THE BOUNDARY SPANNING PRACTICE OF (USER CENTERED) DESIGN

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ABSTRACT

Most products are developed by New Product Development (NPD) teams, composed of specialists that need to collaborate closely. One of those specialists is a user-centered designer, focusing on the usability and experience of use of products. In this qualitative empirical study the contribution of designers to NPD teams is explored, filling a gap in literature. It is found that the user centered framing of designers, their imaginative capabilities and their well-developed expressive skills, have a particular contribution to NPD teams. It enables to span complex boundaries inside NPD teams, e.g. between hard- and software engineers or between marketing and R&D. Designers themselves are not nominated boundary spanners, rather the boundary spanning capabilities is a by-product of their design practice. We named this 'mirroring', which is conceptualized as the dynamical and ongoing redrafting of representations of the intended product, enabling team members to align and coordinate activities cross-disciplinary. The implications concern NPD (management) and design (management), as it sheds a new light on what designers (need to) do and the contribution to NPD teams.

INTRODUCTION

Many products are complex, such as printers, cars, medical equipment, or ICT equipment. Developing these products requires too much knowledge and know-how to be held by one person. A range of specialists need to work together and integrate their knowledge, including mechanical engineers, software engineers, planners, physicists, and marketers. These specialist work together in NPD teams. The word 'team' suggests a group that knows each other and work together well. However, in (large) multi-disciplinary NPD teams, its members may find it hard to understand each other.

Every specialist in an NPD team has its own practice that is related to his specialism. A ‘practice’ is a sociological notion that broadly refers to what people do (Bourdieu 1977) including recurring and improvised activities; the tools and objects deployed; the social identity constructed; how work is done; how knowledge is produced. Individuals are part of different ‘communities of practice’ (Lave & Wenger 1991; Brown & Duguid 2001). *Within practices* knowledge is easily shared and spread (Brown & Duguid 2001), however, sharing and spreading knowledge across practices is difficult. Knowledge sticks to particular practices (Carlile 2002).

Thus, practices inevitably result that team members can experience boundaries (Bucciarelli 1994; Carlile 2002; Dougherty 1992; Smulders 2006). Across such boundaries team members find it hard to make sense of each other’s messages, situations and challenges. For example, technology developers may find it hard to understand the

problems of production technicians, and vice versa. Boundaries hinder the free-flow of knowledge; crippling fast, efficient and effective product development.

One of those specialists inside NPD teams is the 'designer', yet designers as team members seems to be largely overlooked. What we mean by that will be discussed shortly hereafter. There is a vast body on literature on NPD and/or innovation, but "design has been largely absent from theory, teaching, textbooks, and research" (Hobday et al. 2011: p.5). Also, in the many popular books and magazines on design, interactions with non-designers are overlooked, and teams are not discussed. This is hardly different for scientific publications on design that seldom discuss interactions between designers and others, apart from clients. Designers are framed as a profession that has its own logics, principles, norms and that can be practiced relatively apart from those others.
Last years, a growing interest into design and design-thinking can be noticed, precisely because it is assumed that design (-thinking) has an important contribution to teams and organizations (e.g. Boland & Collopy 2004, Boland et al. 2008; Brown 2009; Verganti 2009). Unfortunately, the scholarly discussion is mainly a theoretical discourse, spiced up with clichéd stories like Apple, or experiments in laboratory settings with students. What is missing is an in-depth study of designers in-the-wild, interacting with many other specialists, whereby contradictory aims need to be balanced. This paper describes an empirical study that explores the research question: *what do designers contribute to multi-disciplinary NPD teams in-the-wild, how and why.*

LITERATURE REVIEW: THE HIDDEN DESIGNER IN TEAMS

The choice to study designers incorporates the problem of defining 'design'. It is a notion that defies any definition agreed upon by practitioners and researchers in the field. First, 'design' is referring both to the process of creating something (a verb), and it is referring to the result of this process (a noun). In this study it will be solely used as a verb: the activity of designing. Second, several fairly distinctive almost incomparable perspectives can be discerned in literature.

- *A cognitive perspective:* design is considered a way of problem solving: "every one designs who devises courses of action aimed at changing existing situations into preferred ones" (Simon 1996 3rd ed.: p.111). This stance is adopted in literature on design-thinking.
- *A process perspective:* design is considered "the activity to turn requirements, functions, needs and goals into concepts and specification for the implementation and production of the product" (Visser 2006). This stance is widely adopted in literature on product development management.
- *A humanistic perspective:* design is considered as design philosophy/methodology in which the specific abilities, cognitive skills and cultural backgrounds of the users are given lead attention (e.g., Norman 1986, Norman 2004). Designers can be discerned by their interest to improve conditions for people (Buchanan 1995; Hobday et al. 2011). It is often named 'User Centered Design' (UCD) and 'Human Centered Design' (HCD).

