Surprises are the benefits

Understanding (re-) framing in multidisciplinary design practice

Abstract

New Product Development (NPD) and design are social processes as many specialist work together on one -eventually- integrated product and/or service. Thereby aims have to be defined and negotiated, likewise who does what and in what order. This paper explores the inherently social dimension of NPD, whereby teams of individuals have to collaborate.

The perspective taken is Schön's refection-in-action; a perspective that is one of the dominant paradigms in design research. However, Schön's reflection-in-action neglects the social dimension, as it originated from describing individuals and individual designers. This paper attempts to fill the gap, by describing an in depth study on NPD teams in the wild and how the reflective practice manifests at the level of a team, as the team of specialists aligns and coordinates activities into a unified and coherent whole.

The first finding is that (re-) framing, an essential ingredient in Schön's vocabulary, is an explicitly articulated team activity in a social context, requiring ample time and effort. An activity with the aim to find a new productive frame for all involved, yet that has distinctive features, setting it apart from other steps of reflective practice. The second finding is that this process of (re-) framing has three iterative stages. First, the team detects a surprise, which contradicts prior expectations. For teams, this is not as arbitrary as it may seem. Subsequently, the team has to make sense of the situation they are in. Eventually, the team engages in what we named future framing, an activity that we defined as "the ongoing development of plausible images *of what we will create together*, that rationalizes what we are doing". A new and strong guiding frame is established, only if (1) the constituents of the situation at hand are understood, (2) the relations among the activities of specialist reestablished, and (3) a future frame is developed that extrapolates and enables to reflect on imagined future activities. This frame provides guidance for subsequent activities of individual specialists, who can progress relatively on their own.

1. Introduction

New Product Development (NPD) is process that inherently is complex and requires knowledge of many distinctive specialists. For example, for the development and engineering of a printer mechanical engineers; software engineers; chemists; physicists; strategic planners; marketers; user-centered designers, and the like all need to collaborate closely, in order to develop one unified and meaningful whole. A key process in NPD is designing, which in this paper we consider in a cognitive stance, namely as a characteristic way of problem solving. The briefest definition of design as a cognitive activity was provided by Hrbert Simon:“everyone designs who devises courses of action aimed at changing existing situations into preferred ones” (1996 3rd ed.: p.111).

In design theory, several paradigms on the process of designing co-exist (Bousbaci 2008; Coyne 2005; Crilly 2010; Dorst 1997, 2006; Gale 2011; Melles 2008; Verganti 2009). Mostly a watershed s discerned: on one hand a ‘rationalist’ paradigm is articulated, based on the work of Simon (1996 3rd ed.). It focuses on solving problems in a rational way, and has its zenith in engineering oriented design theory. On the other hand a ‘situational’ or ‘practice-based’ paradigm exists, based on the work of Schön (1983), who described the 'reflective practice'. The latter paradigm focuses on solving problems by experimenting in practice and reflecting on it. The hallmark publication of Schön is the inspiration for an extensive body of literature on design,

above all because it is shown that reflection-in-action is well adapted for design processes (Dorst 1996). The resulting debate of opposing paradigms we will not enter, as it is authoritatively developed by aforementioned scholars.

Instead, we discuss an empirical, long term study on NPD in the wild, described and explained on the base of Schön's reflective practice. Schön described the reflective practice of practitioners, that is: individuals. However: NPD concerns teams of specialists, an aspect that is seldom discussed in relation with the reflective practice. Putting the focus on teams rather than individuals highlights the inherently social dimension of cognition in NPD. In NPD problems and solutions are seldom mono-disciplinary and many relations exist between the activities of specialists. For example, the cooling of a product requires electrical engineers to decide on fans; mechanical engineers to mount these fans; software engineers to write embedded software; product designers to provide slots in covers for the discarding of hot air; sound specialists to reduce the inherent noise, and so on. Specialists have to collaborate, discuss, inform, interpret, negotiate, and co-design, in order to develop a unified whole: a product. As a team they have to think 'collectively', what we refer to as 'team cognition'. This is defined as the binding mechanism that underlies the observable coordination and alignment of activities of interacting team members, while dealing with situations that are encountered (Stompff 2012). In this paper we explore Schön' reflective practice to describe and understand how multidisciplinary teams of specialists co design, and show that the process of 'reframing' is much more articulated and time consuming for teams than for individuals.

Outline of the paper. First we will discuss the theory of the reflective practice, at the level of individuals and for teams. We will discuss the key mechanisms and a framework for analysis. Second we describe the findings of a long term empirical study and specifically an in-depth video analysis of a team of specialists dealing with a genuine surprise. New insights on the process of reframing are presented. Third, we synthesize our findings into an adapted framework, for the reflective practice of teams.

2. Theory: the reflective practice for practitioners and teams

Schön theoretical foundations are to be found in Pragmatism, a philosophical school developed by scholars such as James, Peirce, Mead, Dewey, Blumer, Rorty and Putnam. Above all the work of John Dewey surfaces in Schön's publications (e.g. Schön 1995) and it is hard to comprehend the reflective practice outside this context. For example, Pragmatism denounces the classic object-subject duality, i.e., the distinction between the world that unfolds (object) and a an observer (subject). This duality raises questions on how mind relates to the world and is heavily criticized by pragmatist thinkers, and also e.g., by Ryle (1949) and Polanyi (1966).

2.1 The individual reflective practice

Schön describes the design practice as a ‘reflective conversation with the situation’ (1983, pp. 76-104). The core elements of designing are actions, and designers progress by a range of ‘move-testing experiments’. This is illustrated by Schön by means of an excellent protocol study of an experienced architect (Quist) interacting with a student (Petra), while designing a school for a ‘screwy site’. Quist imposes a ‘kind of discipline’, to provide coherence to the site. It is not that Quist exactly ‘knows’ where he is doing, rather the ‘discipline’ sets the problem at hand in a specific, subjective way. Quist is ‘seeing’ the situation ‘as’ something already present: a ‘frame’. Consequently, Quist does a range of experiments within the frame by means of sketching, to explore and reflect on the effects and unintended by effects of his ideas. In Schön’s vocabulary: the sketches ‘talk back’ to the practitioner.

The pragmatist origins surface clearly in his famous protocol. First, Pragmatism starts from the premise that humans interact with the world: humans are not inert observers in an independent world, but are part of the world, and by their activities actively constitute reality.

Cognition can no longer be explained as an 'internal' process apart from the ongoing flux of events in the world 'out there'. Rather, cognition must be considered as the binding mechanism of coordination in individual action and behavior, dynamically responding to the flux of events. Knowledge is considered a limited and theoretical notion as it does not manifest apart from practice: it emerges from actions. Pragmatists preferred the phrase ‘knowing-in-action’ instead (Cooke & Brown 1999), to express that knowing enables us to cope with the dynamic equilibrium we are part of. Quist does not 'know' a priori what the school may look like, until he made some sketches that enabled him to reflect. He 'learns while doing' (a maxim attributed to Dewey) in order to "to make an artifact that is coherent and an idea that is understandable” (Schön 1983 p.136).

Second, according to Schön, the design practice of Quist and Petra revolves around the sketchpad. In a truly Pragmatist vein, he discusses design as a reflective conversation *with* the situation, and the sketchbook is “the medium for reflection-in-action (..), because the drawing reveals qualities and relations unimagined beforehand” (Schön 1983, p.157). Both the act of sketching and the sketches themselves are crucial ingredients of the reflective practice. The operating (design-) cognitive system includes the designer and his sketchbook, as the sketches enables moves and reflections. Quist only knows how to design in action*:* while sketching.

Possibly one of the biggest challenges for scholars is that Schön developed a vocabulary without providing concise definitions and/or models. To analyze the activity of designing, Dorst and Valkenburg (Dorst 1997, Valkenburg & Dorst 1998, Valkenburg 2000) developed a model that is schematically depicted in Figure 1. Designing revolves around four activities and these are shown, including their interplay. Designers progress by *naming* relevant factors, setting boundaries to what they perceive to be of importance. This naming imposes a *frame*, basically a context for following activities. A frame is a key construct in this paper, we define it as a perceptual framework that categorizes what we see, what we know and guide our conscious thinking (Weick 1995, pp.109-110). Framing is a cognitive process that directs the designers action (Dong et al. 2013). Consequently, a frame is *productive*, i.e., provides guidance for future activities. In a frame *moves* are made: proposals, (mental) experiments, arguments and so on. By means of *reflecting* the value of these moves are considered. Does it solve the problem at hand, is the outcome conform expectations, is something else required? These reflections can evolve into more moves, but also into reframing a problem, as the original frame no longer seems to be appropriate. In the latter case, another frame for guiding activities is embraced, by means of a process of *reframing.*

Although the model is a convenient means for analysis, it unintentionally deemphasizes a key element of Schön’s theories: surprises. Sometimes events happen that were unexpected and therefore do not fit any preceding frame. For Schön, a surprise initiates a refection-in-action process: "Something falls outside the range of normal expectations (..) the practitioner allows himself to experience surprise, puzzlement or confusion in a situation which he finds uncertain or unique. He reflects on the phenomena before him, and on the prior understandings which have been implicit in his behavior. He carries out an experiment that serves to generate both a new understanding of the phenomena and a change in the situation" (Schön 1983: pg.68). A surprise is unsettling for a practitioner, not as much because it is problem, but rather because it is not meeting his expectancies. First the problem setting needs to be done, whereby the practitioner needs to make sense of the situation at hand, turning his puzzlement and doubt into a more or less defined problem and a frame for subsequent moves.

