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SHARING THE DESIGN INTENT BETWEEN INDUSTRIAL DESIGNERS AND ENGINEERING DESIGNERS

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1. Introduction

This study focuses on the integration of industrial design in product development. The integration of industrial design in product development has been identified as a method to ensure competitive [Kotler and Keller 2006], [von Stamm 2010] and financial advantages [Hertenstein et al. 2005] in companies. Still, little focus has been given to the integration of industrial design as the field often has been regarded as a part of engineering design (R&D) resulting in industrial design not been considered as a distinct field. However, the increased focus on industrial design in product development during recent decades has led to a series of studies, e.g., Perks [2005], Veryzer [2005], Zhang et al. [2011], and Micheli et al. [2012] where thrust of their research involves industrial design. This study investigates the integration of industrial design in product development as the collaboration between industrial designers and engineering designers. The integration between industrial design and engineering design is important in order to achieve the integration of industrial design as manifested into the products, because the industrial designers do not have the required technical knowledge and skills to finalize the development of the product themselves [Lofthouse and Bharma 2000], [Ulrich and Eppinger 2012].

The collaboration between industrial designers and engineering designers is part of vast research area often referred to as integrated product development. The main elements of integrated product development are: early involvement of all participants, concurrent activities (rather than sequential), and multidisciplinary teams focusing on collaboration and sharing knowledge [Koufteros et al. 2001]. The use of multidisciplinary teams is seen as a way to create a natural setting for collaboration between team members from different disciplines sharing knowledge [Smith 1997]. However, the collaboration between the team members from different disciplines can be challenging. Griffin and Houser [1996] have for example identified barriers such as: personality, cultural language, organizational, and physical location. Several scholars have proposed different solutions to the challenges focusing at people, processes, and technology.

The literature focusing specific on the collaboration between industrial designers and engineering designers has also reported it as challenging. In an early study, Warell [2001] describes the problems as: “It seemed that the communication suffered from the lack of interdisciplinary understanding of needs and purposes of design solutions” [Warell 2001, p.6]. In a later study Persson [2005] describes the problems of the collaboration as ineffective due to different perspectives and foci emphasizing the different mindsets between disciplines leading to conflicting requirement and needs when developing a common product. In a study from 2009, Pei identifies three main problem areas influencing the collaboration between industrial designers and engineering designers: (1) Conflicts in values, principles or aims, (2) differences in design representations, and (3) differences in Education [Pei 2009]. In a later study focusing the communication of brand value between industrial designers and engineering designers, the challenge is described as brand values and the Kansei [Nagamuchi 1986] concepts were lost during the process due to inefficient communication [Rasoulifar et al. 2014].

Both approaches and means have been suggested (and in some cases tested in practice) to reduce the challenges. Warell [2001] propose a model to describe the aesthetically determined functions and properties of a product form in a functional (normative) way, enhancing the collaboration between industrial designers and engineering designers; Persson [2005] identifies the problems as being too little time and space provided for the disciplines to share their knowledge and experiences arguing for the need of a 'collaborative workspace' creating space and time to share knowledge and experiences; Pei [2009] develops a tool taxonomy comprising of 35 forms of sketches, drawings, models and prototypes allowing a better communication; and Rasoulifar et al. [2014] suggest using annotations, word mappings and multiple-domain matrices, to strengthen the communication of brand values between industrial designers and engineering designers.

Based on the above mentioned studies, there still seem to be challenges ensuring collaboration between industrial designers and engineering designers. Adopting the definition of shared understanding by Kliensmann [2006], the challenges between industrial designers and engineering designers can be described as 'a lack of shared understanding between the participants'. A lack of shared understanding can cause unnecessary iterative loops [Valkenburg and Dorst 1998] and reduce the quality of the final product [Valkenburg 2000]. In this study, the focus will be on the framing of the product (product frames) from the perspective of the industrial designer as this remain uninvestigated. Sharing the product frame is vital in order to understand the intended design and underlying reasoning and moreover creating a shared understanding between industrial designers and engineering designers.