We take a humanistic stance, most of all because the increasing interest into topics as the usability of products underscores the need for specialists who focus on users inside NPD

teams. Thus, design is defined as devising products (tangible and intangible) in which human needs, likings, tasks and particularities are placed centrally. A designer in a NPD teams is a role that concerns devising products with a focus on the product's usability; experience of use; meaning attribution; and elicited emotions of users. These definitions are sufficiently to-the-point to distinguish 'designers' from other NPD team members.

The definitions enable to conduct a literature review on the role and contribution of designers to teams and organizations. Still, empirical studies are fairly rare, if we exclude anecdotic case studies:

- Walsh (1996), glossing over the empirical case studies she conducted, concluded that the role and contribution of design is thoroughly shaped by the organizational context, such as the type of product to be designed, or the historical and cultural context. Designers can be part of marketing, of R&D, or part of an entirely separate entity as a 'design centre'. She argued that design-activities poorly fit classic organizational structures.
- Hargaddon & Sutton (1997) coined the concept of 'technology brokers' as a result of their study on designers in a large design consultancy, interacting with numerous clients.
- Perks et al. (2005) distinguished three roles on the base of interviews. First, the designer-as-'specialist' turns briefings into a proposals, using traditional design skills, such as aesthetics and visualization. Second, the designer-as-'team member in a multifunctional team' enhances communication and interfacing among other departments. Third, the designer-as-'NPD process leader' drives the entire development process. This role emerged in the case of 'radical product development'.
- Johansson and Svengren-Holm (2008) studied the triadic relations between designers, engineers and marketers by means of interviews. They found that engineers seemed to adopt a more creative approach as a result of the interactions with designers. However, marketers and designers showed rivalry.
- Boland et al. (2008) reflected on their collaboration with star-architect Frank Gehry. They found that Gehry in many ways reshaped the original goals and how the team dealt with a problem. Instead of analyzing and choosing among alternatives, Gehry's approach showed that in design problem and solution space co-emerge (see also Dorst & Cross 2001).
- Verganti (2009) induced a theory on 'design-driven innovation'. Designers not only contribute by means of delivering 'designs', but also contribute to the 'design discourse' as part of a network of 'key interpreters'. The discourse comprises among others lead-users, sociologists, artists, and so on. This enables sharing and recombining knowledge to build unique proposals.

What emerges in these studies is that designers contribute 'something' to teams beyond their aims and formal role. It is a contribution well appreciated by those who collaborate with designers. At the same time it is overlooked in the literature on design, and is entirely missing in textbooks and teachings for designers. It seems to be a by-product of designing, overlooked by designers themselves.

Yet understanding this phenomenon may lead to new insights on design and innovation. The aforementioned studies are mostly based on interviews and case-studies, taking a black box perspective on teams (apart from Boland et al. 2008). The black box hides what designers do from the empirical lens of the researcher. In order to understand what designers contribute, we believe that the black box need to be opened to observe interactions between designers and others.

METHODOLOGY: AN INQUIRY INTO THE PRACTICE OF NPD

A field study was conducted for more than two years inside the large NPD organization of Océ Technologies, a large multinational provider of printing systems for professionals. It has 9 R&D sites, and a design department located in the Netherlands, responsible for the design of all Océ products and software applications. It also has a good reputation in the field of design, illustrated by the 100+ design awards that were collected- including several awards for usability. Since 2010 Océ is part of the Canon Group.

An unusual approach was taken to conduct a study inside teams. Instead of having a participating external researcher, the data gathering was done by a designer belonging to Océ; a practioner-researcher. No off-the-shelf methods exists for practitioners to research their own practice. Still, carrying out qualitative case study research is first and foremost a matter of learning-by-doing (De Weerd-Nederhof 2001). Thus, we believed that a method was needed that is based on this premise. A specific philosophical perspective, pragmatism, was taken as a starting point as for pragmatism interventions and learning-by-doing are considered pivotal. Note that it has been argued that pragmatism is 'design's natural epistemological base' (Melles 2008). John Dewey developed a logic for scientific inquiry (Dewey 1938). Unfortunately there are no off-the-shelf methods for researchers based on his writings.

Thus, a specific method was developed, what we named a 'Deweyan inquiry' (Stompff 2012). It roughly can be divided in two stages. First a participatory study was conducted. This stage was a data-driven qualitative research in order to induce new theory, strongly resembling grounded theory method. For this stage, 7 distinctive studies were conducted, among others a stakeholders analysis, an analysis of participatory observations, analysis of filmed meetings and an analysis of working relations within a NPD. Second, these insight were validated by a range of experiments in the practice of Océ's NPD, guided by the insights of the first stage. This stage resembles action research. For this stage, three distinctive experiments were prepared, conducted and reflected on.

