 3 (outside)	1	1	1	1			1	1	1	1	
Question 4 (inside)	1	1	1	1			1	1	1	1	
Question 5 (outside)	0	0	1	0			1	1	1	1	
Question 6 (inside)	1	1	1	1			1	1	1	1	
Case 5											
Question 1 (outside)	0	1	1	1			0	1	0	1	
Question 2 (inside)	1	1	1	0			0	1	1	1	
Question 3 (outside)	0	1	1	1			0	1	0	1	
Question 4 (inside)	1	1	1	0			1	1	1	1	
Question 5 (outside)	0	0	0	1			0	1	0	0	
Question 6 (inside)	1	1	1	1			1	1	1	1	
Case 6											
Question 1 (outside)	1	0	0	0	0	1			1	0	
Question 2 (inside)	1	1	1	1	1	1			1	1	
Question 3 (outside)	1	1	1	0	1	1			1	0	
Question 4 (inside)	1	0	1	1	0	1			1	1	
Question 5 (outside)	1	1	1	1	1	1			1	1	
Question 6 (inside)	1	1	0	0	1	1			1	1	

Notes:
1) Answers to situation A (where the engineering designers are presented only with the product concept) are 'white', and answers to situation B (where the engineering designers are presented with both the product concept and the underpinning product framing) are 'gray'.

6.4 Analysis and Discussion

The study proceeds by analyzing the results by comparing the two situations (A and B).

When analyzing the answers to the dilemmas across the cases it becomes clear that explicitly emphasizing the product framing as part of the handover seems to improve the engineering designer's ability to understand the consequences in relation to the product concept (see figure 6.7 below). In other words, their ability to understand when the dilemmas are aligned or not aligned with the product framing is improved. When the product framing is explicitly emphasized, the percentage of correct answers jumps from 60% to 88%, a raise of 28 percentage points. However, the results also reveal a (relative) high number of correct answers in situation A, where the engineering designers are not explicitly presented with the product framing.

	A	B
Normative	**87**	**126**
In percent	**60%**	**88%**

Figure 6.7 The overall number of correct answers to the dilemmas across the six cases in situation A (without explicitly emphasizing the product framing) and situation B (explicitly emphasizing the product framing).

A significant difference emerges (see figure 6.8) when the result is divided into the dilemmas considered not aligned with the product framing (outside), and the dilemmas considered aligned with the product framing (inside). The dilemmas considered not aligned with the product framing seem to be more (positively) affected by the communication of the product framing than the dilemmas considered aligned with the product framing.

	Dilemmas not aligned with the product framing		Dilemmas aligned with the product framing	
	A	**B**	**A**	**B**
Normative	**29**	**58**	**58**	**68**
In percent	**40%**	**81%**	**81%**	**94%**

Figure 6.8 The number of correct answers to the dilemmas across the six cases divided into 'aligned' or 'not aligned' with the product framing, and further sub-divided into situation A and B.

The answers to the dilemmas considered aligned with the product framing (right side of figure 6.8) have a relatively high percentage of correct answers in both situation A and B, respectively 81% and 94%. However the percentage of correct answers is still improved with 14 percentage points when the product framing is explicitly emphasized.

When analyzing the answers to the dilemmas considered not aligned with the product framing (left side of figure 6.8), the numbers reveal quite different results in the two situations (A and B), 40% and 81%, respectively. Accordingly, the number of correct answers is improved with 41 percentage points when explicitly emphasizing the product framing. The results, however, also reveal a lower number of correct answers in both situation A and situation B, as compared to the dilemmas aligned with the product framing.

The results also reveals a great variance across the cases, see figure 6.9.

	Case 1		**Case 2**		**Case 3**		**Case 4**		**Case 5**		**Case 6**	
	A	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Normative	**17**	**19**	**10**	**21**	**13**	**21**	**19**	**23**	**13**	**20**	**15**	**22**
In percent	**71%**	**79%**	**42%**	**88%**	**54%**	**88%**	**79%**	**96%**	**54%**	**83%**	**63%**	**92%**
Difference in percentage point	**Δ 8**		**Δ 46**		**Δ 33**		**Δ 17**		**Δ 29**		**Δ 29**	

Figure 6.9 The results of the individual cases.

