The Reflective Practice in product design teams

Rianne C. Valkenburg
Stellingen

Behorende bij het proefschrift 'Reflective Practice in product design teams'.

1 Projectleiders dienen bij het managen van ontwerpteams meer aandacht te besteden aan het gezamenlijke beeld (shared understanding) dat teamleden in het project moeten hebben van de inhoudelijke taak.

2 Ontwerpers spelen met ontwerpkaiders. Ze gebruiken deze kaiders enerzijds als denkkader om inhoudelijk een complex ontwerpprobleem aan te kunnen pakken en op te kunnen lossen, anderzijds als praatkader om een gezamenlijk beeld te creëren van de ontwerpinhoud met hun teamleden.

3 Wanneer ontwerpers regelmatig hun activiteiten en de gevolgen ervan kritisch beschouwen, wordt het ontwerpsresultaat positief beïnvloed. Door reflectie kunnen bijvoorbeeld alle tegenstrijdige belangen goed afgewogen en in balans gebracht worden.

4 Onderzoek heeft altijd te maken met een zekere mate van subjectieve interpretatie van de data. Onderzoekers moeten de consequenties die deze onvermijdelijke interpretatie met zich mee brengt in hun onderzoek expliciet maken, in plaats van ze te negeren.

5 Bij goed ontwerpen is het eindproduct meer dan de som van de deelaspecten die geïntegreerd moeten worden (2 + 2 = 5). In onderzoek moeten deelaspecten juist geïsoleerd worden om gemeten te kunnen worden, opdat de som altijd te verantwoorden is (2 + 2 = 4). Ontwerponderzoek zal zich meer moeten richten op de meerwaarde in ontwerpen (het vinden van het additionele punt).

6 In leeromstandigheden waar de docent goede terugkoppeling geeft op het werk van studenten, zal het cijfer gegeven voorafgaande aan de terugkoppeling nooit de juiste waardering zijn voor het totaal behaalde leerresultaat van de student.

7 Het slechts aanleren van de structuur van ontwerpprocessen is onvoldoende garantie voor het goed leren ontwerpen. De kunst van ontwerpbegeleiden zit in het aanleren van de reflectieve manier van ontwerpen.

8 In het sociaal-wetenschappelijke adagium 'Observeren is leren' is waarzien alle niet voldoende. Leren is slechts mogelijk door toevoeging van reflectie.


9 Als meer ontwerpers actief worden in ontwerponderzoek, zal in de kennis over het ontwerpen het aantal vragen sneller groeien dan het aantal antwoorden.

10 Stellingen leiden vaak niet tot opbouwende dialogen, maar slechts tot het bevestigen of verwerpen van eerder ingenomen standpunten. Als deelnemers aan een discussie ervan uit gaan dat er niet één waarheid bestaat, worden hun discussies interessanter en effectiever.
The Reflective Practice in product design teams

Theses

Concomitant to 'Reflective Practice in product design teams'.

1 Project team managers should give more attention to the shared understanding of the design content that team members need to have.

2 Designers play with frames. On the one hand they use these frames to deal with a complex design problem. On the other hand they use these frames to create a shared understanding of the design content within the team.

3 If designers constantly consider design activities and their implications, the design result will be enhanced. For instance, conflicting requirements can be evaluated and balanced through reflection.

4 Research always involves a degree of subjective interpretation of data. Researchers must explicitly deal with the consequences of this subjective interpretation in their work.

5 In good designing the end product constitutes more than just the sum of the aspects that need to be integrated \((2 + 2 = 5)\). On the other hand in research these aspects need to be isolated in order to measure them, so that the sum can be justified \((2 + 2 = 4)\). Design research should aim for the additional value of design (finding the extra element).

6 If teachers give the right kind of feedback to their students, the marks for the students' assignments, awarded preceding that feedback, will never accurately reflect the entire learning experience of the students.

7 Merely teaching the structures of design processes is not sufficient to learn to design well. The art of design tutoring lies in coaching the reflective practice in designing.

8 In the social-scientific maxim ‘Observing is learning’, just observing is not enough. Learning is only possible if it coincides with reflection.
   Supplementing Morel KPN (2000) Theses concomitant to 'Consumers' reactions to ambiguous product information' Delft University of Technology.

9 If more designers get involved in design research, the number of questions about designing will increase faster than the number of answers.

10 Theses often don't lead to constructive dialogue, but merely to confirmation or rejection of previously held beliefs. If participants in a discussion would only accept that there is not one absolute truth, their discussions would be more interesting and constructive.
The Reflective Practice in product design teams
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Proefschrift

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“Ik ben geen held,
tenminste niet één die telt,
maar ik doe mijn best te blijven staan.
Als ik schreeuw lijk ik slecht,
maar wat ik schrijf ben ik echt.
Zo kan ik een beetje van de wereld aan.”

Acda en de Munnik (1999)
Yet another book on teamwork? After the amount of literature on this subject over the recent years, you might well question the need for the study of teams. However, the apparent value and widespread practical applications, provide due justification for the study of design teams. In my professional life, and even during my education as a product designer, I wondered why some design teams perform more smoothly than others do. I found it disturbing that we were taught so little about this subject. We were just assumed to design in teams. Dependent on our individual observation and reflection skills, we were then able to experience what ‘good’ co-operation and communication with team members was. But there was only little know-how available.

One of the difficulties of studying the current body of knowledge on teamwork is that it originates from many different sources. Some of the sources are distinct disciplines, such as psychology or sociology. Other sources emanate directly from authors, describing practical experiences in working with or consulting on teamwork. As with many similar subjects, there has been little integration of knowledge across boundaries of disciplines.

A further complication to the discussion of teamwork is that literature provided by sociology or psychology is relatively unhelpful in the study of design. There are few references to such a complex team activity as designing and it is generally unclear how this task influences the teamwork.

At the start of this research project I was guided by a number of articles on ‘design as a social process’. Then I understood the problem to be how social aspects and design aspects were related in design teams. Therefore I did an experiment together with a psychologist. Among other activities, we watched videotape of a design team at work. We agreed to interrupt the tape when either one of us observed something happening in the team design process. It turned out that both of us chose exactly the same incidents at which to interrupt the tape. From
our extensive discussions I learned two important lessons that influenced this research project heavily.

Firstly, I noticed that on any conspicuous ‘social-like’ moment in the team, also something critically ‘design-like’ happened, for instance as designers disagreed because their approach towards the design problem differed. Noticing this made me realise that design- and social aspects are very closely related, and depend upon each other.

Secondly, I realised that I could never perform a social analysis of a team the way a trained psychologist or sociologist could. On the other hand I, as a designer, could understand everything that was going on in the design project. I decided to rely more on my design expertise and use that to observe and analyse team designing.

Throughout the thesis I will refer to team designing. By using this phrase I wish to step back from the notions of ‘team design process’ ‘or ‘group dynamics’ and look upon the design team at the level of activities. Team designing, to me, is the interaction and communication in the design team as the team is struggling with the complex activity of trying to come up with a new product.

Working from these precepts, the research project accelerated. My premise, observing team designing while focussing on the content of the design communication (the term ‘shared understanding of the design content’ was introduced by then), provided a new and interesting viewpoint on team designing. This research projects tries to bridge exactly this gap between theories on group dynamics and the practice of design. A subject that is acknowledged to be interesting by researchers as well as designers.

The well-known, and often referred to, studies by Donald Schön on Reflective Practice provided the theoretical backbone for the research project. My love-hate relationship with this theory is characteristic for difficulties within this research project. ‘Love’ for the way the theory addresses appealing and integrating issues in design. ‘Hate’ for the way that this integration blurs the researchability of these issues.
It was necessary to develop and specify the reflective practice view theoretically. It was also necessary to empirically evaluate this view by applying it to team design projects. Above all, the empirical studies provided a lot of insights into team designing, not so much a completely new way of designing, but a view on design from a new perspective. It showed a way of communicating, as well as a language to communicate, about issues in design that we recognise from practice but were never able to 'capture' in theory.

From then on my research developed as a reflective practice: research problems and theoretical solutions evolved together: a constantly framing and reframing of my viewpoint towards the research question, and learning by doing, eventually resulted in this thesis. This thesis describes the theoretical struggle, the joys of empirical investigation, and finalising some conclusions on team designing. As is usual in research this project has not only answered questions, it has also raised many new ones. From this thesis any reader will make his or her personal interpretation of the results and learn his or her personal lesson. To me personally, this research project has been very useful, and I can only hope to contribute to discussions currently held in the field of product design research.

I hope that this thesis is not only interesting for design methodologists or other researchers, but also for practitioners: designers and design managers in the inspiring world of design. In the background, the question remains as ever: *How can we improve team designing?*

In studying reflective practices, I learned that it is my natural way of working. This research project has been a reflective practice to me. The *naming* and *framing* took a very long time and were very difficult to do. Once the *frame* for the research project was set (studying team designing with reflective practice), the *moves* (the empirical studies) were relatively easy. In the end, *reflecting* on what I've done in order to come to the right conclusions was also difficult. Reflective practice is no easy method for it leaves many questions unanswered. But in an attempt to answer them, much can be learned. And isn't that ultimately the goal of research, design, and life?
The principal reason for my interest in teamwork may have been my own preference for creating an environment to work in; my true belief that things can only improve in discussion with others. Over the long period of time that this research project has taken, I extensively used reflective conversations to frame and reframe my thoughts. My thanks go out to all who have supported me.

First of all, I like to thank my dearest Peter. Peter, no one can equal your efforts and patience. During difficult moments you gave me all the love, affection, support and advice that I needed. I cherish the way we share our dreams and I hope we will make many more of them come true in the future.

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I am by nature, maybe more than most, a team player. I need a supporting environment to work in. Many colleagues provided this, for which I am very grateful.
I thank my paronymphs Frido Smulders and Peter Lloyd, who will support me to the finish. Frido, we did some odd projects together; we designed a comic book, taught Belgian technologists how consumers want to brush their teeth, and facilitated a creativity course in an hour and a half. I hope we will keep doing these things in the future.
Peter, I like sharing an office with you. You patiently reviewed chapters and helped me develop my ideas into their present form. In our discussions you, as a 'hard-nosed scientist', always surprise me.
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Outside ‘Delft’, I like the field of design research, where people think along with you and are eager to learn new things. I would like to thank Nigel Cross, whose common sense helped me time and again to keep in mind my primary goal. I also thank Bryan Lawson, Maryliza Mazijoglou, Janet McDonnell, Steve Scrivener, and Simone Stumpff for inspiring discussions and valuable comments on proceeding work.

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Fortunately, a lot of people have also distracted me from producing this thesis. I would like to thank them too. My two families and many friends have always reminded me that there is more in life than just work.

I am especially grateful towards my parents, who have raised and loved me. They’ve had so many dreams for me, but always gave me the freedom to fulfil them in my own, unexpected manner. I know you are proud of me. I am one of four ‘sisters Valkenburg’. Engelien, Mieke and Jos, you have been so important for who I am today, somehow I know I will always be your little sister.
Thinking about the many dear friends and colleagues I have worked and lived with makes me feel happy and rich. I realise now how many you are, how important you are, and that I can never mention all of you. I owe all of you people a great debt of gratitude for helping me come this far along the road, but most of all I thank you for having great fun with me along the way!

*Rianne Valkenburg*
*Delft, Schiedam*
*November, 2000.*
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Introduction

It is generally assumed that the need for products is as old as humanity. Product design as an academic discipline, however, is a relatively new field of knowledge. At the Delft University of Technology in the Netherlands an academic school has existed for over thirty years with more than two thousand alumni. The Delft school is rooted in architecture, engineering, humanities and management sciences, but over the years it has grown into a separate discipline [de Wilde 1997].

The products that product designers design are mass-produced products that require systematic design. These products, varying from coffee makers to cars or industrial appliances, all require a strong interface with its user. User and consumer aspects need to be expressed in the product as well as business and production aspects.

Product design problems arise from all sorts of external circumstances, for instance through changes in technological know-how, developments in the market place, or a changing company policy. Design always takes place under open and ever changing circumstances and will require integrating these influences into the product.

We can state that much is changing in the product design environment. One important development over the last few years has been the shift from designing as an individual activity towards team based projects. Team designing introduces new aspects into the design environment. Team designing is also an important educational issue at the Delft product design school. This research project will focus on the team dimension of product design projects.

For a better understanding of the changing nature of product design, we need to take a closer look at designs and designing in day-to-day practice. A number of trends in product design will be described in the next section to address the managerial issues and problems in the real world. This will result in a problem
statement for this research project. Subsequently, a broad overview of the current know-how in the field of design research will be provided, as well as a more detailed review of recent empirical studies. The results of the literature study cannot completely answer that problem statement and therefore this chapter will end with a description of the goal and the research questions for this project. This chapter will conclude with an overview of the remainder of this thesis.

The changing nature of product design

Increasing complexity in product design projects
The size and complexity of product design projects has increased in recent years, due to the increasing complexity of products as well as their changing environment.

Figure 1  The increasing complexity of products over the years.
The complexity of products has increased, due to the fact that a growing number of elements from other domains, such as electronic, software, or human interface factors, have to be integrated in the products (see figure 1). For example the increasing use of electronics has direct implications for the product; use, interface, number of components, it all changes, and with this the complexity of the product and design process increases. With a growing number of elements to be integrated in products, the number of people involved in design projects evidently increases. They are the specialists that have the required knowledge.

The environment, in which companies operate, has also changed. Markets are characterised by higher demands and increased competition. Also the outcome of design projects is expected to be new and innovative. “…Clients usually do want designers to transcend the obvious and the mundane, and to produce proposals which are exciting and stimulating as well as merely practical…” [Cross 1996]. Customers increasingly demand more and more specific qualities. These changing demands require a rapid response to new developments. Product life cycles shorten rapidly so products have to be developed in less time. For example the development of the double-decker for the Dutch railway in 1995 only lasted 18 months, whereas the development of the commuter train ‘SM 90’ in 1990 (the design project prior to the double-decker) took over 72 months [Buijs and Valkenburg 1996].

In order to remain competitive, new approaches to design are needed for effective and efficient design projects. These pressures will only increase due to the required higher level of integration in product design projects: integration of more aspects, more specialist knowledge, and more interested parties.

Designers can no longer do a product design project individually, especially within the allocated time. Also the required knowledge is distributed among several specialists. The increased efficiency requirements lead to a growing number of parallel activities (concurrent engineering). More and more companies have instituted product design teams in the expectation that teamwork will improve control and communication within these large and complex projects. Teamwork requires constant communication on the design in order to meet
these demands efficiently. This communication within the design team, is the responsibility of the project manager. His challenge is to achieve both this and a synchronised co-operation within the product design team.

**Increasing complexity of product design tasks**

Product design tasks are a particular type of problem, often referred to as ‘ill-defined’ [e.g. Cross and Roozenburg 1992]. In ‘How designers think’, based on twenty-five years of observing and interviewing designers, their clients and collaborators, Lawson describes the following characteristics of product design problems and solutions:

“...First of all design problems cannot be comprehensively stated; it is never possible to be sure when all aspects of the problem have emerged. Many aspects cannot be expected until some attempt has been made at generating solutions. During the design process objectives and relative priorities change due to the dynamic tension of design problems and their solutions. Secondly, design problems require subjective interpretation; one should not expect entirely objective formulations of design problems. Thirdly, design problems tend to be organised hierarchically and design solutions are part of other design problems. There is no objective or logical way of determining the right level to tackle the problem; that depends on power, time and resources available. Design occurs in an environment that needs clear communication...” [Lawson 1997, page 121]. This complexity of design tasks occurs throughout the design domains:

“...Just like fashion or houses there are [with cars] no extremes. Within a very small margin you have to touch the right spot. In trying, it’s not the shape, radius or angle as such, but the integrated complex of radii and double curved surfaces that has to appeal to a certain feeling. That is the challenge...”

Fedde Talsma, design manager (cars) [Valkenburg 1996a].

The interpretation of the design task is not objective; there is neither right nor wrong, or at least there is no objective way to determine this. What the nature of the design task is, how to approach it, and what a good solution to that question
is, is determined to a large extent by the designer's interpretation. Practising his craft the designer has to deal constantly with conflicting interests and to consider contradictory product demands. The designer has to make choices depending on what he believes matters most and from which viewpoint he should consider the design. Design tasks require subjective interpretation in order to be able to explore the possible design solutions.

That also implies that design tasks deal with problems that can never be defined conclusively at the start of the project, because the designer has to make assumptions and decisions for himself:

"...You have to deal with so many uncertainties, and if you can't deal with them it will end. But when you learn to live with that and take the uncertainties for granted, then you can go on [with the design project]. I try to show people [in the project] what could be over the horizon ..."

Alex Kengen, application engineer (mobile network applications) [Valkenburg 1999].

In addition to the complex nature of design problems, the growing size of design projects complicates product design tasks. During a design project a team of designers and other specialists has to deal with the complex design task. In team designing every team member has his own subjective interpretation of the task. Therefore team designing has to deal with these different interpretations. Team members have to discuss their individual interpretations of the task in order to co-ordinate their activities. A lack of shared understanding between team members invariably hampers the progress of the design project [Valkenburg 1996b].

Any difference in interpretation of the design task, for example between the product planner and the designer, must be made clear and there has to be mutual trust that in the end things will turn out to be good:

"...When a product planner stutters, you, as a designer, have to be a good listener and try to think with him [...] a large part of your expertise as a designer is to understand what people want [...] But then again, the product planner has to show himself a good critic in the confrontation
with the ideas...”
Fedde Talsma, design manager (cars) [Valkenburg 1996a].

The challenge, and also the problem, facing design teams is: how can they synchronise their communication and activities to arrive at a good design?

**Increasing complexity in product design communication**
Creating a shared understanding among team members requires extensive communication on the nature of the design task. This notion, for which we will use the term ‘design content’, is used to indicate everything related to the design task, from the design problem to the design solution (assumptions, design concepts, design decisions, and other ideas). This design content, the development of both the design problem and design solution, constantly changes during the project.

Shared understanding of the design content is achieved through language and representations such as sketches and models. People with different specialist backgrounds (e.g. designers, marketeers, and engineers) use different languages or forms of expression. The project manager is responsible for this process of communication. He is also responsible for the quality of the design. To help him in his difficult task, there are models that describe the necessary steps in the design project. These models structure and plan the design process more or less separately from its content. From the very start the project manager can indicate the phases and times spent on it without knowing the specific contents of a phase. However, planning design in this manner does not cover everything:

"...It [project management] is not only a matter of time, money and a neat schedule, but mainly of how to get a good solution to this problem. In what way can I bring the right people together, who can contribute to a creative solution? Because in the end it is how designers can imagine themselves in the client's situation that will help them to solve the problem at hand. During design projects you can't make a printout halfway to show that you're on half the budget and half the quality. That's nonsense..."
Ad Kleingeld, product development manager (design agency) [Valkenburg 1997].

The design content of a project can not be planned in advance: problems and solutions evolve together during the project. Ideas and concepts are vague and difficult to communicate. Success often depends on the experience of the project manager, who sometimes feels relieved when this goes well:

"...Then I heave a sigh of relief; the work is done. At the presentation [of a new car design] there's not much more to say; there's a model that says it all..."
Fedde Talsma, design manager (cars) [Valkenburg 1996a].

**Increased use of product design teams**

Designing is a difficult activity. The problems designers face, as we have discussed already, are related to the nature of the task, designing, and the communication involved. Because of the size and complexity of most product design projects, teams rather than individuals nowadays usually practice design. Many companies seek competitive advantages and a better integration of acquired knowledge by using teamwork. Only teamwork enables them to cope with the required efficiency and to deal with the increasing number of parallel activities in new product development.

Teamwork requires social interaction and communication of the team members. This implies the challenge to synchronise their thoughts and activities to achieve a design: communication on the content related aspects of the design task. These content related aspects are difficult to define at the beginning of the project; they constantly develop during the design project and every single team member has a specific subjective interpretation of these aspects. The project manager is responsible for good communication in these difficult situations.
Problem definition

Dealing with vague, subjective, continuously developing design contents is crucial to designers and project managers. Much is known about the planning of design projects. Available management tools, however, refer to planning and organisation in a general manner. They describe phases and milestones for projects, using general terms for the design content, such as 'define concept', 'detailing design' or 'release for production'. The design content related criteria, like "When is a concept finished?" or "What level of detail is required?" are not defined with these tools, for these criteria differ for every project.

No tools exist for managing the design content or communication between team members. In practice, however, important in design activities is exactly this managing of the design content for a better co-ordination in design teams. The problem area that this study sets out to investigate is:

The management of the design contents of product design projects, in order to achieve shared understanding of this content among team members in product design teams.

The notions, indicated in italic script will be explained in more detail.

The product design team

In this research the definition on teams by Katzenbach and Smith is adopted. They based their definition of a team by describing practical experiences: "... A team is a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable..." [Katzenbach and Smith 1993, page 45].

The most outstanding feature in this definition is the number of individual contributors who are complementary (because of technical or functional expertise, problem-solving and decision-making skills, and interpersonal skills) in relation to the common task, defined in a purpose (that sets the tone and ambition), performance goals (that are an integral part of the purpose), and approach (how they will work together to accomplish their purpose). The common task will, in
our situation, be a product design task.

**Management**
Within the team a project manager's responsibility is threefold:

1. The manager has to manage the design process in terms of resources (time, money and man-hours).
2. The manager has to coach the people involved in terms of motivation and team building.
3. The manager has to manage the communication in terms of the design quality, goals, problem solving, and customer satisfaction.

Not all product development projects have a formal project manager. Therefore these responsibilities are defined as roles. If no formal project manager is appointed, these roles are the responsibility of the members of the product design team. Because we are interested in the team members' communication and activities, we will focus on the third management role.

**The design contents**
Earlier the design content was defined as everything related to the design task: from the design problem to the design solution, including all relevant assumptions, concepts, decisions, and other ideas. The assumption is that communication about the design content is difficult, for it deals with indefinite and subjective issues. Design team members have to explain and convey thoughts, interpretations, and budding ideas, which may not yet be clear to themselves. In addition, this design content is constantly developing with the discussion.

**Shared understanding**
Shared understanding within the design team is the result of harmonising the individual perceptions of team members. It is reasonable to assume that shared understanding is a precondition for good team design. In order to synchronise communication and co-ordinate activities team members have to acquire a shared view on the design problem and solution [Valkenburg 1996b]. The shared understanding is illustrated in figure 2.
The Reflective Practice in product design teams

Figure 2 The difference between the individual level and the team level in understanding the design.

The problem statement
The problem statement that follows from the described problem area is:

How can project managers manage the design contents of their product design project while at the same time achieve a shared understanding of this content among the project team members?

This question is not a research question in the sense that it cannot be answered through understanding obtained through scientific research. Research results can contribute to answering this question by delivering relevant information or insights. Answers can never be found directly. Answering this question requires a creative interpretation and application of the newly obtained insights. To be able to define the factual questions behind this problem statement the next section will investigate the currently available know-how through a literature survey.

A theoretical exploration

The field of knowledge
Does the state of the art provide us with an answer to our problem statement? One of the difficulties in studying team design is that information might be
found in either literature on teams or literature on design.

Literature on teams mainly focuses on social processes and group dynamics in teams, without explicit reference to the team's task [Hohn 1999]. If the team's task is considered it is mostly a simple problem-solving task, not a complex task like designing. The object of study of the researchers in this field of knowledge is the team process. Therefore it is not surprising that they do not pay attention to designing. It is, for researchers outside the field of design, also a task that is hard to understand.

Literature on design only very recently considers designing in teams [Valkenburg 1996b]. Design Methodology is a relatively recent science, originating only in the early sixties. It includes studies on different design domains, e.g. engineering, architecture, industrial design, and software engineering.

The object of our research project is the design content. Therefore, we will investigate the current knowledge on designing and design tasks in the discipline Design Methodology. Design Methodology is "...the study of principles, practices and procedures of design..." [Cross 1984]. We will provide a review of this discipline, as team designing can learn from approaches and studies from individual designing. Only after exploring what issues are important in team designing, we can compare or match these with insights from literature on group dynamics of teams.

For this review a chronological approach is chosen in an attempt to provide coherence in the areas of interest in Design Methodology. Figure 3 illustrates these areas and the studies under discussion on a time scale. It indicates the development of the discipline from the early emphasis on design processes to the current interest in the influence of the context of designing. At this stage we won't focus on the product design domain, but enter the broad field of 'designing'. In the end the research standpoint for studying team designing will be stated.
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<th>Year</th>
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**Figure 3** An overview of the areas and studies investigated in the literature exploration in Design Methodology.
Models of the design process

In the early sixties the complexity of design started to increase [Archer 1963], [Jones 1970], due to the introduction of new materials (the invention of synthetics) and the amount of new technologies that this implied. It was commonly believed that a designer needed to know more to work effectively and this led to the need for more structured management of design processes. The primary focus in those first years of Design Methodology was therefore the design process. In 1962 the first conference on design methods took place in London [Jones and Thornley 1963]. In 1970 Jones published one of the first textbooks on design methods [Jones 1970]. Since then several other reviews were written to describe the discipline [Cross 1984], [Finger and Dixon 1989a and 1989b] and [Blessing 1994].

The first generation of design methods offered a systems approach to design. The common idea behind all these systems approach models is that the design process consists of a sequence of distinct and identifiable activities that are executed in some predictable and identifiable logical order. Therefore almost all models of the design process propose a step-by-step approach, that is in most of them subdivided in three steps: analysis, synthesis, and evaluation. These models are based on a systematic thinking process of the designer; an exhaustive information collection is followed by data analysis. Through the subsequent solution synthesis, or ‘creative leap’, the designer reaches, almost as a matter of course, the right solution [Archer 1963] and [Jones 1970]. These first generation design models are prescriptive models with a strong focus on the design process.

It soon was realised that design problems were not so amenable to systemisation as had been hoped. Attention turned to trying to understand the apparent complexity of these particular type of problems. In 1966 Rittel and Webber introduced the terms ‘tame’ and ‘wicked’ problems [Rittel and Webber 1984]. Stating that planning problems are inherently ‘wicked’ and ‘ill-defined’, and the opposite of ‘tame’ problems, where the mission is clear and it is clear whether or not the problems have been solved.

Rittel and Webber argued for a new generation of design methods that would be
based on a model of an argumentative process in the course of which an image of the problem and solution emerges gradually from the participants. Although they were talking about social planning problems, with many policy issues involved, the design research community eagerly adopted this view to characterise design problems [Lawson 1997]. This concept of planning and design problems being wicked problems became quite widely accepted [Cross 1984]. This went together with the idea that design methods up to this time were too rigid in their procedures and based on oversimplified interpretation of the structure of design problems. Still, little research focused on the nature of design problems. There is only a small body of literature on the nature, structure and types of problems designers solve, mainly revolving around the ‘ill-structuredness’ of design problems [Dorst 1993] and [Lloyd and Scott 1994].

However the logical rational approach never disappeared completely. Simon addressed the ideas of Rittel en Webber by stating that a designer can transform a design problem into a ‘tame’ problem, even though the problem seems to be ‘wicked’ [Simon 1984]. However, this transformation process is not explained very well and therefore the difference between the points of view is not solved, but masked behind definitions. Eventually the fundamental difference in the approach to design and design problems led to a division between the development of prescriptive, systematic design models and descriptive, argumentative models.

Some researchers develop design models while they firmly believe that designing is a scientific activity [VDI 1977 and 1985], [Pahl and Beitz 1986] and [Roozenburg and Eekels 1991]. They argue for the need of systematic methods to subdivide complex design tasks into more simple ones that can be solved easily. These models are based on the analysis of problems preceding the synthesis of solutions; design is described as a number of phases, each phase being completed before the next can begin. “... The designer is considered to be an inexhaustibly rational human being, capable of processing all the information necessary to perform the design task. The structure of this design task is characterised by the idea that a design problem can be functionally subdivided into independent sub-problems, and also that the solution can be constructed from independent sub-solutions. The integration and synthesis into a good solution are implicitly left
to the 'professional knowledge' of the designer..." [Dorst 1993].

These models of the engineering design process are strong on rationality, founded as they are on the theory of technical systems, but have some shortcomings with respect to the cognitive processes that take place in the heads of designers. These models have been derived more by thinking about design than by experimentally observing it, and characteristically they are logical and systematic [Cross and Roozenburg 1992]. That makes them suited for the controlling and planning of the design process in general. They don't support the designer in his decision-making or cognitive process, nor do they support team designing. Therefore they are of limited use for this research.

Only very recently these researchers indicated that these models should be amended, because the models don't solve all problems as experienced in practice [Ehrleinspiel 1999] and [Lindemann 1999]. In the engineering design field all the answers are not available yet; literature has progressed only to the point of stating the additional problems. These problems are related to the way the designer acts in the design process. The systems approach to these design processes hampers the solving of these problems.

Descriptive, argumentative processes are developed mainly in the field of architecture, where the focus is on how designing is carried out by practitioners and dealing with the problems actually faced by designers. These models are primarily descriptive [Darke 1978], [Schön 1983], [March 1984] and [Cross 1994]. Hillier et al were among the first to question the orthodox view that designers should resist bringing their own preconceptions to bear on the problem. They argue that designers not only do but inevitably must preconstruct their problems in order to solve them [Hillier et al 1984] and [Cross and Roozenburg 1992]. Because this can imply the introduction of content related aspects into design research we will investigate the ideas behind a few major models in this field.

Darke shows, from interviews with architects, that the use of a few simple objectives to reach an initial concept was characteristic of these architects' approaches to design. They narrow down the range of solutions by introducing a relatively simple idea very early in the design process. Further understanding
of the problem is then gained by testing this conjectured solution. This idea, or ‘primary generator’ as Darke calls it, can be ‘to express the site’, ‘to provide for a particular relationship between dwelling and surroundings’, or ‘to maintain social patterns’ for example. These objectives form a starting point for the designer, which is a way into the problem [Darke 1984]. With these findings Darke suggests a new ‘model’ for designing, based on generator - conjecture - analysis. First the designer decides what might be an important aspect of the problem, and then he develops a crude design on this basis and examines it to see what else he can discover about the problem. These ‘primary generators’ seem to be a first attempt to include the design content into the ‘process of designing’.

Bucciarelli does an ethnographic, empirical study and is the first who recognises design as a social activity [Bucciarelli 1984 and 1988]. He emphasises the significance of different participants thinking about the work on the design in quite different ways. They do not share fully congruent internal representations of the design. Bucciarelli calls this ‘object worlds’: the worlds of the technical specialisations. He states that differences between object worlds are significant. Engineering design requires the collaboration of different forms of professional expertise, all working up, ultimately, to the same artefact. But one and the same object is differently construed within different object worlds. He warns: “…Ambiguity will always be with us in designing, especially in the conceptual design stages. Different participants, each with their own stake in the project, working from within different object worlds, will see the design differently. Concepts need room to be manoeuvred, shaped, and developed. Artefacts, the formal productions participants make in processes, are not the design. They do not uniquely define the design or contain comprehensive knowledge of the design (any but the final stage in the process). Organising for the management of design is no simple task. There will always be design moves that challenge and reach across conditions at the boundaries. Synthesis is not a simple summing of the independent contributions of designers in different groups. How best to structure design teams? Study of designers at work can help answer such questions…” [Bucciarelli 1988, page 168]. He shows examples of how various individuals’ views of the object world differ and how, at any given moment, the current artefact is best understood as a combination of these differing views. This
subscribes to the viewpoint set out in the problem statement.

In 1983 Donald Schön contributed to the discussion about the fundamentals of design and design methodology [Schön 1983 and 1987a]. Schön develops the ideas a step further by introducing an ‘epistemology of practice’; “…one that would stand the question of professional knowledge on its head by taking as its point of departure the competence and artistry already embedded in skilful practice – especially, the reflection-in-action (the thinking what they are doing while they are doing it) that practitioners sometimes bring to situations of uncertainty, uniqueness and conflict…” [Schön 1987a, page xi]. The dominant model of professional knowledge, Technical Rationality, as he calls it, is a process of problem solving. But “…Increasingly we have become aware of the importance to actual practice of phenomena – complexity, uncertainty, instability, uniqueness, and value-conflict – which do not fit the model of Technical Rationality….” [Schön 1983, page 39]. We have, so far, ignored the problem setting, “…the process by which we define the decisions to be made, the ends to be achieved, the means which may be chosen…” [Schön 1983, page 40].

Observing practitioners taught Schön about the artistry of the professional practitioner; the unconscious activities and implicit knowledge they use in day-to-day work. “…Our knowing is ordinarily tacit, implicit in our patterns of action and in our feel for the stuff with which we are dealing…” [Schön 1983, page 49]. Schön calls this ‘knowing-in-action’. “…Our spontaneous knowing-in-action usually gets us through the day. On occasion, however, it doesn't. […] All such experiences, pleasant or unpleasant, contain an element of surprise. Something fails to meet our expectations. […] We may respond to surprise by brushing it aside. [...] Or we may respond to it by reflection…” [Schön 1987a, page 26].

The process of ‘reflection-in-action’ begins with a situation of action to which we bring spontaneous, routinised responses. These reveal knowing-in-action that may be described in terms of strategies, understanding of phenomena, and ways of framing a task or problem appropriate to the situation. The routine responses produce a surprise – an unexpected outcome. This surprise, which gets our attention, leads to reflection on the routine action. Reflection is at least in some measure conscious, although it need not occur in the medium of words.
A crucial function of reflection-in-action is questioning the knowledge used in the knowing-in-action. Then we may, in the process, restructure strategies of action, understanding of phenomena, or ways of framing problems. The reflection gives rise to on-the-spot experimentation. We think up and try out new actions intended to explore the newly observed phenomena, test our tentative understanding of them, or affirm the moves we have invented to change things for the better. On-the-spot experiments may work, again in the sense of yielding intended results, or it may produce surprises that call for further reflection and experiment [Schön 1987a, page 28].

Schön recognises and acknowledges the problems we set out in our problem statement, concerning the designer dealing with insecurity, complex problems and the diverse (even conflicting) views of the situation. He states that this will remain unsolvable as long as we look upon designing as Technical Rationality. Schön’s theory of reflective practice recognises a reality in which the designer creates his own situation. Through continuing reflection-in-action the designer will eventually come to a problem setting and a suitable solution within this setting.

Most of these descriptive models are based on the idea that solution concepts precede problem analysis; the designer needs to generate a preliminary solution to begin to think about the problem. Problem and solution evolve together during the design project. Designing in these models is described as an opportunistic, cyclical, argumentative process, which starts with solution conjecture and accepts prestructures. Design problems are considered to be ‘wicked’ in the sense of being broad and therefore hard to keep under control. This means that in solving this problem a designer has to make a great number of connections between the constraints, between the interdependent decisions and between the problem and solution [Lawson 1997].

These models in architectural Design Methodology reflect design closer to the way practitioners carry it out. They may seem vague, but their strength lies in the attempt to integrate variables of the design problem and the designer into know-how of the design process. This provides descriptions, which contain a wealth of information, linking process and content related aspects. This makes them more suitable for our purposes.
This dichotomy in the research field Design Methodology is extensively described and analysed by Dorst [Dorst 1997].

**Empirical studies of design**

The research of design methods used to have a strong interest in investigating what designers should do. In later work a shift can be detected towards an interest in what designers do, investigating design in practice. Although empirical studies were executed from the early beginning of the research field [Marpl[es 1961], [Ramstrom and Rhenman 1965], and [Akin 1979], they really come to the fore from halfway through the 1980s [Hales 1987], [Wallace and Hales 1987], [Schön 1983], [Bucciarelli 1984 and 1988], [Waldron and Waldron 1988], [Blessing 1994], and [Frankenberger and Badke-Schaub 1998]. The design community developed an interest in how designers handle these design models in practice. The models provide the necessary phases in the design process through their gradual approach. They explain little about the actual performance of the design project or how designers cope within the project.