For Pragmatists, experiences are central as these are rooted in the interactions between humans and the environment. People perceive the world, however what they see is mediated through a process of interpretation as a result of our prior knowledge, experiences and so on (Dewey 1934). In the ongoing stream of events that is minded, some events are noticed and bracketed because they do not meet expectancies, such as a surprise. People suddenly are in a doubtful situation: the situation is indeterminate as no longer the outcomes of activities can be

predicted. Conscious thinking is initiated, showing that consciousness emerges as a result of interacting with the world (Dewey 1938: p.26). In order to deal with the doubtful situation, an 'inquiry' starts: the controlled or directed transformation of a doubtful situation into a situation that is understood, including how to act (Dewey 1938). Although the logic of an inquiry according to Peirce and Dewey are not entirely the same (Talisse 2002), an inquiry concerns (1) the institution of the problem, i.e., problem setting; (2) devising and performing an experiment and (3) reflecting on the outcomes. If these experiments are conform expectations, the doubtful situation is understood.

Of interest here is that the aforementioned notational system of Dorst and Valkenburg does not include surprises, as a ‘surprise’ is not an activity, like ‘moving’ or ‘reflecting’. However, according to us a surprise is pivotal, as it stalls previous activities. Therefore we adapted the notational system by introducing ‘surprise’ (Figure 1).

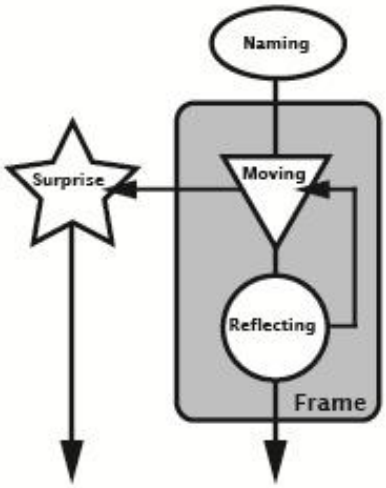

Figure 1

A model for the mechanism of the reflective practice (adapted from Valkenburg & Dorst 1998; Valkenburg 2000). It depicts an overview of the activities and their relations. Naming provides the boundaries of things or events a team attends to. Frames provide the context for activities as moves and reflections. Moves are experiments, proposals, arguments. Reflecting concerns the activities whereby the results of these moves are considered in relation to the problem setting. This can result into more moves, or a reframing. In the original model (Valkenburg & Dorst 1998) surprises are not incorporated, but these are fundamental in the vocabulary of Schön (1983). While doing a move, something occurs that was not expected at all, that is falls outside the frame operating. Surprises result into new names and frames.

2.2 The team reflective practice

Team design introduces the social dimension, and also for the paradigm of the reflective practice this implies new challenges. A kernel idea of the reflective practice is that any practitioner subjectively interprets the situation he is in: he frames the situation. This framing is a result of prior experiences, education, and the like. Each team member in a design team frames the situation differently. Consequently, specialists in NPD teams have trouble to understand each other (Bucchiarelli 1993; Carlile 2002; Dougherty 1992; Kleinsmann 2006; Smulders 2006; Stompff 2012). They deploy distinctive tools and models. They speak different jargon. They have distinctive and often contradictory aims. Also, modern NPD teams are often distributed across sites and organizations, e.g., for knowledge access or cost efficiency. Consequently, teams are spatially, culturally and / or culturally dispersed. In short, the specialists inside this kind of teams have quite distinctive practices. This puts forwards questions like how modern NPD teams align and coordinate their activities.

The reflective practice in teams is hardly studied empirically. Team framing is a collective activity that is performed through exchanging what team members know (Valkenburg & Dorst 1998) and it has been argued that it is discursively constructed during collaboration (Dong et al 2013). Valkenburg (Valkenburg & Dorst 1998; Valkenburg 2000) developed a method to analyze design teams according to the reflective practice, providing a concise description of design activities in the team. She found that design teams reveal different patterns, suggesting that possibly not all designing is according the reflective practice. Other scholars applied and reviewed the method as developed (e.g., Dong et al. 2013; Kleinsmann & Valkenburg 2008; Stumpf & McDonnell 2002), showing the reliability of the method. However, these studies all concerned experimental settings with student teams (McDonnell et al. 2004; Valkenburg & Dorst

1998); few designers doing an exercise (Stumpff & McDonnell 2202) or playing a game (Dong et al. 2013). These situations are quite different from the situation modern NPD teams find themselves, that include many specialists.

No studies have been done for the reflective practice of multidisciplinary teams, yet these kind of teams challenge the reflective practice paradigm at its core. Specialist have to align and coordinate their activities into a unified whole, yet the whole is unknown at first and only becomes known in time. We believe that strong and productive frames are crucial for such teams, as it provide guidance to individual specialists how to approach a problem; what may be considered an expected outcome and what not; what is a preferred solution and why; and what aims the team strives for. Our interest is the content of the design activities, what the team is developing: the eventual product, software applications and/or service. We believe that the process of (re-) framing is crucial for the development of content in a multidisciplinary NPD context. It leads to two research questions we explore by means of a qualitative empirical research:

- Is Schön's paradigm of the reflection-in-action suited for multidisciplinary design practice?
- How do multidisciplinary NPD teams develop guiding frames and reframe?

3. Method

3.1 Context

Our aim is to describe and understand team reflection-in-action of multidisciplinary teams in-the-wild. The study described here was part of a larger research that studied team cognition and the specific contribution of designers in the everyday practice of NPD (Stompff et al. 2011; Stompff 2012; Stompff & Smulders 2013). This concerned a participatory field study, within a large NPD organization over a period of two years (mid 2008 - 2010). The NPD organization is part of a large, high tech multinational company. The company delivers business-to-business printing solutions in a range of markets, including printers; software; consultancy and services. These products, software and services are developed by a R&D organization of 2000+ employees that is based in nine different countries around the world. A topic was chosen that well represents multi-disciplinary NPD teamwork: developing means that enable operators of a printer to solve paper jams that occurred. This topic is named Operator Recoverable Errors (ORE). In the company at hand, ORE is known to be a notoriously complex topic that impacts the work of many developers including mechanical-, software-, and electrical engineers; product- and interaction designers and quality assurance specialists.

Rather than having a participating external researcher, the data gathering was done by a product designer belonging to the NPD organization, one of the authors. In this way a wide range of data could be collected, including full access to internal archival records; 29 semi-structured interviews with team members and stakeholders (transcribed and coded); participatory observations (documented in a research journal); 30 hours of filmed team meetings (partly transcribed and coded); 100+ photos of artifacts, including sketches, prototypes, paper models and so on.

After data gathering, several distinctive studies were done, deploying the same dataset. The analysis of the data was postponed six months to reduce reflexivity Each of these studies had a specific aim and research question, yet all studies together reveal a cumulative and progressive character, revolving around the same topic: team cognition. Over the distinctive studies, several methods were used, to consider the subject matter from different perspectives (triangulation of methods). Each of these studies were prepared and analyzed together with other evaluators, both external (in total 7 researchers) and internal (in total 4 practitioners). Thereby the co-researchers varied across the individual studies (triangulation of evaluators).

One study concerns the team reflective practice and is presented here. An in-depth video analysis is made of a critical team meeting, deploying Valkenburg's method. This meeting lasted an hour, and thus provides a somewhat limited view on team reflective practice. Thus, also insights from other studies (Stompf 2012) are used; such as a journal analysis of participatory observations for analyzing long-term aspects; and quotes from interviews.