1.1 Conceptualizing, concept and product frames

Common to industrial designers and engineering designers is the act of designing. Defined broadly design is described as creating new products (either material or immaterial) addressing human needs [Andreasen et al. 2015]. Design is concerned with: practicality, ingenuity, empathy, and a concern for 'appropriateness', which differ from the values of, e.g., sciences or humanities [Cross 2006]. Conceptualizing is the core synthesis activity of design with the aim of creating something new [Andreasen et al. 2015]. It is a holistic approach covering the following overall activities: exploration, concept synthesis, product synthesis and development [Andreasen et al. 2015]. Central to conceptualizing is concept synthesis - resulting in a concept [Andreasen et al. 2015]. The concept is the result of the exploration and synthesis proposing a solution to the needs and opportunities revealed. The aim of a concept is to develop it far enough to be able to evaluate the physical principles, to ensure that the suggested product will operate as anticipated, meet the targets set and moreover, be finalized with reasonable further effort of development [Ullmann 1997]. Andreasen et al. [2015] defines a concept broadly as being a proposal for the composition of the product and, moreover, detailed enough to evaluate the proposal as an answer to the task and intention. Both industrial designers and engineering designers contribute to the creation of a concept however from different perspectives and with different foci. The engineering designers are primary focused at the different elements within the composition of the concept focusing at issues such at: functionality, manufacturing possibilities, and cost [Michalek et al. 2005], [Anderl et al. 2009]. The industrial designers regard the product as a whole, focusing at issues such as: form, usability and meaning [Krippendorff 2005], [Verganti 2009].

In order to handle the more intangible aspects industrial designers creates frames (product frames) capturing their understanding of the situation and connection between the different elements. The process of framing has been described by Roozenburg and Eekels [1991] as the designer having what seems to be unrelated facts, however sensing that they are somehow connected. Lawson [2005] argues that the designer co-develop the understanding of the problem along with the creation of the solution. Schön [1983] describes this metaphorically as the designer having a: 'reflective conversation with the situation' [p.76]. The result of framing, a (product) frame, is described by Dorst [2015] as the connection between the deep insights regarding the user and the context-of-use (Outcome) connected with solution principles (How).

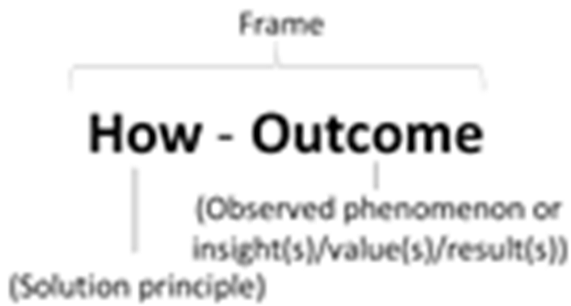

Figure 1. Model adopted from Dorst [2015]

Creating a frame can therefore be regarded as creating a connection between the different elements describing a product, e.g. the intention of the product connected with the interaction of the product supported by the form and the chosen materials. A reframing can accordingly be described as a reorder/replacement of one or more elements e.g. changing the interaction of the product or any other of the elements within an existing frame. The frame is the foundation for understanding a proposed intended design by an industrial designer. An unshared product frame of the design intent will leave the engineering designer with a fragmented understanding of the different elements of the product frame and how they are connected. Sharing and understanding a frame makes it possible not only to understand the design but also to make changes to it without necessary weakening the product frame – at least not unintended.

2. Research goal and structure

The aim of the paper is to understand the challenges better, sharing the frame from the perspective of the industrial designer with the engineering designer. The goal is to get a richer and deeper understanding of what is shared of the frame between industrial designers and engineering designers and what is not. The study builds on several conditions: (1) the product development process following commonly accepted new product development best practices, (2) the sharing of the product framing is regarded as a transfer of knowledge from the industrial designers to the engineering designer and (3) the industrial designer plays an active and integrative role without being process leader.