In view of our problem statement we are especially interested in broad empirical studies, such as the ones performed by Marpl[es, Hales, Whybrew et al, and Frankenberger. These will be described in more detail, looking for interesting approaches to design. At first the studies will be described and then conclusions will be drawn from the four studies together.

Marpl[e’s empirical study, in the very first paper on this subject, aims to indicate the critical decisions in the design process, in order to be able to formulate strategies for examination and choice of possible solutions [Marpl[es 1961]. The analysis of two case studies suggests that designing consists of a sequence of critical decisions leading from the initial statement of the problem to the final specification of the hardware, and describes the decision making processes and strategies along the way.

Hales did a comprehensive study, in which he observed the general activities and techniques in an engineering design project [Hales 1987]. He tried to classify the ‘engineering design effort’, that is ‘the observed time spent on an engineering
design project', according to the Pahl and Beitz 'steps' of the engineering design process. The results are staggering; 53% of the engineering design effort could not be categorised according to the Pahl and Beitz 'steps' of the engineering design process. By adding six more 'general activity' categories this remaining 53% of the observed engineering design effort could be accounted for. Added general activities comprised planning, cost estimating, reviewing, information processing, social contacts, and helping others. Of the observed engineering design effort, 22% could be categorised according to the 'method and aids' recommended by Pahl and Beitz. By adding 13 more techniques for 'working' (making lists, calculating, scheduling, filing), 'communicating' (questioning people, negotiating, reporting) and 'motivating' (becoming involved, injecting enthusiasm, adding humour and team building), a further 74% could be accounted for (4% remained unclassified).

Whybrew et al, in a single case research project, studied the relationship between the product development process applied by the company and several idealised models for the design process, in particular Hales' model [Whybrew et al 1999]. Phase diagrams of the product design project show missing roles and information in the design project that delay the progress of the project.

Frankenberger also did a broad empirical study. In four extensively analysed projects he identified the influences on 'critical situations' in the design project. As influencing factors on the design process and the product he considered individual- and group prerequisites, external conditions, the design process itself, the task and the product. His analysis of the results shows that motivation is the most important prerequisite of the individual. Lack of it being responsible for both deficient analysis of solutions and wrong decisions. The factor group-organisation is the most important group related factor, followed by climate and quality of leadership. Experience is the most important influencing factor in general, according to the frequency of occurrence, but has almost no relevance for deficient analysis and decisions. [Frankenberger and Badke-Schaub 1998], and [Badke-Schaub and Frankenberger 1999].

These four studies report on a 'direct analysis' of the design process in practice;
an actual test of the design models, and an analysis of the difference between the prescriptive models and actual designing. The studies all conclude that the design process as experienced is strongly influenced by contextual factors. These factors strongly refer to social activities. These were well represented among the categories Hales had to add, and among the prerequisites Frankenberger indicated as being influential critical situations. They deserve more attention in design research.

The problems, addressed in these studies, are relevant for this research. Therefore it seems useful to take a look at other empirical studies that do not primarily focus on the design process. We want to investigate full descriptions of design, to see how we can account for the design activities that don’t fit within the prescriptive design theories. Several studies are performed in a more ‘open’ sense, where the researchers look at the data without a preconceived idea of designing and without an explicit focus on the design process [Akin 1979], [Waldron & Waldron 1988].

Akin’s results of a protocol analysis show design activities that do not keep up with the known prescriptive processes, but are more of a searching process and more free: “...as we can see from the protocol, one of the unique aspects of design behaviour is the constant generation of new task goals and redefinition of task constraints. [...] Not only is the compartmentalisation of the design process (i.e. analysis - synthesis - evaluation) untrue, but the tactics implied for each of these compartments is also unrealistic...” [Akin 1979].

Observing an actual engineering design project Waldron & Waldron come to similar observations [Waldron and Waldron 1988]. These observations indicate the influence of individual knowledge and experience, and communication and decision making in design teams. These factors influence the development of the ill-defined concept.

During that time, in the late 1980s, researchers also searched for new design models that represented the behaviour and cognitive skills of the designer [Adelson 1989], [Whitefield and Warren 1989], and [Mazijoglou and Scrivener 1998]. The search for these models resulted in comprehensive case descriptions. The generalisability of these case histories and therefore of their conclusions, is
still under-developed.

Three research techniques for the empirical studies have been used up to now: retrospective reports and interviews ([Marples 1961] and [Ramstrom and Rhenman 1965]), observation ([Bucciarelli 1984 and 1988] and [Hales 1987]), and protocol analysis ([Waldron and Waldron 1988] and [Akin 1979]). Research methods from the field of psychology have been adopted and developed, because of the growing interest in the designer's thinking process. Especially protocol analysis, in which experimental subjects are 'thinking aloud' while performing a specific task (a more thorough description of empirical research method is provided in chapter 3). Through the development of protocol analysis, more and more experiments with designers have been developed. A brief history of protocol analysis in design is described in [Dorst and Cross 1995]. By letting designers participate in a design experiment, where they are asked to 'think aloud' while designing, researchers investigate the designers cognitive behaviour; how designers tackle design problems. The individual designer is observed in terms of his 'information request' [Ullman et al 1989], his 'cognitive style' [Eckersley 1988], handling 'creativity' [Christiaans 1992], 'integration strategies' [Dorst 1997], or 'thinking styles, abilities and personality traits' [Cross 1985 and 1990], [Cross and Clayburn-Cross 1996a]. These studies focus on the thinking process of individual designers, while we are interested in communication on the design content between designers within a team. Therefore these studies are, as starting point, of less interest. They might come to use in the evaluation of results of our research project. Also the applied research techniques can be of great use.

**Design as a team activity**

Up to this point in time, early 1990s, research had focussed exclusively on individual designers. In view of our problem statement we are primarily interested in co-operation within design projects. During these years papers were being published on concurrent engineering and the parallel nature of design. The growing competition in the product's environment speeded up the product development processes. This brought with it more research into parallel processes in product development and the
co-operation of design with other disciplines [Eppinger 1991], [Bond and Ricci 1992], [Taylor 1993], [Duffy et al 1993], and [Eppinger et al 1994]. Eppinger emphasises the need to divide a design task into separate parts, so that tasks can be performed in parallel. For this he develops a 'design structure matrix', with the purpose to break down the large and complex task of design into manageable parts [Eppinger 1991] and [Eppinger et al 1994]. Taylor also stresses the importance of the parallel nature in design. He does not present a model, but encourages the development of various existing models to better perform tasks in parallel [Taylor 1993]. Duffy et al present 'design co-ordination'; a high-level concept of the planning, scheduling, representation, decision making and control of product development. This design co-ordination system is linked to a computer-based support system [Duffy et al 1993].

Considerable efforts in concurrent engineering research is directed at ways of performing tasks in parallel, which have traditionally been carried out relatively sequentially. This leads, again, to the management of design with a strong emphasis on the design process. While Bond and Ricci, in a description of a project in aircraft design practice, stress the importance of communication and co-operation between specialists: "...Aircraft design proceeds by the co-operation of specialists. Each specialist has his own model of the design and may even use several different models for different purposes. Specialists also have limited ability to understand each other's models; they communicate using a shared vocabulary, but not necessarily shared technical knowledge. Design proceeds by successive refinement of the models, which are co-ordinated and updated together. The decisions, which are acts of commitment and model refinement, are negotiated by the specialists among themselves, organised and controlled by the use of commitment steps..." [Bond and Ricci 1992].

This 'parallel nature of design' is particularly well developed in the field of engineering design (concurrent engineering, product quality assurance and quality function deployment) and in the field of management (new product development and integrated product development).

In the field of Design Methodology the focus is still on the designer(s). In 1991 the first publications on design as a team process were published [Minneman
[Olson et al 1992], and [Wong and Siriam 1993]. In 1993 the International
Conference on Engineering Design, an authoritative conference in the field, had
a theme ‘team work’ [ICED 1993]. (This conference was held at the same time
as the start of this research project.) It is remarkable that there is a lack of explicit
themes on team work or design co-operation in the later ICED Conferences
[ICED 1995] and [ICED 1997]. Only the 1999 conference had a sub-theme
‘individual- and teamwork in design’, with two contributions on teamwork
[ICED 1999].

The aim of many of these early papers on teamwork in design is the development
of concrete tools to support co-operation and communication in large design
projects. They either try to improve team design performance in a general
manner: a method for teams [Stuffer and Ehrlenspiel 1993], the success factors of
teams [McCallion & Britton 1991], or designing educational exercises [Brereton
et al 1993]. Or they describe very specific tools: a computer based group design
system to support early design decisions [McMahon 1993], a documentation
procedure to speed up decision making [Mobagunje et al 1993], a systematic
method for creativity [Bauert 1993], video as a reflection tool for teams [Radcliffe
and Slattery 1993], collaborative systems within CAD systems [Sevenler et al
1993], or communication tools [Harrison and Minneman 1993].

These last authors plead for a further development of tools: “... The needs of
designers to communicate is increasing as their projects become more complex and
design teams become more distributed. [...] The design research community must
actively participate in the design of new systems...” [Harrison and Minneman
1993]. But is developing useful effective tools possible if we don’t understand the
nature of the activity yet? We agree with Minneman, stating that: “... Few people
deny that, at some level, working in and as a part of groups is a critical part
of design, but few are taking a serious look at what that involves. [...] Outside
a few exceptions, design researchers largely persist in doing protocol studies of
individual designers and in building design tools without an understanding of
the context of their use...” [Minneman 1991].

The researchers, who attempt to grasp the ‘nature of team design activity’, also
pay attention to the development of a research method that is able to observe
team aspects [Minneman 1991], [Tang and Leifer 1991], [Tang 1991], [Olson et al 1992], and [Crabtree et al 1993]. The results of these studies are either very specific, like the groups’ use of shared drawing surfaces [Tang 1991]. Or they lead to general insight as in the study performed by Olson et al. They observed, videotaped, transcribed and analysed ten early software design meetings, using a coding scheme that looked at the participants’ problem solving and the activities they used to co-ordinate and manage themselves. The results show that 40% of the time is spent on direct discussion of design, 20% on pure co-ordination activities, and 30% on taking stock of their progress through walkthroughs and summaries. These activities have a dual role: they co-ordinate the activities and help the participants to develop their ideas and make them clearer [Olson et al 1992]. Crabtree et al identify project delays that were due to poor co-ordination/integration, divided into six problem categories [Crabtree et al 1993]. Minneman identifies particular practices employed by the participants to accomplish complex interactions: negotiating understanding, preserving ambiguity, tailoring activity for engineering recipients, manipulating mundane representations [Minneman 1991].

The first time a larger group of researchers in Design Methodology really looked at team design activities to try and understand what was happening and to identify relevant research issues, was at the Delft workshop ‘Analysing design activity’ in 1994 (see also [Cross et al 1996a], [Dorst 1995], and [Valkenburg 1998]. The workshop primary focussed on protocol analysis as a research technique. Providing researchers around the world with the same data and asking them to analyse it in any form that they saw fit, would make it easier to compare and criticise each other’s work and discuss the possibilities and shortcomings of protocol analysis [Cross et al 1996b].

Researchers were provided with recordings on video tape and a written protocol, of a three-person group of designers (“Ivan”, “John” and “Kerry”) designing a fastening device for a backpack onto a mountain bike [Dorst 1995 and 1996]. Researchers were also provided with a protocol of an individual designer performing the same assignment. The team video inspired some researchers to analyse team designing in more detail. Focussing on the use of the team video, we divided the researchers into four groups.
The first group of researchers did not use the team protocol, but based their analysis purely on the individual protocol. They state that studying team design is always prey to subjectivity, because occurring social aspects are difficult to quantify. They remained with individual protocol research to avoid problems of interfering social behaviour, as Baykan explains: "...we expected that analysing the problem solving behaviour of the team would also involve looking at other issues, such as group interactions..." [Baykan 1996]. Or because they were used to it: "...we analyse the individual designer's protocol, primarily because it represents a design mode with which we are most familiar..." [Akin and Lin 1996]. Others stuck to the individual's protocol because they are interested in design thinking and information processing aspects of (individual) designers and it was therefore justified within their research aims [Baya and Leifer 1996], [Visser 1996], and [Dorst and Dijkhuis 1996].

The second group of researchers analysed the group protocol, on information processing aspects. Although their analysis is on team designing, their conclusions don't explicitly mention the fact that the designers perform their task together. The conclusions do not deal with team design aspects [Takeda et al 1996], [Popovic 1996], [Trouss and Christiaans 1996], [Mazijoglou et al 1996], and [Ullman et al 1996].

The third group of researchers compared the group protocol (on whatever aspects) with the individual protocol. They approached the team as an “individual”, considering either the “team resultant” or the “speaking team member” at a certain moment (probably to make it easier to compare the team with the individual designer). Interaction between team members is barely noted in these analyses [Dwarakanath and Blessing 1996], [Goldschmidt 1996], and [Günther et al 1996], because the team is approached as a ‘black box’. For example in his paper Günther states that Kerry (one of the three team members) makes ten, out of a total of eighteen, decisions in the entire design process [Günther et al 1996]. It is just that the team does not carry these decisions through in the final design. Looking at the design process, we have to agree with Günther, but interpreting the content of the decisions, his results can raise doubts. The same type of problem occurs in the paper of Goldschmidt; she scores ‘critical links’,
that can be appointed to an individual, but are not always relevant to the shared design content in the team [Goldschmidt 1996].

The fourth group took the group protocol as a starting point to explore aspects concerning team design that do not appear in individual designing. Although these analyses are very explorative, the similarity between these analyses [Cross and Clayburn Cross 1996b], [Brereton et al 1996], [Radcliffe 1996], and [Harrison and Minneman 1996] is striking compared to the diversity of analyses within the individual protocol. Especially within the examples used there is very much overlap. It looks as if these papers address the same moments within the team design project in looking for interesting aspects of the social process in the team.

Cross and Clayburn Cross analyse the social process in the design team [Cross and Clayburn Cross 1996b]. Their observations include: the planning and acting upon it by the team, information gathering and sharing, problem analysis and understanding, and concept gathering and adopting. These observations are illustrated by examples from the protocol, which show how one team member initiates something, and tries to persuade one or both others. The various persuasion strategies used by the team members become quite apparent in the examples. One striking observation is that "...Even when information is apparently shared, misinterpretations and misunderstanding are evident, which means that common, shared understanding cannot be assumed in collaborative work..." [Cross and Clayburn Cross 1996b, page 307]. Here the authors identify the same problems that we have stated earlier. They also address the problem that the team members' interpretation of the design content can differ, in spite of attempts to harmonise these views: "...There is a contrast and perhaps a conflict between attempts at understanding a problem through 'listing' [...] design requirements and specifications] and through 'framing' [...] the problem in some more intuitive or conceptualised form]. Listing enables an externalised specification, but it does not necessarily lead to an internalised conceptualisation or grasping of the problem in the way that attempts to 'frame' the problem do..." [Cross and Clayburn Cross 1996b, page 309]. This 'framing', which relates to creating a shared understanding among the team members, is illustrated to be difficult and sometimes not successful.
Brereton et al also focus on the social interaction in the design team. They identify different strategies of persuasion used by the team members [Brereton et al 1996]. These strategies include 'common sense', 'expert witness', 'commitment', or more opportunistic strategies, like 'give and take', and are all illustrated by examples from the protocol. They conclude by stating that "...There are surely many other methods and interpretations. However the tape provides a valuable means of introspection and reflection for the design student. Watching, discussing and reflecting upon those tapes provides a means for design students to become aware of the variety of productive and counterproductive strategies and processes available to them..." [Brereton et al 1996, page 340]. We strongly agree with the attributed value of these analyses for educational purposes, but we are very sorry to have to say that we don't see that these analyses exceed the anecdotal level. If conclusions cannot be made applicable in a wider context, studies like this will never exceed the level of learning by examples.

Radcliffe describes the development of the design content by following the flow of some concepts in the team design project [Radcliffe 1996]. He describes the development of the 'schedule' through the process, the life cycle of the 'external frame as a rack concept', and the appearance and development of the 'tray concept'. He concludes that "...Team design is inherently concurrent in nature: parallel processes exploring the design space informed by individual knowledge histories. Each individual is an independent cognitive and social agent, whose actions are intertwined through the necessity to produce some group work product. They form an intellectual federation, constituted around a set of agreed understandings and rituals that frame their collective work. These understandings are presumably negotiated over time, restated and reinterpreted, as with any confederation..." [Radcliffe 1996, page 362].

An important difference between the third and the fourth group of researchers is that the third based its analysis mostly on the transcribed protocol, while the fourth considered mostly the videotape. The analyses based on the transcript don't show much interaction between team members and therefore consequences of separate utterances. It seems very difficult to manage the differences between the individual level and the team level in analysing team behaviour.

The explorative studies of the fourth group of researchers, concerning the
social aspects of team design are very appealing. They illustrate the problems and possibilities in team design that we also identified earlier. However the papers also show the difficulties in this type of explorative research: the lack of generalisability of the conclusions, because they only result in case study descriptions of 'anecdotes' in team designing.

Other team design research papers also describe explorative studies, trying to identify the problems in collaboration in design [Crabtree et al 1997] and [Ehrlenspiel et al 1997]. Crabtree et al investigated the time spent on activities in a design project and the problems that were perceived by the participants [Crabtree et al 1997]. Ehrlenspiel et al compared groups of engineering design students working on a one-day design project without supervision and a ten-day design project with methodological approach under supervision. Observations and results from the first day indicate that the students had difficulties with the creation of the overall concept, with comprehension and imagination of solution principles during the discussion in the team, with agreement within the team on the solutions, and with the simultaneity of understanding other team member's proposals and the development of one's own solutions [Ehrlenspiel et al 1997, page 63]. These difficulties refer to the shared integration and understanding in the team. The solution Ehrlenspiel et al applied and evaluated; systematic approaches under supervision, helped in structuring the teamwork and render it more effective. However, they still argue for further research on social, psychological and pedagogical aspects of teamwork in design.

The last group of papers on team designing focus more specifically on communication in design projects [Peng 1994], [Sonnenwald 1996] and [Adelson 1999]. We already discussed the work of Olson et al who analysed the time spent in design meetings [Olson et al 1992]. Their results indicate that participants spent a large amount of time sharing and explaining expertise (total of 33% of the time, see also page 28). Peng looked at the interrelationship between common images shared by the group and domain design expressions known by individuals [Peng 1994]. In three historical architectural design cases he studied communication in this relationship and found instances of communication conveying shared conceptions of unity in design, mostly through common images
or models.
Sonnenwald looked at communication roles that support multi-disciplinary design teams and developed guidelines for the support of these roles and strategies [Sonnenwald 1996]. Adelson developed a computer tool for supporting collaborative negotiation [Adelson 1999]. These studies may seem to be too detailed for our purposes at this point, but the study of communication may be of interest in a later stage of the project.

**Research standpoint**
The review of literature on design research shows that few researchers deny that working in and as part of a team is a critical part of design, only very few have taken a serious look at what that involves. Outside these few exceptions design researchers largely persist in doing studies of individual designers and building tools for them, without understanding the context of the use of these tools.
Studies that do look at co-operation in design reveal more and more insights in the complexity of the design activity. They indicate that 'context variables' influence the performance of the design process, referring to the designer's approach towards the problem and communication within the project. These empirical studies indicate the problems that design teams face in practice. They also show that in studying team designing, researchers should no longer focus merely on the design process. They rather integrate characteristics of the designer (or design team) and of the design task. The studies do not yet provide us with the answers to the problems indicated, for they are still looking for a good approach to study design.
Some explorative studies on design as a social process have taken place. These empirical studies, as do the ones described above, also indicate the problems in communication and co-operation within design teams. They provide detailed descriptions of cases of team designing and examples from team protocols. These explorations also reveal the difficulties in doing this type of explorative research. The studies end in case-descriptions of 'anecdotes' in team designing and lack generalisability of findings and conclusions.

Although there is little knowledge of co-operation in design available yet, current know-how does confirm the relevance of the problem statement of this research.
Current research also indicates the usefulness of a structured approach towards the study of team designing. If this research can provide a good way of looking at team designing to help analysis of team behaviour, it can help the progress of the research in the field of design.

It is our view that the way of looking at design should have a foundation in a general theory of design, to provide a framework to integrate team design aspects into the current know-how on design. One of the theories that are suitable is the view on design as reflective practice, developed by Donald Schön. A recent study in our research group on the usefulness of the reflective practice ideas indicates that reflective practice provides insights in the complex integrative character of designing and the role of the designer and his approach towards the design task within [Dorst 1997]. The theory is also used more and more throughout the design field as a starting point for new research [Lloyd and Deasly 1998], [McDonnell 1996], [Pereira 1999], [Cross and Dorst 1999], and [Stumpff and McDonnell 1999]. This provides enough encouragement to apply it in this research.

Our problem statement requires an empirical study on team designing, focussing on the management of the design content within the team. The reflective practice theory will be used to structure the analysis of team designing. The studies of individual designers are of interest to us to be able to indicate the differences between team designing and individual designing. The studies of teams will also provide comparison material to indicate whether we succeeded in developing a good approach toward team design research. In the next section the research questions will be refined for the empirical study.
Research Questions

On page 25 the problem statement of this research was formulated as:

How can project managers manage the design contents of their product design project while at the same time achieve a shared understanding of this content among the project team members?

In this section the factual questions behind this problem statement will be investigated and research questions for the empirical study will be formulated. Literature research reveals that current insights of how to do design research of teamwork are substantially incomplete. This indicates the need to develop and apply an effective and responsible way of observing and analysing team designing. A method, that both produces satisfying results and does justice to the complex design activity. This research project will look for adequate answers to the demand for knowledge of team designing of project managers as well as the demand for knowledge of design research methods.

We need to gain more insight in the nature of team designing, to extend our notion of what is happening in design practice and to indicate how we might profitably intervene in that activity. In order to improve team designing, we have to understand it. In order to understand we must be able to describe it. Therefore an empirical study will be executed to investigate how design teams design, with an emphasis on team behaviour and communication in achieving a shared understanding of the design content. This study will be of an explorative nature, identifying the issues of interest in team designing regarding the problem statement.

We also need to develop a way to observe and analyse the empirical data. To exceed case study descriptions and be able to generalise empirical results we want to use a theoretical approach to the data. Describing design as reflective practice will form the basis for the empirical study. The theory needs more development and empirical verification.
Two research questions can be formulated, one focussing on the methodology and the other on the required insights to be gained:

How can we describe team design activities?
To answer this first question: “How can we describe team design activities?” we have to develop a theory based on the theory of reflective practice.

What can we learn from design teams at work?
The second question: “What can we learn from design teams at work?” asks after the nature of team designing. Looking at the reflective practice within design teams will provide insights into the nature of team designing.

Conclusion

In this chapter two major changes in the professional field of product design were identified. First of all the nature of designing is changing from an individual activity, that mostly occurred inside the head of the designer and therefore is considered to be mysterious, towards a team activity, in which all persons concerned design together. This implies a new role for project managers of product design projects; they face problems concerning synchronisation and harmonisation in design teams. These problems are related to the nature of the task, designing, and the communication involved. Design projects involve a lot of people and therefore a lot of communication and co-operation; communication about a subjectively interpreted, vague and constantly developing content.

Secondly the view on designing is changing from design as a stage-gate process towards design as a collaborative process. During the 1980s design researchers become interested in execution of design processes, and therefore in designers. At first they investigate the designers’ thinking processes and later on the designers’ social processes. The state of the art in Design Methodology literature is that the design community recognises the growing importance of teamwork, but still provides us with few tools to handle the content related dimension of teamwork. A theory that acknowledges the interpretation and handling of design tasks is the reflective practice theory. Donald Schön provides a view on designing which
stresses subjective *framing* of the design task and *reflecting* behaviour of the designer. We will use Schön's view to gain more insight in the nature of team designing. The study has two major goals. The first goal is to develop and evaluate a research method for studying team design activities. The second goal is to observe team designing from the reflective practice viewpoint in order to gain an understanding of what is important in team designing. The research questions this research sets out to investigate are:

**How can we describe team design activities?**

**What can we learn from design teams at work?**

These questions will provide relevant information and insights that contribute to the solving of the problem statement:

**How can project managers manage the design contents of their product design project while at the same time achieve a shared understanding of this content among the project team members?**

**An overview of the remainder of the thesis**

This chapter set the problem statement, derived from team design practice. We opted for an empirical study on team designing, exploring the nature of team designing and developing a method of description for team design practice. The outline of the research project is illustrated in figure 4.

We need a further exploration of the theory of reflective practice, to develop a method of description for reflective practice and to refine the research questions for the empirical study. This will be described in chapter 2. We also
need to detect how we can collect empirical data from team design practice. We need to develop the research methods and techniques for the empirical study. These will be described in chapter 3.

The empirical study, applying the method of description and analysing team designing will be described in the chapters 4 and 5. In chapter 6 the research questions will be answered, by concluding on how to describe team design activities and what we can learn from design teams at work. These conclusions will also be extrapolated to attribute to the answering of the problem statement of this research.
2 Design as reflective practice

Introduction

In chapter 1 the need for an empirical study of team designing has been identified to investigate how design teams work. In this study, which will be of an explorative nature, we will identify issues regarding the creation of shared understanding of the design content within product design teams. Also the need to develop a way to observe and analyse the empirical data has been indicated. To provide a framework for this the theory of reflective practice, developed by Donald Schön, has been adopted [Schön 1983 and 1987a]. Design as reflective practice provides insights in the complex nature of designing, preserving the interaction between the design activity (process), the design task (content) and the designer(s). Because our interest lies in team communication on the product design content, this theory will suit our purpose.

The aim of this chapter is to investigate the suitability of the theory of reflective practice for describing team design activity. We will describe the theory of reflective practice as Schön presented it, explore its usefulness and develop it a step further, dealing with identifiable failures and criticism on the theory. This will result in a clarification of the reflective practice theory and a descriptive model that can serve our empirical research.

In the first section Schön's view on design and the theory of reflective practice will be described. The second section will investigate the applicability of this theory for our research. For this we will describe the context of this theory by relating it to other and subsequent studies and theories, and by answering the criticisms on the reflective practice theory. This will result in refined research questions for the empirical study. In the last section we will conclude with the development of a descriptive model for design as reflective practice, which will be used in the empirical study.
The reflective practice view of design

A new view of design?
Donald Schön was a professor of urban studies and planning at the Massachusetts Institute of Technology. During his professional life he worked with many students from different disciplines (e.g. architecture and urban planning) and also worked as a consultant with Arthur D. Little. In his work he recognised a gap between science (knowledge) and the real world (usefulness), in other words between the school's perception of professional knowledge and the competence required in practice. He asked himself: "... Can the prevailing concepts of professional education ever yield a curriculum adequate to the complex, unstable, uncertain, and conflictual worlds of practice?" [Schön 1983, page 12].

In several publications Schön stressed the need for theory of practical competence, and based on a sociological study on design behaviour of professionals in practice, Schön introduced an alternative approach to design: design as 'reflective practice' [Schön 1983, 1984, 1987a, 1987b, 1988, and 1992], [Schön and Wiggins 1992] and [Schön and Rein 1994]. Schön originally developed this view by observing professionals at work, amongst them designers [Schön 1983]. He claimed that all professional practice is 'design-like' and it is exactly this artistry of designing, which is left out in current science and education [Schön 1987a]. In later work he explicitly applied and explained his ideas in design situations, using examples from architectural design education [Schön 1987a and 1992].

The main premise of the reflective practice view on design is the idea that a designer subjectively interprets the design task and the situation he is in. From this interpretation the designer reflects on the situation to construct a decision about what to do next. This continuous reflection-in-action guides the progression of the design process.

Schön's view on designing as a profession is that a design situation is unique, uncertain and full of value conflicts. This requires the designer to determine his position in the design situation: "... In contrast to analysts or critics, designers put things together and bring new things into being, dealing in the process with many variables and constraints, some initially known and some discovered through designing. Almost always, designers' moves have consequences other than
those intended for them. Designers judge variables, reconcile conflicting values, and manoeuvre around constraints – a process in which, although some design products may be superior to others, there are no unique right answers...” [Schön 1987a, page 42]. This makes a designer someone, “... who converts indeterminate situations to determinate ones. Beginning with situations that are at least in part uncertain, ill defined, complex, and incoherent, designers construct and impose a coherence of their own. Subsequently they discover consequences and implications of their constructions – some unintended – which they appreciate and evaluate. Analysis and criticism play critical roles within their larger process. Their designing is a web of projected moves and discovered consequences and implications, sometimes leading to reconstruction of the initial coherence – a reflective conversation with the materials of a situation...” [Schön 1987a, page 42].

This view of designing and the designer creating his own situation does not fit the prevailing view of science and professionals in the early eighties. This prevailing view (which Schön refers to as ‘Technical Rationality’) holds that practitioners are instrumental problem solvers who select technical means best suited to particular purposes. Rigorous professional practitioners solve well-defined problems by applying theory and techniques derived from systematic, preferably scientific, knowledge. But daily practice is more complicated than this model. “... Often, situations are problematic in several ways at once. [...] These indeterminate zones of practice – uncertainty, uniqueness, and value conflict – escape the canons of Technical Rationality. When a problematic situation is uncertain, technical problem solving depends on the prior construction of a well-formed problem – which is not itself a technical task. When a practitioner recognises a situation as unique, she cannot handle it solely by applying theories or techniques derived from her store of professional knowledge. And in situations of value conflict, there are no clear and self-consistent ends to guide the technical selection of means...” [Schön 1987a, page 6].

However, in practice professionals do deal with these uncertainties, opacity and value conflicts. Schön was interested in how professionals do that. This he called the ‘artistry’ of a professional. The artistry refers to the kinds of competence practitioners sometimes display in practical situations. From this perspective,
Schön distinguished two types of situations and two types of knowing appropriate to them: "... There are familiar situations where the practitioner can solve the problem by routine application of facts, rules and procedures derived from the body of professional knowledge. [...] There are unfamiliar situations, where the problem is not initially clear and there is no obvious fit between the characteristics of the situation and the available body of theories and techniques. The competent practitioners bring available knowledge to bear on practice situation..." [Schön 1987a, page 33-34].

Schön explained this professional artistry in terms of reflection-in-action. "... Underlying this view of the practitioner's reflection-in-action is a constructivist view of the reality with which the practitioner deals. [...] In the constructionists' view, our perceptions, appreciations, and beliefs are rooted in worlds of our own making that we come to accept as reality..." [Schön 1987a, page 36].

Whether or not reflective practice provides a totally new view for practice and whether there are other useful ideas on its behalf, is one question we will not get into at this moment. We don't want to end up in an either/or type of discussion. The reflective practice way of looking at design has, in the field of design, been further developed by Dorst [Dorst 1997]. Dorst extensively analysed and tested Schön's ideas and stated that Schön's view of design delivers a new (at least a complementary) way of looking at design (see for further explanation of this research the next section). The main constructs of the theory of reflective practice, 'knowing-in-action' and 'reflection-in-action' will now be explained in more detail.

**The process of reflection-in-action**

The basis for reflection-in-action is that there is knowing-in-action. The observation of practitioners shows the unconscious activities and implicit knowledge they use in day-to-day work: "... The know-how implicit in their actions is incongruent with their description of it. I shall use knowing-in-action to refer to the sorts of know-how we reveal in our intelligent action. [...] The knowing is in the action. We reveal it by our spontaneous, skilful execution of the performance; and we are uncharacteristically unable to make it verbally explicit..." [Schön 1987a, page 25]. This knowing-in-action is based on an assumptional structuring
of the situation. Schön illustrated this implicit knowledge by giving examples of riding a bicycle or catching a ball. Activities in which awareness, appreciation, and adjustment play their parts. We know how to do them, but cannot easily explain our actions verbally. Although these examples are recognisable for any reader, they are weak. None of these examples show professional behaviour, and instead of explaining the use of implicit knowledge, they raise questions on the applicability in professional behaviour.

The process of ‘reflection-in-action’ begins with a situation to which we bring spontaneous, routine responses. These reveal knowing-in-action that may be described in terms of strategies, understanding of phenomena, and ways of framing a task or problem appropriate to the situation. Sometimes the spontaneous responses produce a surprise – an unexpected outcome. By definition a surprise gets our attention. This surprise leads to reflection on the action. Reflection is at least in some measure conscious, although it need not occur through the medium of words.

Reflection-in-action can lead to the questioning of the assumptional structure of knowing-in-action, and therefore the restructuring of strategies of action, understanding of phenomena, or ways of framing problems. Reflection initiates on-the-spot experiment. We think up and try out new actions intended to explore the newly observed phenomena, test our tentative understanding of them, or confirm the moves we have invented to change things for the better. On-the-spot experiments may work, again in the sense of yielding intended results, or they may produce new surprises that call for further reflection and experiment [Schön 1987a, page 28]. This reflection-in-action controls the action and corrects the thinking and, thus, feeds both.

“...This process spirals through stages of appreciation, action and reappraisal. The unique and uncertain situation comes to be understood through the attempt to change it, and changed through the attempt to understand it...” [Schön 1987a, page 132].

The reflective practice process can be seen as a cyclic process of activities, where the designers work by naming the relevant factors in the situation, framing a problem in a certain way, making (experimental) moves toward a solution and reflecting those moves.
The process of reflection-in-action illustrated

Schön illustrated design as reflective practice by a protocol of a conversation between a student and her tutor during an architectural design process [Schön 1983, chapter 3] and [Schön 1992]. In this famous design case study Petra (a student) has worked for several weeks on the design of an elementary school to be built on a given site. Petra has taken the contours of the land seriously, accepting the norm that building shape and land contours must fit each other. Then she experimented with the size and arrangement of the classroom units. She had six classroom units, but found them too small in scale to do something with. So she rearranged them in a more significant layout, L-shaped units, trying to “... fit the shape of the building into the contours of the land there - but the shape doesn’t fit into the slope...” This experiment failed and she got stuck (see figure 5). Petra presented her preliminary sketches and described the problems she encountered to Quist (the tutor).

![Figure 5 Petra's sketches of the design of an elementary school [Schön 1987a, page 47].](image)

Quist criticised Petra’s framing of the problem, pointing out to her that she had tried to fit the shapes of the building into the contours of a ‘screwy’ slope that offered no basis for coherence. This did not help her in her design. Quist proposed that Petra should make the Screwy site coherent by “... imposing on it a discipline of her own. A ‘what if’ to be adopted in order to discover its consequences...”

To illustrate his ideas, Quist imposed a ‘geometry of parallels’ on the site, suggested by the L-shaped classroom units. From this he used Petra’s L-shaped two-classroom units to ‘fit’ the landscape. This new frame to approach the situation led to the generation of new moves and Quist played out the consequences of these moves.

The sketches in figure 6 can help to make clear what Quist was doing. Quist
positioned the two-dimensional geometry of the L-shaped classroom units on the ‘screwy’ three-dimensional contours of the slope, as in sketch A. The difference in ‘level’, as shown in sketch B, was created by the drop in the slope over the distance covered by the three classroom units. The slope is now divided in three levels, one for each of the classroom units. Sketch C shows the ‘interval’ from the ground on one level to the roof of the classroom that stands on the next lower level. The roof of the classroom will rise above the ground at the next level up. This turned out to create protected spaces for kids, providing them with ‘nooks’ (sketch C) that were approximately as high as the tallest kid. The resulting elements of the school, the gallery, kindergarten and administration could now be positioned in relation to the design of the classrooms. Quist showed the gallery as a ‘soft back area’ which could go well with the ‘hard’ classroom (see sketch D). Also the cafeteria could in the design make better use of the shape of the rest of the school. Quist invited Petra to ‘soften it’ by taking advantage of the site’s orientation, which would cause sunlight to fall on the slope at different angles in summer and winter (see sketch E). Similarly, he invited her to ‘soften’ the auditorium by relating it to nearby spaces.