3.2 Video analysis of the team reflective practice

According to Schön, surprises instigate reflection-in-action. Yet, team surprises cannot be predicted in a real life situation, otherwise it would not be a surprise. "Methodologically, it is hard to find people in the act of coping with disconfirmations that catch them unaware" (Weick et al. 2005: p.415). So, in the thirty hours of filmed meetings of the team we chose a meeting for further analysis, whereby a genuine surprise was encountered. In this meeting, eleven specialists gathered around a prototype to analyze and solve a multidisciplinary problem. A sheet of paper could get stuck in between two modules and become inaccessible for an operator to remove it. The team discussed the problem in a previous meeting in a meeting room, but decided that without a tangible prototype it was an impossible task. So they rescheduled the meeting to have an assessment of the situation at a prototype. Somewhere half way the meeting, the team discovered that if they jammed the printer intentionally at the specific position, the jammed sheet was removed 'miraculously'. For some reason, a motor started to flush the sheet out, even before they could access it. The team experienced a genuine surprise, as nobody expected that to happen. Only in hindsight it could be established that a lucky combination of prior activities lead to this behavior.

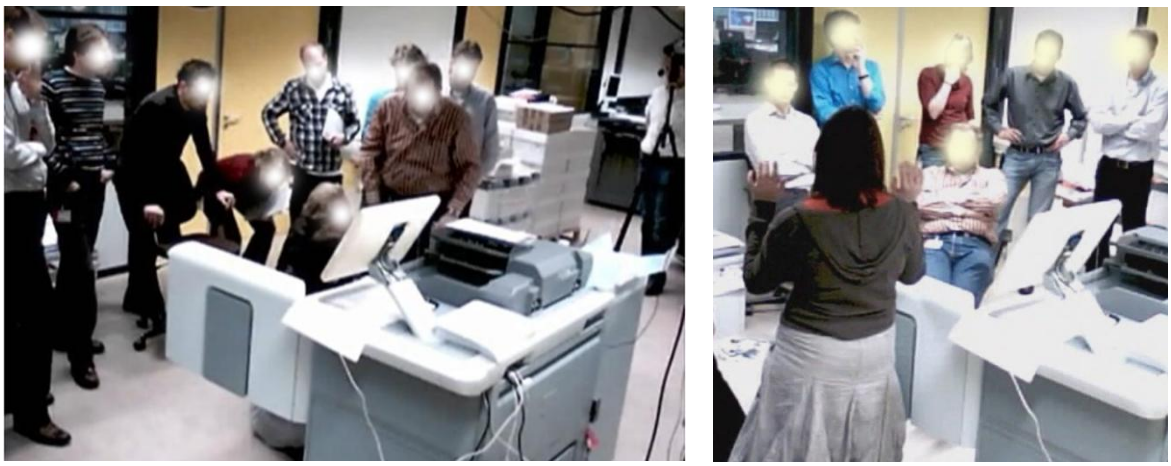

Figure 2

Left: The setting of the team meeting, staged around a prototype. In the back, as second camera is visible. Right: A moment that is marked as (potentially) meaningful: a team member proposes a solution, saying: "one could make a 'next' button, that sais…" (45.10). Thereby she acts out the parentheses around the word 'next' with her hands.

To analyze, we focused on content rather than individuals. Taylor (2005) argued that in empirical sociological research two 'world views' exist. The most commonly used is to focus on the individuals, and how they argue, negotiate, debate, discuss and decide. Such a research highlights distinctions, contesting aims, power and so on. The second worldview focuses on the content. This worldview considers how individuals *collectively* create the content of the topic; a topic is being discussed by means of several agents. This worldview is less preoccupied with debate, conflicts and so on, and focuses on content, which is of interest here. The specialists in the analyzed video are putting forward pieces of information of what they know, and all this knowledge is needed in order to progress. Together the team members create a kind of

monologue, assembling and synthesizing collectively the content. We named this a ‘team monologue’.

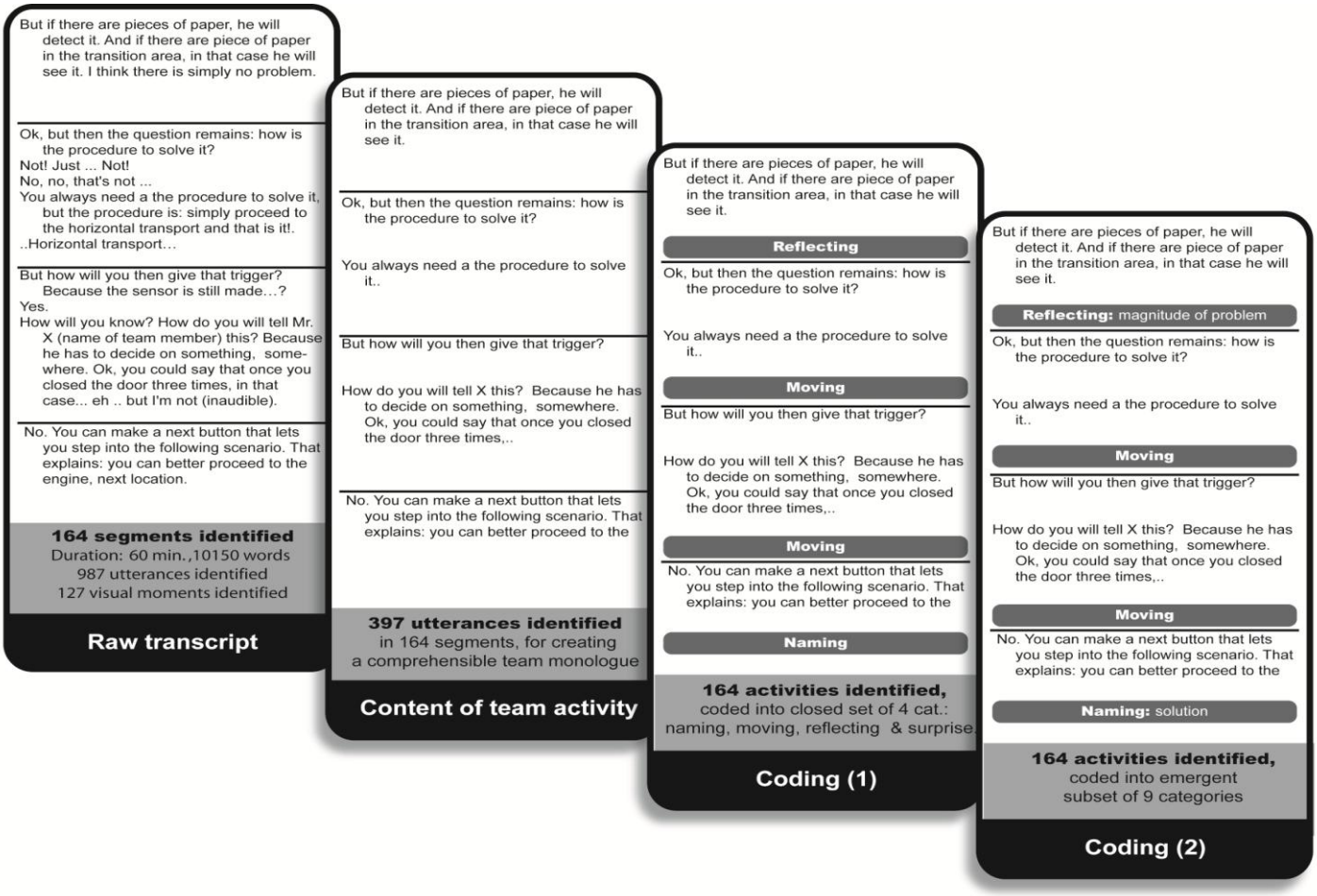

Figure 3
The steps of coding the raw transcript according to the method as developed by Valkenburg (2000). This is explained by means of the 4 steps in the text. Only the coding into subsets is not part of the original method, as is explained in the text.

Valkenburg (2000) developed an extensive reflective coding scheme for studying videos of designing teams. We inserted an additional step (step 4, below) to code the type of reflection and naming. The distinctive steps are:

1. *Preparing data (Figure 3).* The meeting is fully transcribed, as is spoken out by team members[1]. Anything someone mentions that has topical cohesion is considered an utterance, and in the meeting of nearly one hour 982 distinct utterances are identified. Also a storyboard of screenshots is made of (potentially) meaningful moments, e.g. because people kneeled down to see something, or used non-verbal gestures (see Figure 2). In total 127 moments are marked as (potentially) meaningful.
2. *Cleaning the transcript.* First, the raw transcript of the meeting is divided into segments of meaningful team activities. This implies that the raw text of 982 utterances is divided into coherent segments of activities according to the reflective practice. In total 164 segments were identified. Second, the transcript is cleaned into a *content of team activity*, where a coherent and comprehensible team monologue remains. This concerns removing utterances in the segments that have no contribution for understanding the team monologue. The

[1] Note that the meeting was in Dutch, and the analysis is done in Dutch as well. All quotes from the meeting in this paper are translated, thereby inevitably introducing a loss in the translation process.

remaining content of team activity can still be understood well. It consisted of in total 397 utterances, i.e., approx. 40% of the original utterances are used.