3. Research design

3.1 Research approach and cases

A retrospective case study is chosen due to: (1) the limited time - the retrospective approach allowes us to evaluate and consult the final product and thereby early in the process ensuring the relevance of the case and, (2) the natures of the research aim, and the applied focus. Moreover, cases have been selected where the conditions for a successful process (based on Holland et al. [2000]) were mainly considered present. Besides these overall thoughts concerning the approach, several more specific considerations were made in regards to the choice of the specific cases. The main acceptance criteria where: (1) industrial design played an integrative role, (2) the project contain technology integration and development without being technology driven, (3) the industrial designers and engineering designers both where experienced and respected each other's field of work and (4) the chosen cases represented a variety in: business area, size and age, in order to strengthen our findings. All the cases are limited to a Danish context as the empirical data presented in this paper is based on six cases in Danish companies and their partners. The sizes of the project groups were between 3-10 team members and the duration of the projects were between 1-2 years.

3.2 Data and methods

Data was collected using in-deep semi-structured interviews (topic areas where predefined but the order and wording where changed during the interviews). Each interview took approximately 45-90 minutes and was undertaken in Danish. The interviews from each case were coded using the model of Dorst (Figure 1) as an analytical frame. The coding was done through several iterations going in to greater and greater details each time. Instead of transcribing the interviews, relevant ‘timespan’ of the interview was linked to a code, for instance ‘Solution principle’. Afterwards it was possible to identify and listen to all the identified timespan labels with a specific code from either: one interview, one case or all the cases. The interviews within the separate cases were afterwards analysed and compared trying to identify correspondence or lack of correspondence in regards to the understanding between the industrial designer(s) and engineering designer(s). Finally, the results of correspondence or lack of correspondence between the different elements of the frame from all the cases were compared in order to look for patterns among the results.

4. Cases

An overview of the cases is presented in Figure 2 (next page).

Case	Business field	Products / Company background	Partners	Interviewees	Description of the product and process	Comments
1.	Well-fare, DK *(Company 1)*	Develops and produce well-fare products for disabled and other mobility impaired persons. Young company – just above 10 years old. Small company - below 30 employees. No in-house industrial design department.	Engineering Design Consultancy Firm *(Company 2)* Industrial Design Consultancy Firm *(Company 3)*	2 Industrial designers[1] *(ID1 and 2)* 3 Engineering designers *(ED1, 2 and 3)*	The product developed is intended to assist healthcare personal, such as assistants or nurses, when caretaking elderly people. Some of the main challenges connected with the development of the product were: regulations, limited space, safety and usability.	[1] 'ID1' and 'ID2' were consultants in two different companies (Company 2 and 3). Furthermore was 'ID1' a representative for an industrial designer (has not been formally trained as an industrial designer but acted as such in this case).
2.[1]	Industry/production, DK *(Company 1)*	Develops and produce products for professional use mainly in production within varies industries worldwide. Mature company – just below 50 years old. Small company – just below 300 employees. No in-house designers.	Industrial Design Consultancy Firm *(Company 2)* Engineering Design Consultancy Firm *(Company 3)*	1 Industrial designer[2] *(ID1)* 1 Engineering designer[2] *(ED1)* 1 Project manager[3] *(PM1)* 1 Marketing consultant *(MC1)*	The product developed is mainly used by professionals in productions within varies industries worldwide. Some of the main challenges connected with the development of the product were: size of the product (should be kept small), ergonomics, and usability. A newer variant of the product internally developed in 'Company 1' is also included in the interviews.	[1] The design consultancy firm is the same in case 2 and 3. The designers (persons) involved in the two cases are however not the same. [2] The industrial designer, ID1, and engineering designer, ED1, were consultants. [3] The originally project manager died. It was therefore the later project manager of the project who was interviewed.
3.	Industry/service, DK *(Company 1)*	Develops and sale electrical products for professional use within the service industry. Mature company – above 100 years old. Major company – above 5.000 employees. No in-house industrial design department	Industrial Design Consultancy Firm *(Company 2)*	1 Industrial designer[1] *(ID1)* 1 Engineering designer *(ED1)* 1 Product manager[2] *(PM1)*	The product developed is intended for professional use within the service industry worldwide. Some of the main challenges connected with the development of the product were: size of the product (should be kept small), ergonomics, and usability.	[1] ID 1 was a consultant. [2] PM1 has been formally trained as an industrial designer.
4.	Interior, DK *(Company 1)*	Develops and sale interior product for households/professionals. Young company – just above 10 years old. Small company - below 30 employees. No in-house industrial design department	Industrial Design Consultancy Firm *(Company 2)*	1 Industrial designer *(ID1)* 1 Engineering designer[1] *(ED1)*	The product developed is a lighting product intended for professional buildings.	[1] ED1 has been formally trained as an industrial designer but acts as an engineering designer in this case.
5.	Offices, DK *(Company 1)*	Develops and produce office products for professional use. Mature company – above 70 years old. Small company – 60 employees. No in-house industrial design department	Industrial Design Consultancy Firm *(Company 2)* Industrial and Engineering Design Consultancy Firm *(Company 3)*	1 Industrial designer[1] *(ID1)* 1 Engineering designer[2] *(ED1)*	The product developed is mainly used by professionals in offices worldwide. Some of the main challenges connected with the development of the product were: ergonomics, and usability. The product was never put in production mainly due to cost/market issues.	[1] 'ID1' was consultants (Company 2). [2] 'ED1' was consultant (Company 3).
6.[1]	Industry/service, DK *(Company 1)*	Develops and produce products for professional use in households. Mature company – above 60 years old. Major company – above 1.000 employees. No in-house industrial design department	Industrial Design Consultancy Firm *(Company 2)*	1 Industrial designer *(ID1)* 2 Engineering designer *(ED1)*	The product developed is mainly used by professionals in households worldwide. Some of the main challenges connected with the development of the product were: size of the product (should be kept small), ergonomics, usability and cost.	[1] The design consultancy firm (Company 2) including the industrial designer (ID1) is the same in case 7 and 8.