Obviously, the dualistic position of practioner-researcher is prone to biases which reduce the validity and robustness of the inquiry. First, there is the problem of the practitioner's bias. What may seem 'normal' to the practioner, may be 'revelatory' to anyone else, and vice versa. Second, there is the problem that personal engagement to the subject matter results into personal bias. Only those phenomena are noticed that are supportive to often implicit assumptions. Third, there is the 'problem' of reflexivity: the insights the researcher gets while the NPD project progresses, inevitably shapes what he does as a practitioner.

In order to enhance validity and reliability, a specific research design was developed:

1) A case study was chosen that well represented multi-disciplinary teamwork including designers. This case study concerned the development of strategies to solve paper-

jams inside a printer. This is a topic that impacts the work of many developers inside Océ.

2) Extensively data was collected, based on Yin's sources of evidence for case study research (Yin 4th ed. 2009), aimed at corroborating the same topic. The sources included:
   a) Internal documentation and archival records.
   b) A range of semi-structured interviews with team members, in two series. These interviews were transcribed and coded, 29 in total.
   c) Participatory observations of approximately 6 months, documented in a research journal.
   d) Approx. 30 hours of films of team meetings. The most interesting films were transcribed and coded.
   e) Numerous (photos of) artifacts, including sketches, prototypes, paper models and so on.
   f) Photos of the environment, such as office space, or how the team interacted with prototypes and so on.
   g) The deployed tools as CAD programs, dynamic modeling were documented.

3) The analysis of the data was postponed six months to reduce reflexivity. Analysis was done together with other evaluators, both external (TU Delft) and internal (Océ Technologies). Thereby the co-researchers varied across the individual studies (triangulation of evaluators).
4) Over the ten different studies, several methods were used, to consider the subject matter from different perspectives (triangulation of methods). Each of these studies had a dedicated research question and an appropriate body of literature. All studies together reveal a cumulative and progressive character, revolving around the same topic and are grounded in the one dataset (Figure 1).
5) Preliminary findings were presented to and discussed with senior developers and managers in Océ Technologies for feedback.

In short, even though data was gathered by a practioner, all analysis was done by several researchers together, in order to warrant validity and objectivity as much as possible. The distinctive studies are documented (Stompff 2012).

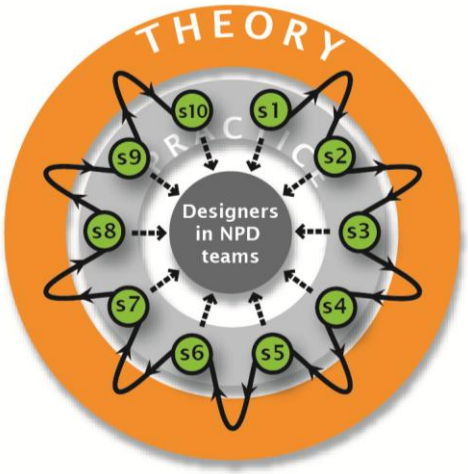


FIGURE 1: The research consists of a series of ten studies, that are all grounded in the same dataset and are focused on one topic: what do designers contribute to teams? Yet, each study has a distinctive research question, deploys an appropriate method and discusses a relevant body of literature. The first seven studies concerned a data-driven qualitative research, to develop new theory. The last three studies concerned three experiments to validate the insights. The synthesis of all studies together provides a comprehensive set of findings.

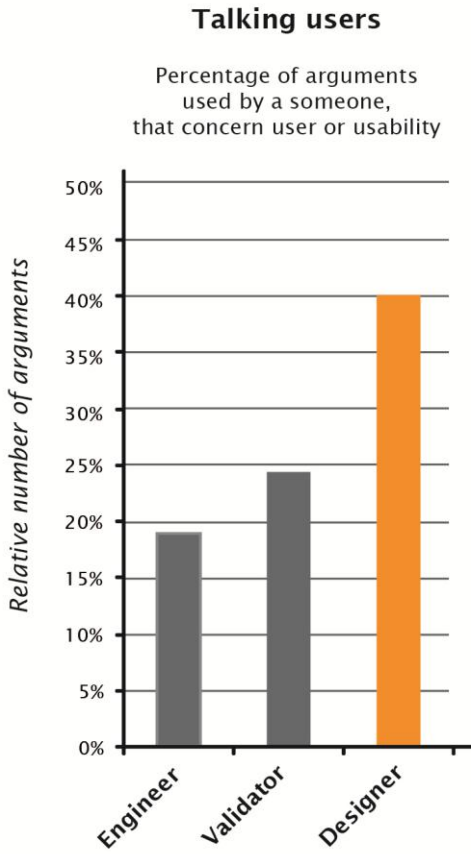
FINDINGS (1): WHAT DISCERNS A DESIGNER FROM OTHER ROLES

The findings will be discussed in two ways. First it will be explained what discerns the role of a designer from other roles inside multi-disciplinary teams, such as engineers. This is necessary, as roles are always contextual: roles emerge out of interactions, and in time a mutual understanding arises on who-does-what (Berger and Luckmann 1966). Second, the contribution of designers to teams and the practice of NPD is discussed.