3. *Coding (1).* Coding is done by two independent coders according the method as developed by Valkenburg (2000: pp.112 - 121). The segments of activities were coded into *a closed set of 4 main categories*. These are the aforementioned activities of naming, moving, reflecting and surprises (see Figure 1). These codings are compared. Disagreements are discussed, and if no agreement could be obtained, the specific data is not used (3 times out of 164).
4. *Coding (2).* We observed that there are different kind of reflections and namings. Some reflections e.g., concern the effects of a move, whereas others concern the consequences for future team activities, like planning. Or concern extrapolating the real-world context of the move, which may be different from an experiment with a prototype. The data suggested that the kind of reflections varies in time. Hence, a data driven and emergent coding scheme is developed. A part of the meeting is coded by two coders together to develop an emerging coding scheme. Subsequently, the two coders independently coded the meeting for the sub-categories. These codings are compared. Disagreements are discussed, and if no agreement could be obtained, the specific data is not used (1 time out of 164). All sub categories are defined and shown in Table 1, presented later.
5. *Visualizing.* The entire meeting is visualized on a timeline according to Valkenburg's notational system (Figure 1) and put onto a wall. Also the segments of utterances of the raw transcript that underlie a segment are added below on the same timeline, likewise the storyboard of the meeting. This enables to trace back any coding or finding to the raw transcript or video, establishing a chain of evidence (Figure 4).

Figure 4 .
Approximately 2/3 of the time line of the meeting is visible. The large map above depicts the team activities by means of distinct shapes according to the notational system in Figure 1. The timeline hanging underneath depicts the segments of the original transcript and the screenshots out of the storyboard. In the cut-out above, part of the emergent map is shown. More than one topic is dealt with simultaneously, or stalled for some time. This manifests itself on the timeline: vertically distinct lines of activities can be seen, depicted by the dotted imposed lines.

4. Results: patterns of activities in a multidisciplinary meeting

The turbulent meeting is described and visualized by means of the reflective practice coding scheme. A table is derived of all team activities, whereby all activities and subcategories are

analyzed on occurrence and order in relation to other (sub-) categories. Table 1 provides the distinct categories and sub-categories, including an explanation, examples, and occurrences. It shows, among others, that the team made relatively more reflections compared to the findings of Valkenburg (2000). We believe that this results from the interactions with a prototype. The situation at hand needed to be extrapolated to real life situations, requiring many reflections on the reality of the situation.

		Definitions	Examples	# 1st halve	# 2nd halve		Total	
Naming	Problem oriented	Frames the problem the team will attend to and / or add new problematic situations	*"Does anyone know where all the sensors are in the finisher?" (11:17)* *"hee (..) what I mostly see is that at that position mostly it s completely fumbled up!" (13:16)*	13	6	19	36	29%
	Solution oriented	Frames a potential direction of a solution the team will attend to in order to solve	*"Hee ..[names teammember]: a small light should be added here." (34:43)* *"..in that case we really have to improve that handle.." (38:08)*	5	12	17		
Moving		Proposals for activities, (mental) experiments, arguments	*Why don't we use this? [points to a small handle] (24:59)* *Could you access it from this side? [points to printer] (26:23)*	30	33		63	51%
Reflecting	On magnitude of a problem	What is the impact of the sub problem for the intended product?	*"How often will this occur in real life conditions and how bad is it than, really?" (20:50)* *"If you are rude you will have shredded paper" (26:13)*	9	6	15	57	46%
	On magnitude of a usability problem	What is the usability of the problem at hand (following active experiments)?	*"How many people will find this anyway? Because you really have to sit on your knees." (19:53)* *"Yes, but that bothers me: why would I [user] choose for 'next'? (45: 24)*	6	8	14		
	On reality of situation	Are the moves representative for real-world situation?	*Is that [sensor] actually 'cleared' by opening the door?" (18:43)* *"This is not a realistic situation, normally that (sheet of paper) would fumble up". (24:36)*	10	2	12		
	On what happened	What explains the surpise that occurred?	*"You actually can hear whether it detects something?" [sensor]* *"It flushed it [sheet] past this pinch, so it was already in the other one. Apparently." (35:39)*	1	1	2		
	On technical consequences	What are the technical consequences of changes: work, cost, planning?	*"But in the end that would imply we only need to change one part" (48:39)* *"that means we have to test it 7x more. (..) That sucks.." (54:02)*	0	5	5		
	On analogies with previous	Are there relations between the move at hand, and decisions made before?	*"what you said before: you solve it by flushing..that is not possible here" (12:02)* *Now that is interesting (..) that handle was precisely the same kind of handle here." (56:04)*	1	1	2		
	Summarizing	What is that we decided so far, and what it mean?	*That is one thing we know for sure: we will not pull it back!" (22:25)* *That bothers me as well: will we really make that handle? (..) or do we consider it rubbish? (39:59)*	1	6	7		
Surprise		Establishing whether a truly unexpected event is experienced by team as a whole.	*"Pay time! [the noise of a tearing sheet is noticed]" (25:57]* *"It [sheet] is actually not here anymore (..) Ooow (laughing)" (34:22)*	2	1		3	2%

Table 1

An overview of the team activities. On the left 4 main categories are mentioned according to the method of Valkenburg (2000). Nine sub categories are found in an emergent approach. On the right the occurrences

of each of the categories and sub-categories can be seen. A distinction is made between the first and second halve of the meeting, which is explained in the text.

The team activities are also conveniently visualized in a map, which enables to study for meaningful patterns in the activities of the team, across time. In Figure 5, a period of five minutes is shown, whereby the timeline is depicted vertically[2].

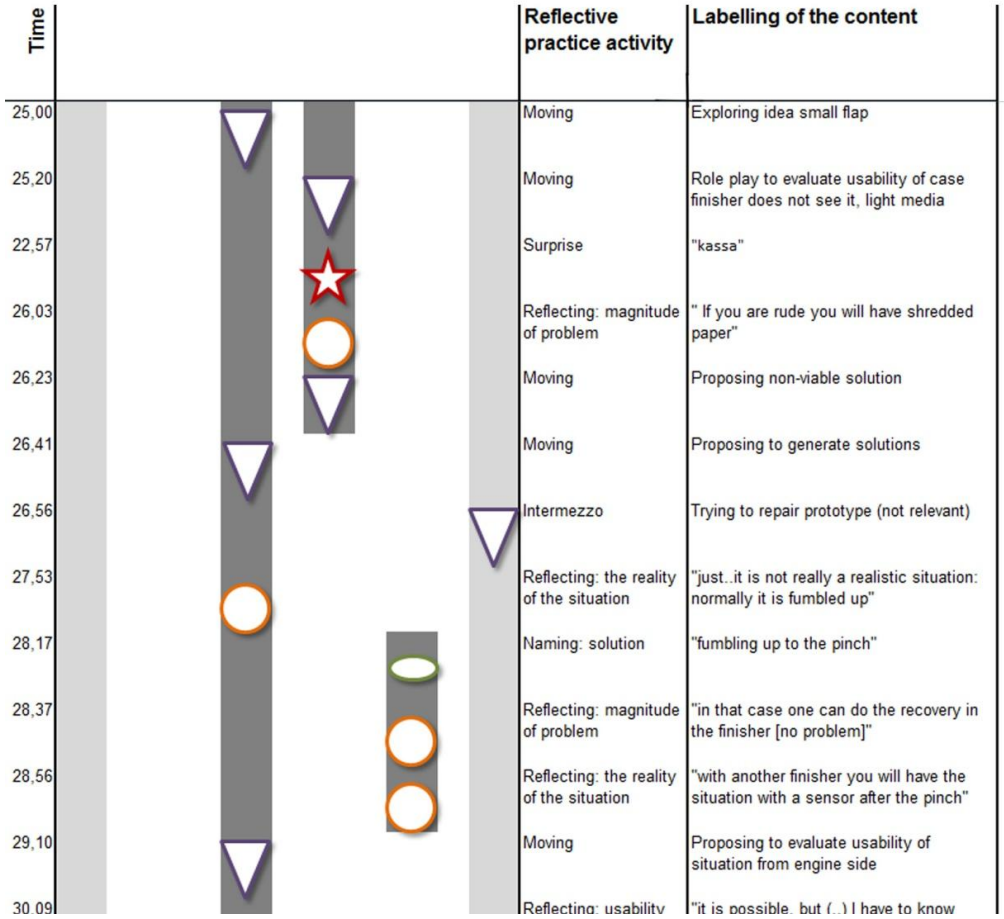

Figure 5
A slice out of the eventual map of the team meeting, according the reflective practice coding scheme. The time is depicted on the left, with the notation of the activities according Figure 1. The frames are accented as background boxes. The activities are mentioned in the middle, and the content is on the right. As some frames have relations with previous frames, the frames are not all aligned vertically. The column the frames are in depicts relation with other frames.