Figure 2. Overview of cases

5. Results

In the following, examples from the different cases are presented, explicating the results of the case study. The terms ID and ED represent, respectively the industrial designer(s) and engineering designer(s) interviewed in each case.

5.1 General findings

The results across the cases showed an overall shared understanding of the key elements of the concept between the industrial designers and the engineering designers. For instance, the interviewee described the same main idea, functionality and market of the products. The results also showed an overall understanding of the engineering concept of the product among the industrial designers. The interviews showed that the industrial designers were aware of the main engineering related issues to the concept, e.g., challenges connected to construction, production, materials, economics or time. However changes to the concept did happen due to lack of technical insight by the industrial designers. Furthermore, we also found that the understanding of industrial design among the engineering designers was focused on form (often shared via 3D files or prototypes) and use (with a functional focus) in relation to the product.

5.2 Product frame

The analysis of the interviews revealed that the product frames were overall difficult to share between the industrial designers and the engineering designers. Through the analysis of the interviews three main situations were identified when the (product) frame was not shared. Using the understanding and model from Dorst [2015] regarding a frame, the findings can be described as differences in the adopted insights/values and solution principles between the industrial designer and engineering designer.

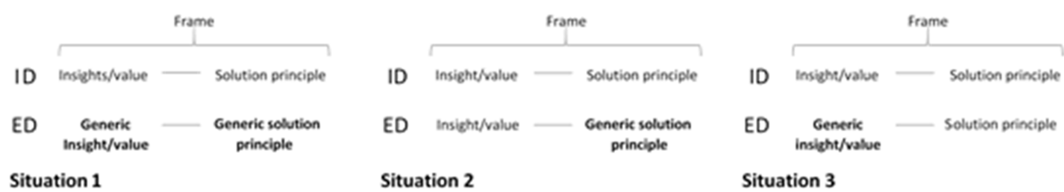

Figure 3. Situaton 1, 2 and 3

In situation 1, the frame as a whole is not shared between the industrial designers and the engineering designers. Neither the insight/value nor the solution principle is shared. In situation 2, the frame is only partly shared as the shared insight/value about the users is connected to a generic solution principle rather than a case related one. In situation 3, the solution principle is shared between the industrial designers and engineering designer but not the related insight/value. Most of the examples identified through the analysis of the cases are related to situation 1, where the frame as a whole is not shared, and situation 2, where the frame only is partly shared. Situation 1 and 2 could be identified in all the cases whereas situation 3 only could be identified in case 1 and 3.