Talking products and users

A first characteristic which discerns designers from other roles is that designers frame any topic from the perspective of the product and user. They quite literally 'talk products and users'.

The best example is provided by an analysis of a filmed meeting. It was studied who in the meeting addressed user and/or usability in his arguments. In the meeting, 272 out of 900 utterances were identified, that concerned user or usability (30%). This is quite high, which can be attributed to the topic of the meeting: a paper jam that could not be solved by users.



However, designers addressed users much more than others. In Figure 2 the *relative* amount of user related arguments is shown per role; i.e., how often in the argumentation a user is named by someone in a distinctive role. This is an average score including all team members deploying a specific role. In this particular meeting, the designers often included user related arguments: up to 40%. The engineers and the validators less, around 20%. Notably, one validator had a designer background and this person also often included users in his argumentation, more than 40%. The other validators had less than 20% user-related arguments.

FIGURE 2. A bar chart showing the relative number of utterances a user or usability is mentioned by a person deploying a specific role. There were three roles in the analyzed meeting: (1) soft- and hardware engineers; (2) validators, a role that concerns quality assurance; and (3) designers.

In interviews the distinctive framing also manifested. The interviewed designers discussed many topics from the perspective of the user, even identifying themselves with the user. They often deploy 'I' when referring to a user: "how can I know what to do next, if there is no feedback provided in the user interface?" Other team members also discuss the user, however, in more detached words, as 'he', 'the operator' or 'the client'. Designers discuss the user experience at length and how the printer supports the user. Users have tasks, and the printer is considered a tool to accomplish the tasks. Also they discuss

irrational user behavior and the printer being capable to deal with that. They implicitly expect technology to be supportive to the whimsical operator, rather than the other way round. For others, the user is seen as subsidiary to the technology at hand: he needs to perform specific activities at the right moments, as the product requires him to do.

A holistic, outside in orientation to problems

A second characteristic of designers that manifested is their distinctive orientation to problems, what we named *a holistic, outside-in orientation* as will be explained below. In order to understand how disciplinary roles (including designers) frame problems, a meeting was analyzed. Two orientations to problems were discerned:

- *Analytic*: dealing with problems by abstracting matters and ignoring details. The aim is to understand the 'core' problem, assuming that if this problem is solved all other problems can be dealt with later.
- *Holistic:* Dealing with problems by to creating proposals and learn while doing what the actual problem is. It is a problem solving strategy based on generating and validating solutions.

The findings showed that designers, more than, others have a holistic orientation, and contrast above all with engineers (see Figure 3). Still, designers are not the only ones who have a holistic orientation to problems. However, what discerned designers is the combination with the first characteristic: they not only have a holistic orientation, but also an 'outside-in' perspective, i.e. from the user perspective When it concerns problems, designers tended to contextualize them by showing the implications for the product or for the user. When it comes to solutions, designers tended to zoom out, rather than attempting to solve it locally. Engineers gravitated to disaggregating problems; to make them local and manageable. They proposed concrete and often local solutions without large effects on the surroundings.

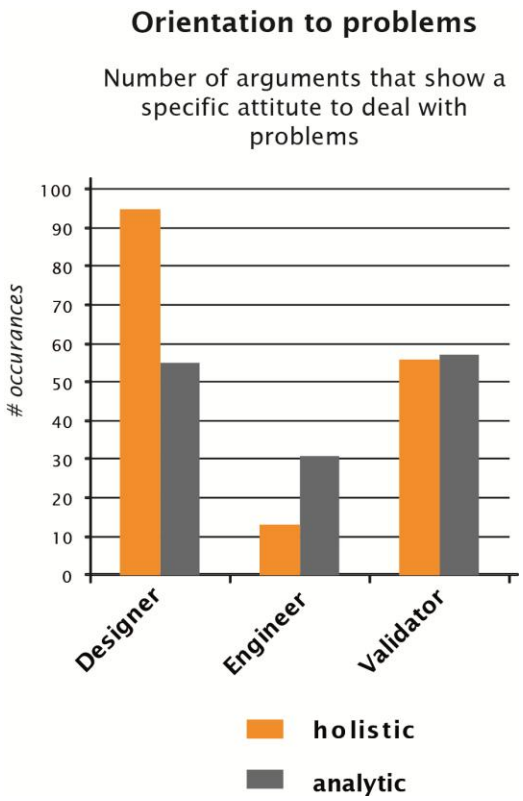


FIGURE 3 A bar chart showing the results of a meeting that was filmed, transcribed and analyzed, whereby the number of arguments was counted that showed a specific orientation to problems. It shows well the different approaches of designers and engineers.