The team experienced three surprises, and these had much impact on the pattern of activities of the team, above the last one (around 34 minutes). Two distinctive patterns are discerned and are discussed below. Yet, only in hindsight it is possible to identify these processes in the stream of activities: while coding these different patterns were not observed by the coders. Arguably, also the involved specialists were unaware of the change.

4.1 A team sensemaking pattern

The first halve of the meeting poorly fits the reflective practice. Actually it was hard to code the first 10 - 15 minutes of the meeting according the reflective practice coding scheme. The main topic the team discussed altered continuously. Specialists shared their individual

[2] The entire map can be downloaded at designinteam.com.

knowledge on the topic at hand and conducted active experiments with a prototype. They attempted to assess who-knew-what on a specific matter. They named things or problems, on which others immediately reflected on the consequence for their own specialisms. Interestingly, most namings concern problems rather than solutions. Thereby, they questioned if the problem at hand is realistic or not: 25 (out of 28) reflections concern the magnitude of the problem including usability, or the reality of the situation. The team is actually not progressing in a reflective way, but assesses the doubtful situation they are in. What is the problem at hand, is it serious, are the considerations realistic? And who knows what on this specific matter?

Also some active experiments (moves) with the integrated prototype are conducted, that resulted into the 3 encountered surprises. Such surprises disruptively ended what the team was doing. Below a quote from the raw transcript shows this pattern, requiring knowledge of different specialists, and people reacting on what the others are saying at a high speed.

QA 1 A **heavy sheet of paper**…
D1 Hee what I want to say is: I often see that it often completely **fumbled up** over there..
D2 But heavy sheets of paper do not fumble….
D1 Ok
QA1 This one is thicker..
SE1 But if it is completely fumbled up, it remains the question whether it actuates **the sensor**.
D2 With a heavy sheet of paper it simply does not fumble. That is the point, it is too thick.
D1 Yes, well..yes. My problem is that thinner sheets do fumble, and I need to open up this flap first before I will see the fumbled sheet.
QA2 **Or is it for every finisher different**?
QA1 Now you say something: that is an additional problem.
QA2 (..) Is at all finishers that the first sensor is before the first pinch?
D1 I don't know, I really don't know…. Maybe the best thing to do is to take a look at it (13:10 - 13:56)

First a quality assurance specialist (QA1) proposes to do an experiment with a ‘heavy sheet of paper’, as he expects that to be most problematic. A designer (D1) immediately adds that he saw that sheets of paper always "fumble up" in that area. Put differently: he adds another problem which is not related to heavy sheets of paper, but to lighter stock. A third person, a software engineer (SE1), extrapolates the consequences of a fumbled up sheet, namely that the sensor that should detect a jam possibly won't detect a jam at all. Without detection of a fumbled sheet, also error recovery will not start. A fourth person, another quality assurance specialist (QA2), grasps the problem, and adds another dimension. The module they are looking at (a "finisher") is just one of the possible modules a client can buy. He wonders whether the situation with the sensor they are assessing is representative for all other modules: "or is it for every finisher different?". Nobody knows, and another constituent of the doubtful situation is added.

Point is that within these 11 lines of text in less than 50 seconds four problems (!) are addressed that came back again and again later in the meeting. More important: these problems could only be named as the specialists are sharing their individual knowledge. For example: designer 1 observed that sheets of paper tend to fumble up in that area, something the others did not know. And software engineer is the only specialist who is aware how a specific sensor should be actuated in order detect a jam. Regardless, in this period of the meeting, none of these namings result directly in focused activities; they are merely mentioned. Put differently: the specialists tried to *made sense* of the doubtful situation at hand, by attempting to set the problem at hand. Nobody knows sufficiently what the situation is, and thus all constituents need to be addressed and the relation among these

This sensemaking period lacked strong frames that provided guidance for activities. Hence, the activities did not follow the pattern of Schön’s reflection-in-action (naming, framing, moving and reflecting, see Figure 1); and even may seem haphazard. Figure 6 shows the pattern of the

team of specialists making sense of the situation they were in. Sometimes several frames seemed to co-exist, and most discerned frames were about problems. These needed to be outspoken and considered by all team members, in order to reflect on the implications across and within their domains, before doing any move. Is it a serious problem, or not? Not until the doubtful situation was sufficiently understood, as a result of the new insights that arose as a result of three surprises, the team could proceed to co develop solutions. In Figure 6 the characteristic pattern in team activities are shown.

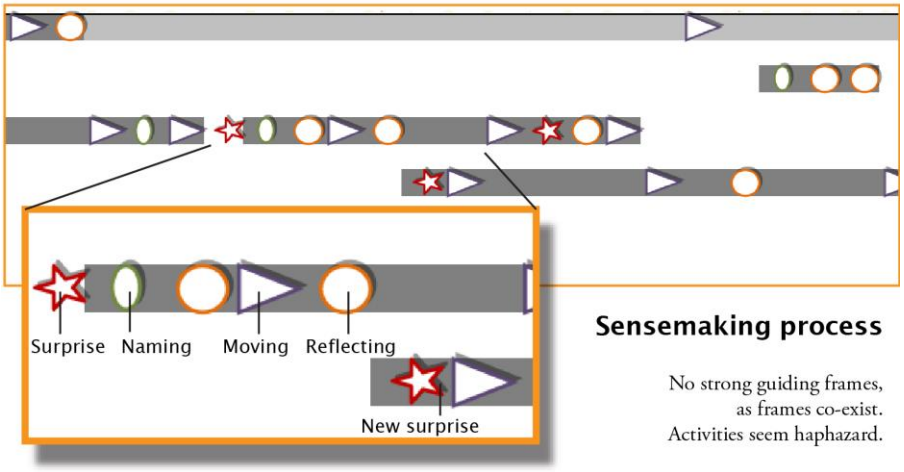

Figure 6
A period of few minutes of the first period of the meeting. The team activities are not according Schön's reflective practice (naming-framing-moving-reflecting) but shows another distinctive pattern without strong guiding frames, as frames temporary co-exist. Problems are named and reflected on, without doing moves. Surprises are encountered. For an outsider, the topic seems to be shifting restlessly.

4.2 A team reflection-in-action pattern

The second halve of the meeting has a character as designated by Schön's reflection-in-action. Hereby a problem is named and framed; moves are made and reflected on within the frame (Figure 7). Typically the character of the namings also changed, from problem oriented to solution oriented. Likewise, the type of reflections are different compared to the first halve. The team reflected on technical consequences if a solution will be implemented. Will it solve the problem? Is it costly? Do we have enough time? The activities were more structured, showing obvious team frames in which moves and reflections were conducted. Yet, even this phase is still pretty hectic, as ideas are put forward and reflected upon swiftly, as can be seen in the example below.

D1 To recap: what we agreed is that in some cases, in extreme cases, we will guide him [operator] to that thing. In that case we need to consider how we will do that with a "next" scenario, and a sort of **small handle**.
D1 At the same time, **we don't want to put the attention to much onto it.**
QA1 One needs it in 1 pro-mille of the cases!
D1 (..) I don't want to have a handle begging 'pull me, pull me!'; if an operator has hardly ever to pull it. (..)
ME1 The **flap will remain the same size**?
QA1 The flap?
D1 We are talking about the handle.
ME1 You also mentioned **a small light**?
QA1 No: we will not deploy a light.
D2 A handle should provide sufficient space for **a sticker, with information**.
QA1 No, no….why? There is no sticker required at all!

D2 It should have I name. I [user interface] cannot guide an operator to a handle without a name!
QA1 Why not?
D1 (..) **Now that is an interesting train of thought**…. (55:13 – 56:04)

The frame that is established is that a specific "handle should not attract attention too much", as it concerns a handle that hardly ever is needed. Several moves within this frame are made, namely the "size of flap"; adding a "small light" or a "sticker". These moves are made cross-disciplinary: for example information on a sticker (with information for a user) is the domain of one of the designers, D2. However: available space is limited, which is the domain of a mechanical engineer, ME1. He proposes to use a light to draw attention of a user, which is the domain of electrical engineering. Interestingly, a reframing occurs: "now that is an interesting train of thought": possibly the user can be guided in other ways than by a sticker for which no space is available.