In this example we see that the student (Petra) has tried to solve the design problem, but has been unable to solve the problem as set. The teacher (Quist) responds by criticising the student’s framing of the problem. As he then reframes the student’s problem he suggests a direction for reshaping the situation. The teacher then takes the reframed problem and conducts an experiment to discover what consequences and implications can be seen to follow from it. He tries to

Sketches illustrating Quist’s demonstration [Schön 1987a, page 51]. Figure 6
adapt the situation to the new frame. This he does through a web of moves, discovered consequences, implications, appreciations, and further moves. But the teacher’s moves also produce unintended changes, which give the situation new meaning; the situation talks back to him, the teacher listens, and he appreciates what he hears. Each framing of the situation sets a direction for further moves, appreciations and reflection.

The described situation can be recognised in similar design situations and the issues that Schön addresses appeal to us, designers, as being important for solving the design task. However, looking very carefully at the protocol also raises questions what it is really about. Firstly, it looks like Petra ‘forgot’ to design a building. That she was waiting for the landscape to shape the design out of the classroom units she experimented with. Quist basically tells her to design the school first and then adjust it to the landscape. What then is the exact frame in this example? And where is the surprise that ought to initiate reflective practice? Is it the ‘getting stuck’ by Petra?

Secondly, recognising the frames and moves, does not necessarily mean that we now know what a frame is, let alone what a ‘good’ frame is. For the example shows that there is apparently good and bad framing of a situation.

Thirdly, an almost misleading aspect of this example is that it describes a conversation between a student and a tutor. Therefore it is not reflection-in-action of a designer at work, but reflection-on-action of a tutor mentoring a student’s work. A tutor-student conversation always contains explicit reflection (that is what the tutor ought to do), but it illustrates no reflection-in-action.

This first elaboration of Schön’s view on design is appealing and recognisable for it tends to illustrate issues, which are relevant to the practice of design and design education. However it also illustrates a few weaknesses and raises a lot of questions. Before looking at the suitability of the theory for this particular research, we will take a closer look at the applicability of design as reflective practice in the next section. This will be done by looking at its contributions over the years (especially in the field of design) and the criticism it received.
The applicability of the reflective practice theory

To be able to judge the usefulness of the reflective practice theory and to identify its strengths and weaknesses, we will investigate the context of the theory a step further. Where did Schön get his ideas? And, being referred to quite often, what are other researcher’s experiences in applying the theory of reflective practice?

The place of reflective practice

In Dewey’s approach to reflection, reflective thinking is initiated during a state of doubt, uncertainty or difficulty. It is the need to solve the ‘perplexity’ that guides the process. Clear is the similarity with the reflective practice process where Schön introduces the element of ‘surprise’, to initiate reflection-in-action. Dewey’s reflective thinking has a strong sense of goal orientation in a form of testing through action on the basis of the ideas, which support Schön’s view on move-testing experiments. And the ‘established belief’ has strong resemblance with frames; a way of making sense of the world. In this way the reflective practice view is not a radically different view towards the world, but the description of the process of reflection-in-action form these general thoughts on the practice of design.

The notion of ‘frames’ has also been introduced earlier in social science research (for an overview see [Gray 1996]). Minsky, often referred to in Design Methodology literature, introduced frames in 1974 in Cognitive Science as an ‘image’ or some sort of ‘skeleton’ (see [Minsky 1985]). He stated that we use frames as “… connection points to which we can attach other kinds of information …” [Minsky 1985, page 245]. The function of frames in his view, is the creation of some sort of ‘stereotype’.

Schön introduced frames in the field of design as part of the reflective practice view and developed them towards ‘standpoints that direct further activities’. The way in which a designer frames a situation gives the direction of further moves.

Schön was the first to introduce these concepts within an overall view onto the world of design, and it is interesting to take a look at what has happened with the reflective practice view since its introduction.
**Reflective practice in design**

Dorst's research provides an extensive study on Schön's work [Dorst 1997]. Dorst poses 'design as reflective practice' as a new paradigm for design opposite 'design as rational problem solving'. In a comparison he constructs a method of description for both paradigms and tests them in an empirical study. The empirical study contains a protocol study of nine individual designers, working in an experimental setting on a given design assignment. While designing, the designers are asked to 'think aloud'. The transcribed protocol is coded both according to the method of description for reflection-in-action and rational problem solving. In his findings Dorst states that:

- Coding design as reflective practice is difficult to do.
  
  "... Frames were not easy to identify: the problem was that only the use of a phrase identifies it as a frame [...] The identification of moves posed a similar problem, and they had the added difficulty of potentially being very quick actions that might easily be missed in the designer's verbalisation ..." [Dorst 1997, page 131]. On the other hand the reflective practice coding required little interpretation, because the designer's words were taken as literally describing designer's actions.

- The description of design as reflective practice works particularly well in the conceptual design phase.

  In this phase of the design project the designer proposes and experiments with problem/solution structures. Especially the concept of frames, and their interplay with names and moves, is very valuable and provides understanding of what is happening in the design project.

- Describing design as reflective practice preserves the interrelation between the design process, the design task and the designer.

  It is this interaction especially that provides new and additional insights to the knowledge gained through research on one of these aspects.

- There is a need for defining 'good' reflective practice.

  The weakness of the underlying theory and its notion of what 'good' design is makes it difficult to theorise or conclude from a reflective practice description.
Dorst makes a similar observation with Roozenburg, stating that: "...taken as an empirical theory, Schön's theory of reflective practice, as it stands, is admittedly weak and fuzzy. One looks in vain for explicit definitions of his central concepts, criteria for 'good' frames are largely missing, and Schön does not come very far in explicating 'the rigor in its own terms' that he ascribes to the process ..." [Roozenburg and Dorst 1998].

McDonnell also compares two forms of design descriptions in order to judge the value of both [McDonnell 1996]. The first description is an interpretation of design activities in the evolution of the design alternatives, and is based upon Schön's view of reflective practice. This description is compared to a formal description comprising a systematic grammar network. Through a case study on the planning and designing of electricity distribution networks, McDonnell provides a description of the design project based on the design alternatives the designer uses and his focus on the problem setting [McDonnell 1996, appendix A].

McDonnell's reflective practice based description clearly provides an overview of the designer's progress through the design project. The description clearly follows the development of design alternatives (moves), evaluations and the designer's focus at that time (frame). In the analysis of the description McDonnell also emphasises the importance of reflection in design. Illustrated by examples from the case study, she shows how the designer's focus of attention (frame) is influenced by reflections and can be seen as testing the 'fit' of a design alternative to the design problem as it is currently framed. This reflection also leads to a greater appreciation of the situation overall and may therefore result in a shift of emphasis (reframing).

In an analysis of reflective practice in design teaching, Pereira uses Schön's view in an attempt to develop her understanding of her own reflective practice [Pereira 1999]. Through the analysis of her teaching of first-year architectural students Pereira describes her own reflection-on-action and reflection-in-action in terms of the notions; 'uncertain situation', 'naming and framing', 'making moves', 'analysing moves' and 'reframing'. Reflection-on-action is explained through quotations from the 'reflective diary',
she wrote while developing the course, whereas reflection-in-action is explained by excerpts from dialogues between her, as a teacher, and the students during the course meetings.

In Pereira’s work the difference between the reflection-on-action and the reflection-in-action examples of the main notions of reflective practice is apparent. For instance the frame in reflection-on-action is explained as “... because architectural students are much more used to ‘visual language’ and are able to read ‘images’, the idea is to use a language that they feel comfortable with ...” [Pereira 1999, page 346]. An example of a move in reflection-on-action is the switching from sub-groups that students have to work in in-between group tasks. In the examples of reflection-in-action, based on the actual dialogue during the course meetings, the frame is “the metaphor of the architect as a juggler”, creating a common frame (a shared understanding) among the students to be able to make further moves. Then the students have to name the aspects an architect has to juggle with while designing. The examples of the next moves within reflection-in-action go much deeper into the meaning and essence of the action, describing the ‘trying to understand each other’-process between the teacher and the students, describing ‘telling and listening’ and ‘recalling’ and even explaining the use of body language, pauses and intonation.

Pereira’s description of reflection-on-action provides a nice description of what happened in the course, but the reflection-in-action examples really provide an understanding of what was going on in the course and how both teacher and students participated in this learning experience. It is a pity that the description lacks an explanation of reflection as a separate activity. In Pereira’s understanding of reflective practice, Schön’s ‘learning cycle’ goes from ‘setting the problem’ (through naming and framing), ‘making moves’ and ‘analysing these moves’, back to ‘setting the problem’ (reframing the problem). ‘Analysing moves’ is the first step in reflection on earlier moves, and ‘reframing’ is the result. By inserting a separate ‘reflection activity’, we think, Pereira would have succeeded even better in illustrating the process of learning in and through action.

These three examples of applications of design as reflective practice in empirical studies of design show the possible value of the theory for describing designing. All descriptions of reflection-in-action clearly present the development of the
design content within the project and the designer's approach towards the task. In our empirical study we will make observations of design teams at work, capturing interaction and communication of the team members about the product design content.

Dorst's difficulties in coding may be due to the analysis of 'thinking aloud' protocols of individual designers. Individual designers don't have to explain their framing of the problem, whereas designers working in a team have to utter their thoughts and convey their ideas in order to be able to co-operate. In teamwork, we expect explicit communication of what and how the team is designing. Therefore the team's reflective practice, like the communication about framing and reflecting, may be much more explicit.

In Pereira's description we notice the difference of reflection-on-action and reflection-in-action. We already pointed this out in Schön's own example of the Petra-Quist protocol. In our empirical study we will observe design teams at work, to try and capture real reflection-in-action of the team while designing, following their natural communication on their activities.

The studies also show that reflective practice is hard to work with. Schön himself did not provide clear definitions of his notions. However, the results up to now, like McDonnell's description of the developing design alternatives, are encouraging. This is the current status of Schön's work in Design Methodology research; many find it appealing, but only few have made the effort to develop it a step further.

Designers at work find the view of design as reflective practice highly recognisable and appealing. In a workshop for design tutors of the Institute for Design Education at the Delft University of Technology, the preliminary ideas of our research on the use and applicability of reflective practice as a 'new view on design' were presented [Dorst and Valkenburg 1997]. Designers immediately welcomed the reflection-in-action activities. These notions provided them with a language to talk about their own design- and tutoring experiences of aspects that were formerly dismissed as intuition or (implicit) personal experience. This enthusiasm of practising designers and design tutors motivated us to persist in finding a way to apply design as reflective practice in this research project. But we also realised that in order to apply the reflective practice view it was necessary
to specify the theory into a more coherent and explicit system of thought.

**Criticism on the reflective practice theory**
Not only in the field of design, but also in other disciplines Schön's work has inspired a great deal of other research. Much criticism has been levelled, in trying to fully understand his ideas, for instance from the field of design [Roozenburg and Dorst 1998]. For comments and criticisms from other disciplines see [Moon 1999]. In our description of Schön's ideas we already pointed out several shortcomings. Taking these criticism all together with the applicability for this research project in mind, a few issues emerge that necessitate taking a closer look at:

**The inadequate empirical evidence for Schön's ideas**
Schön's ideas are based upon empirical studies of professionals, but his examples don't show designers at work, performing reflection-*in*-action, but tutors reflecting on student's work. In other words reflection-*on*-action. A tutor-student conversation automatically contains reflection and by introducing a second person there is also an explicit verbalisation of this reflection. Schön's work does not contain evidence for the occurrence of reflection-in-action by designers at work.
We must agree with Moon, stating that "... Schön's constructs have been subjected to no better testing and have no more claim to be right than the concepts of others, except that many practitioners and their educators demonstrate enthusiasm for Schön's work..." [Moon 1999, page 39].

**Schön's lack of precise terminology**
Throughout his publications Schön uses simple terms and dichotomies to illustrate his ideas. While reading his books this pretends a clarity that is not always obvious throughout his work. Sometimes Schön even fails to hold on to a consistent approach to his own concepts. Also the chosen examples don't always seem to illustrate what he means. We already showed that the examples of 'riding a bicycle' and 'catching a ball' contain no professional behaviour, whereas the Petra-Quist example is really about reflection-on-action. For this lack of precision, both in consistency and in illustrating, we will provide examples.
The first example deals with the consistent use of the difference between reflection-in-action and reflection-on-action. Alongside the concept of reflection-in-action, Schön also introduces reflection-on-action and even reflection on reflection-in-action. He makes clear that these notions are fundamentally different: "... clearly it's one thing to be able to reflect in action and quite another to be able to reflect on our reflection-in-action so as to produce a good verbal description of it; and it is still another thing to be able to reflect on the resulting description..." [Schön 1987a]. But in later publications he seems confused as to how these activities differ at a crucial point [Moon 1999]. He introduces a moment of 'stop and think', but treats these moments inconsistently. In 1987, he implies that the activity of 'stop and think' is reflection-on-action because the reflection is not directly related to current action. In 1992, he describes two examples of reflection-in-action where there is a pause and he comments: "... in examples such as these, reflection-in-action involves a 'stop and think' [Schön 1992, page 136].

Schön's work also contains inconsistencies in the definition of terms and the illustrating examples. The phrase in Schön's work that comes the closest to a definition of a frames is "... the underlying structures of belief, perception, and appreciation, which we call frames..." [Schön and Rein 1994, page 23].

In a design case study, Schön introduces Harold and Franz [Schön, 1984]. Harold, the student, doesn't want to use a hierarchical order for his design of a dormitory for the MIT campus. But while designing he worries whether people could understand his design; "... right now it's a spaghetti bowl..." [Schön 1984, page 133]. Franz, the tutor, defines Harold's problem as follows: "... his consistent avoidance of hierarchical organisation is the reason why that kind of backbone and that kind of a central strategy eludes him - he then is searching for a process in which he can create that kind of coherence which he can achieve without having any hierarchies..." [Schön 1984, page 134].

According to Schön, this framing of the design task is "...not only a way of framing this design task, but an indication of a generic perspective that could be used to frame any design task of comparable scale and complexity..." [Schön 1984, page 134]. So where at first he claims that frames are a way of approaching a specific, unique problem so that the designer can take further steps to solve it, in the example frames are described as a generic perspective for design problems...
in general. By defining the concept of frames in this very open way, Schön has given us such a broad notion that it is almost impossible to use.

Over the years Schön's work repeats a lot in explaining and illustrating his basic ideas, but the explanations do not progress far in providing more refined ideas or definitions. This lack of defining terminology is a serious problem for researchers. The notions and examples Schön has given still leave a lot of questions unanswered. Apparently Schön himself was able to identify frames and intervene in the reflective practice process, but can other people do the same, based on his definitions?

**Making reflective practice work**

While there has been much theoretical speculation about Schön's notions, surprisingly few researchers have set out on the obvious task of operationalising them. Kirby and Teddlie attempted to make the notion of 'reflective teaching' work and failed to achieve this [Moon 1999]. They recommend further attempts to develop instruments and furnish the reflective practice theory with more 'content', meaning concrete definitions and explanations of the notions. If some of the content of reflective practice is tacit, then only applying these notions to empirical observations can help to gain more insight and develop this content.

Dorst operationalised design as reflective practice, defining the notions 'time', 'name', 'frame' and 'move' [Dorst 1997]. Analysing 'thinking aloud' protocols of individual designers, he made descriptions of design as reflective practice in a table showing these notions. He showed the occurrence of reflection-in-action, although he did not explicitly code reflection-moments. He also comments on the difficulty in coding.

**The paradox between generalisation and specification**

To Schön:

- every design situation is unique;
- a designer makes a subjective interpretation of this design situation;
- this way of framing the design situation is part of the personal heritage of the designer;
- and the reflection-in-action is a locally controlled activity.
But in the end he still describes the reflective practice process as a general view on designing. Following Roozenburg and Dorst, we, “... as design methodologists, may have been unjust and over-eager in trying to read into Schön’s book a new ‘practical’ theory of designing, while Schön has just presented what he calls a ‘primer’ for a new theory of problem solving in practice...” [Roozenburg and Dorst 1998, page 40]. However even as a primer these ideas are interesting and deserve the chance to be developed further and tested empirically.

**Emerging questions**

Although the criticisms of Schön’s work are many and diverse, the fundamental approach towards design that it represents is still interesting. Presenting design as a continuous reflection process, involving thinking while acting, relating the design process and design content, the designer’s approach towards the design situation, and learning while reflecting, makes it unique in it’s approach towards design. As illustrated in the last section there is diverse criticism on design as reflective practice, but these criticisms are not insurmountable. Schön’s work raises two fundamental questions that have to be valued in further application of the theory:

- Is reflection-in-action a valid construct in design activity?
- Is reflection-in-action rigorously operationable for use in empirical research?

We already indicated the need for empirical research of team designing in chapter 1. In team designing we are interested in the team’s communication about the creation of a shared understanding of the design content. In team designing designers need to communicate and utter their thoughts in order to harmonise their activities. In this research we want to describe and analyse the team’s communication about the developing design content and their attitude towards the design situation. The reflective practice view provides an interesting and fitting approach for this. The suitability and usefulness of reflective practice for describing team design will be tested in an explorative empirical study. We will attempt to develop a description of design as reflective practice, make the notions work, and test them in an explorative study on team design behaviour. We think that is the only way to be able to test its value and detect its weaknesses.
We already stated the general research questions for the empirical study in chapter 1: "How can we describe team design activities?" and "What can we learn from design teams at work?" Here we will refine these questions for the empirical study. In doing so it is appropriate to evaluate the questions that Schön's work raises.

**How can we describe team design activities?**
The reflective practice theory will be used to develop a method of description for team designing. According to the different criticisms this will be difficult, starting from Schon's definitions. For the empirical exploration we will make the main notions work within the theory of reflective practice, the four design activities, and code the observations of team designing according to this method. First we will have to investigate whether or not we can differentiate these activities. If the results of the explorative study are promising, the definition of these notions, and therefore the method of description, can be evaluated. The research questions for the explorative empirical study can be formulated as:

- Can team design activity be described with reflection-in-action?
- Can the four reflective practice design activities (*naming, framing, moving, and reflecting*) be differentiated in team design practice?

**What can we learn from design teams at work?**
Looking at design as reflective practice seems a supporting concept for observing the creation of shared understanding in design teams. This also has to be proven in the explorative study. The research questions regarding this concept for the first empirical study are:

- Can the occurrence of the four reflective practice design activities be observed within design teams?
- Does reflection-in-action demonstrate part of the team design activity concerning shared understanding of the design content?
A descriptive model for design as reflective practice

Our interest lies in studying the interaction within design teams. We believe that the concept of design as reflective practice offers a useful basis to describe what is going on when designers work together. We will develop the theory and try to be coherent and consistent with Schön’s view. In this section we will present a descriptive model for design as reflective practice that suits this explorative study.

The schematic representation of reflective practice

The basic notions of reflective practice are design activities. Designers work by naming the relevant factors in the design situation, framing this situation in a certain way, making (experimental) moves toward a solution and reflecting on those moves.

Figure 7 presents a schematic representation of the reflective practice process.

Taking Dorst’s empirical findings, the representation of reflective practice in a table, as a lead [Dorst 1997], we want to make a more visual representation. In this scheme, the naming-, moving- and reflecting activities are represented as separate images. For the framing we are not only interested in the framing activity, but also in the result: the frame that will guide further activities. In studying the team’s creation of shared understanding, we are particularly interested in the team’s approach toward the design situation. Therefore we want to know what frame they use at a particular moment and what activities they do inside this frame. Therefore the frame is represented by a box, in which other activities can occur. In this way, we can also indicate what a team does within the frame.

Reflection is a conscious and rational activity that can lead to reframing the problem (when the current frame is not satisfactory), the making of new moves, or attending to new issues (naming, when the reflection leads to a satisfactory result). In this way the reflective process continues; the whole design project can be represented as an ongoing process.
We are interested in the occurrence of all four activities, but also in the flow of these activities and how the designers use them. Such a flow, or pattern, could also illustrate two other dimensions of reflective practice that have to be taken into account:

1. **The implications designers discover and follow within reflective practice.**
   As the designer reflects-in-action on the situation created by his earlier *moves*, he must consider not only the present choice but the following choices to which that leads, each of which has different meaning in relation to the systems of implications set up by earlier *moves*. In doing this a pattern of "if ... then" emerges through reflection-in-action.

2. **The designer's changing attitude toward the situation.**
   Through the complementary acts of *naming* and *framing*, the designer singles out issues for attention and organises them, guided by an appreciation of the situation that gives it coherence and sets a direction for action. As the designer spins out his web of *moves*, his attitude toward the design situation undergoes a series of changes.

As we have shown, describing design as reflective practice is not without its problems, specifically concerning the reliable and reproducible identification of these four activities. We will take a closer look at how well we can define these notions from Schöns's work.

**The four design activities of reflective practice**

**Naming**

"...When a practitioner sets a problem, he chooses and *names* the things he will notice..." [Schön 1987a, page 4]. In a design problem these 'things for attention' can be for instance important design issues emanating from different stakeholders of the product to be designed, sub problems within the design task, or sub functions of the design. In attending to these *names*, the designer makes a choice for what he thinks matters in the design situation. "...Through complementary acts of *naming* and *framing*, the practitioner selects things for attention and organises them, guided by an appreciation of the situation that gives it coherence and sets a direction for action...." [Schön 1987a, page 4].
In team designing different team members might assign different names. In the perception of these names team members may also have different interpretations. Within team designing the naming activity will be the first attempt to share thoughts between the team members.

**Framing**

Schön does not provide a clear, concise definition of the term frame. From the publications we can figure out that frames are sense-making devices that establish the parameters of a problem.

Frames do not only exist in the minds of individual designers, but also need to be shared within the team. We are interested in these ‘team-frames’. For we believe that, in order to work together, team members have to share some common understanding of how they approach the situation. This implies that designers, working in a team, have to make their individual frames explicit and negotiable, in order to share them with other team members. Design team framing, by its very nature, is intricate, due to the necessity of creating a shared perception of the design task in order to be able to co-ordinate joint activities.

**Moving**

“...Each move is a local experiment that contributes to the global experiment of reframing the problem...” [Schön 1987a, page 57]. This activity is where the actual designing takes place. The designer experiments to solve the design problem. Activities, like generating ideas, exploring problems, or looking at the consequences of design decisions, undertaken by the design team, are called moves.

**Reflecting**

“...The designer evaluates his moves in a threefold way: in terms of the desirability of their consequences judged in categories drawn from the normative design domains, in terms of their conformity to or violation of implications set up by earlier moves, and in terms of his appreciation of the new problems or potentials they have created...” [Schön 1983, page 63]. The reflecting activity is, as to be expected, the one best defined in Schön’s books. We have to take into account that Schön’s way of reflection is reflection on activities, in relation to the attribution
to the design content. So within a team we are seeking for activities where team members reflect on what they are doing and question where this is taking them within the design task. Evaluating the content of design activities (e.g. evaluating ideas) are not reflections in terms of reflective practice, but moves; experimental activities within the design task.

The element of 'surprise'

Schön introduces surprises as initiators of the reflective practice process. He provides no further definition, and therefore surprises can be anything, like an interesting design idea, or the intuitive feeling of a designer that he is doing the right thing.

In team designing these surprises become social events. Team members may say: “I didn’t think of that...” and be surprised by activities undertaken by fellow team members. Being surprised may therefore be easier in teams than for individuals. In empirical research we can hardly focus on every moment of surprise that will occur, but the occurrence of surprises might serve as an indicator for the other activities, in particular reflecting or (re)framing.

These descriptions are the limits of how far Schön’s work can take us. Further operationalisation of this model will be described in the explorative empirical study in chapter 4. The next section will illustrate the use of the model applied to Schön’s example of the Petra-Quist conversation.

The schematic representation of reflective practice illustrated

On page 59 the example of Petra and Quist is described to illustrate reflective practice. If we apply the developed method of description to this example this will result in figure 8.

Because we come upon the design situation while it is going on, we missed the naming-activity. The example starts with Petra’s frame: “the building shape and land contours must fit each other”. While experimenting with her classroom units (moving), Petra gets stuck. In reflecting on this move Quist criticises the framing of the problem and encourages Petra to impose a “discipline of her own” on the design situation. As an example, he then imposes his own discipline:
a “geometry of parallels”. This is his framing of the problem (“a geometry of parallels”). This frame enables him to experiment with the L-shaped classroom units (moving). Positioning the L-shaped classroom units on the site, produces differences in levels of the classrooms.

Taking the design of the classrooms as a starting point, Quist positions the other parts of the school. He tells Petra to work on the cafeteria and auditorium by appreciating the outcome of classroom experiment. He also acknowledges the experimental use of frames: “... in order to discover its consequences. If these are unsatisfactory, she [Petra] can always ‘break it open later’.”

This schematic representation provides a good overview of the reflective practice within this example. It indicates the activities as well as the main contents of the design process. In the development of the frames we see the progress of the design content; the changing attitude of the designer towards the design task.

We can also see a pattern of reflective practice occur. The first frame is rejected by the reflection. Within the next frame a ‘web of moves’ is created, each move having implications for the next one and all moves together constructing a coherent design.

Finally the reflective practice process is shown in a very clear way.

This result is encouraging as a representation of design, but will it be possible to apply this onto the observation of team designing?
Conclusion

The theory of reflective practice, developed by Donald Schön provides a useful and interesting approach for studying design team activity, for it provides a way of looking at design with respect to the interaction between the design activity, the design task (content) and the designer(s). A first elaboration of Schön's view on design showed a few weaknesses and raised questions. Examples of application of reflective practice in empirical studies of design showed the possible value of the theory. The descriptions of reflection-in-action provide a clear manner to present the development of the design content within the project and the designer's approach towards the situation. The examples also show that we ought to observe design teams at work. In teamwork we expect communication on reflective practice, for instance on framing and reflecting, to be much more explicit, and we want to capture real reflection-in-action of the team while designing, following their natural communication about their activities.

We also realise that in order to apply the reflective practice view it is necessary to extend the theory into a much more coherent and explicit system of thought. We want to accomplish this by trying to apply the theory in an explorative empirical study. We think that is the only way to test its value and detect its weaknesses. The schematic representation for reflective practice that we developed provides a good illustration of the reflective practice in the Petra-Quist example. It indicated the activities as well as the major content of the design process. In the development of the frames we see the progress of the design content; the changing attitude of the designer towards the design task. And all this is shown very clearly. This result is encouraging as a representation of design, but will we be able to apply this to the observation of team designing?

An explorative study will be performed, to investigate the suitability of the model for describing team designing. The questions we want to investigate in the explorative empirical study concern the usefulness of the theory as a description method for team design activities, as well as the usefulness for investigating the product design content.
The research questions are:

- Can team design activity be described with reflection-in-action?
- Can the four reflective practice design activities (naming, framing, moving, and reflecting) be differentiated in team design practice?
- Can the occurrence of the four reflective practice design activities be observed within design teams?
- Does reflection-in-action demonstrate part of the team design activity concerning shared understanding of the design content?

In the explorative empirical study we will try to detect the inconsistencies within the theory of reflective practice. The study will also provide insight into the occurrence of reflective practice in team designing. In the next chapter the empirical research is designed by determining the research method and outline of the study.
3 Video-based team behaviour analysis

Introduction

In the previous chapters we have decided upon an empirical study of team designing. This study will be an exploration, investigating how design teams design. This explorative nature is due to the object of study, the body of theoretical knowledge, and the nature of the line of thought (both designing and the reflective practice view).

This empirical study has two goals. Firstly the exploration of describing team designing. A way of describing team design activities will be developed. Secondly the exploration of design team activities. We will be looking for patterns of behaviour or issues related to the creation of shared understanding in design teams.

We have adopted ‘design as reflective practice’ as a way of looking at and describing team design activities. With this view the research questions for the explorative study were formulated in chapter 2. Now we will discuss the set-up of the research project. Figure 4 on page 51 showed the outline of the research structure. This can be transformed into a structure for the empirical study (see figure 9).

Overview of the structure for the empirical research (according to figure Figure 9 4 in chapter 1).
Ultimately, we want to analyse and draw conclusions about team design practice, studying it from a reflective practice view (a). To be able to do this we will perform an empirical study. Firstly, we have to derive data from the real world (b). This first phase in empirical research is called data gathering. Data gathering will deliver raw data. Raw data as such are never the actual object of analysis. Data are always processed in some way to make it possible to analyse them (c). In this research project data processing is the application of the method of description for reflective practice.

This chapter will present a step-by-step discussion on these phases in empirical design. The next section will discuss data gathering. We will have to establish what type of data we need, what type of ‘real world situation’ this implies and how we will collect the data. This analysis will result in requirements for the set-up of the empirical study.

Following this data processing will be discussed. We will have to decide on the techniques that we will use for data processing. In qualitative research this phase involves the main subjective judgements and interpretations of the data. Our view, consistent with our view on designing that we described earlier, is that it is impossible to screen out subjective interpretation from observation. Since research always includes an interpretative component it is better to acknowledge and integrate it in the research method [Banister et al 1994]. Therefore we will pay much attention to the reliability of data processing in this research project. This will result in guidelines for the data processing.

This chapter will conclude with a description of the research project and requirements for the explorative empirical study.

Data gathering

The sample of empirical studies discussed in chapter 1 varies considerably in the methods they employed in investigating the nature of design. There are studies using retrospective reports on design projects [Marples 1961] and [Ramstrom and Rhenman 1965], well-defined interviews [Darke 1984] or open-ended interviews. In experimental settings verbal protocols of ‘thinking-aloud’
are collected during the design process [Waldron and Waldron 1988], [Akin 1979] and many others. In practical situations observations can be performed in a highly structured way [Hales 1987], [Frankenberger and Badke-Schaub 1998], or from an ethnographic standpoint [Bucciarelli 1988] and [Lloyd and Deasley 1998]. It is perhaps the diversity of the general subject of design and the interest that it provokes, that allows such a range of methods to exist. Perhaps it is a sign of the state of the art in the research field of design, where researchers are desperately seeking for new ways of studying design, eager to discover interesting new issues. Each approach can be valid for the goals of that study. The aim of this discussion is to identify an approach that suits our purposes.

The empirical study has to answer the research questions set in chapter 2. Therefore choices have to be made for the type of data needed and the way to gather these data. This will result in requirements for the empirical study.

Types of data

Through empirical study we want to discover how team members communicate and create shared understanding of the design content from their individual, subjective interpretations. The research questions the empirical study must be able to answer were set in chapter 2.

Two questions relate to the development of a method for describing design:

- Can team design activity be described with reflection-in-action?
- Can the four reflective practice design activities (naming, framing, moving, and reflecting) be differentiated in team design practice?

Two questions relate to the investigation of the reflective practice within design teams:

- Can the occurrence of the four reflective practice design activities be observed within design teams?
- Does reflection-in-action demonstrate part of the team design activity concerning the shared understanding of the design content?

This requires observation of team design activities. Starting from observation of design teams in action, we have to determine how to observe, in which situations, and what type of design teams.
How to observe

Because we want to identify and understand what issues and relationships are important for the interaction in team behaviour and communication, we must be able to observe, record and interpret design activities in the richness of their social context. Studies of team designing indicate the importance of gestures, movements, and handling of objects in conveying ideas between designers [Harrison and Minneman 1996] and [Radcliffe and Slattery 1993]. We have also indicated the importance of non-verbal communication, for instance to identify surprises (see chapter 2). Therefore if we observe team design we must capture every communication and interaction between team members.

We want to be able to capture designing close to real world, without interference from the experimental setting. It is preferable that the teams co-operate for a longer period of time, for it is to be expected that sharing thoughts is even more important in a longer working relationship.

The number of observed teams is of less importance than the totality of the observation is, due to the explorative character of the study.

Nature of the situation

The nature of the situation required relates to the design task and the design problem to be solved. The problem must concern product design, which requires integration of knowledge and decisions on conflicting interests (see chapter 1). In our view, this requires harmonising thoughts and understanding in design teams.

We have to trace the design project from the first ‘problem understanding’, in order to follow the team’s development of the product design content. We also have to capture the ‘conceptualisation phase’, for this is where the team members have to convey thoughts, ideas and approaches toward the problem. The ‘detailing phase’ is of lesser importance, for the concept of the design has been formulated in this phase, which gives little chance of major changes in the approach toward the design task.

The design task has to be realistic in the sense that it delivers a context for activities and some amount of pressure on the performance. It must provide the motivation for the designers to perform the design task and also to work together as a group.
Type of design teams

The teams, under observation, will have to be set up with product designers and, preferably, also people from other disciplines. This will increase the need for integration of know-how between the team members in order to perform successfully. Experience of the team members, or the team’s maturity are of lesser importance, for we are interested in how teams design, and not necessarily in good or bad designing.

Data gathering techniques

We argue for an ‘open’ way of looking at team designing so we can discover unknown issues and patterns of behaviour. In the light of what we just discussed we have to observe design teams actually at work. This observation will be recorded on videotape. Design activity recorded on videotape can be reviewed again and again with a variety of perspectives in mind, whereas direct observation solely relies on the accuracy, completeness, and objectivity of notes collected by observers.

Video observation of team design behaviour also has its limitations, which we have to take into account:

- Observation captures actual behaviour; therefore only behavioural aspects can be analysed, not the motives behind them [Baarda et al 1995]. This research project aims for insight into behaviour and therefore a conflict does not take place.
- This way of observation is limited to a finite time period; hours rather than weeks or months. This quantitative limitation may seem like yielding a limited amount of observed activity, but it contains a wealth of data that suits an empirical exploration very well.
- Videotape captures all that occurs in the observed time period and postpones selection of the raw data. This ‘richness’ of data, the reason for choosing this data gathering method, also requires a large amount of time and a clear strategy to process them. The validity and reliability of the study depend on a careful, well thought-out method of processing and analysing the data.
Data processing

The raw data have to be processed in order to suit further analysis. In design research a few studies exist based on team video analysis [Tang and Leifer 1991], [Mazijoglu and Scrivener 1998] and [Radcliffe and Slattery 1993]. Tang and Leifer describe a method for observing and analysing group design activity that is based on ethnographic and interaction analysis methods from social sciences [Tang and Leifer 1991]. They refer to a 'workable representation of the data', which is a software system to manage the large amount of data and to link verbal transcripts, notes on non-verbal activity, and comments from other researchers. Mazijoglu and Scrivener also focus on structuring of the obtained data. They use a data-driven approach, where data processing is guided by their observations. In doing this they create a 'rich picture' of design activity, which can serve further analysis [Mazijoglu and Scrivener 1998].

Radcliffe and Slattery use video observation as a medium for learning; facilitating awareness and shaping understanding [Radcliffe and Slattery 1993]. From a videotape of a design team at work a conversation flow chart is constructed. This flow chart is used in an assessment clinic with the design team for group reflection and self-discovery.

In this research we will stick to the original videotapes (and verbal transcriptions taken from those) and represent the team design process following the model of reflective practice. We have to develop a method of description for reflective practice to process the raw data into data suitable for further analysis.

Data processing techniques

In design research literature very little is known about the coding and categorisation of video protocols. The analysis of verbal protocols, however, is very well developed in a research technique called 'Protocol analysis'. Protocol analysis is a way to examine people's cognitive processes in specific tasks by using concurrent and retrospective verbal reports [Ericsson and Simon 1984]. Asking people to think aloud gives a concurrent verbal report of what they are thinking while they are doing. Originating from psychological research in the 1920s, protocol analysis was adopted in the design research community in the 1970s.
Since then a lot of studies were performed and the technique itself was further developed. An overview of these studies is provided by Dorst and Cross [Dorst and Cross 1995].

Our observations concern a design team in action. The verbal protocols are reproductions of the communication between team members. Written verbal transcripts of team communication miss out on vital information about the interaction between team members, such as body language or intonation and information about which utterances are picked up or ignored by other team members. Our data analysis will therefore rely on the videotape merely supported by the written transcript. However, for analysis we can learn from techniques used in protocol analysis to work with verbal data.