For instance, in case 1, the support seems to have very little effect, where as in case 2 the support significantly affects the result positively.

Of the 36 dilemmas in total (see figure 6.6), no improvement could be registered in 15 of the questions (the number of correct answers in both situations were the same (3 or 4 correct answers out of 4 possible correct answers). In addition, in 6 dilemmas, only a limited affect (one more correct answer in situation B compared to situation A) was registered. In one dilemma (case 5 – question 4) a negative effect was registered.

6.4.1.1 The Underlying Reasoning

When looking on the underlying reasoning behind the answers given to the dilemmas by the engineering designers, several differences can be found in the answers given by the engineering designers.

In general, the engineering designers seem to adopt and include more emotional, symbolic, social, and cultural aspects in their argumentation when they have been explicitly presented with the product framing. For instance, in case 3 which is concerned with the development of a breast pump, and question 2, where the color of the fabric on the breast pump is suggested changed to white, the engineering designers presented with product framing, emphasizes the association to 'hospital equipment' that could arise if the color of the fabric was changed to white. For instance, respondent R6: "…*the product becomes too clinical looking*…" (Case 3, R6, 6min and 45 sec.). The engineering designers that were not presented to the product framing accepted the white fabric and still regarding the breast pump as a 'home-product'. Their concern about changing the color of the fabric was more about stains and marks being more visual. They did not consider that changing the color of the fabric could make the product look like a piece of 'hospital equipment' – respondent R5: *"…white easily looks dirty, so that is not a good idea…"* (Case 3, R5, 1min and 18 sec.). Another example can be found in case 4 concerned with the development of a shower fixture for people with Parkinson's, and question 1, suggesting making the fixture mounted on the wall smaller and mounting the handle separately. Again, the engineering designers presented with product framing emphasize the potential association with 'hospital equipment' that can arise when mounting a separate handle

on the wall, whereas the engineering designers not presented with the product framing find it 'natural' to mount the handle separately, as it is a known principle from practice (for instance mounting a separate handle on the wall in a bath for elderly people) – respondent R4.
In other words, the engineering designers presented with the product framing seem to adopt the contextually determined emotional, symbolic, and social aspects embedded in the product framing, whereas the engineering designers who are not presented with the product framing tend to maintain a more rational, functional, and context depended reasoning in regards to the dilemma.

As mentioned in the initial analysis, in 15 of the dilemmas no improvement could be registered the in the number of correct answers given in both situations (A and B). However, when focusing on the underlying reasoning behind the correct answers, a difference that might explain this is revealed. For instance, in case 1 concerned with the cleaning of the floor at the ZOO and question 3, where the 'bar' below the handle is suggested changed to a button, the engineering designers, who were not presented with the product framing, all argue from a rational point of view by focusing on the reduction in safety if the bar is changed to a button (the bar was regarded as more safe). The functionality of the bar is emphasized in their argumentation. However, two of the engineering designers (respondents R4 and R6) who were presented with the product framing also emphasize the 'lost control' which is important to the zoo-keeper, according to the product framing underlying the case. In other words, the engineering designers focus not only on the functional (safety) aspects, they also consider more emotional accepts of the product framing. A similar example can be found in case 3 concerned with the development of a breast pump and question 4 where it is suggested to add an automated rewind for the tubes. The rewind of the tube is generally regarded as a desirable functionality aligned with the product framing by the engineering designers. However, one of the engineering designers (respondent R4) presented with the product framing also emphasize that 'the solution cannot make the same noise as the cord of a vacuum cleaner does', in order to avoid that it becomes an industrial product. Yet, another example can be found in case 4 concerned with the development of a shower fixture for people with Parkinson's disease and question 2, where it is suggested to make the showerhead slightly bigger to get more room for the rotating mechanics inside the showerhead. In general the solution is regarded as a desirable functionality aligned with the product framing. However, one of the engineering designers (respondent R2) presented with the product framing also emphasize that the shower head cannot become too heavy (he fears that the increase in size will significantly affect the weight of the showerhead). In summary, examining the underlying reasoning revealed difference in the understanding of the underpinning logic depending on whether the engineering designers have been presented with the product framing or not. It seems that the engineering designers presented with the product framing seem to adopt more contextual determined emotional, symbolic, and social aspects embedded in the product framing in the reasoning behind the answers.