The multi-disciplinary character and proficiency of the team manifested by the speed at which frames were established, moves were made and reflected on. In less than 50 seconds a new problem is named and explored. This was a consistent pattern: any idea or problem that was put forward was evaluated constructively and swiftly within and across disciplines, sometimes in less than thirty seconds. Decisions required hardly explanations, merely some labels sufficed (“the next scenario”) to align all following activities. Apart from a brief recap by means of an informal email, no formal appointments were made. Subsequent meeting concerned other topics. Yet all proposed solutions were implemented, as we could validate by means of the eventual design six months later.

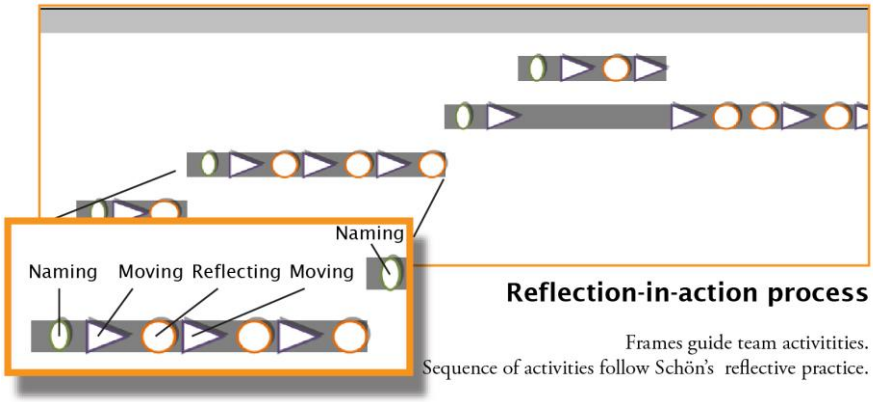

Figure 7
A typical reflection-in-action process, whereby the frames are named the team attends to. Consequently, moves are made and reflected on within these established frames.

Another distinctive feature setting the stage of reflection-in-action apart from the stage of sensemaking, was the contribution of the prototype in both halves. In the stage of sensemaking, the prototype was pivotal in the meeting. Experiments were conducted on the spot, specialist went on their knees to see for themselves what happened. Every detail may provide the cue to understanding the doubtful situation at hand. In the stage of reflection-in-action the prototype lost its value. The moves the specialist made were thought experiments, imagining and reasoning out "what if" proposals. The prototype every now and then serves as a requisite for pointing to imaginary things that the team conceived, but the team could have done without it (Figure 8).


Figure 8
On the left, a video still is depicted from the stage of sensemaking. The specialists conduct experiments with the prototype and observe closely anything what happened. On the right, the team more or less withdraws from the prototype in the stage of reflection-in-action, proposing and discussing proposals.

4.3 Long term: observing similar patterns

The meeting discussed was merely one meeting out of a range of many meetings, in which several specialists participated in order to develop ORE. By analyzing a journal of participatory observations, a similar pattern could easily be traced in these other meetings as well. First the team went through a stage of making sense of the situation at hand, and subsequently through a stage of team reflection-in-action. For sensemaking, the specialists needed to share what they knew on the topic at hand, and deployed objects, drawings, prototypes and the like that best represented their collective activities. Often the specialists explained what was 'on their mind', i.e., could not be observed in the real world of e.g. a prototype, a CAD model or a document. Sometimes small experiments were conducted collectively with a prototype to validate hypotheses. The relations among activities of the specialists turned out to be more complex than expected. Several surprises were encountered as the collective choices enacted new problems:

"We have tested it once (..) The first thing that happened is that the foil broke down when I've introduced the jam. Then the whole module.. it flew apart! Really spectacular! It was shattered, the pieces where everywhere (..). It was a new phenomenon for all of us" (interviewed software engineer). Quintessentially, the previous activities and ideas of individuals were shared and consequences reflected on within and across the distinctive practices of specialists. Or put differently: the distinctive prior frames were shared.

Once the specialists sense they sufficiently understand the situation and its constituents, they start designing often cross-disciplinary solutions. A reflection-in-action pattern emerges. They do moves guided by a clear frame, and reflect on these moves within and across disciplines. Whereas for team sensemaking integrated prototypes, CAD models or detailed documents are pivotal; for the stage of reflection-in-action these kind of objects seem to have less value. Rather, specialists prefer sketches, card board prototypes and 'quick and dirty' CAD models, that are rapidly modeled. These objects enable swift progress, loosely depicting what the 'core idea' is and enable specialists to reflect within and across their practices. At the same time these objects defy 'closure', as the ideas need subsequent development by specialists. There is a specific quality residing in these crude sketches and objects, providing both a clear pointer for all involved for future activities and providing sufficient slack defying closure.

Interestingly, we believe that not only *within* these meetings but also *across* these meetings (in a period of approx. six weeks) a similar pattern of sensemaking and subsequent reflection-in-action can be observed.

The first series of meetings together shows a typical sensemaking pattern and started when a user-centered designer doubted if he could solve a usability problem. In a first meeting, four specialists together had to acknowledge they couldn't solve the issue, which was a surprise for them all. However, in subsequent meetings the problem showed to be more complex than they expected. By proposing solutions to a known problem, new problems became known. Consequently, the problem transformed several times disruptively. In succession, the usability

problem became a cost price issue; a reliability issue; and a serious safety hazard. The team got to the bottom of the problem when they learned that a basic assumption proved to be wrong. Once an door was engineered and prototyped, the team mounted it on an integrated prototype. The specialists discovered that all sensors were shut off for safety reasons if the door is opened. It was an unwanted result of few separate choices of distinct specialists. Problem was: all ORE strategies were based on the assumption that sensors could detect what is going on, also when the door is open. The 'blind printer' problem rendered all previous design activities useless.

In order to make sense of the situation, more and more specialists became involved (up to 12 persons), even including the project leader. Meetings were staged next to prototypes; behind CAD stations; or before enlarged technical drawings that were stuck to a wall. Everybody explained his or her considerations, that were discussed cross-disciplinary. Appointments made in one meeting were discarded quickly as a result of new insights. For outsiders it may seem as if the team was indecisive and little progress was made. In reality, the team was paralyzed by the doubtful situation that was not understood well. The team was forced to look back to what everybody involved had designed and/or decided previously. The surprises laid bare that no overarching frame was operating to align all prior activities.

In the later stage of this hectic period, the team was collectively involved in solving the problems that were better understood. The specialists were guided by a strong and productive frame that enabled them to align and coordinate activities, named ‘do 1-2-3'. This concept was slowly developed across disciplines as it had consequences for all involved. Often individual team members proposed solutions to sub-problems, and others were invited to reflect and validate the proposal. These proposals often were cross-disciplinary. Also, a new joint representational space was developed on-the-go, quintessentially mapping relations among hardware development, software development and user interface development. The overview enables to design and evaluate cross-disciplinary, including the physical world of mechanical hardware (normally depicted in CAD), the invisible world of software behavior (normally depicted in documents and dynamical models) and the world of human operators (normally depicted in sketches of user interfaces).

No longer disruptive new problems were discovered. The appointments that were made in one meeting, served as an agenda for the next. No unexpected additional meetings were required. Progress could be monitored even by means of email. Also, the relations between team members were stabilized: who-does-what. Hence the team activities depicted steady progression.

It may seem that the two stages were two clearly distinguishable processes in the ongoing stream of activities. However, the distinction can only be articulated in hindsight. The aforementioned distinction between sensemaking and reflection-in-action shows in the patterns of activities, rather than the activities themselves. In both stages specialists named the things they attended to, made moves, and reflected. However, in the stage of sensemaking, the moves seemed to go in all directions, forcing specialist to go back on what they did: "now you say something: that is another problem". Proposals revealed new unknown problems, rather than solved the known ones. Frames had a limited lifespan and often several frames co-existed at the same time.

In the stage of reflection-in-action a more structured pattern emerges: team members named a strong and productive frame, did moves both within and across practices and reflected on the moves and/or frames: "now you say something: that is a an interesting train of thought". The frame was not altered anymore and consequently, the team shows steady progress.

5. The structure of (re-)framing in a multidisciplinary team

Most interesting of the findings as discussed above, was (1) the impact of surprises on team activities; and (2) how the team reframed. As described in chapter 2, for a practitioner a surprise results into reflections on his/her prior frame. For a moment, someone experiences doubt, starts

questioning himself what he has been doing before and what he observes in the here-and-now. As a result the practitioner reframes; i.e., he adopts another frame for subsequent activities. The process of individual reframing is swift, done mentally, and whilst being in-action. Therefore the process of individual sensemaking often goes unnoticed. However, we found that (re-)framing processes are amplified in the context of teams. Creating a new guiding frame for a team of specialists takes considerable time and efforts, paralyzing current activities. Also, the process of (re-) framing has typical characteristics that discern it sharply from other stages of the team design process. The meeting that was analyzed in depth included a genuine surprise, and made the team reframe their activities. We believe that the changing pattern of activities can be attributed to the process of reframing, both in the meeting of an hour, and in the long term period across meetings. We distinguish three, partly overlapping steps: detecting a team surprise; sensemaking of past activities; and future framing for subsequent activities.