Protocols are always segmented and categorised in some way to shape the data to be analysed. Segmentation divides the protocol into smaller pieces, which can then be coded according to the notation system of the study. We will discuss different ways that are used to segment and code protocol data.

**Segmentation of protocol data**

In order to code a protocol, it has to be divided in smaller pieces. Looking at earlier protocol analysis research projects we find three ways to segment a protocol:

1. **Segmentation without any interpretation of the data.**
   
   In studies of individual designers many researchers use fixed time intervals of for instance 15 seconds [Akin and Lin 1996], [Günter et al 1996] and [Dorst 1997]. This way of segmentation does not require interpretation of the data. In studies of team protocols the separate utterances of the team members are often used as segments [Mazijoglou et al 1996]. In this way all utterances are considered equal and of equal importance, so no interpretation is required in the segmentation. As stated before, a potential problem of this way of segmenting is that the interaction between the separate utterances of the team members is missed.

2. **Segmentation with interpretation of the data.**
   
   The data are divided into meaningful segments denoting coherent activities.
The segments are identified by criteria such as pauses in the flow of words, or by semantic/syntactic criteria for recognising discrete utterances [Goldschmidt 1996], [Dwarakanath and Blessing 1996] and [Baykan 1996].

3 Segmentation with interpretation from the theory.

The data are divided in category-based segments, where the segmentation is assigned during the analysis on the basis of predefined categories [Ullman et al 1996], [Purcell et al 1996] and [Lloyd and Scott 1995]. In this way the segmentation is interwoven with the coding. In most studies dealing with category-based segments, researchers do not even code the entire protocol, but just look for those segments that refer to a specific issue to be studied.

Coding of the segments

Protocol segments then have to be coded according to the notation system of the study. This coding varies, depending on the aims of the study, and can be:

A A notation system according to a closed set of categories. These categories derive from theory or earlier observational studies. This technique is the one most used, e.g. by [Purcell et al 1996], [Dorst 1997], [Dwarakanath and Blessing 1996] and [Akin and Lin 1996].

B A notation system according to a ‘open’ set of categories. The data are allowed to generate the categories. This can be added to a fixed list of categories [Akin and Lin 1996], or in reference to design issues for that particular study [Ullman et al 1996].

Choices in data processing techniques

In our empirical study the raw data are video observation of team designing. Design as reflective practice focuses on the actual activities in designing (see chapter 2). The segmentation of the protocol will therefore be based on team design activities. This requires segmentation with interpretation of the data (option 2). In the team design project separate team design activities have to be identified. A team design activity will be defined as a part of the team protocol where the team acts with the same goal (e.g. generating ideas, discussing a part of the design problem, creating an overview of ideas).

We are interested in the reflective practice activities in team designing. We
identified four reflective practice activities: *naming, framing, moving, and reflecting* (see chapter 2). The segmented team design activities will have to be coded according to the reflective practice activities. This coding will be based on a notation system according to a closed set of categories (option A in coding of the segments).

We also want to keep track of the design content of the project. Therefore we have to note what the activity really implies. For this we will *label* the *coded* reflective practice activities to adjust additional 'meaning' on what they are about. This labelling will be data-driven.

The method of description, and the notation system for reflective practice, will be further defined in the empirical study (see chapter 4).

**Reliability of the data processing**

An important issue in analysing data is reliability. Reliability in research is the extent to which the same results will be obtained if the research is repeated [Baarda and de Goede 1995]. The search for reliability rests on the assumption that it is possible to replicate good research. We agree with Banister et al, stating that “…a qualitative researcher will never make the mistake of claiming that their work is perfectly replicable. It is certainly possible to repeat the work that has been described, but that repetition will necessarily also be a different piece of work…” [Banister et al 1994, page 11].

Repeatability of the data processing process is a matter of attention in qualitative research. Many studies in protocol analysis refer to multi-coder evaluation by indicating the percentage of agreement between coders. However, very few studies explain how to deal with disagreement between coders. In many cases of protocol research an external system of coding is imposed upon the protocols to test existing hypotheses. Data analysis is then based on the frequency and pattern of occurrence of these categories.

This multi-coder evaluation is easy to do when the analysis is based on time-based segments and a notation system with fixed categories. In our study we may encounter other potential problems in segmenting and coding data. These
problems concern firstly, the segmentation into meaningful segments; team design activities. Secondly, the coding of these activities, according to the four activities of reflective practice. And, thirdly, the labelling of these activities indicating the design content of the activity. So there is potential for variation between coders in the number and length of the segments to be identified, and the notation and labels to be coded. Indicating the reliability of this coding process requires more than a straightforward counting of overlaps and misfits between multiple coders.

The problems we perceive here are very similar to those described by Purcell et al [Purcell et al 1996]. In their study Purcell et al introduce an 'arbitration-discussion' between the separate coders, not only to check the agreements and disagreements on the actual coding between them, but also to make sense of differences in interpretation in order to develop the method of description: "... The strategy we adopted acknowledges differences in interpretation between coders and views these differences as a legitimate opportunity to explore the data in greater detail to develop a coherent, consensus coding which reflects the structure in the data..." [Purcell et al 1996, page 234]. Our goal of multi-coding is also not only to demonstrate the degree of similarity between coders, but also to synthesise the multi-view results into a better interpretation of the data and to improve the instructions of the method of description for reflective practice.

We want to produce a reliable method of description for reflective practice. We are not sure that reflective practice occurs in design practice. Neither are we sure that we will be able to describe the reflective practice of design teams. Therefore we will use a two-step approach for the empirical research. The first step is a explorative study. We will explore the suitability of the reflective practice model for describing team design activity, by trying to differentiate the four design activities. If this application of the notation system for reflective practice proves to be suitable and useful, we will evaluate the method in a second empirical study, using an arbitration discussion between multiple coders.
Conclusion

In this chapter we have indicated that the empirical study will be of an explorative and qualitative nature. This is due to the object of study and the application of Schön's ideas. We have chosen the research techniques for the separate phases in empirical research and set up the requirements for the research.

We will observe design teams in action, as close to a real-world experience as possible. This will be captured on video tape. To process these video data we will segment the video protocol in team design activities, code these team design activities with the reflective practice activities and label them with the content of the activity. These data will then be used for analysis, trying to indicate issues of team interaction, which are important for shared understanding of the design content. To answer the research questions for the empirical study requirements are set, indicating the sort of observation, the nature of the situation, and the type of design teams.

The empirical research has a two-step approach. In a first empirical study we will explore both the method of description for reflective practice to describe team design activities, and the reflective practices of the observed teams. If this explorative study will prove to be useful, a second study will be performed. In this second study the method of description will be evaluated, using a multi-coder approach and an arbitration discussion between coders. Also a further analysis of team designing will be performed, based on findings from the first study. The first study will be described in the next chapter. The second study in chapter 5.
4 The Philips design competition

Introduction

The first empirical study has two goals. The first goal is to explore the suitability of the method of description for the reflective practice theory to describe team designing. The second goal is to explore what a description of design as reflective practice can teach us about team designing.

In chapter 2 the research questions for this exploration were set. Two questions relate to the description of design:

- Can team design activity be described with reflection-in-action?
- Can the four reflective practice design activities (naming, framing, moving, and reflecting) be differentiated in team design practice?

Two questions relate to the investigation of team designing:

- Can the occurrence of the four reflective practice design activities be observed within design teams?
- Does reflection-in-action demonstrate part of the team design activity concerning the shared understanding of the design content?

For this study we observed two, multidisciplinary, product design teams participating in a design competition: the Philips design competition 1996. The teams are located in one room for two days; from the first moment they receive the design task until the presentation of their conceptual design.

In chapter 3 the requirements for the empirical study were set. The observation must capture all communication and interaction between team members. It is to be preferred that the teams are in action for a longer period of time. The number of teams is of less importance than the totality of the observation. The design problem must be a product design problem, which requires integration of design issues. The design project must capture the problem definition and
conceptualisation phase; the detailing phase is of less importance.

It is preferable that the configuration of the design teams is multidisciplinary. It is also preferred that the team members are motivated to perform and to work as a group. The experience of the team members and the maturity of the team are of less importance.

In this study we were able to observe two days of conceptual designing, while capturing all communication and interaction of the teams. The design problem is of a technical nature. At the end the product will be tested in a competition. The fact that the design has to be built and has to operate, makes the task highly realistic and motivating. The teams consist of senior engineering students. In this exploration we are interested in what the teams are doing while designing, not so much how well they perform. Therefore we think any lack of experience of the designers will not impede the results of the explorative study.

This chapter will begin with an outline of the empirical study, describing the competition, the product design teams, the design task and the team design projects. The development of the notation system for the description of reflective practice will be presented. This will lead to descriptions of the two teams according to this notation system. Then we will explore what we can learn from design teams at work, looking at them from a reflective practice viewpoint. This chapter will conclude on the aims for this first explorative empirical study and with new questions for the second empirical study. Parts of this chapter have been published before in Design Studies [Valkenburg and Dorst 1998].

The Philips design competition

Outline of the study

The observed teams participated in a students design contest. The Philips design competition is an annual competition for students from all the Dutch Universities of Technology. The competition aims to be a simulation of a design problem in professional engineering practice. Nine multidisciplinary teams of four senior students compete for eight days, building and testing a product that has to perform a specific task. The task for 1996 concerned the transfer of small balls
from a competition table into a basket (an extensive description of the design task is given on page 96).

The design project is divided into three parts (see figure 10). After collecting the design brief the teams start with a two-day design session in a studio, where they have to establish the design concept. This design concept has to be presented to a team of experts at the end of the second day. The second part is a five-day building period in a workshop, where the design has to be realised. Finally, on the eighth day, the product is tested in a knockout race, where the designs compete in pairs. After a series of rounds the winner is known.

<table>
<thead>
<tr>
<th>the design brief</th>
<th>presenting the design concept</th>
<th>a working model</th>
<th>the end</th>
</tr>
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<tbody>
<tr>
<td><strong>design session</strong></td>
<td><strong>conceptualisation</strong></td>
<td></td>
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<tr>
<td><strong>building session</strong></td>
<td><strong>realisation</strong></td>
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<tr>
<td><strong>competition</strong></td>
<td><strong>test</strong></td>
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<tr>
<td>day 1</td>
<td>day 2</td>
<td>day 3</td>
<td>day 4</td>
</tr>
</tbody>
</table>

The outline of the Philips design competition. **Figure 10**

We observed the conceptual design activities of two teams, which we captured on videotape. On the morning of the first day the teams are instructed and the design assignment announced. Then the teams have to develop a conceptual design, working together in one room each. We were able to videotape the whole first two days of co-operation, which provided us with approximately nine hours of videotape per team.

The next five days span the building period in the workshop where the teams have to realise the design. Philips did not allow us to videotape these days for reasons of security. This phase was only recorded on observation lists, which contain the movements and activities of the team members in the workshop, and audio recordings of conversations among three or more team members. In this study we primarily focus on the first two days, ending with the presentation of the design concept to a team of experts at the end of the second day.
The design teams

The first team consists of four senior students with different backgrounds; one industrial design engineer (a product designer), one electromechanical engineer and two mechanical engineers. They name themselves 'The Delft Pitchbulls' after the basic principle of their design (shooting or pitching).

The second team also consists of four senior students with three different backgrounds: one industrial design engineer, one mechanical engineer and two electromechanical engineers. They called themselves 'Tecc', after the building material from the tool kit. Their product was called 'Tecc-man'.

We chose these two teams out of the total number of nine participating teams, because of the similarities in composition (knowledge and experience) and the participation of a product designer in each team. Both teams are multidisciplinary, composed of the same three disciplines and they have one nearly graduated industrial design engineering student. Teams from other Universities of Technology are made up from people with a mechanical and electromechanical engineering training. Because of our research goals, we were especially interested in the teams including an industrial design engineering student.

These industrial design engineering students both participated in a qualifying workshop in Delft, where they were members of the same design team that won the competition of that workshop. The team members of The Delft Pitchbulls and Tecc knew each other vaguely before participating in the Philips design competition, but had never worked together as a group before.

All students were highly motivated to participate. Not only because of the element of competition, but also because the organising company, Philips, is the leading company in the Netherlands in consumer electronics.

The design teams did not have formally appointed project managers. However, they were performing a project and therefore we expected to find the project manager's roles, as described in the problem statement in chapter 1, in some of the team member's behaviour. These roles can be assumed in the behaviour of either one person, or be divided among different team members. These roles will also include the responsibility for creating a shared understanding of the design content among team members. If a team has a project manager, responsible for
this task, it is to be expected that this will be explicitly structured or formalised. In this case, with no formal responsibility, we will be able to observe if creation of shared understanding of the design content will take place.

The design task

The design assignment is to design and build a remote controlled robot, which can score as much as possible. Scoring means the transportation of small balls from a ball bin on the competition table into a basket, in a three minute period.

The competition table (see figure 11) consists of two platforms, connected by a slope. At the start of the game the robots are positioned on the lower platform. The ball bin is positioned on the higher platform. The ball bin is 50 mm deep with two slopes and two steep sides and contains 30 small balls. Next to the lower platform is a moat, with a depth of 150 mm and 1000 mm wide. Beyond this moat are two boxes, which are the baskets for the balls (one basket for each team). Both baskets are 600 mm high and 500 mm deep and wide. Behind the baskets is a heightened partition that is 300 mm higher than the basket itself. The total size of the competition area is 4000 by 3500 mm, including the moat and excluding the baskets.

The robots will be controlled remotely by one team member. He can use two channels for the remote control. The parts that can be used to build the products are limited to those found in the toolbox provided. Electronic components can be chosen and ordered from a restricted list.

The competition table for the Philips design competition Figure 11 1996. The remote controlled robots compete in pairs and have to transport as many balls as possible from the ball bin into the basket.
This type of design task is used more often in the simulation of integrated product design. Other design schools use similar design assignments in courses or competitions, for instance Stanford University [Brereton et al 1993], [Brereton 1999] and the Massachusetts Institute of Technology.

**The team design projects**

Both teams start right after instruction, where they received the design assignment and toolbox, and lunch on the first day, reading the assignment and instruction manual. We will provide a short description of the behaviour of both teams. Just to get a first impression.

**The Delft Pitchbulls**

Team The Delft Pitchbulls refer to the different remote control functions they have to design: ‘shooting the balls’, ‘collecting the balls’, ‘steering’ and ‘driving’. Then the team starts to explore how to position the balls after having collected them. They attend to the tactics of the game; they try to imagine what to do when the competition starts. During the following discussion the team deals with different issues in parallel. For instance they consider the motors provided and which one to use for which function. They decide on a thrower for shooting the balls, and think about how to position the balls into the thrower, also every now and then attending to tactics during the game. They try to find solutions for the functions. Often detailed solution possibilities come up during discussions, but the team continues with another subject without making a decision and without elaboration of the idea. At the end of the first day they begin to make an inventory of the ideas they discussed; a thrower for shooting the balls, a shovel for collecting the balls, the different control functions for the remote control, caterpillar tracks for driving, and a global lay-out of the chassis. This making of the inventory is interrupted by a discussion on the shovel until the end of the first day session.

On the morning of the second day The Delft Pitchbulls continue in the same manner, discussing all relevant aspects of the solutions in parallel. Just before lunch, they decide to choose the materials that are necessary for building. Right after lunch they sketch the lay out of the product. While doing this they decide
upon the sizes and positions of the functions. Then they make a drawing for the presentation to the team of experts. From 15.15 until 15.30 on the second day they present their product to the team of experts. The sketch they produced is shown in figure 12.

One of the team members presents the design concept to the team of experts:

"We are the Delft Pitchbulls. We just came up with that name. We are going to try to build a small, fast cart, that might not be able to transport a lot of balls at once, but will be accurate. And we didn't really decide on the number of balls yet. We have a sort of shovel up front (1) to collect the balls. That will go up, swing back and the balls will roll in some sort of supply mechanism. You can also see that over here (2). Now, we thought of a very ingenious mechanism; the ball will be shot away by this arm (3), which will go up like this (4). When the arm goes down again, it will put the next ball on it and shoot that one as well. This will automatically continue until the supply is empty.

This (5) is a sort of action-picture. The balls will come into this (6), the shovel goes up, and the balls will line up over here (7). The arm goes down, loads a ball and shoots it immediately. Brief and to the point. And this is how we see the cart run for the balls."

It is interesting to notice that in the presentation The Delft Pitchbulls refer to the different functions in the design. After this short presentation the experts ask questions and a discussion takes place about the design. The experts ask what measures the team took to make sure the balls get into the shovel and won't get stuck in the shovel. The Delft Pitchbulls explain that this can be dealt with by choosing the correct angle in the shovel and, if the

* The numbers in the presentation are indicated in the drawing; this is what the presenter points at while speaking.
balls do get stuck, shake the shovel. There is a discussion about the number of balls that the cart can collect and how many times the team thinks to be able to drive back and forth during the game.

The experts also have doubts about using an automatic shooting principle. If the cart is not aimed right for the first shot, then the experts are afraid all the balls will be lost, for they are automatically shot in the same direction. The Delft Pitchbulls explain that they will know where to position the cart from practicing before the game. Then they discuss the control of the cart. The teams can only use two channels in the remote control. The Delft Pitchbulls use one channel for driving and, through a rotary switch, use the other one for steering and shooting. When the experts notice that the cart can't be steered while shooting, they refer back to the earlier discussion about automatically shooting and the reliability of the shooting process.

Then the experts ask questions about the working of the separation mechanism of the catapult. The Delft Pitchbulls explain that that part is not yet solved in detail. The experts ask the team whether they thought of any alternatives. The team is confused by this question. After a pause, they explain that they tried to formulate sub problems and they solved those first. They have chosen these solutions, so why should they think of alternatives. The experts explain that they think it would be a good idea, for instance for the shooting concept, because they doubt the reliability of this mechanism. The Delft Pitchbulls say that they have thought about it and think it's a good idea. The experts say that it still worries them.

Back in the design studio The Delft Pitchbulls try to recall the remarks and questions of the experts. They are disappointed with the amount of criticism that they received. In the discussion that follows they are confused by the problems that the experts pointed out. They recall the criticisms but also reject them. They are obviously disappointed. They don't come up with solutions for the problems that the experts pointed out. They decide that everything will be all right and don't change the design. They only decide to make a larger shovel, so they will be able to collect more balls at once. They end the design session at 16.15 on the second day.
Tecc

Team Tecc also refers to the different functions of the product and decides to generate ideas on these functions. Tecc’s division is ‘shooting the balls’, ‘collecting the balls’, and ‘driving the product’. The team chooses ‘shooting’ as the most important one, and starts generating ideas for shooting principles. After generating ideas individually the team discusses these ideas one by one. Then Tecc discusses which function to tackle next, ‘collecting the balls’, or ‘driving the product’. The team discovers that ‘shooting’ is not the only way to get the balls into the basket. The team reformulates this problem as ‘getting the balls into the basket’ and generates ideas on ‘bridging’ and ‘through the moat’ solutions. After generating ideas twice, Tecc collects all the ideas, formulates selection criteria and starts evaluating the ideas one by one and selecting one. The team finishes this by choosing a shooting concept. Tecc recalls their remaining functions of the product: ‘collecting the balls’ and ‘driving the product’. The team starts with ‘driving the product’, and discusses the pro’s and con’s of caterpillar tracks for driving. The team decides to test them in a model on the third day (in the workshop).

Then Tecc generates ideas on ‘collecting the balls’ and tries to integrate these with the chosen shooting concept. After only five minutes the team decides that the design concept is becoming too complex and discusses how to continue. The team comes up with a simple solution, a bulldozer, to collect the balls and just throw them in the direction of the basket; a simple product with an uncontrolled action. The team decides to concentrate on an integrated solution for collecting the balls and getting them into the basket, reminding each other to keep this integrated solution simple.

On the morning of the second day it is obvious that the team has worked for another hour the evening before. Tecc generated new ideas on this integrated collecting and shooting-principle and chose a concept with which the team starts on the morning of the second day. Tecc subdivides this concept in parts and every team member builds one part to test. After testing the (very preliminary) models, the team confirms the chosen concept and divides the task in two large pieces, to be worked on in pairs. Until lunch the team works in pairs, every now and then discussing the fit between the parts with the whole team. After lunch
Tecc sketches the design for the presentation to the team of experts. The team evaluates the product and draws up a list of strong and weak elements of the solution.

From 15.30 until 15.45 on the second day Tecc presents its product to the team of experts. The sketch the team produced is shown in figure 13.

One of the team members presents the design concept:

“We are Tecc. We named ourselves after the building material from the tool kit. We tried to keep things as simple as possible. So we had several ideas that we rejected, for they didn’t lead to anything. Eventually we arrived at the old catapult principle. I will explain how it all works.

The cart drives forwards. It is a tank, with tank propulsion. The balls will arrive over here (1). The cart will drive halfway over them. This (2) is a caterpillar track. As the ball hits the caterpillar track, it will flatten a little bit because of this small plate (3). The track will transport the ball up and put it in this reservoir (4). This (5) is, so to say, the cannon. The cannon will be tensioned by a spring, which will be pulled. Tensioning will be done by a piece, which is attached to a motor. And the ball will be shot away.

We built in a number of securities. For instance, that not all the balls will fall into this (6) at the same time. And that this (7) will be closed while you shoot, so the balls can’t go through. Eh… well, we use two channels for the remote, or we’ll talk about that later. Did I forget something?”

* The numbers in the presentation are indicated in the drawing; this is what the presenter points at.
It is interesting to notice that in the presentation, Tecc refers to the 'working' of the machine by indicating the route of the balls through the machine. After this short presentation the experts ask questions and a discussion takes place about the design. First the experts ask what the strengths and weaknesses of the design are. In the answer Tecc refers to their own investigation into this and explains which parts the team already tested and which will be tested later on. The experts express their doubts on the transportation mechanism of the balls, using the caterpillar track. Tecc explains that they already tested that and it does work. There is a discussion about the forces on the balls and the exact size of the balls. Another point of interest of the experts is the separation mechanism for the canon. Does it influence the shooting process and is the shooting reliably repeatable? Tecc explains that they also came up with that question themselves. The team still has to work out this idea in detail, but also presents alternatives for if this may fail to work in the tests. Then they discuss the control of the cart. The teams can only use two channels in the remote control. Tecc explains that they will use one for speed control and the other one can be switched for the functions steering and shooting. There is also a brief discussion about this.

Back in their design studio, having heard the remarks and considerations of the experts, the first reaction of Tecc is that they tell each other that this is the task of the experts; they will always point out weak points in the design. They also notice that they haven't heard anything that they didn't think of themselves. They make an inventory of the principal comments of the experts and decide what to do with these. The rest of the day they spend on building models to test their concepts. For instance they build the transportation system of the balls. It works very well and they have the following discussion:

"I can't understand the problem these men have"
"Well, some people don't trust anything that they don't know"
"They only point out what the bottlenecks are"
"There is no harm in that, is there?"
"We mustn't be too pigheaded, they can be right, you know"
"But we tested it and already it works pretty well"
"We can't say that for sure. You never can with these things"
"Suppose it doesn’t work, what else can we do?"
"We could make a shovel...."

This example is typical for Tecc’s attitude towards their design. They constantly question their ideas and search alternatives if necessary. The design weekend closed at 16.30 at the second day.

We only observed the first two design days of the Philips design competition in this detailed manner, but we did observe both teams for the rest of the week. At the time of the actual competition, on the eighth day, The Delft Pitchbulls didn’t have a working cart. While building the design in the workshop, the problems that occurred within the different parts of the design took all their attention and the connection between the shovel and the thrower wasn’t working at the end of the week.

Tecc won the Philips design competition ‘96. They built their design in two days and used the rest of the building period for testing and improving the product. Photographs of both designs on the eighth day morning, right before the contest, are shown in figures 14 and 15.

![Figure 14](image1.png) The final design of The Delft Pitchbulls.  

![Figure 15](image2.png) The final design of Tecc.

Of course we could never have imagined studying both the winning team and a failing team, or even hoped for it, when we selected the teams at the start of the competition. However the differences in the achievements of the teams and in their design process provide enough encouragement to continue future analysis of the teams’ design behaviour and results.
Describing team designing: developing a notation system

A notation system for the reflective practice model

In data processing we identified two phases: segmenting the data and coding these segments (see chapter 3). First we have to divide the video data into meaningful, coherent segments; team design activities. A team design activity is a segment of the team protocol where the team acts with the same goal (e.g. generating ideas, discussing a part of the design problem, creating an overview of ideas).

These segments will be coded according to a closed set of categories. In the reflective practice theory we distinguished four different design activities: naming, framing, moving, and reflecting (see figure 7 on page 72) To recognise the four different activities we have to look at what the team is doing and which goals they have in mind.

When the team is explicitly pointing at parts of the design task as being important, we code the activity as naming. During the naming activity the team is looking for relevant objects in the design task.

When the team describes a (sub) problem or (partial) solution to explore further, then we code the context as a frame. A frame is the context a team sets for further activities.

Actions, such as generating ideas, making an inventory, sorting information, combining ideas, or comparing concepts are coded as moving. During the moving activity, the team not only tries to solve the design problem, but at the same time also explores the quality of the frame.

An explicit reflection on earlier activities is coded as reflecting.

These definitions of the notions naming, framing, moving and reflecting are as far as we can get from Schön's work. We realise that they are weak. But in the attempt of applying them to the data we will be able to identify the exact weaknesses and to deal with them.

We are also interested in the developing design content within the team's project and therefore the design content of the team activity. We will label the reflective practice activities by the actual content of the activity. Naming will be described using the actual terms that the teams use. A move will always be characterised by
a verb, identifying the activity, complemented with the contents of the activity. A frame, like a name, will be labelled by the actual words that the team use for it.

**Processing the video data**

We will provide a step by step demonstration of the processing of the data. We will use the first half-hour of video observations of design team Tecc to illustrate the relation between the raw data, the video, and the description of the team’s design activities according to the notation system for reflective practice. We chose this particular part of the protocol for demonstration, because it contains all four activities and the various relationships between them.

From the videotape a written transcript is made of the teams’ communication. Please note that this transcript is a translation of a Dutch design team, and that a faithful translation of a transcript is nearly impossible. The designers express their thoughts and ideas in ambiguous words and (incomplete) phrases that are hard to translate into their English equivalents. The translated text is therefore not totally dependable: many of the subtleties of the language are lost in the translation process. Therefore the presented transcript has limited value outside the context of this study. These problems did not affect our original data processing, since that was all done in Dutch.

The verbal protocol contains the first half hour (Tecc, day 1: 14.03 - 14.30) of designing:

[14:03]

Et1: “How shall we approach this?”
Et2: “The best we can do is a brainstorm. So everyone writes in a few minutes a number of ideas for the first item on his own sketch pad and then we circulate the sketch pads and someone else does the next one”
Me: “Yes, but…”
Et1: “Yes, but the first solution is to divide in suitable sub problems”
Et2: “We already did that”
Me: “Did we do that already?”
Et2: “Yes, driving the product, collecting the balls, shooting the balls…”
Me: “We need two ways to drive…”
Ide: “I suggest we start with shooting, that’s what it’s all about…”

* “Et” indicates the Electrotechnical engineering students (1 and 2), “Me” the mechanical engineering student and “Ide” the industrial design engineering student.
Me : “Let’s get a part”
I de : “...Then look at how to load the shooting mechanism”
Me : “Yes, shooting, driving...”
Et2 : “Driving the product, collecting the balls, shooting the balls. ...”
Me : “The rest is no use”
Et1 : “Remote control perhaps...”
Et1 : “We’ll begin with the part shooting the balls”
I de : “Yes we will”
Et1 : “How much time per idea?”
[14:05]
Et2 : “I think we must try to draw five concepts each. We’ll divide the paper in length in four pieces... or five?”
Et1 : “Four is enough”
Et2 : “Paper divided in four”
Et1 : “Do you want to handle all parts at once?”
Et2 : “No, only shooting”
Me : “We’ll begin with shooting and see about the other ones later”
During the ‘brainstorm (14:05 – 14:11) everyone is individually and silently working on his ideas.
I de : “Well, everyone has something on paper, hasn’t he?”
Me : “Mm, yes”
I de : “Shall we do it like this, that everyone tells...explains his drawings?”
Me : “Yes, you’ll start”
I de : “Well, this is the old Roman principle”
Me : “A catapult”
I de : “You put a stone in... A problem, I think, with this system is to aim. But when the ball is in there right then it will succeed. It won’t get stuck”
Et2 : “These problems are mechanical. If I see it like that it’s because he has to strike over there”
Me : “Yes look, I had something similar. It does come to this point where it hits this. Well, that is still to be decided of course. By adjusting that you can aim”
Et2 : “No, what I meant is that the whole mechanism gets hell if you apply a construction like that”
Me : “Ehh... yes”
I de : “But this is supposed to be a brainstorm session”
Me : “Ok, let’s just continue”
I de : “Ehh... this is some sort of gun with a giant spring, which just again and again gets pulled, and that you can stuff a ball in there from above through a hole, and that’s how it is reloaded”
Et2 : “So the force comes from the spring that is tensioned in an earlier stage?”
Ide: "Yes"
Et2: "OK"
Ide: "Well, this idea is"
Me: "Yes, well, you don't have to explain that one... come on"
Ide: "...Well easy to aim. It could, however, easily get jammed. It's very sensitive to these kinds of things... This is sort of that you place a ball somewhere and then press it with something and it will be shot away. It is basically the same idea, but the advantage of this one is that you can make a tube with all the balls that will fall through here... tick, tick, tick... that you, so to say, that this continues"
Me: "If necessary you can make this turn around so it won't have to stop"
Et1: "Some sort of tennis racket principle"
Me: "Yes, and it continues to hit, so it won't have to stop and start again"
Et1: "That will be difficult to time, but that doesn't matter"
Me: "Well, I also had a construction like that, that you can drop the balls from above and everytime you stretch the spring, so a sort of pinball machine. Yes, exactly, like a spring board, so you put this beam in some sort of groove... and that they... that the balls will be pushed from the side and then through this spring board it will be given a direction... with a little bit of an angle..."
Ide: "Wait a minute, wait... just... again .... so this is the same mechanism as this in here, isn't it?"
Me: "Yes, but only, you don't need a tube, but just that it is situated in one position and then you just hit it"
Ide: "Oh... yes"
Me: "So it won't be as precise as that one. Ehm, then this one... this is with a sort of lever, which you position and then it jumps against something and then it continues by itself. I also came up with something like this: some sort of disc, in which all the balls are hung and that you spin around real fast but they can't get out. And then at a certain moment you open a lid and they, the balls, come into a tube and are shot all at once"
Et2: "Yes, ok"
Me: "But I don't know if it's feasible. I didn't look at that... but I think that it could look nice if you can make it work. That you spin this really fast and then you say... ok, enough and then... pjaw pjaw pjaw"
Et1: "And then they pop out there one after another. So if you weren't aiming right you would hang"
Me: "but then you could make arrangements to make sure you aim right"
Et1: "yes, exactly, but..."
Me: "Look, I sketched it like this now. But of course you can put the disc horizontal en this can be vertical"
[14:15]

Et1: "Yes, well then my ideas, I suppose... A lot of things have been mentioned already, of course. I also thought about a spring, that is the same construct as earlier. And I thought of a tube with some sort of piston in it"

Et2: "A piston! That's a good one"

Et1: "A piston attached to a turning wheel that makes it go up and down so it can shoot a ball. Well this is the Roman principle... And I thought of a tube with turning wheels, two or four, which continuously turn. Then you can put a ball behind it, and then in it and as soon as the ball hits those wheels it will be pressed through and be shot"

Me: "I don't think that will work, it's too slippery. I think it won't go through and with so much power..."

Et2: "We are brainstorming, so we'll just leave it like that"

Et1: "Yes, and I think it is possible"

Ide: "I have seen it before, in the former workshop. They had to collect small cubes, so they would ride towards them and while this was spinning as soon as it hit a cube, it was...wup, wup, put on a conveyor belt, to collect them so to say. So it could be fun to do that with the balls, if..."

Et1: "The advantage is that you don't have to control it. You can just put it on and it will move constantly. You only have to push a ball in there when necessary"

Et2: "As soon as you put a ball in there it will be... whoosh...shot away"

Et1: "Yes, that's the idea"

Et2: "My ideas all contain tubes. This is a tube that is loaded with balls. It doesn't matter right now how they got in there. The tube has a groove and this is a special mechanism to make sure that if it spins up, it will follow the groove and hit exactly this ball and not the next one. And then it should contain something to push these balls to the front...tjew, tjew...so they will be shot one by one. So this one can also continuously shoot and as soon as you stop feeding balls, it will stop. So you should make something that will position the ball just right and so quickly that it won't get stuck half way through its rotation. So there are some weak aspects.... This one is simpler. Ehhh... horizontal, tube, vertical, tube. This one is filled with balls and as long as you don't do anything they will stay there. This is a magnet, and this lever goes like that and... pouf... it will hit the ball out. The advantage is that you can adjust the force by the power you put through the magnet. In that way you can adjust the distance of the shooting"

Et1: "But I don't think we have a magnet available..."

Et2: "We can make one, that's not too difficult. But well, it was only an idea. This is the same idea, but with a fan. The fan will turn continuously and we should make some sort of closure over here that will drop one ball at the
time. And this is the same idea as he told us, only I made a wheel with
grooves in it. The grooves are open at the outside and around the wheel is an
edge so the balls can’t get out. But if the wheel turns like this and it passes
the open space then it will pop out”

**Ide**: “Oh.. yes”

**Et2**: “So if you can make a closure again over here, you can feed in ball by ball and
overcome the disadvantage that you spill everything at once”

**Me**: “Yes, well... look, this is nice, but...”

**Et1**: “Because that is easy to make, and in fact, adjusting the speed is also
possible”

**Et2**: “But it definitely needs a disclosure-manager; something to feed in the balls”

**Et1**: “That will be difficult, but we could solve that mechanically”

**Me**: “Won’t a simple slide do?”

**Et2**: “Turn the space that fits just one ball, or something like that”

**Et2**: “I see another objection; what if this slide moves too fast for the ball to roll
in, than it will be pushed up again and again”

**Et1**: “We couldn’t let that happen, of course”

**Et2**: “So that’s a disadvantage”

**Me**: “There is a possibility that these mechanisms become too complex”

**Et1**: “Or they just won’t, you don’t know”

**Ide**: “I think this is a very solid construct”

**Me**: “Let’s go to the next one. Then later on we can, with all the other ideas...”

**Et2**: “Yes, how do you want to proceed?”

**Me**: “Well, ehh... For example sketch the little cart so we have some ideas on that as
well, and then we can start combining. You always have a chance that later on
you get something that provides you from applying this...so...”