6.4.1.1 Discussing the Influence of the Research Design

The high number of correct answers, especially within the dilemmas considered inside the product framing, could be explained by the way the dilemmas have been designed and how the engineering designers answered the questions. In general, the dilemmas considered outside the product framing required the engineering designers to reject the proposal, e.g., case 2 (equipment for rust protection) and replacing the buckles with Velcro (question 3). Whereas, the dilemmas considered inside the product framing were considered correct if the engineering designers accepted the proposal, e.g., case 3 (breast pump) and making (on the breast pump) in a series of pastel colors (question 6). As the engineering designers had a tendency to accept, rather than to reject these proposals, the number of correct answers seems to have been positively influenced by the dilemmas that were considered to be inside the product framing, whereas the dilemmas considered outside the product framing seem to have negatively influenced the numbers of correct answers. A comparison between the numbers can be found in figure 6.10.

	A
Dilemmas inside	**81%**
In general	**60%**
Dilemmas outside	**40%**

Figure 6.10 A comparison between the percentages of correct answers of: (1) the dilemmas considered inside the product framing, the dilemmas considered outside the product framing, and the percentage of correct answers given to the dilemmas, all in situation A, where the engineering designers not are explicitly presented with the product framing.

As it can be seen in figure 6.10, the percentage of correct answers to dilemmas considered inside the product framing (81%) is much higher than the general level (60%) and the percentage of correct answers is lower for dilemmas considered outside the product framing (40%). This approach by the engineering designers, who mostly accept the proposals could be explained by their emphasis on all of the three perspectives (human, technology, and business) as discussed in chapter two. In general, the content of the dilemmas is primarily embedded in the human perspective. Consequently, the engineering designers are less concerned with the consequences of these kinds of dilemmas, as they regard the human perspective to be outside their area of responsibility or even competence (see chapter 2). For instance, several of the engineering designers refer to the dilemmas as related to industrial design and not engineering design. However, the research design and the general approach of the engineering designers who answer the questions, strengthen the results. The dilemmas considered outside the product framing are the most interesting as they have potential to erode the intended design, if it is implemented. Therefore, the significant change in the number of correct answers to dilemmas considered outside the product framing implies the importance of emphasizing the underpinning logic in a handover situation.

The high number of correct answers could also be explained by the product framing being communicated and transferred in both situations. Despite the product framing not being explicitly emphasized in situation A, it still underpins the product concept and is embedded in the proposed solution, as a strong product framing is a prerequisite for the projects being chosen. Consequently, the product framing is potentially communicated as part of the 'traditional' handover situation where the product concept is presented. Accordingly, the engineering designer only presented with the product concept will potentially also be able to answer the dilemmas correctly. In the documentation of 'reasoning aloud' done by the engineering designers who were only presented with the product concept, examples can be found where engineering designers use arguments embedded in the product framing. This implies that parts of the product framing are still communicated and transferred, even if it is not emphasized during a handover. This could also explain the variance across the cases, see figure 6.9.

6.5 Conclusion of the Second Descriptive Study

The initially analysis across the cases indicates that explicitly emphasizing the underpinning logic and using the design support seem to improve the communication and transfer of the underpinning product framing. The analysis also indicates that the improvement in the transfer was most significant in the situations where the dilemmas were considered not aligned with the product framing. Moreover, the results indicate that there were also a relatively high number of correct answers in the situations where the engineering designers were not explicitly presented to the product framing. The high number of correct answers can be explained by: (1) the way the dilemmas have been design combined with the way the engineering designers answered the questions and accepted the proposals, (2) the product framing being (partly) communicated and transferred, as it is embedded in the presentation of the product concepts. Moreover, the analysis also revealed that in those situations where the answers in both cases were predominantly correct, indicating no improvement, the 'reasoning aloud' revealed differences in the argumentation. The engineering designers who were presented with the product framing seemed to adopt aspects of the underpinning product framing in their argumentation. This indicates that the product framing has been transferred to the engineering designers and an ability among the engineering designers to understand the consequences in relation to the product concept.