These distinctive orientations showed to be a source of conflicts every now and then. For example, it was observed that the involved designers preferred to combine a range of unsolved problems they were working on, rather than sticking to confined problems. It is a strategy that enlarges the solution space, providing slack that otherwise is missing.

The engineers at the other hand preferred to work on well confined problems, one by one, and assigned to specific persons. This enables individuals to progress relatively independently. These two approaches are fundamentally at odds.

Imaging the intended product

In order to infer the implications of technical choices of others for the product and the user, designers need to rely on their imagination skills. A third characteristic that discerns designers, is their skill to quickly translate technical choices to the consequences for the intended product. In a filmed meeting the designers often made these reflections instantly. The swiftness echoes 'snap judgments': instantly a problem or solution is seen, which only later can be explained.

Quite interestingly, what was found is that designers discern themselves from other team members as they respond relatively more often than others to what is said. An analysis was made of the cues that shaped a team meeting. A cue is an extracted event or thing in the world that is potentially meaningful for us (Weick 1995). For example, if somebody is making a print, the sound of tearing paper immediately draws the attention, because it sensed that something is going wrong. Cues can be an event that occurs in the world, such as something that breaks down, or a small anomaly from what is expected. It can also be something that is said by someone, that incites an idea or a problem with someone else.

What was found is that designers are more than others reacting to cues in the ongoing dialogue. They imagine what others say, reason out the consequences and respond to that:

> *"Why do you say that? This troubles me, because if it is right what you say, the user is guided to the wrong spot."*

Designers extrapolate what is said; imagine the consequences for the intended product and translate it in such a way that it is understood by others. As designers pre-eminently are concerned with the eventual product and the user, they are skilled and trained to make the leap between what they see and/or hear and the intended product.

Also, designers easily translate their ideas into vivid representations. They make quick sketches of preliminary ideas; photo-realistic renders of how a product might look like; animations of how a user interface may look like; and so on. Instead of using generic and multi-interpretable language, they have the skill to show well what is on their mind. These representations are sufficiently to the point that everybody 'gets the picture'. Often these representations facilitate a dialogue, enabling others to agree or disagree on what the designer shows.

FINDINGS (2): THE BOUNDARY SPANNING PRACTICE OF DESIGN

In short: what discerns designers in multidisciplinary teams is that designers imagine, visualize and discuss what the intended product is, while interacting with team members. This ability has a particular contribution to NPD teams, as will be discussed in this section. In short, it enables to span complex boundaries inside team. Also, the designers in the study were not nominated to span boundaries nor had an inclination to span boundaries. It poses an intriguing paradox, and it will be argued that this paradox can be solved by taking a practice perspective.

Designers spanning a boundary

In order to learn about the interactions between designers and other team members, a dedicated study was conducted. Team members were interviewed in a semi-structured way about their activities, who they collaborated with, the order of activities and so on. Across the interviews, it was possible to map the patterns of relations among team members: who collaborates with who, in what way and when.

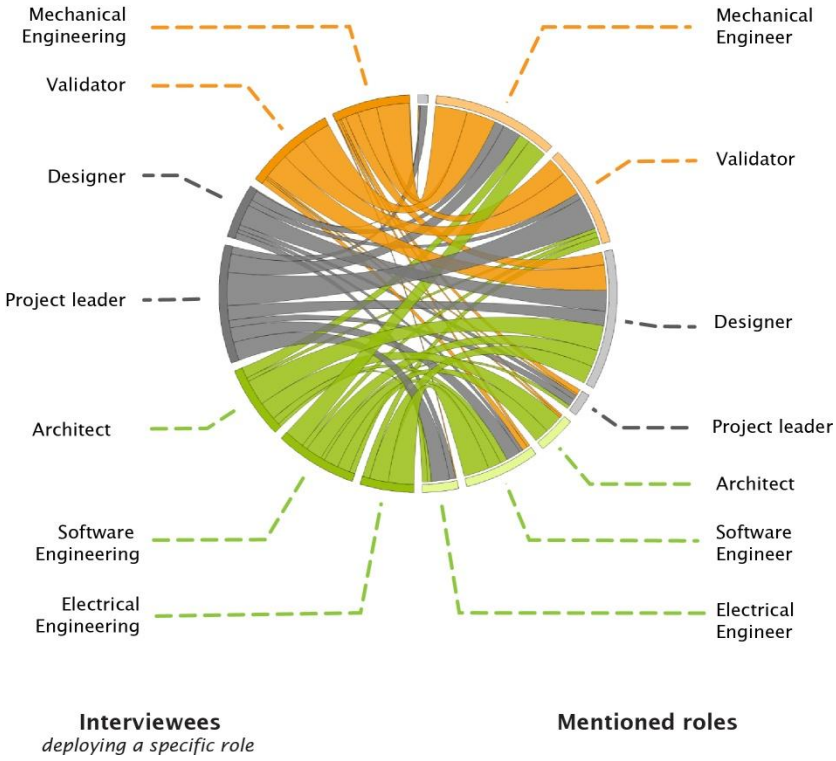
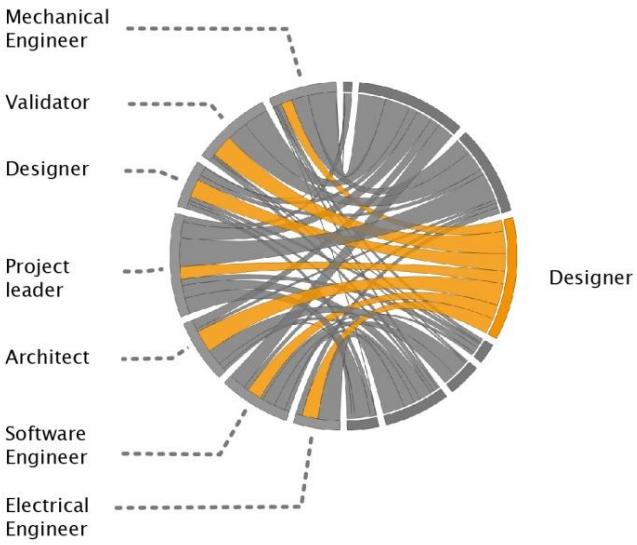