**Et2**: “I think more relevant is ...eh... how can you collect the balls?”

**Me**: “That’s all right it doesn’t matter much... collecting the balls”

**Et2**: “Yes, or the little cart?”

**Me**: “That doesn’t matter much”

**Et1**: “The sequence doesn’t matter, it’s fundamentally independent”

**Me**: “Yes precisely, collecting the balls”

**Ide**: “I think we should continue this...”

**Me**: “...That we, in any case, cross some off?”

**Et1**: “...Think further on the shooting perhaps?”

**Ide**: “I mean, yes, ...because... we’ve got all these solutions with tubes and so, but
is this all there is...”

**Et2**: “No, but a tube like this can also be made by a plate”

**Ide**: “No, that’s way too thick”

**Et2**: “That white plate?”
Et1: “I think you can very well shoot a ball with this”

[14:20]
Et2: “With that plate, standing by the wall, we can make a tube, there’s nothing wrong with that, is there?”
Me: “But if you smash it real hard, how far will it go? That might be difficult, you have to have some mass behind it”
Et1: “That is too heavy. You have to give the ball speed, not smash it”
Me: “Let’s think about that a bit more. Then you return to the Roman thing”
Et1: “Wait a minute, the function of the tube is guiding the ball in the right direction. How you speed the ball is separated from the tube”
Et2: “There is an alternative, that is to make a half, turned tube with three pieces of wire. Then you use the centrifugal force”
Me: “But take a look: how much force is half... it’s not very special...”
Et2: “I think that once you've centered the mechanism, it will work ok. Because if you make a wire-way, like I said, the centrifugal force will keep it in track, so if you put it in there it will move with the track...
Et1: “At least we need some sort of track to give direction. So you can use tubes, wires, whatever.”
Ide: “You can make a V-shaped track”
Me: “That’s not so good, because then the ball rolls over two points, you’d better make it more round, because...”
Et1: “That doesn’t matter much”
Me: “It does, because it will reduce the speed”
Et1: “But it isn’t...”
Ide: “We can just test that. We can also make it out of cardboard. With this you can easily make something to go up and then pulls down so the ball will be shot”
Me: “The problem is, again, to tighten this”
Ide: “That’s with everything you shoot of course”
Et1: “You could also move it like this, so it will shoot like that, but how would you aim the?...”
Me: “Well, then you have to speed it up real fast”
Et1: “Or turn around or something”
Et2: “A disclosure on the tube. Put the ball in, turn the tube, then you open the disclosure and the ball will fly away”
Et1: “How about timing? That will be very difficult”
Et2: “We’ll have to test that”
Et1: “That will be too difficult, we shouldn’t do that”
Me: “Fill it with balls and then spin around? No, that’s nothing”
[14:25]
I: “Yes, do we have to shoot? That’s another thing isn’t it?”
E: “You just say that, but that isn’t a bad idea at all…”

For a minute everyone is silent; Ide reads and sketches an idea.

I: “Shall we also think about.....because I sketched this idea that has nothing to do with shooting. You can also bridge this by making something over here... that you fill the tube with balls and then... here is the basket and at a certain moment it goes... zzzzzz.... and the bottom is closed, and then... plop... six balls at once in the basket, just like that”
E: “Yes, but you need something very high”
M: “But if you have a cart of 40 by 40 centimetres and you make the arm...”
I: “The distance is this.... This is 1 meter and this is 45 centimetre”
E: “What is 45 centimetres? The height of the basket?”
I: “No, the difference between this and this”
E: “OK”
E: “That is at least 45 centimetres”
M: “Yes, but I mean, you have to make something on the cart that is at least 1 meter tall and I think it will make the cart unstable. It will fall over, I think”
E: “It will fall over the balls are too far out”
M: “You should balance that”
I: “It depends, you can also drop this thing on this. That you have something like this from 1,5 meter and drop it like this...boom...on this edge, and then you lift it up here”
E: “The cart must fit into 50x50x50 centimetres, so we have to make it foldable”
I: “No, this will just be standing up”
M: “No, I think we have to shoot, or something like that...but....because, look this also requires a tube of 1 meter, how do you want to make that?”
I: “Well, you could also...”
M: “Yes, but we probably need the material for the rest of the cart. That’s a lot of material. And once you put it like this how will you get it up straight again?”
E: “You have to shoot again, of course”
M: “Yes, and while driving, you have to carry all this along with you, even the balls that you are collecting”
I: “Yes, but in the former workshop we had something that was this high and built out of small mechanisms with motors and it went perfectly well”
E: “How high are we allowed to go?”
E: “50 centimetres, but I think we are allowed to fold out and make it bigger”
E: “Yes, of course”
Ide: “50 centimetres high, is that really a restriction?”

[14:30]
Me: “Hey, let’s get on with idea generation, or otherwise we’ll stick to this too long. Let’s first do the other things and then later we know for sure that... or in any case that we have a little cart or a chassis, more or less, and then on that basis we can look more in detail...to the...eh...”

Ide: “No I don’t think so. I think the way you get the balls into the basket, that’s to what you should adjust everything else to, not the other way around”

Et2: “Yes, I think so too. Driving is driving, that’s plain”

Ide: “Driving is the easiest part”

Et2: “Collecting the balls can be combined with driving it, but how to get them into the basket is the most difficult problem, I suppose. We have to find a way to aim the balls from the storage into the basket as accurate as possible. If we have that, I say OK, then we adjust the collecting to that... because... how can we transport a storage bin with that form...”

Me: “OK, yes, let’s regard that as our main problem for now”

Tecc continues with a brainstorm on ‘getting the balls into the basket’.

The first step in data processing is dividing the protocol in meaningful segments; team design activities. Each segment between two lines in the next representation of the verbal protocol represents one team design activity.

One of the problems of written-out communication of a team is that it does not contain any information on the importance the team attaches to the individual utterances. The other team members ignore some utterances, while others are picked up. Our analysis is based on the videotape itself, in which it is clear how much importance is assigned to an utterance within the team design process, by listening and looking at gestures, intonations, matters of attention of other non-verbal expressions. To conserve some of these accents in this transcript, we indicate the utterances, which are of importance to the team’s attention in bold script.

This first step leads to the next representation of Tecc’s verbal protocol:
1  
[14:03]  
Et1: “How shall we approach this?”  
Et2: “The best we can do is a brainstorm. So everyone writes in a few minutes a number of ideas for the first item on his own sketch pad and then we circulate the sketch pads and someone else does the next one.”  
Me: “Yes, but…”  
Et1: “Yes, but the first solution is to divide in suitable sub problems”  
Et2: “We already did that”  
Me: “Did we do that already?”  
Et2: “Yes, driving the product, collecting the balls, shooting the balls…”  
Me: “We need two ways to drive…”  

2  
Ide: “I suggest we start with shooting, that’s what it’s all about…”  
Me: “Let’s get a part”  
Ide: “…Then look at how to load the shooting mechanism”  
Me: “Yes, shooting, driving…”  
Et2: “Driving the product, collecting the balls, shooting the balls. …”  
Me: “The rest is no use”  
Et1: “Remote control perhaps…”  

3  
Et1: “We’ll begin with the part shooting the balls”  
Ide: “Yes we will”  
Et1: “How much time per idea?”  
[14:05]  
Et2: “I think we must try to draw five concepts each. We’ll divide the paper in length in four pieces… or five?”  
Et1: “Four is enough”  
Et2: “Paper divided in four”  
Et1: “Do you want to handle all parts at once?”  
Et2: “No, only shooting”  
Me: “We’ll begin with shooting and see about the other ones later”  

4  
During the ‘brainstorm (14:05 – 14:11) everyone is individually and silently working on his ideas.  

5  
Ide: “Well, everyone has something on paper, hasn’t he?”  
Me: “Mm, yes”  
Ide: “Shall we do it like this, that everyone tells...explains his drawings?”  
Me: “Yes, you’ll start”  
Ide: “Well, this is the old Roman principle”
Me: “A catapult”

Ide: “You put a stone in... A problem, I think, with this system is to aim. But when the ball is in there right then it will succeed. It won’t get stuck”

Et2: “These problems are mechanical. If I see it like that it’s because he has to strike over there”

Me: “Yes look, I had something similar. It does come to this point where it hits this. Well, that is still to be decided of course. By adjusting that you can aim”

Et2: “No, what I meant is that the whole mechanism gets hell if you apply a construction like that”

Me: “Ehh... yes”

Ide: “But this is supposed to be a brainstorm session”

Me: “Ok, let’s just continue”

Ide: “Ehh... this is some sort of gun with a giant spring, which just again and again gets pulled, and that you can stuff a ball in there from above through a hole, and that’s how it is reloaded”

Et2: “So the force comes from the spring that is tensioned in an earlier stage?”

Ide: “Yes”

Et2: “OK”

Ide: “Well, this idea is...”

Me: “Yes, well, you don’t have to explain that one..... come on”

Ide: “.....Well easy to aim. It could, however, easily get jammed. It’s very sensitive to these kinds of things... This is sort of that you place a ball somewhere and then press it with something and it will be shot away. It is basically the same idea, but the advantage of this one is that you can make a tube with all the balls that will fall through here.... tick, tick, tick... that you, so to say, that this continues”

Me: “If necessary you can make this turn around so it won’t have to stop”

Et1: “Some sort of tennis racket principle”

Me: “Yes, and it continues to hit, so it won’t have to stop and start again”

Et1: “That will be difficult to time, but that doesn’t matter”

Me: “Well, I also had a construction like that, that you can drop the balls from above and everytime you stretch the spring, so a sort of pinball machine. Yes, exactly, like a spring board, so you put this beam in some sort of groove... and that they... that the balls will be pushed from the side and then through this spring board it will be given a direction... with a little bit of an angle...”

Ide: “Wait a minute, wait... just.. again .... so this is the same mechanism as this in here, isn’t it?”

Me: “Yes, but only, you don’t need a tube, but just that it is situated in one position and then you just hit it”
Ide: "Oh...yes"
Me: "So it won't be as precise as that one. Eh, then this one...this is with a sort of lever, which you position and then it jumps against something and then it continues by itself. I also came up with something like this: some sort of disc, in which all the balls are hung and that you spin around real fast but they can't get out. And then at a certain moment you open a lid and they, the balls, come into a tube and are shot all at once"
Et2: "Yes, ok"
Me: "But I don't know if it's feasible. I didn't look at that...but I think that it could look nice if you can make it work. That you spin this really fast and then you say...ok, enough and then...pjew pjew pjew"
Et1: "And then they pop out there one after another. So if you weren't aiming right you would hang"
Me: "but then you could make arrangements to make sure you aim right"
Et1: "yes, exactly, but..."
Me: "Look, I sketched it like this now. But of course you can put the disc horizontal and this can be vertical"

[14:15]
Et1: "Yes, well then my ideas, I suppose...A lot of things have been mentioned already, of course. I also thought about a spring, that is the same construct as earlier. And I thought of a tube with some sort of piston in it"
Et2: "A piston! That's a good one"
Et1: "A piston attached to a turning wheel that makes it go up and down so it can shoot a ball. Well this is the Roman principle...And I thought of a tube with turning wheels, two or four, which continuously turn. Then you can put a ball behind it, and then in it and as soon as the ball hits those wheels it will be pressed through and be shot"
Me: "I don't think that will work, it's too slippery. I think it won't go through and with so much power..."
Et2: "We are brainstorming, so we'll just leave it like that"
Et1: "Yes, and I think it is possible"
Ide: "I have seen it before, in the former workshop. They had to collect small cubes, so they would ride towards them and while this was spinning as soon as it hit a cube, it was...wup, wup, put on a conveyor belt, to collect them so to say. So it could be fun to do that with the balls, if..."
Et1: "The advantage is that you don't have to control it. You can just put it on and it will move constantly. You only have to push a ball in there when necessary"
Et2: "As soon as you put a ball in there it will be...whoosh...shot away"
Et1: "Yes, that's the idea"
Et2: "My ideas all contain tubes. This is a tube that is loaded with balls. It doesn't
matter right now how they got in there. The tube has a groove and this
is a special mechanism to make sure that if it spins up, it will follow the
groove and hit exactly this ball and not the next one. And then it should
contain something to push these balls to the front...tjaw, tjew...so they will
be shot one by one. So this one can also continuously shoot and as soon as
you stop feeding balls, it will stop. So you should make something that will
position the ball just right and so quickly that it won’t get stuck half way
through its rotation. So there are some weak aspects.... This one is simpler.
Ehh... horizontal, tube, vertical, tube. This one is filled with balls and as
long as you don’t do anything they will stay there. This is a magnet. and this
lever goes like that and... pouf... it will hit the ball out. The advantage is that
you can adjust the force by the power you put through the magnet. In that
way you can adjust the distance of the shooting”

Et1 :  “But I don’t think we have a magnet available...”
Et2 :  “We can make one, that’s not too difficult. But well, it was only an idea.
This is the same idea, but with a fan. The fan will turn continuously and
we should make some sort of closure over here that will drop one ball at
the time. And this is the same idea as he told us, only I made a wheel with
grooves in it. The grooves are open at the outside and around the wheel is an
edge so the balls can’t get out. But if the wheel turns like this and it passes
the open space then it will pop out”

Ide : “Oh.. yes”
Et2 :  “So if you can make a closure again over here, you can feed in ball by ball and
overcome the disadvantage that you spill everything at once”

Me : “Yes, well... look, this is nice, but...”
Et1 : “Because that is easy to make, and in fact, adjusting the speed is also
possible”
Et2 : “But it definitely needs a disclosure-manager; something to feed in the balls”
Et1 : “That will be difficult, but we could solve that mechanically”

Me : “Won’t a simple slide do?”
Et2 : “Turn the space that fits just one ball, or something like that”
Et2 : “I see another objection: what if this slide moves too fast for the ball to roll
in, than it will be pushed up again and again”

Et1 : “We couldn’t let that happen, of course”
Et2 : “So that’s a disadvantage”

Me : “There is a possibility that these mechanisms become too complex”
Et1 : “Or they just won’t, you don’t know”

Ide : “I think this is a very solid construct”

6 Me : “Let’s go to the next one. Then later on we can, with all the other ideas...”
Et2 : “Yes, how do you want to proceed?”

Me : “Well, ehh... For example sketched the little cart so we have some ideas on
that as well, and then we can start combining. You always have a
chance that later on you get something that provides you from applying
this...so...

Et2: "I think more relevant is...eh...how can you collect the balls?"
Me: "That's all right it doesn't matter much...collecting the balls"
Et2: "Yes, or the little cart?"
Me: "That doesn't matter much"
Et1: "The sequence doesn't matter, it's fundamentally independent"
Me: "Yes precisely, collecting the balls"
Ide: "I think we should continue this..."
Me: "...That we, in any case, cross some off?"
Et1: "...Think further on the shooting perhaps?"
Ide: "I mean, yes, because...we've got all these solutions with tubes and so, but is this all there is..."

Et2: "No, but a tube like this can also be made by a plate"
Ide: "No, that's way too thick"
Et2: "That white plate?"
Et1: "I think you can very well shoot a ball with this"

[14:20]

Et2: "With that plate, standing by the wall, we can make a tube, there's nothing wrong with that, is there?"
Me: "But if you smash it real hard, how far will it go? That might be difficult, you have to have some mass behind it"
Et1: "That is too heavy. You have to give the ball speed, not smash it"
Me: "Let's think about that a bit more. Then you return to the Roman thing"
Et1: "Wait a minute, the function of the tube is guiding the ball in the right direction. How you speed the ball is separated from the tube"
Et2: "There is an alternative, that is to make a half, turned tube with three pieces of wire. Then you use the centrifugal force"
Me: "But take a look: how much force is half...it's not very special..."
Et2: "I think that once you've centered the mechanism, it will work ok. Because if you make a wire-way, like I said, the centrifugal force will keep it in track, so if you put it in there it will move with the track..."
Et1: "At least we need some sort of track to give direction. So you can use tubes, wires, whatever."
Ide: "You can make a V-shaped track"
Me: "That's not so good, because then the ball rolls over two points, you'd better make it more round, because..."
Et1: "That doesn't matter much"
Me: "It does, because it will reduce the speed"
Et1: "But it isn't..."
Ide: "We can just test that. We can also make it out of cardboard. With this you can
easily make something to go up and then pulls down so the ball will be shot”

Me : “The problem is, again, to tighten this”

Ide : “That’s with everything you shoot of course”

Et1 : “You could also move it like this, so it will shoot like that, but how would
you aim the...?”

Me : “Well, then you have to speed it up real fast”

Et1 : “Or turn around or something”

Et2 : “A disclosure on the tube. Put the ball in, turn the tube, then you open the
disclosure and the ball will fly away”

Et1 : “How about timing? That will be very difficult”

Et2 : “We’ll have to test that”

Et1 : “That will be too difficult, we shouldn’t do that”

Me : “Fill it with balls and then spin around? No, that’s nothing”

[14:25]

Ide : “Yes, do we have to shoot? That’s another thing isn’t it?”

Et2 : “You just say that, but that isn’t a bad idea at all...”

For a minute everyone is silent; Ide reads and sketches an idea.

Ide : “Shall we also think about.....because I sketched this idea that has nothing
to do with shooting. You can also bridge this by making something over here...
that you fill the tube with balls and then... here is the basket and at a certain
moment it goes... zzzzzz.... and the bottom is closed, and then... plop... six
balls at once in the basket, just like that”

Et1 : “Yes, but you need something very high”

Me : “But if you have a cart of 40 by 40 centimetres and you make the arm...”

Ide : “The distance is this.... This is 1 meter and this is 45 centimetre”

Et2 : “What is 45 centimetres? The height of the basket?”

Ide : “No, the difference between this and this”

Et2 : “OK”

Et1 : “That is at least 45 centimetres”

Me : “Yes, but I mean, you have to make something on the cart that is at least 1
meter tall and I think it will make the cart unstable. It will fall over, I think”

Et2 : “It will fall over the balls are too far out”

Me : “You should balance that”

Ide : “It depends, you can also drop this thing on this. That you have something
like this from 1,5 meter and drop it like this...boom....on this edge, and then
you lift it up here”

Et2 : “The cart must fit into 50x50x50 centimetres, so we have to make it foldable”

Ide : “No, this will just be standing up”

Me : “No, I think we have to shoot, or something like that...but....because, look
this also requires a tube of 1 meter, how do you want to make that?”
Ide: “Well, you could also...”
Me: “Yes, but we probably need the material for the rest of the cart. That’s a lot of material. And once you put it like this how will you get it up straight again?”
Et2: “You have to shoot again, of course”
Me: “Yes, and while driving, you have to carry all this along with you, even the balls that you are collecting”
Ide: “Yes, but in the former workshop we had something that was this high and built out of small mechanisms with motors and it went perfectly well”
Et1: “How high are we allowed to go?”
Et2: “50 centimetres, but I think we are allowed to fold out and make it bigger”
Et1: “Yes, of course”
Ide: “50 centimetres high, is that really a restriction?”
[14:30]
Me: “Hey, let’s get on with idea generation, or otherwise we’ll stick to this too long. Let’s first do the other things and then later we know for sure that... or in any case that we have a little cart or a chassis, more or less, and then on that basis we can look more in detail...to the...eh...”

7 Ide: “No I don’t think so. I think the way you get the balls into the basket, that’s to what you should adjust everything else to, not the other way around”
Et2: “Yes, I think so too. Driving is driving, that’s plain”
Ide: “Driving is the easiest part”
Et2: “Collecting the balls can be combined with driving it, but how to get them into the basket is the most difficult problem, I suppose. We have to find a way to aim the balls from the storage into the basket as accurate as possible. If we have that, I say OK, then we adjust the collecting to that... because... how can we transport a storage bin with that form...”
Me: “OK, yes, let’s regard that as our main problem for now”

8 Tecc continues with a brainstorm on ‘getting the balls into the basket.’

The first team design activity is exploring the design problem, looking for a way to start. The team mentions the relevant functions in the design problem and plans how to deal with these. Then they choose to start with one function, ‘shooting the balls’. The next team design activity is a brainstorm, to generate ideas on shooting the balls. Then they explain these ideas to each other. After this they discuss how to proceed again, interrupted by a discussion on tubes and
plates. They wonder whether shooting is the only possible way to get the balls into the basket and decide to reformulate the problem as how to get the balls into the basket. On this problem they start generating ideas again in a brainstorm.

Putting these separate team design activities in a sequence results in the next ‘team design activity flow chart’. We also indicate the ‘content’ of the team design activity, for instance by indicating the important utterances that indicate the activity:

<table>
<thead>
<tr>
<th>Team design activity</th>
<th>Content of the team design activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 exploring the problem</td>
<td>“how shall we approach this” “divide into separate sub problems” “driving the product, collecting the balls, shooting the balls”</td>
</tr>
<tr>
<td>2 planning the approach of the problem</td>
<td>“I suggest we start” “let’s get a part” “then look at…”</td>
</tr>
<tr>
<td>3 choosing to start with ‘shooting balls’</td>
<td>“we’ll begin with the part shooting the balls” “yes we will” “only shooting”</td>
</tr>
<tr>
<td>4 brainstorming</td>
<td>silently, individually generating ideas</td>
</tr>
<tr>
<td>5 discussing ideas</td>
<td>explaining and discussing the individual ideas one-by-one “shall we do it like this, that everyone tells....”</td>
</tr>
<tr>
<td>6 discussing how to proceed</td>
<td>“let’s go to the next one” “how do you want to proceed” “but is this all there is?” discussing tubes and plates “do we have to shoot?” discussion idea without shooting</td>
</tr>
<tr>
<td>7 reformulate the problem</td>
<td>“I think the way you get the balls into the basket…” “...is the most difficult problem” “let’s see that as our main problem for now”</td>
</tr>
<tr>
<td>8 generating ideas</td>
<td></td>
</tr>
</tbody>
</table>
The next step is coding these segments according to the Reflective Practice activities. The first activity of the team is *naming* relevant objects within the design task: ‘shooting the balls’, ‘collecting the balls’, and ‘driving the product’. The second activity is *moving*, choosing the most important name to handle first. The third activity is creating the *frame* ‘shooting the balls’. The next activity is *moving*, generating ideas on ‘shooting the balls’ (The team design activities 4 and 5 are combined as one *move*). We chose to do this, because we saw no use in coding a silent, individually undertaken activity as a separate team design activity). After this a moment of *reflection* occurs; the team discusses ‘what to do now’, ‘what do we have’, ‘is this all’, and ‘do we have to shoot’? This results in the seventh activity: resetting their *frame* into ‘getting the balls into the basket’ as the most important problem issue. They proceed by generating ideas within this *frame*, *moving*.

In the same step of processing the segments are labelled with the content of the activity. This results in the next representation:

<table>
<thead>
<tr>
<th>Team design activity</th>
<th>Reflective Practice activity</th>
<th>Labelling of the content of the activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>exploring the problem</td>
<td>naming</td>
</tr>
<tr>
<td></td>
<td>naming</td>
<td>naming the subfunctions ‘shooting the balls’, ‘collecting the balls’, ‘driving the product’</td>
</tr>
<tr>
<td>2</td>
<td>planning the approach of the problem</td>
<td>moving</td>
</tr>
<tr>
<td>3</td>
<td>choosing to start with ‘shooting the balls’</td>
<td>framing</td>
</tr>
<tr>
<td>4</td>
<td>brainstorming</td>
<td>moving</td>
</tr>
<tr>
<td>5</td>
<td>discussing ideas</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>discussing how to proceed</td>
<td>reflecting</td>
</tr>
<tr>
<td>7</td>
<td>reformulate the problem</td>
<td>framing</td>
</tr>
<tr>
<td>8</td>
<td>generating ideas</td>
<td>moving</td>
</tr>
</tbody>
</table>
Figure 16 shows the result of the data processing: a schematic representation of the team’s reflective practice. In the notation of the reflective practice activities we added a horizontal dimension. Both teams start by dividing the design assignment into functions for the product. We specifically indicated this in the description method to make clear on which issue the team is working at a specific moment. Because we used the divisions that the teams made themselves, the horizontal axis differs for both descriptions. This addition to the structure of our method of description shows what issues the teams attend to.

<table>
<thead>
<tr>
<th>Time</th>
<th>Reflective practice chart</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14:03</td>
<td></td>
<td>naming subfunctions: (1) shooting the balls, (2) collecting the balls, (3) driving the product</td>
</tr>
<tr>
<td>14:04</td>
<td></td>
<td>moving; choosing a subfunction</td>
</tr>
<tr>
<td>14:04</td>
<td></td>
<td>frame: shooting the balls</td>
</tr>
<tr>
<td>14:05</td>
<td></td>
<td>moving; generating ideas for shooting the balls</td>
</tr>
<tr>
<td>14:18</td>
<td></td>
<td>reflecting</td>
</tr>
<tr>
<td>14:30</td>
<td></td>
<td>frame: getting the balls into the basket</td>
</tr>
<tr>
<td>14:32</td>
<td></td>
<td>moving; generating ideas for getting the balls into the basket</td>
</tr>
</tbody>
</table>

The first half-hour of reflective practice activities of team Tecc. Figure 16

The entire design projects of both teams are described in this way. In the next section we will work out these descriptions in more detail. At first, however, we will discuss the difficulties we had in processing the team design observations.

**Difficulties in data processing**

The four reflective practice design activities can be differentiated in team design behaviour. However, some difficulties arise when processing the data.

Tecc reflect every now and then on what they are doing, and explicitly frame their view on the design problem. This makes their progress easy to understand in reflective practice terminology. The Delft Pitchbells are much more difficult to capture in code, but it is also difficult to understand what they are doing. They discuss a lot of important issues within the design task, but often without really
dealing with them. Discussions are open-ended, and *framing* and *reflecting* hardly occur.

Schön derived his theory of reflective practice from practical examples, saying that all designing is reflective practice. But it seems like The Delft Pitchbulls design in a different manner and are therefore difficult to capture in a reflective practice description.

Secondly, *frames* are difficult to detect in the team’s design activities, mainly because they can only be recognised by way of further activities. Sometimes the team explicitly verbalises the *framing* of the problem, for instance when Tecc agrees to define the problem as a shooting problem (Tecc, day 1, 14:04). Other times the adoption of a *frame* is more implicit in the team’s behaviour. For instance when Tecc explicitly verbalises the *framing* of ‘collecting the balls’ and ‘driving the product’, then decides to investigate ‘collecting the balls’ and sets this as the next *frame* (Tecc, day 1, 16:45). But by a side remark by one of the team members (“... because driving is simple”) the team is dragged into a discussion on caterpillar tracks and is in reality dealing with the *frame* ‘driving the product’.

These difficulties in data processing will be dealt with in the evaluation of the notation system for reflective practice in the second empirical study.

**Descriptions of the team’s design activities**

**Team The Delft Pitchbulls**

The Delft Pitchbulls’ reflective practice is shown in figure 17.

The Delft Pitchbulls start by *naming* the remote control functions of the design: ‘shooting the balls’, ‘collecting the balls’, ‘steering’, and ‘driving’. In the following discussion they attend to several issues within the design problem. They *name* ‘tactics during the game’ or ‘different motors’ as being important aspects to think of. During their discussion they deal with many items in parallel. They try to find solutions for their problems, but *naming* other things that are important often interrupts their discussions. They often continue with a new subject without making a decision and without explicit elaboration of an idea.
The reflective practice design activities of team The Delft Pitchbulls. Figure 17
The Reflective Practice in product design teams

Figure 17 continued
continued Figure 17
Figure 17 continued

At the end of the first day, they make an inventory of what they have done and opt for the discussed solutions. They decide to use a thrower, a shovel, caterpillar tracks, a way to put this on the chassis of the product and a way to control these functions in the remote control. The first day ends in the middle of a discussion on positioning the balls with the shovel.

The second day they start with recalling the important parts of the design, which they have to attend to: ‘the shovel’, ‘the rear wheel drive’ and the ‘product chassis’. They attend to these aspects in the same way as on the first day. After lunch they make a drawing of their design for the presentation to the team of experts. They present their product to the team of experts and, back in their design studio, reflect on the comments and criticism they received from the experts.

**Team Tecc**

Tecc’s reflective practice is shown in figure 18.

Tecc starts by *naming* the different functions in the design task; ‘shooting the balls’, ‘collecting the balls’, and ‘driving the product’. They decide to start with ‘shooting the balls’ and make that their first *frame* to approach the problem.

Tecc generates ideas within this *frame*. In several *reflection* cycles, where they *reframe* into a broader perspective of ‘getting the balls into the basket’, they choose a shooting concept.

Then they recall the remaining items (*names*). They first consider ‘driving the product’ and quickly decide on caterpillar tracks within this *frame*. Their next
The reflective practice design activities of team Tecc. Figure 18
The Reflective Practice in product design teams

<table>
<thead>
<tr>
<th>Time</th>
<th>Reflective practice chart</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td></td>
<td>frame: simple integrated solution for collecting the balls and getting them into the basket</td>
</tr>
<tr>
<td>17:15</td>
<td></td>
<td>moving: generating ideas on integrated solution</td>
</tr>
<tr>
<td>17:16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 2</td>
<td></td>
<td>frame: new concept</td>
</tr>
<tr>
<td>10:26</td>
<td></td>
<td>moving: individually building models of subparts</td>
</tr>
<tr>
<td>10:28</td>
<td></td>
<td>reflecting</td>
</tr>
<tr>
<td>10:59</td>
<td></td>
<td>moving: detailing parts (in pairs)</td>
</tr>
<tr>
<td>11:00</td>
<td></td>
<td>moving: discussing the fit between the parts</td>
</tr>
<tr>
<td>11:40</td>
<td></td>
<td>moving: detailing parts (in pairs)</td>
</tr>
<tr>
<td>11:43</td>
<td></td>
<td>moving: discussing the fit between the parts</td>
</tr>
<tr>
<td>11:46</td>
<td></td>
<td>moving: detailing parts (in pairs)</td>
</tr>
<tr>
<td>11:53</td>
<td></td>
<td>moving: discussing the fit between the parts</td>
</tr>
<tr>
<td>12:04</td>
<td></td>
<td>moving: detailing parts (in pairs)</td>
</tr>
<tr>
<td>12:22</td>
<td></td>
<td>reflecting</td>
</tr>
<tr>
<td>12:32</td>
<td></td>
<td>lunch</td>
</tr>
<tr>
<td>13:43</td>
<td></td>
<td>reflecting</td>
</tr>
<tr>
<td>14:03</td>
<td></td>
<td>moving: drawing the design</td>
</tr>
<tr>
<td>14:25</td>
<td></td>
<td>moving: evaluating the design</td>
</tr>
<tr>
<td>14:57</td>
<td></td>
<td>moving: drawing electronics schema</td>
</tr>
<tr>
<td>15:30</td>
<td></td>
<td>moving: giving presentation to the team of experts</td>
</tr>
<tr>
<td>15:45</td>
<td></td>
<td>reflecting on comments of experts</td>
</tr>
<tr>
<td>16:30</td>
<td></td>
<td>end of design session</td>
</tr>
</tbody>
</table>

Figure 18 continued
frame is 'collecting the balls'. They want to investigate this in relation to what they have already done. Therefore they generate ideas on an integrated concept for collecting the balls in their chosen shooting concept. They get stuck very quickly. In reflecting on this getting stuck (it's all becoming too complex), they come up with a bulldozer idea. They explore the bulldozer as a concept for their design problem and decide that a bulldozer is a very simple and reliable product, but very inaccurate in the activity of aiming for the basket. Reflecting on this they decide that their cart must be simple and therefore they have to look for an integrated solution for collecting and shooting the balls. With this new frame the first design day ends as they are still busy generating ideas.

On the second day they start with a new integrated concept. This is their frame. All morning long they build models and refine their design while working in pairs, every now and then discussing of the fit between the parts. Before lunch they reflect on what they are doing, and are satisfied with their progress and their concept. After lunch they sketch the design for the presentation to the team of experts, and extensively evaluate the design.

They present their product to the team of experts and, back in their design studio, reflect on the comments and criticism they received from the experts.

The reflective practice in design teams: an exploration

Both team design projects are described in reflective practice terms. Now we will explore what this can show us about team designing. We will analyse the teams' design activities and look for patterns in their reflective practice behaviour.

Team design activities

First we will explore the four reflective practice activities (naming, framing, moving, and reflecting) of both teams.

Naming

Naming is the main activity of The Delft Pitchbulls. They divide their attention over every aspect of the design task. Whenever they try to get deeper into one subject, another subject is mentioned as being important and the activity is
interrupted. As an example we look at the team half an hour into the design project (The Delft Pitchbulls, day 1, 14:51): they are discussing how to position the balls (14:51 ‘naming: positioning the balls’). They want to drive through the ball bin, collect as many balls as possible, then drive onto the lower platform and shoot into the basket (14:52 ‘naming: tactics during the game’). They wonder how many balls are necessary to score a win. In total there are 31 balls, but do they really need to score 16 balls to win? And is that possible, or are 3 or 4 balls enough and more realistic? The electrotechnical engineer tries to focus their attention (14:53 reflection):

Et : “Shall we make an inventory of all mechanisms for collecting and shooting and then make a choice?”
Me1: “Yes, but they have to be combined in a good way”
Ide : “The functions of the machine, that’s it. The driving of the product, that’s what we have to keep in mind. That’s the limit, that’s the precondition”
Et : “Yes”
Ide : “What we can do…”

Et : “Yes, and I am a bit worried about the motors. They are 12 volts, but the battery is 7 volts.”
Ide : “Yes”
Me2: “Are they all 12 volts?”
Et : “No, only those two…..” and he gets up and walks to the tool kit to show the motors.

The moment of reflection, where the team seems to go towards a focus on the design process, is interrupted by a discussion of the motors. For the next five minutes the team gathers around the tool kit to look at the motors that are available. (14:54 ‘naming: the different motors provided’)

Tecc also starts by using names to divide the design task. Then they choose one of the names and make that their frame for the moment. During the rest of the project they keep referring to earlier names (e.g. Tecc, day 1, 16.45) as a stepping stone to create a new frame.
Framing
In the first stage of designing by The Delft Pitchbulls we can’t identify a frame. They attend to the whole design problem, without focussing or setting priorities. The only focus they make is while choosing the solutions for the different functions. Then they frame the chosen solutions as their concept (The Delft Pitchbulls, day 1, 16:46). Their next activities are guided by the adoption of these ideas, which therefore serve as a frame for the activities.

Tecc uses six different frames sequentially during the design project. These frames originate from the different functions they have named early in the process (‘shooting the balls’, ‘collecting the balls’, and ‘driving the product’), but also from insights that the team gains while designing. For instance when Tecc broadens their view by reframing ‘shooting the balls’ into ‘getting the balls into the basket’ (Tecc, day 1, 14:30). Or when they decide to design a ‘simple and integrated solution’ when they notice that combining the designed solutions would make the product too complex (Tecc, day 1, 17:15). By explicitly stating these viewpoints of the problem, team Tecc focus their attention on a shared goal and shared activities.

In the description of the frames used we can make a distinction between frames concerning the design task (the problem) and frames concerning the solution(s). If we do this for both teams we can see that Tecc first extensively explores the design task, before choosing and developing the solution. The Delft Pitchbulls almost immediately start searching for the solution, without exploring the design task. Once the concept is set, the chosen functions serve as a frame for their next activities. These functions, and therefore the frame, are never questioned again in the design project.

Moving
Figure 19 provides an overview of all moves by both teams, and the time that they take.