7 Conclusion

The aim of this chapter is to summarize the findings from the analyses to answer the research questions. The findings are connected to the theoretical framework, positioning them within the existing knowledge. The chapter also contains a discussion of the reliability of the study relating to the findings and the implications of the study to the research design. Finally, future research perspectives based on the findings and implications of this study are suggested and discussed. The chapter commences with answering the research questions.

7.1 Answering the Research Questions

The answers to the research questions have already been briefly touched upon in the analyzes of the first and second descriptive study. However, a summary is needed to provide clarity. The research questions have emerged based on the specific research settings that focus on a handover situation between industrial designers and engineering designers in product development projects. The handover have been regarded as both a gap between disciplines and as a processual transition embedded in the product development process. The answers to the research questions should, therefore, be understood in this context. It has to be noted that, the answers to the research questions are both closely linked to the more thorough review of the analysis found in chapter 4 and 6, respectively. The answers given here should, therefore, be regarded as summarized versions of these.

The research questions will be answered individually in the following:

Research Question 1:

> *Which aspects of the underpinning logic of a product concept are challenging for the industrial designer to communicate and transfer to the engineering designer in a product development project in a handover situation?*

Based on the research presented in this study it was found that:

The elements of the underpinning logic of a product concept that are most challenging to communicate and transfer in a handover situation are the elements which relate to the human perspective and go beyond the

functionality and technology of the product, and the elements which contain e.g., emotional, symbolic, and social aspects. When focusing on the elements of the underpinning logic which are challenging for the industrial designer to communicate and transfer to the engineering designer in a handover situation, three situations have been identified.

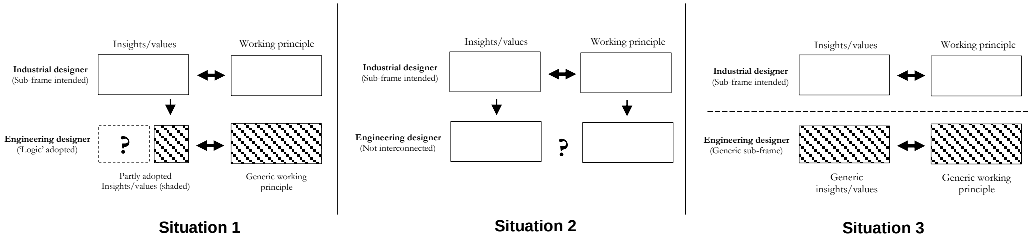

Figure 7.0 The three identified situations where the underpinning logic is most challenging to communicate and transfer in a handover situation.

In the **first situation**, only the rational and functional aspects of the underpinning logic are adopted by the engineering designers in the handover situation. The emotional aspects of the insights are either valued differently or not emphasized by the engineering designers. Regardless of the reason, the engineering designers seem to create their own 'logic' based on the fragmented understanding of the insights/values. The engineering designer forms an alternative underpinning logic less connected to the context by connecting the partly adopted insights and values with working principles predominately driven by (generic) engineering design values, rather than case related values.

In the **second situation**, the insights/values and working principles of the underpinning logic is communicated and transferred, but the connection (frame) between them is not. The engineering designers are, accordingly, left with insights and values about a situation and context which is experienced as detached from the product concept. The engineering designers are also presented with a product concept where the working principles are 'crafted' into the product, but detached from the underpinning logic (values/insight). Consequently, the engineering designer is left with what seems to be fragmented knowledge about insights/values that are detached from the product concept, and working principles that are embodied in the product concept, and without understanding the logic behind the principles/solutions chosen.

In the **third situation**, the entire sub-frame of the underpinning logic is not communicated and/or transferred. Consequently, the engineering designers are left with a lack of understanding of the foundation for the proposed solution (product concept). Instead it seems that the engineering designers create generic sub-frames predominately driven by (generic) engineering design values, e.g., faster, less expensive, stronger, rather than case related values. Consequently, they create their own rather than case related underpinning logic to support the product concept.

To recognize the impact of these findings, they should be connected with the positioning of engineering design and industrial design given in this study. The focus on the contribution of industrial design as primarily concerned with the meaning of the products connected with the underpinning logic provides a different approach to understanding the challenges between industrial designers and engineering designers.