FIGURE 4. A visual depiction of the relations between hard- and software related roles inside a multi-disciplinary NPD team. For the visualization CIRCOS software is used, and an explanation is provided in the text.
What can be seen is that hardware related roles, such as mechanical engineers, hardly interact with software related roles. There are no ribbons from top-left to bottom-right. Likewise, software related roles hardly discussed interactions with hardware related roles, as there are also only few ribbons from bottom-left to top right.

The analysis laid bare a boundary between hard- and software engineers. Across this boundary, team members did not know each other *("what is his name, I forgot?");* didn't knew what knew what the other does *("I suppose he contributed to that some way")*; or what someone's role is *("I really don't know what his role is, to be honest").* More important, across the boundary, team members hardly interacted. Figure 4 represents the findings visually. The circle depicts the number of occurrences a specific disciplinary role is mentioned and by whom. On the *left* side, the segments depict the formal roles of the interviewees. If this segment is wide, the interviewees having a specific role mentioned of other roles. On the *right* side the segments concern the number of times a specific disciplinary role is mentioned in the interviews. If a segment is wide, a role is often mentioned by the interviewees, i.e., it is a role many team members interacted with. Wide ribbons across the circle depict that interviewees occupying a specific role often mentioned another role, i.e., interacted often with these roles, according to themselves. In Figure 5, the hardware related roles and software related roles are articulated. The small top segment depicts non-R&D roles that for ORE were hardly mentioned.

The figure expresses that software related specialists hardly mention hardware roles, or the activities of hardware specialists. Vice versa, hardware related specialists seem to overlook software specialists.

Interestingly, across the boundary many differences could be found. For example, the jargon differed considerably, distinct tools were used, and each group had specific prototypes and so on. Also the timing of activities varied: when hardware nearly finalized its activities, software was ramping up activities.



If the same dataset is used to analyze how often the role of designer is mentioned, it is found that designers were named by all and fairly evenly distributed (Figure 5). Apparently designers sit amidst the practices of hard- and software and have a boundary spanning capability.

FIGURE 5. A visual depiction of the occurrences that designers are named in interviews. It is the same figure as shown in Figure 4, however, designers are highlighted. Designers were relatively often named, and evenly distributed by all specialists. It shows well that the designers interacted with both hard- and software specialists.

Designers were mentioned by all because they bridged between two practices that found it hard to understand each other. For example, an interviewed mechanical engineer mentioned:

> *"So there were persons who made a link between the dependencies in the controller software and to the inner parts of the printer engine. Including the handles, the inner covers, the accessibility for an operator, and the like. The concept behind that…. That was the work of the designers".*

The interviewee explained that it is hard to see the relationship between the inner parts of a printer, such as a handle (the practice of hardware) and controller software, such an error code (the practice of software). However, the relationship can be established by means of projecting what a handle and an error code implies for the user. The implications for a user, such as accessibility, is an issue that is understood by all and can be reflected on across practices. All team members understand more or less 'products' and 'users'. The skill to imagine the consequences of technical choices for the intended product enables to share knowledge across difficult boundaries that exist within a NPD team. Providing a common language by means of the intended product facilitates knowledge sharing across boundaries.