The Delft Pitchbulls use 72% of their total design time for moving (up to the presentation moment). The average time of a move is 9 minutes. The moves The
### The Delft Pitchbulls

<table>
<thead>
<tr>
<th>moves (chronologically)</th>
<th>duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>challenging shooting</td>
<td>1 min</td>
</tr>
<tr>
<td>generating ideas for getting</td>
<td>1 min</td>
</tr>
<tr>
<td>the balls into the thrower</td>
<td></td>
</tr>
<tr>
<td>discussing the thrower</td>
<td>1 min</td>
</tr>
<tr>
<td>discussing the thrower</td>
<td>3 min</td>
</tr>
<tr>
<td>discussing how to collect</td>
<td>1 min</td>
</tr>
<tr>
<td>the balls</td>
<td></td>
</tr>
<tr>
<td>discussing the lay out of</td>
<td>6 min</td>
</tr>
<tr>
<td>the chassis</td>
<td></td>
</tr>
<tr>
<td>discussing the shovel</td>
<td>6 min</td>
</tr>
<tr>
<td>combining caterpillar tracks</td>
<td>23 min</td>
</tr>
<tr>
<td>and steering</td>
<td></td>
</tr>
<tr>
<td>drawing the lay out of</td>
<td>4 min</td>
</tr>
<tr>
<td>the chassis</td>
<td></td>
</tr>
<tr>
<td>combining steering functions</td>
<td>7 min</td>
</tr>
<tr>
<td>in the remote control</td>
<td></td>
</tr>
<tr>
<td>discussing caterpillar tracks</td>
<td>4 min</td>
</tr>
<tr>
<td>discussing pro's and con's of</td>
<td>4 min</td>
</tr>
<tr>
<td>caterpillar tracks</td>
<td></td>
</tr>
<tr>
<td>making an inventory of the</td>
<td>4 min</td>
</tr>
<tr>
<td>control functions</td>
<td></td>
</tr>
<tr>
<td>choosing discussed functions</td>
<td>8 min</td>
</tr>
<tr>
<td>from the inventory</td>
<td></td>
</tr>
<tr>
<td>discussing the shovel as</td>
<td>30 min</td>
</tr>
<tr>
<td>positioning mechanism for the</td>
<td></td>
</tr>
<tr>
<td>balls</td>
<td></td>
</tr>
<tr>
<td>discussing the tensioning</td>
<td>10 min</td>
</tr>
<tr>
<td>mechanism of the catapult</td>
<td></td>
</tr>
<tr>
<td>discussing the drive of</td>
<td>5 min</td>
</tr>
<tr>
<td>the catapult</td>
<td></td>
</tr>
<tr>
<td>discussing the electromechanical</td>
<td>20 min</td>
</tr>
<tr>
<td>parts for the catapult</td>
<td></td>
</tr>
<tr>
<td>discussing how to make</td>
<td>9 min</td>
</tr>
<tr>
<td>the parts</td>
<td></td>
</tr>
<tr>
<td>sketching the cart lay out</td>
<td>7 min</td>
</tr>
<tr>
<td>choosing the materials for the</td>
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</tr>
<tr>
<td>parts</td>
<td></td>
</tr>
<tr>
<td>positioning the parts</td>
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</tr>
<tr>
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</tr>
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</tr>
<tr>
<td>the parts in the drawing</td>
<td></td>
</tr>
<tr>
<td>trying out the parts with</td>
<td>8 min</td>
</tr>
<tr>
<td>the materials</td>
<td></td>
</tr>
<tr>
<td>drawing the design for</td>
<td>30 min</td>
</tr>
<tr>
<td>the presentation</td>
<td></td>
</tr>
</tbody>
</table>

### Tecc

<table>
<thead>
<tr>
<th>moves (chronologically)</th>
<th>duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>choosing a function</td>
<td>1 min</td>
</tr>
<tr>
<td>generating ideas for shooting</td>
<td>13 min</td>
</tr>
<tr>
<td>the balls</td>
<td></td>
</tr>
<tr>
<td>generating ideas for getting</td>
<td>32 min</td>
</tr>
<tr>
<td>the balls into the basket</td>
<td></td>
</tr>
<tr>
<td>evaluating and choosing a</td>
<td>73 min</td>
</tr>
<tr>
<td>concept for getting the balls</td>
<td></td>
</tr>
<tr>
<td>into the basket</td>
<td></td>
</tr>
<tr>
<td>considering pro's and con's of</td>
<td>2 min</td>
</tr>
<tr>
<td>caterpillar tracks</td>
<td></td>
</tr>
<tr>
<td>generating ideas for integra-</td>
<td>3 min</td>
</tr>
<tr>
<td>ting collecting the balls in the</td>
<td></td>
</tr>
<tr>
<td>chosen shooting concept</td>
<td></td>
</tr>
<tr>
<td>evaluating bulldozer idea</td>
<td>4 min</td>
</tr>
<tr>
<td>generating ideas on integrated</td>
<td>15 min</td>
</tr>
<tr>
<td>solution</td>
<td></td>
</tr>
<tr>
<td>individually building models of</td>
<td>31 min</td>
</tr>
<tr>
<td>parts</td>
<td></td>
</tr>
<tr>
<td>detailing parts (in pairs)</td>
<td>40 min</td>
</tr>
<tr>
<td>discussing the fit between parts</td>
<td>3 min</td>
</tr>
<tr>
<td>detailed parts (in pairs)</td>
<td>3 min</td>
</tr>
<tr>
<td>discussing the fit between parts</td>
<td>7 min</td>
</tr>
<tr>
<td>detailing parts (in pairs)</td>
<td>3 min</td>
</tr>
<tr>
<td>discussing the fit between parts</td>
<td>13 min</td>
</tr>
<tr>
<td>detailed parts (in pairs)</td>
<td>18 min</td>
</tr>
<tr>
<td>discussing the design</td>
<td>22 min</td>
</tr>
<tr>
<td>evaluating the design</td>
<td>32 min</td>
</tr>
<tr>
<td>drawing electronics scheme</td>
<td>33 min</td>
</tr>
</tbody>
</table>

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**Figure 19** The moves of both teams.

*From this moment on The Delft Pitchbulls have set a frame. All following moves are within this frame.*
Delft Pitchbells make are short and, before their frame is set, consist mainly of ‘discussions’. Only after stating the frame of the chosen functions, their moves become longer and more concrete.

Tecc use 84% of their total design time for moving. Moving is the main activity of Tecc. Their moves last for longer periods of time, for instance ‘generating ideas’ for 32 minutes, or ‘evaluating ideas’ for 73 minutes. The average time of a move is 19 minutes. The only move outside a frame is the first one: ‘choosing a function’.

The actual designing takes place within moves; when the team is really handling and changing the design content. There seems to be a difference between moves in the context of a frame, or moves without a frame. Moves outside frames appear to lack a shared goal. This makes it difficult to aim the team’s discussion. Once the context for moving is set, by stating a frame, the moves work towards exploring the design task and challenging the chosen frame.

Reflecting
Tecc reflects throughout the design project. The Delft Pitchbells only at the end of the project, initiated by the comments of the team of experts. Then The Delft Pitchbells don’t really know what to do with the outcome of their reflections. Tecc mostly reflects at the beginning of the project (on day 1), and does so frequently and in brief periods.

Tecc’s reflection is initiated by evaluating what the team is doing in relation to the frame they are working in. For example (Tecc, day 1, 14:18), Tecc is generating ideas for shooting the balls. In the discussion on these ideas, they realise that shooting is not the only way to get the balls into the basket and reframe the problem as ‘getting the balls into the basket’. Or (Tecc, day 1, 14:49) Tecc is generating ideas on ‘getting the balls into the basket’, and in the discussion on these ideas, they are not satisfied with the quality of the ideas. They decide to generate more ideas. These reflections occur after finishing an activity and occur therefore more or less logically in the process.

A reflection can also be initiated by the design content. (Tecc, day 1, 16:54) Tecc is generating ideas in order to integrate ‘collecting the balls’ into the chosen
‘shooting concept’. In doing this they get stuck. They reflect on being stuck and the idea of a bulldozer comes up. Evaluating the bulldozer idea makes them realise that their current frame ‘collecting the balls’ will provide them with a too complex product. They reframe in order to get an integrated and simpler solution.

The reflections of The Delft Pitchbulls are aimed at their current activity and concern making a choice for the next activity. The reflections of Tecc always occur in relation to the current frame and the team’s progress in the design project.

The element of ‘surprise’
In chapter 2 we indicated that surprises in team designing are social events. We also expected that focussing on every moment of surprise might be difficult, for team members can be surprised by many activities or ideas of their fellow team members. This does not necessarily mean that all these surprises are of relevance for the reflective practice process.
However, there is a moment in Tecc’s design project where a surprise, noticed and picked up by the whole team, has a major influence on the course of the project. When Tecc has set the frame ‘collecting the balls’ (Tecc, day 1, 16:51), they are generating ideas for integrating collecting the balls in the chosen shooting concept. After generating ideas for five minutes, they decide that this will provide them with too complex a product. In the moment of reflection, while looking for a way to proceed, the idea of a bulldozer comes up. The exploration of the bulldozer idea makes them realise that they have to keep their product really simple and integrated. With that in mind they reframe their approach to the problem.

The bulldozer exploration is a very odd activity in the team’s design process. The idea does not fit their earlier way of working (which was very structured), nor does it fit their earlier ideas (which were about functions of the product). However, all team members participate in the discussion of this idea. Imagining how the bulldozer will collect the balls and just throw them all at once in the direction of the basket. Maybe one or two balls will hit; some may even score for the other party. The idea of the bulldozer seems to function as a catalyst
to discover what is of importance in the design problem, namely keeping the product very simple.

The teams' reflective practice strategies
All four activities can be found in these team design projects. Schön describes a reflective practice as being controlled locally, and does not deal with higher level strategies. However, applying the detailed mechanism of naming, framing, moving and reflecting onto a total design project reveals patterns and large-scale strategies.

The descriptions of both teams reveal a big difference in the strategies the teams use to approach the assignment.
The Delft Pitchbulls deal with different names simultaneously through the whole project, representing all relevant aspects of the design task as they see it. They divide their attention over every aspect and interrupt each other whenever they get deeper into one subject, arguing that another subject is also important to attend to. They are searching for the one best solution to fit the problem, but without generating any alternatives. The solutions they decide on are not compared to other ideas, or being developed from idea to working solution, but are chosen as being the best ones. In the sketch of their design (figure 12) The Delft Pitchbulls present the design as four sub solutions. When the team of experts asks for the connections between the solutions, the team can't give them adequate answers.
Looking at this approach towards the design task we can't help but wondering what is going on in this design team. It seems that The Delft Pitchbulls are anticipating things to come; waiting for someone to take control. This raises the question whether there may be preconditions for reflective practice. The lack of experience of the designers might have had an influence on the outcome of our study.
Team Tecc, on the other hand, determines a frame concerning that which they see as the main aspect of the design task, from the beginning of the design project. Tecc develops this, and subsequent frames throughout the design project. They try to integrate new aspects of the design task in earlier frames and, in this way, build an integrated view of the design task and the design solution.
Looking at the sketch of the team’s design (figure 13) we can see that Tecc presents the ‘working’ of the machine by indicating the path of the ball through the machine.

The teams’ descriptions are not just a flow of separate activities; patterns occur in the reflective practice of the teams. Frames mostly end with a moment of reflection, where the team ends the current activity and moves on to the next. If necessary by reframing the problem. Such a mechanism indicates an underlying learning process, where the team creates an understanding of what they are doing and of the developing design content. The exploration of the frame is concluded by reflection and so is the learning cycle within.

Using a frame to focus on a particular part or viewpoint of the design task enables a team to explore the task in detail and ‘learn’ about the problem and possible solutions. The Delft Pitchbulls deal with many different items in parallel, which looks like the general design rule of ‘parallel development’, but they hardly build understanding of the design task (as we can see in the discussion with the team of experts). Tecc starts by exploring a part of the problem in a set frame. By continually reframing this viewpoint, they build an understanding of the design task. The rejecting of frames (Tecc, day 1, 14.30 and 17.14) also increases their understanding of the possibilities of the design task.

Not only frames help in this ‘learning process’. Also conscious reflection on what the team is doing and where it gets them in solving the design problem, builds this knowledge and understanding of the design task. Regular reflecting in the project, also in a sequence of moves, seems to be a precondition for reflective practice.

**Design outcomes**

In order to trace the progress of the two design projects it is useful to take a closer look at the design assignment and the ways that the teams approach and solve the design problem. In order to create a design concept, the teams will have to consider certain issues of the design task.

Important issues to be tackled in this design assignment are:

1. How to get the balls into the basket. In order to do this the distance between the ball bin and the basket has to be bridged and, therefore, the balls have to be
transported.

(2) How to collect the balls, and control them while doing so. The balls must be positioned in the cart, carried, and released into the basket.

(3) The control of the cart. The cart must be able to move and steer. This issue also has a bearing on the functions to be designed in the remote control. The teams can only use two channels for the remote control to operate all necessary functions.

In order to create a design concept, the teams have to integrate these issues, attending to the product layout and the relationships between the separate functions (e.g. collecting the balls, aiming the balls, carrying the balls, driving and steering).

Looking at the issues that both design teams pay attention to in the conceptual design phase, we see that The Delft Pitchbulls name all important issues in the design task. They refer to 'shooting the balls', 'collecting the balls', 'steering', 'driving', 'positioning the balls', and the 'product chassis'. They decide on using a 'thrower', a 'shovel', 'caterpillar tracks', and the remote control functions.

Tecc generates different ideas for 'shooting the balls', 'getting the balls into the basket', and 'collecting the balls'. For driving they decide on caterpillar tracks very quickly. By exploring the design problem extensively, the concept that Tecc presents to the team of experts is well thought out. Tecc already knows the strengths and weaknesses of their design and can reply to every question or comment that the experts have. Even if they have to respond criticism by 'we'll have to test that', they have an alternative for that idea.

The Delft Pitchbulls present loose solutions for the separate functions to the team of experts. When the experts ask about the integration between the functions (like the positioning of the balls or the separation mechanism for the thrower), the Delft Pitchbulls don't deal with these criticisms.

**Conclusion**

Having described and analysed the team's reflective practice, the research questions must now be answered. The empirical study set out to answer four questions. Two questions relate to the description of design:
• Can team design activity be described with reflection-in-action?
• Can the four reflective practice design activities (naming, framing, moving, and reflecting) be differentiated in team design practice?

Two questions relate to the investigation into team design practice:

• Can the occurrence of the four reflective practice design activities be observed within design teams?
• Does reflection-in-action demonstrate part of the team design activity concerning the shared understanding of the design content?

Now we will answer these questions as we discuss the outcome of the first empirical study. We will leave this chapter with new questions and requirements for the second empirical study.

Describing team designing as reflective practice

Can team design activity be described with reflection-in-action?

Looking at the reflective practice of the teams provides a good picture of what the teams are doing. We can see the design progressing, including the development of the design content, higher level reflective practice strategies, and the flow of design activities. This way of describing team activities provides a framework for interesting issues in the team design project and their interrelationships.

At the end of the design weekend during the data gathering phase we straightaway marked in our notes those moments in the project where we thought something interesting was happening. Comparing those marks with the later descriptions of the teams, showed that all the interesting moments tended to occur when the teams made a transition between frames.

The view a team creates about the context it is working in, seems very important in team designing. The descriptions of reflective practice lend structure to research into design behaviour; they provide a way of describing the entire design process.

Can the four reflective practice design activities (naming, framing, moving, and reflecting) be differentiated in team design practice?

As a research method the notation system for reflective practice seems to work.
Not only for design observations like the Petra/Quist example, but also for observations of design teams at work. This first exploration of the notation system brought up some difficulties in processing the data. These problems relate to the identification of frames and the understanding of non-reflective activities with the aid of the theory of reflective practice. In the evaluation of the notation system we will have to deal with these difficulties.

**The reflective practice in design teams**

Can the occurrence of the four reflective practice design activities be observed within design teams?

In the analysis of the teams' reflective practice we indicated that the teams name different issues in the design task. The team members convey these names to each other and then decide upon a focus within the design problem. They do so by framing a view on the problem or the solution.

The actual designing takes place within moves; when the team is really handling and changing the design content. Moves outside frames appeared to lack a shared goal. This makes it difficult to aim the team's discussion. Frames are therefore important elements for they improve the team's moves, and therefore their designing.

The development of frames, both stating a frame and modifying or rejecting it again, is important in building an understanding of the design task and its solution. This underlying learning process is guided by the mechanism of framing, reflecting and reframing. Therefore, reflection is crucial in designing. Only by reflecting on its behaviour a team of designers can rationally make a decision to start a new activity or to reframe their approach towards the problem. Reflections are used to guide the progress and the quality of the design project.

Does reflection-in-action demonstrate part of the team design activity concerning the shared understanding of the design content?

Naming is an important activity concerning all relevant issues in the design task. As a team activity, it becomes an activity aimed at diversity; making sure every relevant issue is mentioned. Framing is an important tool to deal with
the complex task of designing. *Frames* help to define the problem or solution in manageable parts. As a team activity *framing* also helps to focus the teams' attention. By explicitly verbalising *frames*, thoughts and interpretations of the design task are passed on and harmonised. *Moving* is the activity through which the product design content changes and develops. Ideas are generated, worked out in more detail and evaluated. Once the context for *moving* is set, by stating a *frame*, the *moves* work towards exploring the design task and challenging the chosen *frame*. *Reflections* critically look at the design activities and the *frames*. While *reflecting* the team is trying to co-ordinate their activities and decide upon a direction for further actions.

Looking at the four reflective practice design activities it seems that *naming* and *moving* in teams tend to work towards diversity of thoughts, whereas *framing* and *reflecting* produce convergence of thoughts. Because *frames* and *reflections* are explicitly stated, they also aid the sharing of these thoughts within the team. Especially while *framing* and *reflecting* the team is creating shared understanding of the design task (*frame*) or the direction to take (*reflecting*) at the same time. In order to verify these findings and develop a better understanding, the second study will analyse design teams' *framing* and *reflecting* in more detail.

**Towards the second empirical study**
The second empirical study has two goals. The first goal is to evaluate the notation system for reflective practice. In this evaluation process we will measure the extent of correspondence in a multi-coder approach. We will also deal with the disagreements between coders in an arbitration discussion (see chapter 3). In this way we are able to deal with the difficulties in data processing that we identified in this first exploration. The research question for the second empirical study is:

- Is the method of description for reflective practice repeatable?

The second goal is the investigation on the *framing* and *reflecting* behaviour of the design teams. Our first study raised questions on the use and communication of *frames* and *reflection* in designing. A reflective practice description provides a picture of the teams' design process. In the second empirical study the moments
in this design process where framing and reflecting occur will be analysed in more detail. The research questions for the second study are:

- How are frames used by a design team?
- How is a frame communicated in a design team?
- How are reflections used to direct the framing or reframing of the team?
- What can frames contribute to the shared understanding of the design content?

The first empirical study raised some issues regarding the requirements for the empirical study. The observation confirms that especially the problem- and conceptual phases are interesting for our purposes. Once the teams decide upon a concept design, they change little in their frame. Having set the concept, the teams also start making sketches or models. Communication about the design content is therefore easier than in the phase of ‘problems’ or ‘ideas’, which are more difficult to pass on between team members.

In this study the team design task was rather technical and there was a possibility to split up the task into sub problems or sub functions. However, applying an integral approach to the problem offered a better result. This complex nature of design can be observed by looking at design as reflective practice. It would be fruitful to look at a design task that requires even more, or more evidently, integration of contradictory design issues in the next study.

We already indicated the possibility that observing student designers might cause difficulties for processing non-reflective behaviour. According to Schön good designing is reflective practice and therefore should contain reflection and framing of the design task. The lack of experience of the designers might have influenced our results. Reflective practice, as a skill, may very well be more developed in professional practice. Contrasting this first study, in the second empirical study we will observe experienced designers, working on a more ‘product-like’ design problem. That study will be described in the next chapter.
The Delft workshop teams

Introduction

This second empirical study builds on the results of the first empirical study, described in chapter 4. In the first study the suitability of the method of description for reflective practice is explored by applying it to two team design projects. Describing the team design projects with reflective practice proved to be very useful. The description provides a good picture and insight in the teams' design activities, the development of the design content and the teams' reflective practice strategies. The notation system for reflective practice seems to work. However, the question remains whether the processing of the data is reliable.

In this second empirical study the notation system will be evaluated. We will use a multi-coder approach and an arbitration discussion between coders, as described in chapter 3, to indicate the extent of agreement between the coders and to investigate the disagreements between the coders. This will not only result in a better understanding of the data, but also in an improvement of the definitions in the notation system.

We will use data well known in the design research community. There are team design observation data available in the design research community. For the Delft workshop "Design Thinking II – Analysing Design Activity - 1994" team design data were collected, which were used and analysed by different design research groups around the world [Cross et al 1996]. For this second study we have chosen to use these data. It provides us with videotapes of two design teams, both composed of three experienced designers, working on a conceptual design task for two hours.

In the first empirical study we also explored the reflective practice of the design teams. The analysis of the team's behaviour indicates how the teams generate and communicate issues on the design task ('naming'). How they decide upon a focus within the design problem ('frames'). How reflections are used to guide the progress and the quality of the design project ('reflecting'). And how this
mechanism of framing, reflecting and reframing serves as a guiding principle for their designing ('moving'). Especially while reflecting and (re)framing, the teams work on a shared understanding of the design task. The importance of frames as tools to pass on thoughts on the product design content in teams, as well as tools to deal with the complex task of designing is indicated. Further questions arise on the use of and communication about frames within the teams and the role of reflection in developing frames in design projects. In this second empirical study we will analyse the reflective practice of the design teams a step further by studying the teams' communication on framing and reflecting. The Delft Workshop team protocols suit this purpose well, for the design projects are very well documented, providing not only the videotapes and transcripts of the team's communication, but also all the writings and sketches that the teams have produced.

In chapter 4 the research questions for this second study were set. One of the questions relates to the description of design projects:
- Is the method of description for reflective practice repeatable?
Four questions relate to the investigation into team design practice:
- How are frames used by a design team?
- How is a frame communicated in a design team?
- How are reflections used to direct the framing or reframing of the team?
- What can frames contribute to the shared understanding of the design content?

As stated before, in this second empirical study we observed two product design teams, both composed of three experienced designers, participating in a design experiment. The teams were located in one room and asked to design a fastening device to attach a backpack onto a mountain bike. The teams were videotaped from the first moment they received the design task up to the presentation of their conceptual design after two hours. The team design observation captured all communication and interactions between the team members. The period of time the teams worked together was limited to two hours. However, they had to do the entire conceptual phase of the design project. In this study we want to focus on the communication between
team members at specific moments of *framing* and *reflecting*. As well as building on the findings of the earlier study, this study is still an exploration. Now we will explore the team communication and behaviour. The number of teams is therefore of lesser importance than the completeness of the observations.
The design problem is a product design problem. This design problem is, compared to the task in the first study, even more related to a 'normal' product and discussions on conflicting interests (for instance use, manufacture or technology) have to be integrated in one design concept. The data, again, capture the problem definition and conceptualisation phase of designing.
The design teams consist of three designers. The first empirical study demonstrated a possible lack of experience of the team members (students). This second study involves experienced designers, who have also worked as a team before. The experimental setting of the study might bring a divergence from practice and, even more importantly, influence the motivation of the team members. However, the experimental setting was designed to be close to a real life experience and the team members volunteered to participate in the project.

This chapter will begin with an outline of the empirical study, describing the experiment, the product design teams, the design task and the team design projects. The multi-coder method used for evaluating the method of description for reflective practice will be explained. This will result in the descriptions of the two teams according to the notation system. Then we will further analyse what we can learn from design teams at work, looking at them from a reflective practice point of view. This chapter concludes by answering the research questions of this second empirical study. Parts of this chapter have been published before [Valkenburg and Dorst 1999].

**The Delft workshop teams**

**Outline of the study**
The empirical data for this second study were originally collected for the Delft Workshop "Research in Design Thinking II - Analysing Design Activity" in 1994 [Dorst 1995] and [Cross et al 1996]. The aim of this workshop was to
bring together a distinguished group of design researchers to compare analyses, to discuss the state-of-the-art in protocol research and to work out where to go in future research. To make it easier to compare and criticise each other’s work, it was decided to work with a common set of data. Every participant of the workshop was asked to perform an analysis in any form they saw fit. They were provided with videotapes, transcribed protocols and the drawings of a three-person team and an individual designer working on the same design assignment. For the preparation of the workshop more design sessions are recorded, containing another three-person design team. For this research we use the team protocol, well known from the workshop, indicated by ‘Ivan, John and Kerry’, and the other design team, which is called ‘Fran, George and Harold’.

The teams are working on a design assignment for two hours and asked to work as they would normally do. They have to design a fastening device that should allow a given backpack to be fastened onto a mountain bike (a full description of the design task is given on page 148).

The design teams
Both teams consist of three experienced designers. Both teams are composed of two men and one woman, who all work for the same leading American product consultancy firm. All designers have approximately five to eight years design experience in engineering product design. Both teams have worked together as a team before on other projects.

The design task
The design assignment is to design a fastening device that should allow a given backpack to be fastened onto a mountain bike. The teams are instructed to work for two hours. Figure 20 shows the design brief that the teams received.

The experiments are conducted in a room equipped with video and audio recording facilities, and supplied with table and chairs, drawing pad, pen and pencils and a white board. A mountain bike and the backpack to be used for the design assignment are also in the room.
An experimenter is present in the room, who has a file of information and
HiAdventure Inc. is a fairly large US firm (some 2000 employees) making backpacks and other hiking gear. They have been very successful over the last ten years, and are well known nation-wide for making some of the best external-frame backpacks around. Their best selling backpack, the midrange HiStar, is also sold in Europe. In the last one and a half years, this European activity has suffered some setbacks in the market; in Europe internal-frame backpacks are gaining a larger and larger market share. As a response, HiAdventure has hired a marketing firm to look for new trends and opportunities for the European market. On the basis of this marketing report, HiAdventure has decided to develop an accessory for the HiStar: a special carrying/fastening device that would enable you to fasten and carry the backpack on mountain bikes. The device would have to fit on most touring and mountain bikes, and should fold down, or at any rate be stacked away easily. A quick survey has shown that there is nothing like this on the European market. This idea is particularly interesting for HiAdventure, because the director, Mr Christiansen, has a long-standing private association with one of the chief product managers at the Batavus bicycle company (one of the larger bicycle manufacturers in northern Europe, based in Holland). Mr Christiansen sees this as an opportunity to strike up a co-operation and to profit from the European marketing capabilities of Batavus. The Batavus product manager, Mr Lemmens, is very enthusiastic about putting a combination product on the market, a mountain bike and a backpack that can be fastened to it. The idea is to base the combination product on the Batavus Buster (a midrange mountain bike), and to sell it under the name Batavus HikeStar. The design apartment at Batavus has made a preliminary design for the carrying/fastening device, but both Mr Christiansen and Mr Lemmens are not very content with it. The user's test performed on a prototype also showed some serious shortcomings.

That is why they have hired you as a consultant to make a different proposal. Tomorrow there is going to be a meeting between Mr Christiansen and Mr Lemmens, scheduled as the last one before presenting the idea to the board of Batavus. Before then, they need to have a clearer idea of the kind of product it is going to be, its feasibility and price. You are hired by HiAdventure to make a concept design for the device, determining the layout of the product, concentrating on:

- ease of use
- a sporty, appealing form
- demonstrating the technical feasibility of the design
- ensuring that the product stays within a reasonable price range

You are asked to produce annotated sketches explaining your concept design.

Good luck!
data for supply to the designers if they ask for it. Information included market research, user trials, the preliminary design, technical drawings of a bike and the backpack, information on comparable products, and technical reference books.

**The team design projects**
Both teams start by reading the assignment individually.

Ivan, John and Kerry
Ivan, John and Kerry start a discussion of the problem. They discuss important issues in the assignment to gain an understanding about them. They interpret the assignment as the designing of a “carrying fastening device”. They prepare a schedule for the next two hours.
Then they formulate constraints for the design. To do so, they ask for information. With the provided information comes a drawing of the existing design. They start evaluating that design. In doing this they notice that they are starting to generate ideas and ask themselves whether they already have all the constraints. First they complete their schedule by making a time scale for their activities and then they reread the information for missing constraints.
Then they start generating ideas for the location of the backpack and explore the back of the bike as a possible location. They notice additional problems and add them to the list of constraints for the design. They notice that their ideas up to this point aren’t concepts for the whole product, but concepts for positions. They call this a classification, and generate more classifications to explore: “joining techniques” and “materials”. They choose joining technology to explore first and split this problem into two sub problems; one for joining the pack to the rack and one for the rack to the bike.
They generate joining concepts for the pack to the rack. During this an idea evolves. It is a product as a sort of “leg that attaches straight onto the external frame” of the backpack. They work on that idea for a while and notice that they are focussing on the rear of the bike, without having explicitly eliminated the front. They first evaluate all concepts for positioning, eventually choosing the rear as position for the backpack.
Then they proceed to the next problem: concepts for materials. A second idea is introduced; an injection moulded rack that transforms into a little trailer.
After exploring this idea, they write down the concepts for materials. They almost immediately evaluate these materials by attending to cost, strength and measurements of the rack.

Referring to their progress and their time-schedule, they agree to look at what they have done so far and make some decisions. In doing this, the idea of a 'tray' evolves. They work on that idea for a while.

When they notice they only have 15 minutes left to finish their design (according to their own schedule), they start visualising some of the solutions chosen for joining and materials.

When the experimenter tells them that there are 30 minutes left they decide to explore the tray-idea further. After a rough sketch, they decide to make a sketch of the complete design, while paying attention to the constituent parts and dimensions (see figure 21).

They also decide to make an estimation of the costs. To do this they make an inventory of the parts and determine the costs of these. Just before the end of the session they are finished and decide to evaluate their design against their functional specifications. Up to the end of the session they keep evaluating their design. After two hours the experimenter ends the session.

Fran, George and Harold

Fran, George and Harold start a discussion questioning the usefulness of the product and discussing their own experiences with backpacks. Then they consider the problem from different points of view: "typical places to hang bags off", "The design result of team 'Ivan, John and Kerry'. Figure 21"
“common themes between mountain bikes and touring bikes”, and the “carrying and fastening device”. They decide to focus on the things that mountain bikes and touring bikes have in common. They make an inventory of similarities and differences between those bikes, and start discussing different positions for the backpack on the bike. They notice that “we’re starting with ideas here”, stop that, sit down and return to the problem.

They generate possible requirements and restart their discussion on positions. They try out different locations, discuss the need for a low centre of gravity, and evaluate the rear as a possible location. They opt for the rear of the bike as the location, and explore attachment to the seat tube and the seat itself. The question of adjusting the attachment for different bikes comes up again, so they explore the technical drawing of the bike and find that the seat itself is the only common part on different bikes. They also explore the technical drawing of the backpack. By handling the seat (that they remove from the bike) and the backpack they analyse the problems of usage and attachment. They conclude that they have different types of attachment problems; the “bracket to the bike” and “the frame to the bracket”. After checking the bearing span beneath the seat they opt for an attachment to the seat tube.

Then they work individually for a while. George copies the drawing of the bike and the backpack on transparencies, whereas Fran and Harold sketch on the white board. When George finishes, they have a discussion about the orientation of the backpack on the bike. They discuss issues like controlling the shoulder straps and the effects of rain and splash. In this discussion the idea of a “pouch” evolves, and they decide to generate more ideas. One of the ideas is a “hands free” idea, where the backpack is attached while it lays on the ground behind the bike. The backpack is attached to swinging tubes, which are then rotated and attached under the seat. They discuss the swinging tubes and the attachment.

Then they decide to check their progress on more of the available information. They analyse the market research, and modify their concept with railings, a bag and a zipper. Then they analyse information on currently available racks and compare the attachments. They discuss the user tests, the shortcomings of the currently available racks, and evaluate their own concept with these. They are satisfied, and establish the concept. They decide to look at the storage and removability of their concept and other details.
When there are about thirty minutes left, they divide tasks and start sketching the design, every now and then conferring with each other about details that affect one another's work. They end with four individually made sketches of the design. Figure 22 shows the sketches of the concept.

The design result of team 'Fran, George and Harold'. Figure 22

Describing team designing: validating the notation system

A multi-coder evaluation of the notation system for reflective

All forms of qualitative research involve some extent of subjective interpretation of the data by the researchers. As a result, there can be variation between individuals who process the same set of data. To demonstrate the accuracy of data processing results, interrater reliability is often used to illustrate the extent of correspondence. Purcell et al were the first who realised that if multi-coder checks are used in a study, it is not enough to measure the degree of similarity between coders. It is also relevant to trace the disagreement in interpretation between coders and deal with that in a discussion [Purcell et al 1996]. For the validation of the notation system for reflective practice, a separate multi-coding process and arbitration discussion, based on the one Purcell et al describe, will be used to identify problems in the application of the method of description. In the discussion these problems will be solved, and in solving them we will be able to improve the notation system.
In chapter 4, we discussed a first application of the notation system to a videotape of team designing. The notation system for reflective practice can be implemented, although a few difficulties in processing the data were noticed (see page 122). In this second study coding by more individuals will show whether every coder in the end will make the same decisions upon the data.

The multi coder process
Processing the data is closely related to understanding what the team is doing and how the design content develops. Understanding is therefore dependent on the coders' knowledge and experience. We decided to use three designers as coders, for they would be able to understand the activity, as well as the design.

The first coder (a product design engineer) was the researcher of the project, who coded the teams of the first empirical study and developed the notation system. The second coder (a maritime engineer) was a researcher of ‘creativity and visualisation’ in product design teams. The third coder was a research student (student product design).

The second and the third coder were instructed by a paper, describing the notation system and the application in the first empirical study [Valkenburg and Dorst 1998]. They were provided with the videotape, transcript and sketches of the team, as were all the participants in the Delft workshop.

The individual coding processes
During the coding process the coders slowly developed an understanding of the structure of the design project, but there was little to start from at first. Therefore observation of the coders switched between “minding details” and “looking for the structure of the team”. It was proved to be necessary that the coders watched the video several times. Although they were looking for the same sort of information every time, the intensity and extent of detail differed. The coding process was a search in trying to understand what was happening in the team.

The arbitration discussion between coders
To compare the results of the three individual coders and to detect any problems in coding or in the final descriptions, we set up a discussion between the coders,
chaired by an independent expert (also a product design engineer).
In the discussion at first the difficulties in processing the data were identified. Then the disagreements in the codings were indicated and compared. The conflicts were made explicit by trying to find the individual arguments behind the conflicts. Then the arguments were discussed and a decision was made for the final coding.

The evaluation process will be illustrated by showing the results of the multcoder process and the arbitration discussion of the Ivan, John and Kerry data. The Fran, George and Harold data were processed in the same way. The results were similar to the results of the discussion on the Ivan, John and Kerry data. Therefore we will only use one team to illustrate the evaluation process. The next sections will discuss the reliability of the entire data processing. First the segmentation of the video data will be described, followed by the coding of these segments.