5.2.1 Situation 1

Case 3 (Industry/service) offers an examples of an entire frame not been shared between the industrial designer and the engineering designer. The product being developed is for indoor cleaning, e.g., in an office. The product is developed for professional use within the service industry. ID1 describes a solution 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 same description and understanding cannot be found in the interview with the engineering designer ED1. The description and understanding of the product by the engineering designer is focused on functionality, technical values and principles. Moreover, ED1 describes the product (based on the 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 influence the business it is worth going fore"(Interview: case 3, ED1, 13.4min.). The unshared frame between ID1 and ED1 is further underlined by the description of the process where ED1 explains how he prefers to show the solutions before too many details are added as especially PM1 often have changes.

Based on the interview with PM1, it is clear that these changes are changes done in order to maintain the frame proposed by ID1. A similar example can be found in case 2 (Industry/production). The product developed is used in varies productions within many industry e.g. in building ships. The product is developed for professional use by trained craftsmen. ID1 describes the product associated with values such as modern and advanced (authors: productions). ID1 describes the solution principle for the product as a transformation: "…from tool shop… It might a bit exaggerated…. from tool shop to "laboratory" (Case 2, ID1, 9.32 min.). The term 'laboratory' is later in the interview explained as the modern and advance productions facilities of for instance the auto or yacht industry. However, is it not possible to find the same understanding in the interview with the engineering designer (ED1). ED1 rather describe the project based on generic insights, values and solution. ED1 is aware of the strong focus on ergonomics but regard it as a detached part from the construction - ED1s area of focus. The unshared frame is emphasized by an example actually outside the case. Company 1 (case 2) have after the finalization of case 2 internally developed and designed a variant of the product based on the originally version. Except the main materials and colour the relationship between the two products is very limited. The engineering designer's (not the same as interviewed in the case mentioned here) later version of the product is hard to correlate to the industrial designer's value: modern [production] and advanced [production] and solution principle 'from tool shop to "laboratory"'- indicating that the frame is not shared. The industrial designer has not been involved in the development of the later version of the product.

5.2.2 Situation 2

An example unshared solution principle can be found in case 4 (interior). Both the industrial designer and the engineering designer express the same insights regarding the users and the use-of-context (ED1 is a formally trained industrial designer but act as an engineering designer in the company). Through the interview ED1 mentions a solution principle for the product (a visual direction) which is unclear to him which leads to a fragmented understanding of the use of the product.

Another example can be found in case 1 (welfare). The product developed is intended to assist healthcare personal, such as assistants or nurses, when elderly people have fallen and they cannot get up by themselves. ID1 and ED1 describes a similar set of values regarding the users (ED1 emphasize the functional view regarding the use). However, ID 1 describes a solutions principle which metaphorically speaking could be describes as two (strong) persons, kneeling on each side of the elderly person fallen, carefully putting their hands and arms around the person and gently lifting the person up again whereas the solutions principle described by ED1 could almost be describes as a football player fallen on the field getting helped up again by one of his teammates – reaching his arm out to help him up again - focused on speed (getting "fast" up again).

5.2.3 Situation 3

In case 3 ID1 describes a solution principle of the product as being dynamic (reliable and robust) relating it to insights about the users (mainly craftsmen). "…it is moving. It is leaning back a bit" and "…it gives an impression of effectiveness (authors: important to the users)…" (Case 3, ID1, 11.01 min.). ED1 describes indirectly the solution principle commenting the form but does not relate it to the insight about the users and the use-of-context (the social and cultural aspects). He refers to a general set of values (easy, cheap and fast) rather than the project specific values mentioned by ID1when commenting the solution principle. In other words the solution principle becomes meaningless to ED1 as it is not connected to the insights. The unshared insights regarding the users between ID1 and the engineering designers (ED1, 2 and 3) also influenced the solution principles adapted to the product.

In case 1 (welfare) ID1 described a solution principle as 'few parts' (authors) - preferable one (healthcare personal have a tendency of being "afraid" of technology and may choose not to use welfare-technologies, if it makes them feel insecure or limit their focus on caretaking). This solution principle potential makes the product easy to use (from a healthcare personal perceptive) leaving them with the possibility to focus on the caretaking of the person fallen. From the interviews with the engineering designers (ED1, 2 and 3) it was clear that the idea of a product in one piece was not possible due to regulations combined with the technical and economical possibilities. However, more importantly did we only found a few considerations regarding the consequence of leaving the originally principle structure of one piece in regards to users. This indicates that the insights and values have not been shared. Overall, the solution principles showed difficult to share between the industrial designers and engineering designers. It seems as the solution principle based on more abstract aspect, e.g., social or cultural terms were more challenging to share than solution principle based on functional principles.