Research Question 2:

> *To which extent does explicitly emphasizing the underpinning logic of a product concept affect the engineering designer's ability to understand whether potential production changes are coherent with the product concept´s underpinning logic?*

Based on the research presented in this study it was found that:

Explicitly emphasizing the underpinning logic seems to improve the engineering designer's ability to understand whether potential production changes are coherent with the product concept´s underpinning logic? Overall the data indicated that explicitly emphasizing the underpinning logic improved the communication and transfer of it. This is particular clear when the engineering designers were faced with dilemmas considered 'outside' the framing of the product concept. When presented with the product framing, the engineering designers gave answers based on reasoning more aligned with the framing underpinning the product concept. This indicates that the engineering designers' ability to decode and operationalize the sub-frames was improved. In summary, the study indicates that explicit emphasizing the underpinning logic improves the engineering designers understanding of the product framing and ability to operationalize it.

7.2 Discussing the Reliability of the Findings

Having answered the research questions, the reliability of the findings will be discussed. Despite the efforts made to ensure the reliability of the study, unintended influence on the research material need to be reviewed and discussed, as they potential weaken the conclusions of the study. The discussion will focus on: (1) the limitations of the findings, (2) the role of the researchers, and (3) the methods and data.

7.2.1 The limitations of the findings

As described in the discussion of the research framework, the philosophical positioning of this study is based on pragmatism. Having taken a philosophical position within pragmatism, the findings in this study can consequently not claim to be 'objective' or 'universal true' in a traditional (positivistic) scientific understanding. Especially the findings of the first descriptive study can be seen as a mainly 'social construction' between the researchers and the respondents. In order to counteract this and to enhance the reliability and generalization of the findings, data was collected from several different projects in different organizational contexts. Being able to identify similar situations across different cases is regarded as a way to enhance the generalizability of the results.

Moreover, embedded in the research design is the aim of taking the understanding gained from the first descriptive study and using it in another context to see if it improves the understanding of the situation. This can also be regarded as a way to enhance the generalizability of the results. However, it can be argued that the empirical material contains limitations as all the cases take place in a Danish context, which may limit the extent to which the conclusions of this study can be generalized.

7.2.2 The Role of the Researchers

The researchers and in particular the author have influenced the research in many ways both intendedly and unintendedly. As noted in the description of the research design (chapter 3), the researchers were involved in the documentation of the product framing in both the first and second descriptive study. This may have influenced the content of the product framing constructed for each of the cases, e.g., which sub-frames, insights/values, or working principles that were identified, and in particularly how they were 'named', which is of great importance in the process of framing (Schön 1983). Moreover, in the first descriptive study, the main analysis of the empirical material was conducted by the author. The author may, therefore, unintentionally, have pointed the attention of the other researchers and respondents in a certain direction and influenced the collective validation of the analysis. In the first descriptive study, these issues were addressed by showing the results to the respondents afterwards in order to get the results verified. These issues could have been approached by having other researcher conduct the same analyses to see if they came up with a similar underpinning logic for each of the product concepts.

In the second descriptive study, the researchers were involved in the documentation of the underpinning logic in order to ensure the experience needed (see chapter 6 for a detailed explanation) in identifying and formulating the sub-frames, as the students were regarded as unexperienced. The challenge was, accordingly, to ensure that the researchers had sufficient insights into the project. To ensure deep insight into the projects, the researchers carefully followed the projects during the entire the semester. The role of the researchers could have been limited by choosing ongoing projects from practice with experienced industrial designers familiar with explicitly constructing and documenting the underpinning logic. However, the use of ongoing cases is connected with a lot of uncertainties and practical issues as earlier discussed (chapter 3). Moreover, the concept of solution framework emerged during the same time as this research project was underway (not part of the findings of this project). The concept of solution framework was, accordingly, not known to the author when the cases where identified and selected. Thus, it was not possible to choose cases were the concept of solution framework was known to the industrial designers beforehand.

7.2.3 Methods and Data

As mentioned earlier, the use of retrospective cases is widely criticized for the respondents' possibility to post-rationalizes, resulting in a constructed understanding of the situation, which may not stem with the actual situation. This could have been counteracted by also have included ongoing projects, which would have made it possible to "triangulate" the data. However, as already discussed in chapter 3, the use of ongoing cases was connected to a lot of uncertainties and practical issues, and therefore not regarded as possible in this study.