**Segmenting the video data**
Splitting up the protocol was based on the meaning of the respective segment. The coders had to divide the videotape into team design activities. Potential disagreements may occur on the total number of these activities and/or the length of the activities. Figure 23 shows the segmentation of activities of each of the three coders and the final coding results.
<table>
<thead>
<tr>
<th>First coder</th>
<th>Second coder</th>
<th>Third coder</th>
<th>Final coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>team design activity</td>
<td>team design activity</td>
<td>team design activity</td>
</tr>
<tr>
<td>00:04:00</td>
<td>reading the assignment</td>
<td>reading the assignment</td>
<td>reading the assignment</td>
</tr>
<tr>
<td>00:06:48</td>
<td>understanding the problem</td>
<td>discussing the problem</td>
<td>qualifying the problem</td>
</tr>
<tr>
<td>00:10:04</td>
<td>stating the problem 'carrying fastening device'</td>
<td>limiting the design space</td>
<td>reflecting &quot;sounds like we're moving to ideation&quot;</td>
</tr>
<tr>
<td>00:11:45</td>
<td>preparing a schedule</td>
<td>making a time schedule</td>
<td>preparing a schedule</td>
</tr>
<tr>
<td>00:13:28</td>
<td>formulating constraints</td>
<td>making space</td>
<td>collecting and analyzing information</td>
</tr>
<tr>
<td>00:19:02</td>
<td>evaluate existing prototype</td>
<td>reflecting</td>
<td>reflecting &quot;it sounds like we're starting to move to ideation&quot;</td>
</tr>
<tr>
<td>00:19:43</td>
<td>reflecting &quot;sounds like we're moving to ideation&quot;</td>
<td>reflecting</td>
<td>reflecting &quot;shall we move to ideation?&quot;</td>
</tr>
<tr>
<td>00:20:22</td>
<td>adding time</td>
<td>trying out bike and backpack</td>
<td>reading the marketing report</td>
</tr>
<tr>
<td>00:22:48</td>
<td>schedule to planning</td>
<td>trying out bike and backpack</td>
<td>naming an idea &quot;non-solution, just wear it&quot;</td>
</tr>
<tr>
<td>00:22:57</td>
<td>dawdling</td>
<td>trying out bike and backpack</td>
<td>generating concepts for locations</td>
</tr>
<tr>
<td>00:25:47</td>
<td>generating non-solution</td>
<td>&quot;just wear it&quot;</td>
<td>generating concepts for locations</td>
</tr>
<tr>
<td>00:26:00</td>
<td>generating concepts positions</td>
<td>trying out bike &amp; backpack positions</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:31:13</td>
<td>formulating new constraints</td>
<td>generating ideas/features for rear mounts</td>
<td>reflecting &quot;what we're doing is creating lots of classifications&quot;</td>
</tr>
<tr>
<td>00:32:00</td>
<td>formulating design features</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:32:50</td>
<td>reflecting &quot;classifications&quot;</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:33:20</td>
<td>generate classifications</td>
<td>&quot;joining&quot;, &quot;poelotions&quot;, &quot;materials&quot;</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:33:45</td>
<td>generate classifications</td>
<td>looking for other concepts as ideation tools</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:34:50</td>
<td>splitting up joining techniques</td>
<td>&quot;back to rack,&quot; &quot;rack to bike,&quot; &quot;frame is rack&quot;</td>
<td>choosing and discussing joining techniques</td>
</tr>
<tr>
<td>00:35:14</td>
<td>copy white board</td>
<td>copy white board</td>
<td>copying</td>
</tr>
<tr>
<td>00:38:13</td>
<td>formulate features (sheet proof)</td>
<td>generate ideas</td>
<td>discussing attachments</td>
</tr>
<tr>
<td>00:39:32</td>
<td>generating joining concepts</td>
<td>generating joining concepts</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:43:09</td>
<td>combine &quot;leg that attaches to the external frame&quot;</td>
<td>&quot;legs on external frame&quot;</td>
<td>evaluating ideas of legs on external frame</td>
</tr>
<tr>
<td>00:44:01</td>
<td>working on ide 1</td>
<td>trying out on backpack</td>
<td>trying out on backpack and rack</td>
</tr>
<tr>
<td>00:45:01</td>
<td>reflecting &quot;eliminated the front?&quot;</td>
<td>reflecting</td>
<td>reflecting &quot;we keep turning the focus on the back&quot;</td>
</tr>
<tr>
<td>00:49:10</td>
<td>evaluating positions</td>
<td>choosing solutions</td>
<td>reflecting &quot;keep turning the focus on the back&quot;</td>
</tr>
<tr>
<td>00:50:26</td>
<td>formulating constraint about weight</td>
<td>&quot;stuff stays with pack,&quot; &quot;stuff stays with bike&quot;</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:51:22</td>
<td>analyzing weight</td>
<td>weight of product</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:53:37</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:54:15</td>
<td>looking at existing rack</td>
<td>generating ideas based on existing products</td>
<td>analyzing and evaluating rack literature</td>
</tr>
<tr>
<td>00:56:42</td>
<td>generating concepts rack to bike</td>
<td>making an inventory on options (rack to bike)</td>
<td>attaching rack to bike</td>
</tr>
</tbody>
</table>

**Figure 23** Comparison of the data processing: segmenting the video data into team design activities.

*In a later discussion with Mazijoglou and Scrivener on a comparison of notation systems, it was decided to split up this move. "Generating concepts for positions is divided into separate moves, indicating in what manner the concepts are generated, e.g. "by manipulating the backpack on the bike" and "by comparing with a child seat" [Mazijoglou et al 2000].*
<table>
<thead>
<tr>
<th>Time</th>
<th>Activity and Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:57:35</td>
<td>Discussing adjustability of rack</td>
</tr>
<tr>
<td>00:59:00</td>
<td>Evaluating horizontal position; bedroll facing forward, &quot;adjustability&quot;</td>
</tr>
<tr>
<td>01:00:20</td>
<td>Reflecting on &quot;let's go to materials&quot;; reflecting (materials)</td>
</tr>
<tr>
<td>01:00:30</td>
<td>Introduction idea: &quot;trailer&quot;; &quot;fold away trailer&quot;</td>
</tr>
<tr>
<td>01:01:55</td>
<td>Working on idea 2; discussing materials</td>
</tr>
<tr>
<td>01:03:54</td>
<td>Generating detail options</td>
</tr>
<tr>
<td>01:04:00</td>
<td>Reflecting</td>
</tr>
<tr>
<td>01:04:37</td>
<td>Generating material concepts; making an inventory on materials</td>
</tr>
<tr>
<td>01:05:22</td>
<td>Evaluating material solutions; exploring geometry &amp; strength; discussing strength, minimum cost/weight</td>
</tr>
<tr>
<td>01:09:08</td>
<td>Discussing rack to bike connections; idea orientation possibilities for connections</td>
</tr>
<tr>
<td>01:12:30</td>
<td>Introducing idea: &quot;super simple solution&quot;; &quot;buy regular rack and bungees&quot;; people's use/ease of use</td>
</tr>
<tr>
<td>01:12:55</td>
<td>Working on idea 3; examining built up production costs; estimating manufacturing costs</td>
</tr>
<tr>
<td>01:14:59</td>
<td>Reflecting &quot;decisions so far&quot;</td>
</tr>
<tr>
<td>01:15:51</td>
<td>Decision making (1); making an inventory on design decisions made; evaluating joining concepts</td>
</tr>
<tr>
<td>01:18:58</td>
<td>Introduction tray idea; making design decision; considering idea of tray</td>
</tr>
<tr>
<td>01:19:21</td>
<td>Generating ideas</td>
</tr>
<tr>
<td>01:20:18</td>
<td>Reflecting</td>
</tr>
<tr>
<td>01:20:33</td>
<td>Decision making (2); &quot;tray&quot;</td>
</tr>
<tr>
<td>01:23:34</td>
<td>Investigating use of braze-ons; investigating usability of braze-ons Blue Buster</td>
</tr>
<tr>
<td>01:24:36</td>
<td>Design applicable for all bikes; detailing braze-ons</td>
</tr>
<tr>
<td>01:28:10</td>
<td>Reflecting &quot;shall we go ahead and design it?&quot;</td>
</tr>
<tr>
<td>01:28:47</td>
<td>Sketching concepts; generating ideas; details; &quot;fractals&quot; form; tray idea</td>
</tr>
<tr>
<td>01:33:36</td>
<td>Sketching tray concept</td>
</tr>
<tr>
<td>01:33:47</td>
<td>Sketching concept</td>
</tr>
<tr>
<td>01:38:02</td>
<td>Detailing concept</td>
</tr>
<tr>
<td>01:38:43</td>
<td>Discussing tray/back connection; discussing snaps or straps</td>
</tr>
<tr>
<td>01:40:00</td>
<td>Reflecting</td>
</tr>
<tr>
<td>01:40:34</td>
<td>Sketching tray idea; setting dimensions; reflecting</td>
</tr>
<tr>
<td>01:44:00</td>
<td>Sketching tray idea</td>
</tr>
</tbody>
</table>
| 01:44:59 | Making an inventory of parts |}

*In the same discussion the move "evaluating materials by discussing strength and cost issues" is interrupted by a reflection. The team notices that they are no longer generating ideas for materials, but are evaluating them, by attending to strength, geometry and costs. However, this is seen to be a useful activity and the team continues evaluating the materials [Martzigoulo et al 2000].
Comparing the segmentation of the video data among the coders
The number of segments identified by the coders is different. The first coder identified 50 team design activities, the second 65, and the third 43.

Comparing the second and the third coder with the first coder, shows an interrater reliability of 88 and 70 % (see figure 24).

<table>
<thead>
<tr>
<th>1st coder</th>
<th>total of 50 activities</th>
<th>88 % fits</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd coder</td>
<td>total of 65 activities</td>
<td>12 % missed activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40 % extra activities</td>
</tr>
<tr>
<td>3rd coder</td>
<td>total of 43 activities</td>
<td>70 % fits</td>
</tr>
<tr>
<td></td>
<td></td>
<td>28 % missed activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16 % extra activities</td>
</tr>
</tbody>
</table>

**Figure 24** The reliability of the segmentation: comparing the second and the third coder with the first.

One of the aims of the arbitration discussion is to create a better understanding of the data by discussing it among the coders. The result of the arbitration discussion is an improved coding, on which all coders agree. In figure 25 the three codings are compared with this final coding. The interrater reliability of 74, 86, and 65 % seems reasonably high. (The misfits are missed activities, as well as extra activities and therefore the total of fits and misfits can be higher than 100 %).

<table>
<thead>
<tr>
<th>coding after arbitrating discussion</th>
<th>total of 66 activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st coder</td>
<td>total of 50 activities</td>
</tr>
<tr>
<td></td>
<td>74 % fits</td>
</tr>
<tr>
<td></td>
<td>26 % misfits</td>
</tr>
<tr>
<td>2nd coder</td>
<td>total of 65 activities</td>
</tr>
<tr>
<td></td>
<td>86 % fits</td>
</tr>
<tr>
<td></td>
<td>24 % misfits</td>
</tr>
<tr>
<td>3rd coder</td>
<td>total of 43 activities</td>
</tr>
<tr>
<td></td>
<td>65 % fits</td>
</tr>
<tr>
<td></td>
<td>35 % misfits</td>
</tr>
</tbody>
</table>

**Figure 25** The reliability of the segmentation: comparing three codings with the final coding.
Disagreements in segmentation of the video data between the coders

Of course, there were also disagreements in the codings. These disagreements can be categorised into two groups.

Firstly, there were moments in the team design project where each coder had difficulties in understanding what was happening. Each coder made his own interpretation of what the team was doing and segmented according to this interpretation. None of the coders was very convinced that he or she segmented and coded correctly. Discussing this disagreement also requires looking at the coding of the segments and will therefore be dealt with in the next section (see figure 29 on page 165).

Secondly, there were disagreements on the level of detail, which the coders used. A team design activity, segmented by one coder, may be seen by another coder as two or three separate team design activities. Figure 26 shows an example.

Once Ivan John and Kerry have chosen the tray concept as their design, they sketch and evaluate the design. In this phase the team is sketching the concept and several other solutions. The first coder, influenced by the first empirical

<table>
<thead>
<tr>
<th>Time</th>
<th>First coder</th>
<th>Second coder</th>
<th>Third coder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Team design activity</strong></td>
<td><strong>Team design activity</strong></td>
<td><strong>Team design activity</strong></td>
</tr>
<tr>
<td>01:44:59</td>
<td>making an inventory of parts</td>
<td>making an inventory on parts</td>
<td>refining and estimating the design</td>
</tr>
<tr>
<td>01:49:35</td>
<td></td>
<td>attending to costs</td>
<td></td>
</tr>
<tr>
<td>01:50:30</td>
<td></td>
<td>pinning down solutions</td>
<td></td>
</tr>
<tr>
<td>01:51:01</td>
<td>estimating costs</td>
<td>estimating costs</td>
<td></td>
</tr>
<tr>
<td>01:54:00</td>
<td></td>
<td>detailing tray</td>
<td></td>
</tr>
<tr>
<td>01:57:00</td>
<td></td>
<td>deciding mode of shipping</td>
<td></td>
</tr>
<tr>
<td>01:57:30</td>
<td></td>
<td>estimating costs</td>
<td></td>
</tr>
<tr>
<td>01:58:23</td>
<td></td>
<td>reflecting</td>
<td></td>
</tr>
</tbody>
</table>

An example of disagreement on the level of detail between coders. **Figure 26**
study, was mostly interested in the conceptual phase of the design project and segmented this phase into two team design activities. The third coder segmented it only as one team design activity. The second coder, a researcher of visualisation in design, segmented this phase in much more detail, noting all aspects the team put in the sketches.

The coders were instructed on how to perform the data processing. However, they were not informed about the aims of the data analysis. These aims have a bearing on the level of detail, which is required in data processing. Simply defining a segment as a team design activity is not sufficient for this. Sometimes an extra interpretation has to be made to segment an activity in “generating ideas”, or in “generate idea 1”, “generate idea 2”, etceteras. This interpretation is made upon the level of detail required for the data analysis, for example whether or not we need to identify “idea 1” and “idea 2” separately.

Dealing with disagreements in the arbitration discussion

The disagreements are dealt with in the arbitration discussion. This will be illustrated by using the same example as above. Figure 27 shows the same part of the coding, put next to it the result after discussion. The first coder identified two team design activities. We will take a look at these two segments.

Where the first coder identified “making an inventory of parts”, the second coder subdivided this team design activity into three separate activities: “making

<table>
<thead>
<tr>
<th>time</th>
<th>First coder</th>
<th>Second coder</th>
<th>Third coder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>team design activity</td>
<td>team design activity</td>
<td>team design activity</td>
</tr>
<tr>
<td>01:44:59</td>
<td>making an inventory</td>
<td>making an inventory</td>
<td>refining and</td>
</tr>
<tr>
<td></td>
<td>of parts</td>
<td>on parts</td>
<td>estimating the</td>
</tr>
<tr>
<td>01:49:35</td>
<td>attending to costs</td>
<td>pinning down solutions</td>
<td>design</td>
</tr>
<tr>
<td>01:50:30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>01:51:01</td>
<td>estimating costs</td>
<td>estimating costs</td>
<td></td>
</tr>
<tr>
<td>01:54:00</td>
<td>detailing tray</td>
<td>deciding mode of</td>
<td></td>
</tr>
<tr>
<td>01:57:00</td>
<td></td>
<td>shipping</td>
<td></td>
</tr>
<tr>
<td>01:57:30</td>
<td>reflecting</td>
<td>estimating costs</td>
<td></td>
</tr>
<tr>
<td>01:58:23</td>
<td></td>
<td>reflecting</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Final coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>reflecting</td>
</tr>
<tr>
<td>practice</td>
</tr>
<tr>
<td>team</td>
</tr>
<tr>
<td>design</td>
</tr>
<tr>
<td>activity</td>
</tr>
<tr>
<td>moving:</td>
</tr>
<tr>
<td>making an</td>
</tr>
<tr>
<td>inventory</td>
</tr>
<tr>
<td>of parts</td>
</tr>
<tr>
<td>moving:</td>
</tr>
<tr>
<td>estimating</td>
</tr>
<tr>
<td>costs</td>
</tr>
<tr>
<td>moving:</td>
</tr>
<tr>
<td>questioning</td>
</tr>
<tr>
<td>design</td>
</tr>
<tr>
<td>decision</td>
</tr>
<tr>
<td>moving:</td>
</tr>
<tr>
<td>estimating</td>
</tr>
<tr>
<td>costs</td>
</tr>
<tr>
<td>reflecting</td>
</tr>
<tr>
<td>&quot;ok, so we've got a design&quot;</td>
</tr>
</tbody>
</table>

Figure 27 An example of dealing with disagreement between coders.
an inventory on parts”, “attending to cost”, and “pinning down solutions”. Reviewing the team protocol indicated that the team started their discussion on the costs at 01:49:35 and ended this at 01:59:23. However, during the activity indicated by the second coder as “pinning down solutions” (01:50:30 until 01:51:01) it appeared that the team questions an important decision on the design, which they made earlier in the process. Because this might be of importance in analysing the development of the design content during the project, this was added in the final coding of the team’s activities.

For the second segment the first coder identified “estimating costs” as one team design activity, whereas the second coder subdivided this into “estimating costs”, “detailing tray”, “deciding mode of shipping”, estimating costs”, and “reflecting”. In the discussion it was decided that the activities “detailing tray” and “deciding mode of shipping” served the estimation of the costs of the product and could therefore be included in one activity. The reflection (“OK, so we’ve got a design”) is coded as a separate team design activity, for it indicated the transition from this activity to the next one, being “evaluating the design”.

For all disagreements in segmentation the consequences for data analysis were considered before deciding upon the final coding. Most times, the choice for the final coding was the most detailed description. At this moment in data processing it is better to have a too detailed description, than to miss an important activity while data analysing.

**Coding the segments**

The next step in data processing is the coding of the segments according to the reflective practice design activities. Figure 28 shows this coding for all three coders.
<table>
<thead>
<tr>
<th>Time</th>
<th>First coder activity</th>
<th>Reflective practice activity</th>
<th>Second coder activity</th>
<th>Reflective practice activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:04:00</td>
<td>reading the assignment</td>
<td>move</td>
<td>reading the assignment</td>
<td>move</td>
</tr>
<tr>
<td>00:06:48</td>
<td>understanding the problem</td>
<td>move</td>
<td>discussing the problem</td>
<td>move</td>
</tr>
<tr>
<td>00:10:04</td>
<td>stating the problem 'carrying fastening device'</td>
<td>framing</td>
<td>limiting the design space</td>
<td>move</td>
</tr>
<tr>
<td>00:11:45</td>
<td>preparing a schedule</td>
<td>move</td>
<td>making a time schedule</td>
<td>move</td>
</tr>
<tr>
<td>00:13:28</td>
<td>formulating constraints</td>
<td>move</td>
<td>making space</td>
<td>move</td>
</tr>
<tr>
<td>00:19:02</td>
<td>evaluate existing prototype</td>
<td>move</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00:19:43</td>
<td>reflecting &quot;sounds like we're moving to ideation&quot;</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:20:22</td>
<td>adding time schedule to planning</td>
<td>move</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00:22:48</td>
<td>dawdling</td>
<td>move</td>
<td>trying out bike and backpack</td>
<td>move</td>
</tr>
<tr>
<td>00:25:47</td>
<td>generating non-solution</td>
<td>move</td>
<td>&quot;just wear it&quot;</td>
<td>naming</td>
</tr>
<tr>
<td>00:26:00</td>
<td>generating concepts positions</td>
<td>move</td>
<td>trying out bike &amp; backpack positions</td>
<td>move</td>
</tr>
<tr>
<td>00:31:13</td>
<td>formulating new constraints</td>
<td>move</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00:32:00</td>
<td>formulating design features</td>
<td>move</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00:32:50</td>
<td>reflecting &quot;classifications&quot;</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:33:20</td>
<td>generate classifications</td>
<td>reflecting</td>
<td>discussing strategy</td>
<td>move</td>
</tr>
<tr>
<td>00:33:45</td>
<td>generating concepts</td>
<td>move</td>
<td>&quot;joining&quot;, &quot;positions&quot;, &quot;materials&quot;</td>
<td>naming</td>
</tr>
<tr>
<td>00:34:50</td>
<td>splitting up joining technique</td>
<td>framing</td>
<td>&quot;pack to rack&quot;, &quot;rack to bike&quot;, &quot;frame is rack&quot;</td>
<td>naming</td>
</tr>
<tr>
<td>00:35:14</td>
<td>copy white board</td>
<td>-</td>
<td>copy white board</td>
<td>-</td>
</tr>
<tr>
<td>00:36:00</td>
<td>formulate features ( theft proof)</td>
<td>move</td>
<td>generate ideas</td>
<td>move</td>
</tr>
<tr>
<td>00:39:32</td>
<td>generating joining concepts</td>
<td>move</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00:43:09</td>
<td>intro idea &quot;key that attaches to the external frame&quot;</td>
<td>framing</td>
<td>&quot;legs on external frame&quot;</td>
<td>naming</td>
</tr>
<tr>
<td>00:44:01</td>
<td>working on idea 1</td>
<td>move</td>
<td>trying out on backpack</td>
<td>move</td>
</tr>
<tr>
<td>00:45:51</td>
<td>collecting ergonomic requirements</td>
<td>move</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:49:03</td>
<td>reflecting &quot;eliminated the front?&quot;</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:49:10</td>
<td>evaluating positions</td>
<td>move</td>
<td></td>
<td></td>
</tr>
<tr>
<td>00:50:26</td>
<td>formulating constraint about weight</td>
<td>move</td>
<td>&quot;stuff stays with pack&quot;, &quot;stuff stays with bike&quot;</td>
<td>naming</td>
</tr>
<tr>
<td>00:51:22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>00:53:37</td>
<td>reflecting</td>
<td>move</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:54:15</td>
<td>looking at existing rack</td>
<td>move</td>
<td>generating ideas based on existing products</td>
<td>move</td>
</tr>
<tr>
<td>00:58:42</td>
<td>generating concepts</td>
<td>move</td>
<td>making an inventory options</td>
<td>move</td>
</tr>
<tr>
<td>00:57:35</td>
<td>discussing adjustability</td>
<td>move</td>
<td>discussing adjustability</td>
<td>move</td>
</tr>
<tr>
<td>00:59:00</td>
<td>evaluating horizontal position</td>
<td>move</td>
<td>&quot;bedroll facing forward&quot;, &quot;adjustability&quot;</td>
<td>naming</td>
</tr>
<tr>
<td>01:00:20</td>
<td>reflecting &quot;let's go to materials&quot;</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>Third coding</td>
<td>Final coding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>--------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>team design activity</strong></td>
<td><strong>reflective practice team design activity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reading the assignment</td>
<td>moving: reading the design assignment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>qualifying the problem</td>
<td>moving: discussing the problem</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>preparing a schedule</td>
<td>moving: limiting the design space</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>collecting and analyzing information</td>
<td>moving: preparing a schedule</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>quantifying problem</td>
<td>moving: collecting and analyzing information to formulate constraints</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reading the marketing report</td>
<td>moving: evaluating existing prototype</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>generating concepts for locations</td>
<td>reflecting &quot;it sounds like we're starting to move to ideation&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>generating ideas/features for rear mounts</td>
<td>moving: scheduling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reflecting</td>
<td>reflecting &quot;what will we move to ideation?&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>looking for other concepts as ideation tools</td>
<td>parallel moving: reading the market report and filling the backpack</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>choosing and discussing joining techniques copying</td>
<td>naming an idea &quot;non-solution, just wear it&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>discussing attachments</td>
<td>moving: generating concepts for positions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>generating joining concepts</td>
<td>moving: formulating new constraints</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>evaluating idea of legs on external frame</td>
<td>moving: formulating design features</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>analyzing user/ergonomical issues</td>
<td>reflecting &quot;we're creating lots of classifications&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reflecting (positions)</td>
<td>naming concepts for ideation tools &quot;positions&quot;, &quot;joining techniques&quot;, &quot;materials&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>choosing solutions rearward</td>
<td>naming categories for the joining technology &quot;rack to wall&quot; and &quot;rack to bike&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>weight of product</td>
<td>moving: formulating additional features</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reflecting</td>
<td>moving: generating joining concepts &quot;rack to wall&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>analyzing and evaluating rack literature</td>
<td>naming pack = rack &quot;legs on external frame&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>attach rack to bike</td>
<td>moving: trying out on backpack and rack</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>discussing adjustability of rack</td>
<td>moving: analyzing ergonomical issues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reflecting (materials)</td>
<td>reflecting &quot;we keep turning the focus on the back&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reflecting</td>
<td>moving: evaluating positions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>discussing constraint about weight</td>
<td>moving: discussing constraint about weight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reflecting</td>
<td>moving: analyzing rack literature</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>analyzing and evaluating rack literature</td>
<td>moving: formulating constraint about weight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>attach rack to bike</td>
<td>moving: generating ideas based on existing products</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reflecting</td>
<td>moving: generating concepts rack to bike</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>discussing adjustability</td>
<td>moving: discussing adjustability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reflecting</td>
<td>moving: making an inventory on concepts rack to bike</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reflecting (materials)</td>
<td>reflecting &quot;it's getting too materials&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 28**

Comparison of the data processing: coding the segments into reflective practice activities.
<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Action</th>
<th>Description</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>01:00:30</td>
<td>introduction idea</td>
<td>move</td>
<td>&quot;fold away trailer&quot;</td>
<td></td>
</tr>
<tr>
<td>01:01:55</td>
<td>working on idea 2</td>
<td>move</td>
<td>discussing materials</td>
<td></td>
</tr>
<tr>
<td>01:05</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td></td>
</tr>
<tr>
<td>01:04:37</td>
<td>generating material concepts</td>
<td>move</td>
<td>making an inventory on materials</td>
<td></td>
</tr>
<tr>
<td>01:05:22</td>
<td>evaluating material solutions</td>
<td>move</td>
<td>exploring geometry &amp; strength</td>
<td></td>
</tr>
<tr>
<td>01:09:06</td>
<td>introducing idea &quot;supersimple solution&quot;</td>
<td>move</td>
<td>discussing rack to bike connections</td>
<td></td>
</tr>
<tr>
<td>01:12:30</td>
<td>working on idea 3</td>
<td>move</td>
<td>examining built up production costs</td>
<td></td>
</tr>
<tr>
<td>01:14:59</td>
<td>reflecting &quot;decisions so far&quot;</td>
<td>reflect</td>
<td>reflecting</td>
<td></td>
</tr>
<tr>
<td>01:15:51</td>
<td>decision making (1)</td>
<td>move</td>
<td>making an inventory on design decisions made</td>
<td></td>
</tr>
<tr>
<td>01:18:58</td>
<td>introduction tray idea</td>
<td>move</td>
<td>making design decision</td>
<td></td>
</tr>
<tr>
<td>01:19:21</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td></td>
</tr>
<tr>
<td>01:20:18</td>
<td>sketching concepts</td>
<td>move</td>
<td>&quot;tray&quot;</td>
<td></td>
</tr>
<tr>
<td>01:23:34</td>
<td>investigating use of braze-ons</td>
<td>move</td>
<td>design applicable for all bikes</td>
<td></td>
</tr>
<tr>
<td>01:24:36</td>
<td>reflecting &quot;shall we go ahead and design it?&quot;</td>
<td>reflect</td>
<td>reflecting</td>
<td></td>
</tr>
<tr>
<td>01:26:10</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td></td>
</tr>
<tr>
<td>01:28:47</td>
<td>sketching the tray concept</td>
<td>move</td>
<td>sketching concept</td>
<td></td>
</tr>
<tr>
<td>01:30:02</td>
<td>detailing concept</td>
<td>move</td>
<td>detailing concept</td>
<td></td>
</tr>
<tr>
<td>01:30:43</td>
<td>discussing tray/back connection</td>
<td>move</td>
<td>discussing tray/back connection</td>
<td></td>
</tr>
<tr>
<td>01:40:00</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td></td>
</tr>
<tr>
<td>01:40:34</td>
<td>sketching tray idea</td>
<td>move</td>
<td>setting dimensions</td>
<td></td>
</tr>
<tr>
<td>01:44:00</td>
<td>making an inventory of parts</td>
<td>move</td>
<td>making an inventory parts</td>
<td></td>
</tr>
<tr>
<td>01:44:59</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td></td>
</tr>
<tr>
<td>01:49:35</td>
<td>estimating costs</td>
<td>move</td>
<td>estimating costs</td>
<td></td>
</tr>
<tr>
<td>01:50:30</td>
<td>pinning down solutions</td>
<td>move</td>
<td>pinning down solutions</td>
<td></td>
</tr>
<tr>
<td>01:51:01</td>
<td>evaluating the design with the constraints</td>
<td>move</td>
<td>evaluating design compared to specs</td>
<td></td>
</tr>
<tr>
<td>01:52:23</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td></td>
</tr>
<tr>
<td>01:55:31</td>
<td>determining volume of parts</td>
<td>move</td>
<td>determining volume of parts</td>
<td></td>
</tr>
<tr>
<td>02:03:18</td>
<td>end of design session</td>
<td>move</td>
<td>end of design session</td>
<td></td>
</tr>
<tr>
<td>02:04:00</td>
<td>end of design session</td>
<td>move</td>
<td>end of design session</td>
<td></td>
</tr>
<tr>
<td>Task</td>
<td>Team 1</td>
<td>Team 2</td>
<td>Team 3</td>
<td>Team 4</td>
</tr>
<tr>
<td>-----------------------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Reflecting the ideas</td>
<td>move</td>
<td>move</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>We've got a new plan</td>
<td>move</td>
<td>move</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>Designing the concept</td>
<td>move</td>
<td>move</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>Development of ideas</td>
<td>move</td>
<td>move</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>Exploring potential</td>
<td>move</td>
<td>move</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>Identifying challenges</td>
<td>move</td>
<td>move</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>Overcoming barriers</td>
<td>move</td>
<td>move</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>Finalizing the design</td>
<td>move</td>
<td>move</td>
<td>move</td>
<td>move</td>
</tr>
</tbody>
</table>

5. The Delft workshop teams
Reflecting

If a moment of reflection is segmented by the coders as a separate team design activity, then it is always coded as a reflection (100 %). Out of the total 11 moments of reflection of the coding after the arbitration discussion, 64 % are segmented as a separate team design activity by two or more coders.

These reflections always include explicit announcements of the team what they are doing and/or what they should do next, for example “it sounds like we’re starting to move to ideation”, “what we’re doing is creating lots of classifications”, “let’s talk about the decisions that we’ve made”, “keep moving, we have fifteen minutes to finish our design. shall we go ahead and design it?”.

Disagreement occurs, where a reflection is not segmented as a separate activity, but is included in an earlier activity. Then this activity is coded as moving, and the reflection is seen as a transition from the current move to the next one. For example when the experimenter indicates: “you have thirty minutes left”. This is not coded as a team design activity, for it is initiated by someone outside the team. However, triggered by this remark the team decides to chose their design concept: “ok, we all like this tray idea right?”. This should be coded as a reflection.

Moving

Moving is the category most used for coding the team design activities. Out of their total number of activities, the first coder coded 69 %, the second coder 60 %, and the third coder 88 % as a move. The only disagreement between the coders is when moving in the arbitration discussion becomes naming. Figure 29 shows an example.

<table>
<thead>
<tr>
<th>First coder</th>
<th>Second coder</th>
<th>Third coder</th>
</tr>
</thead>
<tbody>
<tr>
<td>generate classifications</td>
<td>move</td>
<td>naming for other concepts as ideation tools</td>
</tr>
<tr>
<td>move</td>
<td>“joining”, “positions”, “materials”</td>
<td>move</td>
</tr>
</tbody>
</table>

Figure 29 An example of dealing with disagreement between coders.

The team has just realised that they are not generating concepts for the whole design, but rather positions for the backpack on the bike. They call

*Indicating the last half hour of the design session and the end of the session are the only moments where the experimenter intervenes in the team’s process.
this a 'classification' or 'ideation tool', and decide to generate more of these classifications. These classifications indicate a specific view of the design problem, approaching the problem as if it is a positioning or a joining problem. This approach toward the problem will be the frame that the team sets later. Therefore these classifications are coded as names.

**Naming and framing**

As could be expected from the outcome of the first study, coding the naming and framing of the team appeared to be most difficult and contained the most disagreements. Comparing the three codings shows this clearly; only two frames are segmented and coded the same by two coders. *Naming* and *framing* are strongly related and therefore discussed at the same time. Figure 30 shows the coding of the *naming* and of the *frames* by all three coders. Numbers indicate the *frames*. These numbers relate to the label of the *frames* indicated at the bottom of the table. All coded *names* are indicated in bold script.
First coder

<table>
<thead>
<tr>
<th>Time</th>
<th>Team Design Activity</th>
<th>Reflective Practice Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:04:00</td>
<td>reading the assignment</td>
<td>move</td>
</tr>
<tr>
<td>00:06:48</td>
<td>understanding the problem</td>
<td>move</td>
</tr>
<tr>
<td>00:10:04</td>
<td>stating the problem of developing the device</td>
<td>framing</td>
</tr>
<tr>
<td>00:11:45</td>
<td>preparing a schedule</td>
<td>move</td>
</tr>
<tr>
<td>00:13:28</td>
<td>formulating constraints</td>
<td>move</td>
</tr>
<tr>
<td>00:19:02</td>
<td>evaluating existing prototype</td>
<td>move</td>
</tr>
<tr>
<td>00:19:43</td>
<td>reflecting &quot;sounds like we're moving to ideation&quot;</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:20:22</td>
<td>adding time schedule to planning</td>
<td>move</td>
</tr>
<tr>
<td>00:22:48</td>
<td>dwelling</td>
<td>move</td>
</tr>
<tr>
<td>00:25:47</td>
<td>generating non-solution</td>
<td>move</td>
</tr>
<tr>
<td>00:26:00</td>
<td>generating concepts and positions</td>
<td>move</td>
</tr>
<tr>
<td>00:31:13</td>
<td>formulating new constraints</td>
<td>move</td>
</tr>
<tr>
<td>00:32:00</td>
<td>formulating design features</td>
<td>move</td>
</tr>
<tr>
<td>00:32:50</td>
<td>reflecting &quot;classification&quot;</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:33:20</td>
<td>generate classifications</td>
<td>move</td>
</tr>
<tr>
<td>00:34:50</td>
<td>splitting up joining techniques</td>
<td>framing</td>
</tr>
<tr>
<td>00:35:14</td>
<td>copy white board</td>
<td>-</td>
</tr>
<tr>
<td>00:38:13</td>
<td>formulate features (full proof)</td>
<td>move</td>
</tr>
<tr>
<td>00:39:32</td>
<td>generating joining concepts</td>
<td>move</td>
</tr>
<tr>
<td>00:43:09</td>
<td>intro idea &quot;join that attaches to the external frame&quot;</td>
<td>framing</td>
</tr>
<tr>
<td>00:44:01</td>
<td>working on idea 1</td>
<td>move</td>
</tr>
<tr>
<td>00:45:51</td>
<td>reflecting &quot;eliminated the front&quot;</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:46:10</td>
<td>evaluating positions</td>
<td>move</td>
</tr>
<tr>
<td>00:50:26</td>
<td>formulating constraint about weight</td>
<td>move</td>
</tr>
<tr>
<td>00:51:22</td>
<td>looking at existing rack</td>
<td>move</td>
</tr>
<tr>
<td>00:53:37</td>
<td>generating concepts related to bike</td>
<td>move</td>
</tr>
<tr>
<td>00:54:15</td>
<td>discussing adjustability</td>
<td>move</td>
</tr>
<tr>
<td>00:56:42</td>
<td>evaluating horizontal position</td>
<td>move</td>
</tr>
<tr>
<td>01:00:20</td>
<td>reflecting &quot;let's go to materials&quot;</td>
<td>reflecting</td>
</tr>
</tbody>
</table>