(1) Detecting a surprise

For an individual, the detection of a surprise is beyond his/her conscious thinking. A cue is noted that draws the attention, causing doubt, and in a short period of time leads to another frame. For example, in Schön's protocol on design, Quist discovers in the sketches of Petra that the site is 'screwy' and therefore decides that it needs 'a kind of discipline'. However, for a team of specialists, the detection of an surprise is not an 'automated' cognitive process. Rather, the detection of a surprise is a distributed process. A surprising cue is noted by an individual specialist, who first has to find out whether the doubt he/she experiences is shared by other specialists. What is a surprise for one, might well be an anticipated outcome for another. In order to do so, they need to decide whom to involve; explain events to each other; share expectations; and so on. Only if more specialists agree that the cue contradicts all their expectations, we can name the event a team surprise.

Surprises in teams often result into ambiguity: multiple, conflicting interpretations exist for the same surprising event. Team members do not agree if an event is a problem; what caused it; what the consequences are; who is responsible or should be involved. Both the constitutive factors and the relations are debated. They no longer agree on what to do, hence ambiguity is stalling progress. The ambiguity is a result of multi-disciplinary collaboration, as team members interpret situations differently as a result of their past experiences. Ambiguity is the antonym to a guiding frame: ambiguity is felt precisely because a strong frame is missing

We observed that the distributed detection of a surprise a vulnerable process. First (1), events may be observed by some specialists who will not note the event at all, as it fits his/her expectations. However, the event may be an important indication for other team members that something is wrong. An interviewed software specialist explained that the team members that interact often with prototypes no longer ‘see’ problems that occur, or solve things so quickly that they miss important cues that hint at problems:

“He is the one who spends most time at the prototype, at least of our team. Well, he knows far too good where a sheet is jammed, he ignores all information and just opens the flap on the left, the door and so on.”

Second (2), boundaries inside team constitute what team members see and what they don't see. If specialists are not located at one location, or for other reasons cannot see what others are doing, they no longer may see the cues that hint at problems, or opportunities. The 'blind printer' problem as discussed in chapter 4.3 was not discovered before by any specialist, simply because all prototypes lacked a door. The door was engineered somewhere else, and later in time. How could the team reflect on what they were developing, until they could see what they were creating collectively?

(2) Team sensemaking

The second step of the (re-) framing process, is team sensemaking. Sensemaking is an attempt to understand what caused the problem at hand; what are its constituents; and to deal with the ambiguity. Consequently, it is about looking back and reconstructing what all specialists did and planned to do. Thereby specialists articulate, assess, combine, and synthesize what they know into a meaningful whole, thereby reflecting within and across practices. Basic matters are addressed, as: do we have a problem or not? How serious is it? Whose problem is it? They have to meet face-to-face because every small piece of information may provide the cue that settles what is the problem. They gather around and experiment with objects that best represent the current state of affairs of their collective activities, such as integrated prototypes. We observed that specialist are reluctant to simplify the situation they assess, as any detail may provide crucial information. For example, in the video protocol the team conducted role play to assess a specific error scenario. Thereby they meticulously performed all steps of the scenario, even those that hardly seem to have a relation with the situation at hand. These steps provided many, varied, small yet possibly meaningful events. The pattern of activities does not follow the pattern of reflection-in-action as described by Schön, but is characterized by (1) naming problems followed by subsequent reflections on the magnitude of the problem; and (2) the co existence of several frames without a dominant one.

The stage of sensemaking quintessentially is reconstructing prior (and often implicit) frames of the individual specialists. This stage is not about solving the problem at hand, but about problem setting, i.e., the process before the problem solving starts, setting the stage. It is about dealing with ambiguity, assuring that all specialist agree on 'what seems to be the problem'. We did not chose the notion 'sensemaking' arbitrary. Weick defined sensemaking as the "ongoing retrospective development of plausible images that rationalize what we are doing" (Weick et al. 2005). As some scholars discussed (Elkjaer & Simpson 2011; Goia 2006), Weick preeminently highlights looking back to past activities to rationalize a doubtful situation, rather than looking forward. This framing of sensemaking fits well the stage we describe here, as an activity concerned with past activities and prior frames that are often implicit. Yet, sensemaking, as an activity preoccupied with the past, is not sufficient for providing a new, strong and productive frame for all specialists in a multidisciplinary design team. A strong cross disciplinary frame facilitates that specialists can work relatively on their own once again.

(3) Future framing

For (re-) framing a third stage is needed that is future oriented. We named this stage of (re-) framing future framing, which we define as: the ongoing development of plausible images *of what we will create together*, that rationalizes what we are doing. Although the problem is set and relations among specialists are re-established, the situation requires that team members explicitly align and coordinate their future activities, by means of an image that directs to a possible solution. Frames are not ‘final’ solutions, well described in all sorts of details. Rather frames should provide guidance for subsequent activities for all involved *across* their practices, without spelling out what each specialist need to do *within* their practices. The frame includes future consequences of hypothetical actions of specialists together, that are meaningful for activities in the here and now. Even though this future framing is based on past experiences, , these expectancies are projected forward into the future to provide a meaningful image to inform individual specialists and their current actions.

For multi-disciplinary design teams, developing these frames is hard as these require to be developed cross-disciplinary, consequently involving several specialists to co-develop these frames. In a meeting specialists propose ideas, argue, discuss. They somewhat withdraw themselves from the world of accurate representations and resort to sketching, mapping, storytelling and role play. The team activities change considerably compared to the sensemaking process before, showing a stable reflection-in-action process. Problems and solutions are framed and thought experiments are conducted and reflected on cross disciplinary. Below an example is provided (from the video analysis) of such a thought experiment. The

Quality Assurance specialist (QA2) summarized what he had learned so far, thereby checking whether this was correct. He talked about imaginary things that were not actually designed at that moment in time, yet he discussed it as if the design and engineering already happened, i.e., in the future perfect tense. Also he pointed to imaginary parts, such as the 'next button' or the 'small flap for which G. will make something nice.' This pointing and acting out enabled others to envision and reflect on what he was proposing. This enabled the team to reflect on the situation as if it already happened. Eventually he introduced a new problem that was concealed in their collective choices, namely whether or not a sensor will be 'checked'.

QA2 Ho, wait, wait, let's go back. There is a sheet detected by the finisher. I [operator] cannot access it, I solved all other problems and close the door. Correct? (..) I close the door, but it is still detected over there. Now there appears [points at user interface] "Next". (..) So I'll press "Next". I am guided from the user interface to the small flap for which G. will make something nice.

QA1 It says: "open front door, and open that small flap".

QA2 Right, right. I open the flap and remove the jammed sheet.

D2 In that case is the sensor no longer detects a sheet.

QA2 Will we [future product] check that sensor? (51:35 – 52:20)

Often fledgling ideas suffice for team members to discuss and reflect. Eventually these collective sessions result in few ideas that are labeled and/or depicted by simple iconic sketches. The sketches or names, like 'do 1-2-3', are robust enough to maintain a common identity *across practices,* yet plastic enough to be adapted *within practices*. Also these have a specific quality that aptly can be named the *'*charm of the skeleton' (Weick 2004: p.43). The 'skeleton' of a good idea has a vigor and a charm that is persuasive so that individuals can commit themselves; leaves open sufficient space for individuals to explore solutions; and is sufficiently constrained so that everybody knows the generic line of thought.

An iterative process

The stages as described may suggest a strict temporal order, however that is not what we observed. Rather, (re-) framing should be conceptualized as an iterative process whereby stages of detecting surprises, sensemaking and future framing alternate, until a frame has been established that stabilizes activities and relations for a prolonged period (Figure 9). A surprising event often includes many cues, that poorly fit to what specialists know: there is "a pile of cues in need of some frame to organize them" (Weick 2001: p.460). Specialists need to look back to past activities to reconstruct and scrutinize their prior frames in a sensemaking process, often only to discover more surprises. And they need to look forward to explore for a new meaningful frame, by means of future framing. Past experiences shape the ideas that embody this future frame, i.e., these ideas are projections and anticipations of what is known already. Thus, a new surprise or insight inevitably recasts the future framing as well.