The practice of design as an intermediate

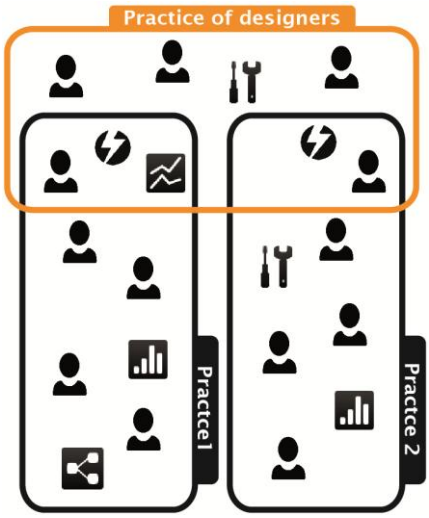
Next to the discussed boundary of hard- and software practices, in a stakeholders analysis (Stompff 2012) it was found that designers also can span the well known boundary between the practices of marketing and R&D. For example, an interviewee explained:

> *"And then this competency, I really appreciate it, which is about transferring the message from R&D towards marketing and sales. So this may seem to be a kind of low profile, but it really makes the difference....." (VP Business Development).*

Apparently, it is hard to 'get the message' across, and designers have capabilities to do this. It was observed, for example, that in a meeting developers and marketers had problems understanding what the implications were of some requirements that were important for marketers. However, once sketches of a user interface were shown, the implications were immediately understood by all, moderating the discussion considerably.

The finding that designers sometimes span troublesome boundaries and have a contribution to the creation and knowledge sharing inside NPD teams was persistent across the studies. By means of experiments, even promising results were obtained to span difficult language and cultural boundaries in teams composed of several organizations.

Strangely, the designers themselves were unaware of this contribution, regardless of the kind of boundary that is spanned. Designers span boundaries between practices, not because designers are (nominated) boundary spanners, but because it is the practice of designing that spans boundaries. Designers translate any topic into the realm of user and product, a language that is understood by marketers, hard- and software specialists. Designers have a holistic orientation to problems, integrating a range of problems that belong to distinct practices, rather than attempting to solve these within a practice. Also, designers not only imagine what might be but also develop vivid representations providing a common language for all involved. By means of looking at a proposal for a user interface, a mechanical engineer can learn what the intended software behavior of the system is. By means of a persuasive render of a product, a marketer learns what the NPD team is developing in time. The human-centered framing on any topic designers encounter facilitates that team members learn about relations across practices, as their activities in the here-and-now are 'projected' onto the intended product.



Interestingly, designers are not part of one of the practices in between a boundary exists, and thus are not archetypal boundary spanners. In order to do their work, they have to participate with the two practices in between a boundary exists in order to obtain their aims: such as a high usability and a good user experience. Consequently, designers built a bridge that spans the two practices, often without being aware of it (Figure 6).

FIGURE 6. A model showing how the practice of design spans boundaries between two other practices in between a boundary exists, such as the practices of soft- and hardware.

DISCUSSION: MIRRORING TEAM ACTIVITIES

If specialists deploy distinctive tools; built and test their own prototypes; have a characteristic jargon; are located at different sites and so on, their practices hardly

overlap. In those situations, the specialist will find it hard to understand each other and thus, to align and coordinate activities. The practice of design enables team members to learn about what the product is about they contribute to. And what the impact is of technical choices on the intended product, cross-disciplinary. Designers interpret what requirements and technical choices possibly mean for the intended product. Also, they are capable to express their interpretation by means of sketches, renderings or demonstrators of user interfaces. These are representations of the intended product, but not like text based documents e*xplaining it or to specifying it.* Rather these representations are *expressing the intended product.* Expressions that provide 'the big picture', a macro view on what the product is about. Expressions that are compelling, elegant, and easily obtaining commitment. For example, it was observed that team members have prints of designerly sketches prominently exhibited in their working place. Expressions that show the product loosely and appealingly, capturing the essence rather than all sorts of details, like a list of requirements.

It is a language that is understood by all, including specialists who may have a hard time understanding each other. It provides a 'common ground', as most specialists can understand the consequences of technical choices of other specialists, once these choices are translated to the realm of the product/user (see also Stompff et al. 2011). These representations are robust enough to maintain a common identity across practices, yet are sufficiently 'plastic' to be adapted to distinctive interpretations within practices.

We named the boundary spanning capabilities of designers 'mirroring', because the translation of technical choices to the realm of product/user is like holding a mirror in front of the specialists. A mirror that shows the consequences of technical choices and enables to reflect on these choices, cross-disciplinary. A mirror that shows the whole, rather than its parts, and enables to span boundaries across practices.

Mirroring possibly explains why designers surfaced as 'technology brokers' across industries (Hargaddon and Sutton 1997), as the swift translation of technology to the realm of products and users enables others to understand the potential of unknown technology. Likewise, mirroring explains the finding that designers enhance communication in multi-disciplinary teams (Perks et al. 2005). By interpreting and translating technical choices for their implications on product and user, designers facilitate dialogue and discussion between specialists and departments. And lastly, mirroring highlights a specific aspect of 'design driven innovation' (Verganti 2009). Namely, that in order to enable the 'discourse' among 'key-interpreters', expressive means are needed, that show propositions; rather than text based requirements.