In the second descriptive study, the study essentially seeks to 'measure' the understanding of the underpinning logic among engineering designers and to reveal the respondents' cognitive processes through interviews. This clearly implies some difficulties as it is not possible, objectively, to gain this insight through the use of interviews. The findings are, therefore, also merely regraded as implications rather than final conclusions, which resonates well with the underpinning explorative aim of the study. Moreover, the research setup revealed a weakness in regards to simulating a handover situation in practice, and the dilemmas that emerge during the development phase. This could have been counteracted by included ongoing projects from practice. However, this would most likely have introduced other challenges such as, the creation of comparative situations and the ability to control the validity of test. This will be discussed further in future research.

7.2.4 Summary

Given the overall philosophical position within pragmatism, the research questions, and methods, this research project has an underpinning explorative nature. The findings in this study should, therefore, be regarded predominantly as implications that set a foundation for further research, rather than final conclusions. This study does, therefore, not claim to hold the entire truth. Other researcher with other theoretical angles or perspectives would be able to supplement or provide new knowledge about the subject. However, when accepting the perspective of the research, the research design, and the limitation embedded in it, the conclusions are regarded as the most applicable, plausible, and reliable within the limitation highlighted in this chapter.

7.3 Position the Findings within the Existing Knowledge

Having discussed the reliability of the study, the aim of this section is to position the findings of this study within the existing knowledge of design research, focusing on the different areas this study is positioned within.

In the introduction, it was clarified that this study builds on the assumption that sharing the underpinning logic in a handover situation between the industrial designer and the engineering designers is important to ensuring the integration of industrial design into the product development process on a project level. This assumption is linked to previous research on interdisciplinary teams that identify the collaborative aspects, including a shared understanding, as vital to the effort to ensure integration between different disciplines in teams (Kleinsmann 2006). Moreover, the assumption also builds on an understanding of industrial design as primarily concerned with the 'meaning' of products (Krippendorff 2006). Consequently, for instance form, functionality, and the use of a product becomes a 'means' and not and 'end' to industrial design (Krippendorff 2006; Verganti 2009). Accordingly, the findings of this study potentially offer a different explanation to some of the challenges previous identified in the relationship between industrial designers and engineering designers (see chapter 1 for a full overview). Specification comprehension, different languages, product interpretations (Persson 2002), and conflicts in personal principles, poor communication skills, not understanding each other (Pei 2009) could potentially also be explained by the underpinning product framing of a product concept not been communicated or transferred between the industrial designer and engineering designer. In summary, the three main situations, where the industrial designer communicate and transfer the underpinning logic of a product concept to the engineering designer, represent a novel approach towards understanding the relationship and the interconnected challenges between the two groups of professionals. The findings, therefore, open up a new research area in the relationship between industrial designers and engineering designers.

The findings in this study can also be seen as an effort to approach the gap between industrial designers and engineering designers, by improving the communication between industrial designers and engineering designers in a handover situation. As the situation is part of the process of product development, an improvement of the communication in a handover situation between the conceptual and development phases is believed to also improve the overall process, which is assumed to lead to a better integration of industrial design in the product development process.

This study the focus has been limited to situations in practice where handover situations exist, understood as both a gap between disciplines and a processual transition in the product development process. Accordingly, the findings of this study can be used in situations where the concept of IPD not is applicable. However, as the handover is also regarded as a gap between disciplines, the findings could potentially also be relevant to situations within IPD, as the handover as a gap between disciplines also exists in situations where IPD is applicable. This will be further discussed in the next chapter.

This research project represents only one way of approaching the relationship between industrial designers and engineering designers in product development projects. Accordingly, this project has opened up a number of research potentials and new questions that can be further explored. A selection of these will be discussed and reviewed in the next chapter.

7.4 Perspectives and Future Research

The chapter ends with a discussion of potential future research questions directly or indirectly related to this study.

As already mentioned in the description of the design support in chapter 5, the design support presented in this study is only regarded as the first 'minimum variable product' and further development is needed. Despite the positive indications in the second descriptive study, there is a vast and obvious research potential in developing the current design support, e.g., answering the overall research question: *How can the communication of the product framing be improved*? A natural step could be to combine the product framing documented in the solution framework with one or more forms of visual design representation to support the communication. For instance, the industrial designer could build models (e.g. using LEGO or video) of the sub-frames contained in the product framing in order to visualize the sub-frames. Further sub-questions could be to investigate if the need for communication and transfer would decrease if the industrial designers and engineering designers were to co-build the models of sub-frames rather than the models being built in advance and used in the presentation.