The other way round, future frames not only align future activities, these also may incite new sensemaking processes. These frames on the consequences of imagined future activities also make specialists reconsider what was done so far. Put differently: a future frame may introduce doubt on matters and decisions made in the past no one doubted before. In the ORE case, at some moment in time the team composition changed considerably, as an important milestone was passed and more production engineers were added to the team. Inadvertently these new team members introduced surprises to the team, as their experience and framing -directed towards production- was different. As one of the involved mentioned:

"When I joined the project (..) we assessed the entire paper handling function with a group of experts (..) also from other parts of the organization [production]. That was the moment we

concluded: this will not function. We never get it prepared for production. That was a bit of a culture shock".

A new frame was established, namely for the preparation of production. 'Suddenly' a load of new problems was discovered nobody considered before, inciting a difficult sensemaking process.

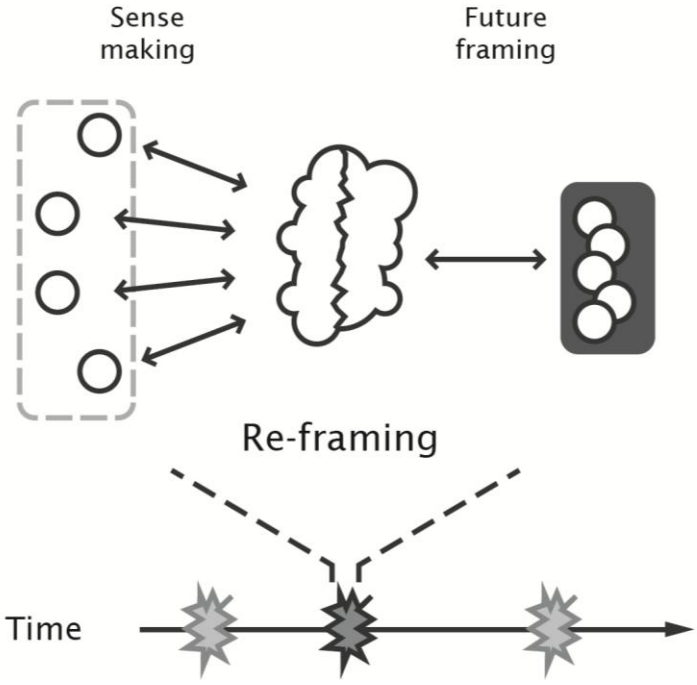

Figure 9

A visualization of the process of (re-) framing, envisioned as the cloud-like shape in the middle. At the bottom, the stream of events is depicted. Every now-and-then a surprising event occurs, and the process to detect and inform the team of such a surprise is the first step of the process. Subsequently, a sensemaking process starts, aimed to reconstruct a plausible image to rationalize what happened. Thereby the often implicit prior frame (depicted by means of the dotted rectangle) needs to be reconstructed. The frames of individual specialists (depicted by means of circles) inform the sensemaking process, by articulating, assessing, combining and synthesizing these into a plausible whole. Lastly, on the right, a future framing process starts. A new strong frame is developed for future activities, that includes future consequences of hypothetical actions of specialists together, that are meaningful for activities in the here and now. These three stages iterate until a strong and productive frame is developed.

6. Conclusions

In this study we explored the social dimension of multidisciplinary team design, a topic that is seldom studied yet is everyday reality for most product development teams. We deployed Schön's theories on the reflective practice and the first research question was: does the paradigm of the reflection-in-action fit the multidisciplinary design practice? Even though Schön (1983,1987) only discussed individual practitioners, we found that three kernel ideas of the reflective practice also fit the context of a multidisciplinary design team.

First, the descriptive model of design activities of naming, framing, moving and reflecting also is an adequate means to describe and understand the reflective practice of a multidisciplinary team. The method of Valkenburg (2000) showed to be a fruitful method to study patterns according to Schön's reflective practice. By means of these patterns, new insights arose on how teams of specialists discover problems, make sense of doubtful situations and co develop productive frames for future activities. These patterns seem persistent, not only in the short term but also in the long term.

Second, our findings highlight the pivotal influence of the environment, objects, sketches and the like on the team reflective practice. Schön discussed design as a 'reflective conversation *with*

the situation' (Schön 1983). As discissed in chapter 2, 'with' must be interpreted quite literally: interacting with the situation. Sketching enables a designer to do quick-and-dirty experiments within a frame he imposed on the situation at hand, and to reflect on the intended effects and unintended by-effects. These by-effects can be unwanted, but also may incite new ideas. As such, sketching should not be conceived as an activity to document what a designer knows a priori. Sketching should be conceptualized as an interaction between designer and the situation at hand, as he frames it. Thereby both the design and the designer are subject to change as both the design develops and what the designer 'knows'. To paraphrase Dewey's maxim of learning by doing: a designer learns by creating. Take away the sketchbook, and the process of designing will collapse.

This is no different for multidisciplinary design teams. Due to the multidisciplinary character the sketch is often transformed into cardboard models, integrated prototypes, CAD models and the like, that are imbued with meaning for all specialists. The team interacts with these representations of the situation at hand. Thereby they learn by doing and develop their collective design simultaneously. Take away the prototypes, cardboard models, sketches and the process of team design will collapse as well, simply because they do not 'see' what needs to be done.

A third kernel idea is (re-) framing, which corresponds with the second research question: how do multidisciplinary NPD teams develop guiding frames and reframe? Multidisciplinary design teams need strong and productive guiding frames, so that all involved specialists can do their work relatively apart from others. We believe the process of (re-) framing is under-theorized, possibly because it is done so swiftly when it concerns an individual practitioner. However, we found that for multidisciplinary team design, the process of (re-) framing becomes much more articulated, as what the team 'knows' is distributed among its specialists and the practices they engage in. We developed a model that describes the structure of reframing, by means of three iterative stages: the identification of a surprise; sensemaking of (often implicitly) operating prior frames; and future framing to extrapolate future consequences of imaginary new activities. A new frame cannot be developed without understanding prior frames of specialist as these incorporate how they see the situation, based on their diverse experience.

At the same time, (re-) framing requires future framing, to envision alternative futures as a result of imagined activities, to reflect on collectively. These alternatives provide novel possibilities to act, beyond what specialist conceived beforehand, on the base of what they knew. Future framing recasts they way how specialist see the situation they are in. Thereby the specialists still must project prior experiences on the situation at hand in order to anticipate the future. A new and strong guiding frame consequently is established, only if (1) the constituents of the situation at hand are understood, (2) the relations among the activities of specialist reestablished, and (3) a future frame is developed that extrapolates and enables to reflect on imagined future activities. This frame provides guidance for subsequent activities of individual specialists, who can progress relatively on their own.

Out findings shed a new light on the contribution of surprises, and we need to rethink what surprises 'do' for teams. The essence of multidisciplinary design is two or more specialists who co design something none of them is capable to design individually. Surprises are intrinsically part of the design process, simply because also problems are encountered nobody conceived beforehand. Surprises and the subsequent doubt as a result of ambiguity paralyze the design teams. Planning and ongoing activities become meaningless, as it is unclear what the magnitude of the problem is, what to do or who should be involved. Hence, surprises and subsequent (re-) framing processes are mostly considered a nuisance, appallingly ineffective and 'unprofessional'.

Yet, surprises are also beneficial. Surprises lay bare that the frames no longer suffice to deal with the situation at hand, if there is such a frame operating at all. Surprises hint that relations among the activities of specialist are not known well. Surprises are cues for team learning. And surprises even are the seeds for innovations.

The subsequent process of 'reframing', shows another face of multi-disciplinary design than textbooks prescribe. Above all the stage of sensemaking seems chaotic and going anywhere, rather than predictable. Progress is disruptive, rather than ongoing. Problem setting seems haphazard, rather than well considered. Meetings are occasional rather than recurrent. Team composition is fluid rather than stable. And specialists are preoccupied why things do not work as expected, rather than constructively developing solutions. The subsequent stage of future framing resembles a more classic design process, whereby frames are set to conduct thought experiments to reflect on, cross disciplinary. However, future framing is an activity to shed new light on the situation at hand, and does no guarantee the problem is solved. Often new problems are found or surprises encountered as a result of the new framing of the situation at hand and the subsequent experiments that are conducted. Only in hindsight it becomes clear when the team got to the bottom of the problem and established a productive frame that ensured steady progress. It may seem that (re-)framing is unproductive, a process to be left behind as soon as possible. However: (re-) framing is a necessity to set the frame for the more 'productive' stages whereby specialists ca progress relatively on their own. (Re-) framing covers the bulk of design decisions at team level, as subsequent activities merely ratify the outcome of the reframing. (Re-) framing is quite literally setting the stage in which the specialists have to play; a stage which is set by the specialists themselves.