The above may suggest that mirroring is about goal setting, drafting a vision that is 'executed' by others. However, mirroring must be conceived as a process *parallel* to other development activities in NPD teams. The representations of the product made by the designer are a result of the many and ongoing interactions between designers and other specialists, while developing the product. Already in early phases of an NPD project, designers produce representations that show the intended product, based on what they interpreted. Interestingly, these are the only tangible and visual representations of the product in these early phases. Thus, these are a valuable addition to requirements and project briefs. An interviewed project leader explained it well:

"We are still learning what the project is about. (..) We need to have a mock up [a 1:1 model of the product] as soon as possible, so that we can invite everybody around it…so that everybody knows what we are doing in the first place".

Also, a NPD team inevitably has to deal with many surprises, such as new legislation; products that are launched by competitors; changing requirements and technical drawbacks. What the intended product needs to be is constantly adapted to the latest insights. Consequently, the representations of the intended product need to be adapted. Thus, mirroring is actually a team effort, facilitated by specific capabilities of designers. It starts with crude sketches and cardboard models, and in time becomes a detailed representation, e.g. a demonstrator of a user interface people can experience or a real-life model of the product. These representations become a genuine mirror of team efforts. In short, we conceptualize mirroring as *the continuous redrafting of what the product will be, in increasing levels of detail.*

CONCLUSIONS AND IMPLICATIONS

The qualitative study adds new insights on the topic of (user-centered) design. The main finding is that designers have an additional contribution beyond their formal role, as their practice spans complex disciplinary boundaries inside NPD teams. Boundary spanners are in literature conceptualized as individuals who facilitate the sharing of knowledge by linking two or more groups of people separated by location, hierarchy, or function. These boundary spanners belong to one of these groups. In this inquiry the boundary spanning capability of designers was found, yet this capability needs to be conceptualized somewhat differently. Some specialists have trouble understanding each other, as their practices hardly overlap. The activities of designers adhere to the intended product. Designers swiftly translate any topic they encounter to the realm of product and user, and vice versa. Thereby they express what they conceive and interpret into vivid representations of the intended product. Representations that are compelling, coherent, elegant, unified. Expressions that operate in the domain of human experience, namely that of product and user. It provides a platform for other team members to understand and reflect on technical choices, cross-disciplinary. Hence, the practice of design spans troubling disciplinary boundaries inside NPD teams, such as between hard- and software, or between marketing and R&D.

The first implication concerns NPD and NPD management. NPD teams are nowadays often composed of teams that are spread across the world; belong to different organizations; hardly meet face-to-face; speak different first languages, and so on. Put differently: teams are distributed and apart from disciplinary boundaries, several other boundaries exist, such as organizational and/or cultural. Also, these teams hardly have a joint practice, as they deploy different tools, language, objects and methods. We believe that in those situations the ongoing development of representations of the intended product - i.e., mirroring - are critical for aligning and coordinating activities. That is what designers can contribute, if they are part of the multi-disciplinary teams. Some of the experiments were targeted to span complex organizational boundaries in NPD teams, and the results are promising.

The second implication relates to designers and design management. Designers and organizations are often unaware of the boundary spanning capability of the design practice. For example, designers are often separated from NPD teams spatially and temporary, often located in a 'creative' design studio with specific tools and methods. However, we believe that this separation reduces the positive effects the mirroring capabilities of designers have on NPD. Mirroring is conceptualized as the dynamical and ongoing redrafting of representations of the intended product. It facilitates interactions with other team members, including awareness of choices being made. For mirroring to be effective it requires that the activities and artifacts of designers are transparent to others. E.g., if others can see preliminary sketches of designers, they learn about the intended product and can respond or discuss with designers whether or not the 'big picture' that is drafted is correct. Thus, we believe that designers need to be embedded some way or other within NPD teams, not different than many other disciplines as mechanical or software engineering.

The third implication concerns design education. The unawareness of the boundary spanning capabilities of design is also reflected in theory, textbooks, teaching and research of designers, as topics as 'multi-disciplinary teams' are largely missing. At one hand, this seems not be a big problem, as designers moderate boundaries anyway, simply by means of their activities, their user-centered outside-in framing and their expressive artifacts. On the other hand, designers who become aware of this capability can knowingly enhance alignment and coordination inside teams. Or even incite new, exciting NPD projects (Buijs 2012). So, why not bring this quality explicitly to the students and let them experiment with it instead of waiting till they realize this after many years of design experience. Such a capability enables them to bridge isolated practices and might be particularly valuable for distributed teams from day one. Mirroring is an art that can be mastered, so start as soon as possible.

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