6. Discussion

At the end of the project the team members will normally have an (better) overview of the project and product. The findings regarding the key aspects of the concept are therefore typically and positively influenced by this as the cases are retrospective. Moreover, we have selected cases where the conditions for a successful process were considered mainly present. The overall understanding of the engineering related challenges among the industrial designers is most likely positive influenced by the fact that all the industrial designers are consultants. Both the industrial designers and engineering designers mentioned the importance of the industrial designer's ability to understand the challenges connected to engineering design in order to be chosen as partners. A lack of understanding of the engineering related challenges among the industrial designers might result in not being chosen next or even taken off the present assignment.

In situation 1 (where either the insights/values or the solution principles is shared) it seems as the engineering designers form their own "frames" based on generic (not case related) insights/values about the users and use-of-context and connects them with already existing and known generic solution principles. In situation 2, the social and cultural aspect of the insights regarding the users are either not shared or not fully related to the case by engineering designers. This seems to affect the later connection to and adoption of more generic engineering design based solution principles. The adoption of generic insights and values, in situation 3, makes the solution principle less important or even meaningless to the engineering designers. In all three situations the result is an unshared or only partly shared frame between the industrial designers and engineering designers leaving the engineering designers with a fragmented understanding of the foundation for the design.

The findings regarding the sharing of the design concept and the emotional, social and cultural aspects of the insights and values might be negatively influenced by the fact that all the industrial designers in this study were consultants. As mentioned prior, both the industrial designers and engineering designers emphasized the ability to present design proposals being feasible in terms of construction, production and cost. Trying to share emotional, social and cultural aspects might be seen as dangerous for future commercial collaboration from the industrial designer's point of view.

The lack of shared product frames between the industrial designers and the engineering designers did however not mean that the product frames was not implemented and maintained into the final product. In four of the six cases (case 2, 3, 4, and 5) the industrial designers evaluated that the suggested design intent predominantly was implemented and maintained into the final product (it was not possible to make the evaluation in case 1 and 6). Investigating these cases (case 2, 3, 4, and 5) it seems that they succeeded in implementing and maintaining the product frames because the industrial designers was still involved in the process after it was "handed over" to the engineering designers, e.g., in case 3 the product manager (PM1) acted as a 'product champion' which further ensured a successful implementation of the product frame into the final product. In other words the product frame was not shared, it was ensured by the continuous involvement of the industrial designer. Despite the product frame being implemented, there seems to be many iterations between the industrial designers and engineering designers due to the lack of unshared product frames. Moreover it also seems to affect some of the engineering designers slightly negatively. The engineering designers try to solve a task (e.g. making needed correction to the suggested design) without knowing when they are right or wrong.

7. Conclusion

Based on the findings in this study an unshared product frame can be divided into three main situations: (1) the insights/values and related solution principles are not shared, (2) the insights/values are (partly) shared but connected to generic solution principles and (3) the solution principles are shared but connected to generic insights/values. In the cases where the insights, values and solution principles are not shared or only partly shared the engineering designers replaces them with generic (rather than case related) ones. The generic insights, values and solution principles seem to be based on some fundamental engineering aspects (technical, functional and financial oriented) and/or their own personal (rather than the users´) understanding of the situation. However, in general the insights seem less challenging to share than the solutions principles. Especially the insights related to the context-of-use (physical) seem to be shared. It is however often only the more functional aspects of the insights (related to the users) that are fully shared between the industrial designers and engineering designers. The solution principles are more difficult to share between industrial designers and engineering designers. However, the study does indicate that solution principles based on a functional or technical principle rather than a social or cultural principle seem easier to share. Further research needs to be done in order to understand how the sharing of product frames between industrial designers and engineering designers can be supported. One future direction for the research could be to investigate if product frames could be e.g. visualized (different visual design representations are used by industrial designer and engineering designers), and furthermore if this could help as a boundary object in the communication between the industrial designer and engineering designers.

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