In parallel to the further development of the design support, a stronger focus on the communication perspective could be interesting. Recapturing the discussion of the communication perspective in chapter 2, this study has been limited to a predominantly mechanist view of the communication between industrial designers and engineering designers in a handover situation. Despite the fact that the research focus entails a predominantly mechanist view on the communication between industrial designers and engineering designers, the aspects contained in systemic understanding of communication still affect the situation. Applying a more systemic view on the situation could, accordingly, provide a more nuanced and more profound understanding of the communication and transfer of the underpinning product framing between industrial designers and engineering designers.

This study has focused on the relationship between industrial designers and engineering designer in product development projects. However, other relationships between industrial designers and other groups of professionals involved in the product development process can be identified e.g. the relationship between marketing and industrial design. There is therefore a more general research potential in relation to developing the tool for other contexts of use, where there is a similar need for communicating the underpinning logic of the products. There are accordingly potentials for further development within the present context, as well as developing the tool for other contexts. In other words, sharing the underpinning logic of a product concept can be seen as a general approach to align and create a shared understanding for a product development team handling wicked design problems.

Notes

1. In this study, the product development process is understood as the complete process of bringing a new product to market. The product can be an improvement of an exciting product or a completely new product (Krishnan et al. 2001).
2. In this study, a team is understood as: "*A small number of people with complementary skills, who are committed to a common purpose, set of performance goals and approach for which they hold them-selves mutually accountable*" (Katzenbach et al. 1993, p.112).
3. According to EU, SME are defined as companies with 250, or below, headcounts and a turnover of 50 m euros, or below, yearly. In this study the definition is used as a guideline.
4. In this study the design process is seen as a planning approach due to two main reasons. Firstly, the empirical material underlying this study predominately represents a planning approach. Secondly, handover situations are more likely to occur using the planning approaches than the agile approaches.
5. Adopted from Dorst (2006): "*"Paradox" is used here in the sense of a complex statement that consists of two or more conflicting statements. In the initial state of the paradoxical problem situation, all the statements that make up the paradox are true or valid, but they cannot be combined. A paradox, a real opposition of views, standpoints, or requirements, thus requires a redefinition of the problematic situation in order to create a solution*" (p. 14).
6. Schön (1983) describes it as: "…*the context in which we will attend to them*" (p. 40).'Context' is here understood as the perspective (paradigm) through which the situation should be valued (Schön 1983, p.41).
7. The transactive memory system can be described as a: "…*shared awareness about who knows what*…" (Mohammed, S., & Dumville 2001).
8. Paradigms are "*the entire constellation of beliefs, values, and techniques and so on shared by the members of a given [scientific] community*" (Kuhn 1970).
9. Peirce is normally regarded as the founder of pragmatism, whereas as James was the first to use the term 'pragmatism' (referring to the work of Peirce),

and moreover the one to make pragmatism known to the public (Rylander 2012).

10. The ‘researchers’ consist of the author and the supervisors.
11. For a full overview of the research design, please see chapter 3, ‘Research framework’.
12. In this context ‘designers’ covers both industrial designers and engineering designers and other professionals participating in the projects.
13. Two of the industrial designers, case 2 and 4, are educated in Germany and Russia, respectively. However, both of them have worked as industrial designers in Denmark for many years.
14. Due to confidentiality, additional project documentation was not handed over to the author but only made available during the interviews.
15. The five interviews are: case 2/ED1, case 4/ID1 and ED1, and case 5/ID1 and ED1.
16. The ‘researchers’ consist of the author and the supervisors.
17. Known to the project team.
18. For a full overview of the research design, please see chapter 3, ‘Research framework’.
19. 6th semester: 10 projects, 8th semester: 10 projects, and 10th semester: 12 projects.
20. The supervisors of this Ph.D. are also the supervisors of the student projects.
21. The researchers consist of the author and the supervisors.
22. A flight case is a storage container for transportation of equipment.
23. The people setting up and taking down the equipment before and after a concert.

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