Second coder

<table>
<thead>
<tr>
<th>Time</th>
<th>Team Design Activity</th>
<th>Reflective Practice Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:04:00</td>
<td>reading the assignment</td>
<td>move</td>
</tr>
<tr>
<td>00:06:48</td>
<td>discussing the problem</td>
<td>move</td>
</tr>
<tr>
<td>00:10:04</td>
<td>formulating the design space</td>
<td>move</td>
</tr>
<tr>
<td>00:11:45</td>
<td>making a time schedule</td>
<td>move</td>
</tr>
<tr>
<td>00:13:28</td>
<td>making space</td>
<td>move</td>
</tr>
<tr>
<td>00:19:02</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:19:43</td>
<td>trying out bike and backpack</td>
<td>move</td>
</tr>
<tr>
<td>00:22:48</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:25:47</td>
<td>&quot;just wear it&quot;</td>
<td>naming</td>
</tr>
<tr>
<td>00:26:00</td>
<td>trying out bike and backpack positions</td>
<td>move</td>
</tr>
<tr>
<td>00:31:13</td>
<td>reflecting strategy</td>
<td>move</td>
</tr>
<tr>
<td>00:32:50</td>
<td>&quot;joining&quot;, &quot;positions&quot;, &quot;material&quot;</td>
<td>naming</td>
</tr>
<tr>
<td>00:33:20</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:34:50</td>
<td>&quot;peck to rack&quot;, &quot;rack to bike&quot;, &quot;frame vs rack&quot;</td>
<td>naming</td>
</tr>
<tr>
<td>00:35:14</td>
<td>copy white board</td>
<td>-</td>
</tr>
<tr>
<td>00:38:13</td>
<td>generate ideas</td>
<td>move</td>
</tr>
<tr>
<td>00:39:32</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:43:09</td>
<td>&quot;legs on external frame&quot;</td>
<td>naming</td>
</tr>
<tr>
<td>00:44:01</td>
<td>trying out on backpack</td>
<td>move</td>
</tr>
<tr>
<td>00:45:51</td>
<td>collecting ergonomic requirements</td>
<td>move</td>
</tr>
<tr>
<td>00:46:10</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:50:26</td>
<td>&quot;stuff stays with peck&quot;, &quot;stuff stays with bike&quot;</td>
<td>naming</td>
</tr>
<tr>
<td>00:51:22</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>00:53:37</td>
<td>generating ideas based on existing products</td>
<td>move</td>
</tr>
<tr>
<td>00:54:15</td>
<td>making an inventory on options (rack to blue)</td>
<td>move</td>
</tr>
<tr>
<td>00:56:42</td>
<td>discussing adjusability</td>
<td>move</td>
</tr>
<tr>
<td>00:57:35</td>
<td>&quot;bed rail facing forward&quot;, &quot;adjustability&quot;</td>
<td>naming</td>
</tr>
<tr>
<td>00:59:00</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>01:00:20</td>
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</tr>
<tr>
<td>Third coder</td>
<td>Final coding</td>
<td></td>
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<tr>
<td>-------------</td>
<td>--------------</td>
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</tr>
<tr>
<td>team design activity</td>
<td>reflective practice team design activity</td>
<td></td>
</tr>
<tr>
<td>reading the assignment</td>
<td>moving: reading the design assignment</td>
<td></td>
</tr>
<tr>
<td>qualifying the problem</td>
<td>moving: discussing the problem</td>
<td></td>
</tr>
<tr>
<td>preparing a schedule</td>
<td>moving: limiting the design space</td>
<td></td>
</tr>
<tr>
<td>collecting and analysing information</td>
<td>moving: preparing a schedule</td>
<td></td>
</tr>
<tr>
<td>quantifying problem</td>
<td>moving: collecting and analysing information to formulate constraints</td>
<td></td>
</tr>
<tr>
<td>reading the marketing report</td>
<td>moving: evaluating existing prototype</td>
<td></td>
</tr>
<tr>
<td>generating concepts for locations</td>
<td>reflecting &quot;it sounds like we're starting to move to ideation&quot;</td>
<td></td>
</tr>
<tr>
<td>generating ideas/features for rear mounts</td>
<td>moving: scheduling</td>
<td></td>
</tr>
<tr>
<td>reflecting</td>
<td>reflecting &quot;shall we move to ideation&quot;</td>
<td></td>
</tr>
<tr>
<td>looking for other concepts as ideation tools</td>
<td>parallel moving: reading the market report and filling the backpack</td>
<td></td>
</tr>
<tr>
<td>choosing and discussing joining techniques</td>
<td>naming an idea &quot;non-solution, just wear it&quot;</td>
<td></td>
</tr>
<tr>
<td>copying</td>
<td>moving: generating concepts for positions</td>
<td></td>
</tr>
<tr>
<td>discussing attachments</td>
<td>moving: formulating new constraints</td>
<td></td>
</tr>
<tr>
<td>generating joining concepts</td>
<td>moving: formulating design features</td>
<td></td>
</tr>
<tr>
<td>evaluating idea of legs on external frame</td>
<td>reflecting what we're doing is creating lots of classifications</td>
<td></td>
</tr>
<tr>
<td>analysing user ergonomic issues</td>
<td>naming concepts for ideation tools &quot;positions&quot;, &quot;joining techniques&quot;, &quot;materials&quot;</td>
<td></td>
</tr>
<tr>
<td>reflecting (positions)</td>
<td>naming categories for the joining technology &quot;pavement to rack&quot; and &quot;rack to bike&quot;</td>
<td></td>
</tr>
<tr>
<td>choosing solutions rearranged</td>
<td>moving: formulating additional features</td>
<td></td>
</tr>
<tr>
<td>weight of product</td>
<td>moving: generating joining concepts &quot;pavement to rack&quot;</td>
<td></td>
</tr>
<tr>
<td>reflecting</td>
<td>moving: generating joining concepts &quot;pavement to rack&quot;</td>
<td></td>
</tr>
<tr>
<td>analysing and evaluating rack literature</td>
<td>moving: trying out on backpack and rack</td>
<td></td>
</tr>
<tr>
<td>attaching rack to bike</td>
<td>moving: analysing ergonomic issues</td>
<td></td>
</tr>
<tr>
<td>discussing adjustability of rack</td>
<td>reflecting &quot;we keep turning the house on the rack&quot;</td>
<td></td>
</tr>
<tr>
<td>reflecting (materials)</td>
<td>moving: evaluating positions</td>
<td></td>
</tr>
<tr>
<td>reflecting</td>
<td>moving: discussing constraint about weight</td>
<td></td>
</tr>
<tr>
<td>analysing and evaluating rack literature</td>
<td>moving: analysing rack literature</td>
<td></td>
</tr>
<tr>
<td>attaching rack to bike</td>
<td>moving: formulating constraint about weight</td>
<td></td>
</tr>
<tr>
<td>discussing adjustability of rack</td>
<td>moving: generating ideas based on existing products</td>
<td></td>
</tr>
<tr>
<td>reflecting (materials)</td>
<td>reflecting &quot;it's getting to materials&quot;</td>
<td></td>
</tr>
</tbody>
</table>

Comparison of the data processing: the coding of naming and framing Figure 30
<table>
<thead>
<tr>
<th>01:00:30</th>
<th>4</th>
<th>introduction idea &quot;trailer&quot;</th>
<th>move</th>
<th>&quot;fold away trailer&quot;</th>
<th>naming</th>
</tr>
</thead>
<tbody>
<tr>
<td>01:01:55</td>
<td>reflecting</td>
<td>reflecting</td>
<td>generating</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:03:54</td>
<td>generating material concepts</td>
<td>move</td>
<td>generating detail options</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>01:04:00</td>
<td>evaluating material solutions</td>
<td>move</td>
<td>inventing materials</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:04:37</td>
<td>01:05:22</td>
<td>involving geometry &amp; strength</td>
<td>move</td>
<td>discussing rack to bike connections</td>
<td>move</td>
</tr>
<tr>
<td>01:05:26</td>
<td>introducing idea &quot;super-simple solution&quot;</td>
<td>framing</td>
<td>&quot;buy regular rack and bungees&quot;</td>
<td>naming</td>
<td>move</td>
</tr>
<tr>
<td>01:11:30</td>
<td>working on idea 3</td>
<td>move</td>
<td>examining built up production costs</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:12:30</td>
<td>reflecting &quot;decisions so far&quot;</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>01:12:55</td>
<td>01:13:50</td>
<td>making an inventory on design decisions made</td>
<td>move</td>
<td>making design decision</td>
<td>move</td>
</tr>
<tr>
<td>01:14:59</td>
<td>decision making (1)</td>
<td>move</td>
<td>&quot;tray&quot;</td>
<td>naming</td>
<td>move</td>
</tr>
<tr>
<td>01:15:51</td>
<td>introduction tray idea</td>
<td>framing</td>
<td>investigating use of brazes</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:18:58</td>
<td>reflecting</td>
<td>reflecting</td>
<td>design applicable for all bikes</td>
<td>naming</td>
<td>move</td>
</tr>
<tr>
<td>01:19:21</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>01:20:18</td>
<td>decision making (2)</td>
<td>move</td>
<td>&quot;shelf&quot;</td>
<td>naming</td>
<td>move</td>
</tr>
<tr>
<td>01:30:33</td>
<td>reflecting &quot;shall we go ahead and design it?&quot;</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>01:28:47</td>
<td>sketching concepts</td>
<td>move</td>
<td>sketching concept</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:33:36</td>
<td>sketching the tray concept</td>
<td>move</td>
<td>detailing concept</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:33:47</td>
<td>discussing tray/rack connection</td>
<td>move</td>
<td>discussing tray/rack connection</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:38:02</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>01:38:43</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>01:40:00</td>
<td>sketching tray idea</td>
<td>move</td>
<td>making an inventory of parts</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:40:34</td>
<td>making an inventory of parts</td>
<td>move</td>
<td>attending to costs</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:44:00</td>
<td>reflecting</td>
<td>reflecting</td>
<td>pinning down solutions</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:44:59</td>
<td>estimating costs</td>
<td>move</td>
<td>estimating costs</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:49:35</td>
<td>deciding mode of shipping</td>
<td>move</td>
<td>deciding mode of shipping</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:50:30</td>
<td>estimating costs</td>
<td>move</td>
<td>reflecting</td>
<td>reflecting</td>
<td>reflecting</td>
</tr>
<tr>
<td>01:51:01</td>
<td>reflecting</td>
<td>reflecting</td>
<td>estimating costs</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:54:00</td>
<td>01:57:00</td>
<td>evaluating the design with the constraints</td>
<td>move</td>
<td>evaluating design compared to space</td>
<td>moving</td>
</tr>
<tr>
<td>01:57:30</td>
<td>end of design session</td>
<td>move</td>
<td>&quot;weight&quot;</td>
<td>naming</td>
<td>move</td>
</tr>
<tr>
<td>01:58:23</td>
<td>evaluating the design with the constraints</td>
<td>move</td>
<td>determining volume of plastic parts</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>01:58:23</td>
<td>end of design session</td>
<td>move</td>
<td>design</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>02:04:00</td>
<td>frames</td>
<td>frames</td>
<td>frames</td>
<td>frames</td>
<td>frames</td>
</tr>
<tr>
<td>02:04:00</td>
<td>carrying fastening device</td>
<td>move</td>
<td>pack + rack</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>02:05:31</td>
<td>ideation/concepts</td>
<td>move</td>
<td>to add trailer</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>02:08:18</td>
<td>joining technology</td>
<td>move</td>
<td>general design concepts</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>02:09:31</td>
<td>a: pack to rack</td>
<td>move</td>
<td>design</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>02:11:01</td>
<td>b: rack to bike</td>
<td>move</td>
<td>design</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>02:12:26</td>
<td>4: materials</td>
<td>move</td>
<td>design</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>02:13:46</td>
<td>5: decision making</td>
<td>move</td>
<td>design</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>02:14:41</td>
<td>6: designing</td>
<td>move</td>
<td>design</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>02:15:29</td>
<td>7: tray idea</td>
<td>move</td>
<td>design</td>
<td>move</td>
<td>move</td>
</tr>
<tr>
<td>Frames</td>
<td>Comparison of the data processing: the coding of naming and framing</td>
<td>Figure 30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>---------------------------------------------------------------</td>
<td>-----------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>analysis problem solving concept</td>
<td>5.4.12.3.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Black Box</td>
<td>5.4.12.3.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Black Box on Schematic</td>
<td>5.4.12.3.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Black Box on Schematic</td>
<td>5.4.12.3.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Black Box on Schematic</td>
<td>5.4.12.3.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Black Box on Schematic</td>
<td>5.4.12.3.2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The table is incomplete and requires additional information to be fully understood.
The last example (figure 29) already indicates the tension between moving and naming. At some moments the coders have a tendency to describe the content of the design project. Some issues are so intensely discussed by the team, that coders indicate them as names. For instance one coder coded “discussing adjustability” as a move, where another indicated “adjustability” as a name.

The interpretation of what constitutes a frame differed systematically amongst the coders. The second coder interpreted a frame as an “idea or sub problem, some sort of idea behind their thinking”. He indicated four different frames during the design project, for instance “fold away trailer” and “tray design”. The third coder interpreted a frame as “a phase in the design process”. She identified six frames, like “analysing the problem” or “ideation phase”. The first coder used a mix of both interpretations, identifying seven frames, like “carrying fastening device”, or “joining technology”. None of the coders was initially satisfied by his or her coding of the frames. The second and the third coder complained about the vagueness and broadness of the provided definitions.

Although the coding seems to be very different among the coders, during the discussion it appeared that what they understood to be the main frames of the teams was not very different. During the arbitration discussion it was decided first to redefine the notions naming and frame and then code the video protocol again.

The sole justification for calling a name is when the named content has a consequence for the following activities of the team. In other words: the name must have potential to become a frame. Sometimes this consequence can be indicated right away, for instance when the team names “joining techniques” as a possible direction for idea generation. At other moments the consequence can only be indicated after following the teams activities a bit further along in the process, for instance when the team names a “trailer” and later on this idea is used by the team to explore different materials.

One of the problems in identifying the team's frames might be that it works very systematically. Initially the team memebers define explicit process steps in their planning, and they work according to those. One moment for instance they
say, “let’s go to ideation”. This is some sort of planning about what to do next. But ‘ideation’ is a design phase and can not be coded as a frame. However, the specific direction in which they generate their ideas, namely ‘positions’, is the team’s viewpoint on the problem at that time; a context to direct their thinking. This can be coded as a frame.

Looking back into the team’s design project their principal frames are now evident. The different views the team uses to investigate the design problem are “positions”, “joining technology, pack to rack”, “joining technology, rack to bike”, and “materials”. The solution frame they adopt is “the tray design”. According to the new definition for naming and framing, frames have to be named first, before they can be adopted as a new view for the problem. Figure 31 shows an example of the coding of naming and framing after the arbitration discussion.

<table>
<thead>
<tr>
<th>First coder</th>
<th>Second coder</th>
<th>Third coder</th>
<th>Final coding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>generating non-solution</td>
<td>“just wear it” naming</td>
<td>move</td>
</tr>
<tr>
<td></td>
<td>generating concepts positions</td>
<td>trying out like a backpack positions move</td>
<td>move</td>
</tr>
</tbody>
</table>

An example of dealing with disagreement between coders. Figure 31

The team said they would move to ideation in the reflection on 00:22:48. In their next move they seem to hesitate to do this; therefore they read the information again, looking for missing constraints and they fill the backpack. When one of the team members comes up with a non-solution “do nothing, just wear it” this triggers the generation of ideas. Two of the coders have indicated this “non-solution” as a separate activity, for it is an important trigger for the next step. Therefore in the final coding the naming of the non solution is indicated (00:25:47), and the frame starts right after this with the generation of concepts for positions (00:26:00). So in this case the naming does not mention the exact frame that will follow, but the first idea in an idea-generation frame.

The rest of the names and beginning of the frames are coded again in the same way.

In the team design project another pattern can be indicated. This team explicitly uses ideas to explore problem areas like ‘joining technology’ and ‘materials’. They
work on an idea for a while and then drop the idea itself, but keep the results from the idea analysis. They do this three times, so it seems to be some sort of design strategy. These moments were difficult to capture. Just coding them as a move “working on idea”, wasn’t clear enough. We chose to describe them as sub frames. After all the idea is the “thinking context” that they are working in at that time. The aim of the ‘idea exploration’ is to explore the larger frame (“joining techniques” or “materials”). Figure 32 shows an example of the coding of a sub frame.

**Figure 32** An example of the coding of a sub frame.

**Labelling the segments**

Labelling the activities indicated no problems at all. For the *naming* the exact words that the team said were used. Although the place of the *frames* was difficult to establish, the description of them was not. Describing the *moves* was closely related to “understanding what the team is doing”, using a verb and the content, this provided no difficulty at all. The *reflection* could also be described literally from the teams’ words.

**Descriptions of the teams’ design activities**

**Team Ivan, John and Kerry**

Ivan, John and Kerry’s reflective practice is shown in figure 33.

The team starts off by trying to understand the design problem by attending to several issues of the design assignment. In a first moment of reflection they remark upon the fact that they are starting to generate ideas. They are not sure whether they want that and hesitate to take the next step. They read again the information for missing constraints and investigate the backpack. They come up with a non-solution; to design nothing and just carry the backpack. This triggers
The reflective practice design activities of team “Ivan, John and Kerry”. Figure 33
Figure 33 continued
moving: making an inventory on concepts rack to bike
reflecting
"it's getting the materials"
frame: materials
naming an idea: "fold away trailer"
frame: fold away trailer
moving: build on trailer idea
moving: evaluating trailer idea for this situation
moving: making an inventory on materials
moving: discussing strength and cost issues
reflecting:
" kinda disrupted our materials discussion"
moving: exploring geometry and strength
moving: exploring rack to bike connections
moving: exploring people's use
moving: examining manufacturing costs
reflecting:
"let's talk about the decisions that we've made"
moving: evaluating and integrating positions and joining concepts
naming an idea: "little vacuum formed tray"
frame: tray
moving: considering tray idea
reflecting:
"what we're doing right now...is again classifications of solutions"
<table>
<thead>
<tr>
<th>Time</th>
<th>Reflective practice chart</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>01:20:33</td>
<td></td>
<td>moving: evaluating and integrating positions and joining concepts</td>
</tr>
<tr>
<td>01:23:34</td>
<td></td>
<td>moving: investigating usability of braze-ons like Buster</td>
</tr>
<tr>
<td>01:24:36</td>
<td></td>
<td>moving: discussing use of braze-ons for all bikes</td>
</tr>
<tr>
<td>01:28:10</td>
<td></td>
<td>reflecting &quot;keep moving we have fifteen minutes to finish our design&quot;</td>
</tr>
<tr>
<td>01:28:47</td>
<td></td>
<td>moving: sketching design details</td>
</tr>
<tr>
<td>01:33:36</td>
<td></td>
<td>reflecting &quot;you have thirty minutes to end the session&quot; &quot;we know we like this tray idea right&quot;</td>
</tr>
<tr>
<td>01:33:47</td>
<td></td>
<td>frame: tray</td>
</tr>
<tr>
<td>01:36:02</td>
<td></td>
<td>moving: sketching tray concept</td>
</tr>
<tr>
<td>01:38:43</td>
<td></td>
<td>moving: detailing the design</td>
</tr>
<tr>
<td>01:40:00</td>
<td></td>
<td>moving: discussing tray-pack connection</td>
</tr>
<tr>
<td>01:40:34</td>
<td></td>
<td>reflecting &quot;are we designing three different things?&quot;</td>
</tr>
<tr>
<td>01:44:59</td>
<td></td>
<td>moving: setting dimensions on design</td>
</tr>
<tr>
<td>01:49:35</td>
<td></td>
<td>moving: making an inventory of parts</td>
</tr>
<tr>
<td>01:50:30</td>
<td></td>
<td>moving: estimating costs</td>
</tr>
<tr>
<td>01:51:01</td>
<td></td>
<td>moving: questioning design decision</td>
</tr>
<tr>
<td>01:58:23</td>
<td></td>
<td>reflecting &quot;ok, so we got a design&quot;</td>
</tr>
<tr>
<td>01:58:24</td>
<td></td>
<td>moving: evaluating the design with specs</td>
</tr>
</tbody>
</table>

*Figure 33 continued*
<table>
<thead>
<tr>
<th>Time</th>
<th>Reflective practice chart</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>01:59:31</td>
<td></td>
<td>moving; estimating weight</td>
</tr>
<tr>
<td>02:03:18</td>
<td></td>
<td>moving; evaluating the design</td>
</tr>
<tr>
<td>02:06:00</td>
<td></td>
<td>end of design session</td>
</tr>
</tbody>
</table>

Continued Figure 33

the generation of ideas. Their first frame is ‘positions’ and they generate ideas for locations for the backpack on the bike in different ways.

In a later moment of reflection they realise that they have generated concepts for locations (and not for the entire concept) and name other concepts for ‘ideation tools’; joining technologies and materials. They choose joining technology and divide this in two parts and name ‘joining pack to rack’ and ‘joining rack to bike’.

Their next frame is attaching the pack to the rack. The idea of a leg, attached to the external frame of the backpack, is explored and ideas for attachments are developed from this exploration. Their next frame is attaching the rack to the bike and they also generate ideas for that. In the next frame, materials, another idea comes up: a little trailer. They also explore this idea and get ideas for materials from that exploration. They then evaluate those ideas by looking at costs, strengths and geometry.

In a reflection they agree to look at what they have done so far and make a selection from their ideas. In looking through their generated ideas (which they have written up in lists on the white board) the idea of a tray comes up. After elaborating the idea of a tray for a while, they go back to making decisions again. When the experimenter tells them they have only 30 minutes left, they reflect on the tray idea, which they all liked. This then becomes their next frame and they explore the suitability of the concept for the rest of the design session.

**Team Fran, George and Harold**

Fran, George and Harold’s reflective practice is shown in figure 34.

The team starts off by trying to understand the assignment by moving and naming different aspects of the problem. In their first moment of reflection they
<table>
<thead>
<tr>
<th>Time</th>
<th>Reflective practice chart</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:03:10</td>
<td></td>
<td>moving: reading the assignment</td>
</tr>
<tr>
<td>00:07:00</td>
<td></td>
<td>moving: questioning the usefulness of the product</td>
</tr>
<tr>
<td>00:08:08</td>
<td></td>
<td>moving: discussing backpacks (internal/external frame)</td>
</tr>
<tr>
<td>00:08:11</td>
<td></td>
<td>naming: &quot;typical places you can hang bags off&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>naming: &quot;common themes between mountain bikes and touring bikes&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>naming: &quot;special carrying and fastening device between them&quot;</td>
</tr>
<tr>
<td>00:10:18</td>
<td></td>
<td>reflecting &quot;wanna think and so stuff and later ask what kinda problems it had&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>frame: mountain bikes and touring bikes</td>
</tr>
<tr>
<td>00:10:36</td>
<td></td>
<td>moving: making an inventory on common things for mountain bikes and touring bikes</td>
</tr>
<tr>
<td>00:12:40</td>
<td></td>
<td>moving: generating ideas for positions</td>
</tr>
<tr>
<td>00:15:00</td>
<td></td>
<td>reflecting &quot;we're starting with ideas here&quot;</td>
</tr>
<tr>
<td>00:15:05</td>
<td></td>
<td>moving: defining the problem</td>
</tr>
<tr>
<td>00:18:24</td>
<td></td>
<td>moving: generating possible requirements</td>
</tr>
<tr>
<td>00:18:52</td>
<td></td>
<td>moving: discussing positions</td>
</tr>
<tr>
<td>00:18:10</td>
<td></td>
<td>moving: filling up the backpack</td>
</tr>
<tr>
<td>00:20:00</td>
<td></td>
<td>moving: trying out locations</td>
</tr>
<tr>
<td>00:21:10</td>
<td></td>
<td>moving: discussing low CG</td>
</tr>
<tr>
<td>00:23:00</td>
<td></td>
<td>moving: evaluating the back as position</td>
</tr>
<tr>
<td>00:24:10</td>
<td></td>
<td>moving: making a list of support possibilities</td>
</tr>
</tbody>
</table>

**Figure 34** The reflective practice design activities of team “Fran, George and Harold”.
Time | Reflective practice chart | Activity
---|---|---
00:24:30 | moving: choosing the back
00:25:30 | naming: "different bikes?"
00:26:04 | moving: exploring attachment to seat tube
00:29:10 | naming: exploring attachment to seat
00:32:18 | moving: discussing using different bikes
00:35:00 | moving: exploring the backpack
00:40:49 | moving: analysing use and attachment
00:43:00 | reflecting "bunch of different features"
00:43:00 | naming: "the bracket to the bike"
00:43:00 | naming: "the frame to the bracket"
00:43:00 | reflecting "organise and check"
00:44:10 | moving: checking barin span underneath seat
00:45:36 | moving: deciding on attachment
00:46:46 | moving (G): copying bike and backpack on transparencies
00:46:46 | naming (F+H): "quick idea on top of your brain"
00:47:58 | moving: F+H both drawing individually
00:48:35 | moving: discussing orientation bag on bike
00:50:20 | reflecting "It's like a whole idea then"
00:59:35 | moving: generating ideas

continued Figure 34
<table>
<thead>
<tr>
<th>Time</th>
<th>Reflective practice chart</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:57:30</td>
<td></td>
<td>moving: discussing rotating tubes while not carrying the backpack</td>
</tr>
<tr>
<td>01:00:00</td>
<td></td>
<td>moving: discussing attachment</td>
</tr>
<tr>
<td>01:03:15</td>
<td></td>
<td>reflecting 'If we ever want to ask about like market research'</td>
</tr>
<tr>
<td>01:04:00</td>
<td></td>
<td>moving: analysing marketing research information</td>
</tr>
<tr>
<td>01:05:11</td>
<td></td>
<td>moving: adjusting the idea with railings</td>
</tr>
<tr>
<td>01:06:10</td>
<td></td>
<td>moving: talking about the idea of bag and zippers</td>
</tr>
<tr>
<td>01:07:07</td>
<td></td>
<td>moving: analysing info on current racks</td>
</tr>
<tr>
<td>01:08:26</td>
<td></td>
<td>moving: looking attachment current racks</td>
</tr>
<tr>
<td>01:11:03</td>
<td></td>
<td>moving: discussing adjustability</td>
</tr>
<tr>
<td>01:13:12</td>
<td></td>
<td>moving: analysing pictures current product</td>
</tr>
<tr>
<td>01:15:49</td>
<td></td>
<td>moving: discussing shortcomings from user test current product</td>
</tr>
<tr>
<td>01:17:15</td>
<td></td>
<td>moving: evaluating own design</td>
</tr>
<tr>
<td>01:18:30</td>
<td></td>
<td>frame: the concept</td>
</tr>
<tr>
<td>01:24:00</td>
<td></td>
<td>moving: looking at storage and removability</td>
</tr>
<tr>
<td>01:28:40</td>
<td></td>
<td>moving: detailing idea</td>
</tr>
<tr>
<td>01:29:00</td>
<td></td>
<td>moving: asking for cost requirement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>moving: dividing tasks (G frame/&quot;bracket&quot;, H bag, F attachment frame and rails)</td>
</tr>
</tbody>
</table>
01:30:30  moving: working individually
01:31:17  moving: G+H consulting on orientation backpack
01:31:20  moving: working individually
01:31:28  moving: F+G consulting on width and narrowness rack
01:33:17  moving: working individually
01:35:51  moving: F+G consulting one or two pieces
01:36:40  moving: F+G+H consulting on backpack
01:37:00  moving: F+G consulting on number of pieces
01:38:10  moving: working individually
01:38:40  moving: F+G consulting on rigidity
01:43:20  moving: working individually
01:44:05  moving: F+H consulting on backpack
01:45:13  moving: working individually
01:45:40  moving: F+G+H consulting on "pivot"
01:46:38  moving: working individually
01:47:28  moving: F+G consulting on width and stiffness
01:50:30  moving: working individually

continued Figure 34
decide to focus on one aspect and they set their first frame: 'the common themes between mountain bikes and touring bikes'. While looking at what these bikes have in common, they start generating ideas for locations. In their reflection they decide that this is not what they want right now, and they go back to defining the problem. In the next process the team takes one aspect of the problem at the time, explores and solves that. Then take the next one and integrate that in the earlier decision. In this way they ‘build’ their design. They refer to locations, support possibilities, different bikes, and the use of the product.

In a moment of reflection they notice that there are a lot of different features possible and they name a few. In the next reflection they decide to organise their ideas and check the suitability of the ideas. They do so and also add other issues to the concept.

They also ask for information in order to check whether the idea is useful. After having evaluated their design, they state the concept as their next frame. The rest of the time they spend detailing and sketching the design.
The reflective practice in design teams

Both team design projects are described in reflective practice terms. The reflective practice descriptions of the teams provide a picture of the teams’ design project. Within these descriptions the moments of framing and reflecting can be identified. These moments will be discussed in detail, analysing the teams’ communication and behaviour on framing and reflecting. We will describe this, while addressing the research questions for this part of the study:

- How are frames used by a design team?
- How is a frame communicated in a design team?
- How are reflections used to direct the framing or reframing of the team?
- What can frames contribute to the shared understanding of the product design content?

We will start by exploring the teams’ strategies on the entire reflective practice process.

The teams’ reflective practice strategies

The two teams have (again) very different ways to solve the design problem. Fran, George and Harold don’t use explicitly set frames. They start with an issue of the design task that they see as important and generate a solution for it. So first they come up with a “flap over”-idea that allows one to attach the backpack “without hands” (meaning that you can put the backpack on the ground, then attach it to a frame, and eventually flip it over until it’s on top of the back wheel, 00:15:40). When their concept is finished they check it with the available information and they decide to stick with it. Throughout the rest of the project they are refining the design. There is hardly any reflection going on. They develop the product by designing parts of it, and putting these together into a whole.

Ivan, John and Kerry divide the design problem into different ‘classifications’, that they extensively analyse, using different frames. Then a ‘frame less’ period occurs, where they don’t want to jump to conclusions, and systematically evaluate everything they have done so far. In doing this, the concept of a ‘tray’ evolves and this concept becomes the design they will work out in detail until the end of the design project.
Fran, George and Harold seem to handle the design problem as a division of separate design issues. They solve these issues one by one and integrate them into one concept. They design by doing and deciding. We have already observed that in reflective practice framing and reflecting are important ingredients. Fran, George and Harold’s design process resembles a ‘chain of decisions’ instead of a reflective process. However, the step by step approach to the design problem, integrating every next issue into an earlier developed idea, seems to work well in this project.

In the beginning of the project, Fran, George and Harold set a frame “commonalities between mountain bikes and touring bikes” (00:10:36). However, they reject this frame very quickly, because it doesn’t get them anywhere. As soon as they realise they are discussing different locations for the backpack on the bike (00:12:40), they reflect that this move does not fit their current frame and they reject the move (00:15:00). They return to ‘discussing the problem’ as they did before (00:15:05). This reflection did not cause a learning moment in the team; at first the team does not like where the move is leading them. Second, they reflect on it in relation to the current frame. Then they reject both the move and the frame. Finally, they return to exactly the same move as before the frame and moment of reflection.

Ivan, John and Kerry, on the other hand, decide from the beginning upon exploring different viewpoints of the design problem. They do this by exploring different frames and generating many alternatives, before integrating them into a total solution. Ivan, John and Kerry extensively explore four problem frames (“positions for the backpack”, “joining technology: pack to rack”, “joining technology: rack to bike”, and “materials”) before thinking about an integrated solution. Exploring the four frames they generate solutions for the whole design. The frame less part of the design project is an interesting period (01:15:51 up to 01:33:36), where Ivan, John and Kerry try to evaluate every discovered potential solution and try to integrate them into one design.

There is a moment in the project where both teams are doing similar things:

At 00:35:14, Ivan, John and Kerry are naming the different aspects they have to consider; first the concepts for ideation tools “position”, “joining techniques” and
“materials”. Then they divide joining techniques into “pack to rack” and “rack to bike”.

Fran, George and Harold have a similar discussion at 00:43:00, where they name the different features they have to design: “the bracket to the bike” and “the frame to the bracket”. After this naming-activity Ivan, John and Kerry continue by choosing and exploring the frames “attaching pack to rack” and “attaching rack to bike” one by one, by generating different solution for them. Fran, George and Harold continue to check the idea they generated earlier and integrate an attachment solution into it.

How are frames used by a design team?
We can see that frames are used throughout the project, and that their use differs between the teams: Ivan, John and Kerry use frames to guide their whole project, Fran, George and Harold use fewer frames to design. Now some moments of framing and reframing will be studied in more detail.

Ivan, John and Kerry use frames to approach the design task. Half an hour into the design assignment the team is generating (naming) frames for the design task; which they call “classifications” (00:33:45). In all following quotes, the words, which are of importance to the framing by the teams, are indicated in bold script.

J  ehm really what we’re doing up here is creating lots of classifications of
I  solutions
J  solutions and then we need to sort of ...at some point evaluate the clas
sification and go toward one or two classifications in a row
I  OK so let’s think of of large
J  wait
I  when you were talking about classifications I think of the whole ease as we
were looking at different places to put it
J  right exactly
I  the other locations or whatever
J  so then let’s think of another one em
I  oh some of the other let’s think of what are the other concepts we’re
gonna have to use? we’re gonna have to use
I  position we’re gonna have to look at mounting or or
J: yeah joining techniques
I: joining
J: whatever snaps on or bolts on or clamps on or em what other
I: em we're gonna have to look at materials
J: materials yeah that's gonna be a biggy

The team generates "classifications" of the design task. These "classifications" will become their frames in the project.

The descriptions of the design project show that frames are not only used in analysing the design problem, but that they are also used in creating solutions. In Ivan, John and Kerry's use of frames there are moments where one can hardly tell whether they are analysing or generating; both activities merge within one frame. During the detailing phase of the concept, the frame that both teams work in is the concept itself (see figure 33: Ivan, John and Kerry 01:33:47, and figure 34: Fran, George and Harold 01:23:06). The team does not redefine the frame in this phase of the project; the most important decisions are made by the choice of the concept.

In Ivan, John and Kerry's design project we also identified sub frames. The team uses ideas, like "a leg that attaches right to the external frame" (00:43:09) or a "a little fold away trailer" (01:00:30), not as solutions to the overall problem, but as "spring boards" to explore a frame's design possibilities. For example within exploring the 'fold away trailer' (01:00:25) the team is starting to generate ideas for materials:

J: OK OK so well it's getting the materials
I: yeah it's getting my vote sorta something like this em we need to move on
J: yeah let's get to the materials a bit I mean it looks like everything we're looking at right now is wire form but actually a friend of mine em suggested a product that they would do an injection moulded rack that would kind of like fold down a couple of years ago and I was thinking yeah sounds interesting
I:(yawn) it's -injection moulding like the little rack that was er flat it had em these panels it looked just like one of these but these panels were solid it bad little wheels and actually em you would swing it around
and it would come off and then it would be like a little trailer

K  mmm
J  mmm
I  do er two wheels and you could put whatever you want to back there when you weren’t using you just fold it up and it would be like a bike rack
J  can you sketch that (inaudible)
I  yes it was em let’s see what it looked like it was it had .. bicycle here... bars ... so there was er..when it was down it came off of here and was (inaudible)......so if you just em
K  dragged it
J  drag it (laugh) drag it you know y’know one way to y’know just to build on your idea a little bit
I  here
J  one way to get that adjustability for the seat post height and all that stuff is if this say this was a single bar and it went like this
K  mm mm
J  and it could slide along here that way if you need to come up more y’know pivots around the braze-ons if it needs to come up more for a taller person or for better wheel clearance or whatever you just kinda slide it forward and put little lock downs on it
K  yeah yeah I don’t think you need to change this length ‘cos the wheel is fixed enough that you can rotate about the braze-on and I mean if if you really need a adjustment I think all these Blackburn racks would have adjustments
....
J  em all this stuff up the forming probably not so bad but
I  right
J  it’s certainly not material
I  yes OK well maybe em OK let’s look at materials you were talking injec-
tion moulding
J  injection moulding em wire form what else comes to mind on top of these “that’s obvious” maybe like er cloth with some sewn in em
diecut pieces or something for plastic reinforcement
I  oh yeah
J  like sorta like backpack construction technology
I  oh

During this generation of of ideas for possible materials for the backpack holder, Ivan suggests a little trailer. The team explores this a little more, before getting
back to the notion of materials. The exploration of the “little trailer”, provides
them with a new approach and new ideas for materials.

We chose to describe these ideas as sub frames, because of their importance for
the developing design content. The ideas represent more than just one of all
ideas; these ideas are extensively explored. All sub frames involve a move (the
exploration) and a reflection, where the team reflects on where the sub frame has
brought them. (Except the sub frame ‘fold away trailer’; this frame ends with a
move. But the move is “evaluating the idea”, which is a logical way to end a series
of moves).

The occurrence of these sub frames (ideas for further exploration) does not seem
to be random. The ideas appear at the beginning of frames that seem difficult
to approach. The team is looking for a way to deal with ‘joining technology’
or ‘materials’, which seem very abstract issues. Especially compared to the
generation of ideas for ‘positions’. They solve this by introducing a concrete
idea to explore. The idea is discussed on the issues of the frame (‘joining’, and
therefore ergonomical issues, and ‘materials’), and in doing so they explore the
frame itself.

Ivan, John and Kerry’s third sub frame is the tray idea (01:19:41). This idea is
introduced in the frame less period, where the team systematically evaluates their
earlier ideas. The tray idea provides them with a context to evaluate and integrate
earlier solutions.

**How is a frame communicated in a design team?**

The designers, working with frames, somehow develop and pass on to each
other the frames with which they approach the problem and solution. Looking
at the earlier examples shows that the sentences designers use to pass on
frames are comparatively long, and the frame-conveying designers speak for
uncharacteristically long times, compared to other parts of the protocol. In the
Ivan, John and Kerry-team, John is the one that initiates most frames, and he
passes on his ideas in what looks like a rambling way:

J: So I keep thinking that there’s all this weight in this area between the
seat but that could be used but I wonder if that would really work when
you’re like pumping really hard pedalling up a hill it sounds like

This was early on in the process, when things were vague and designers may have needed some extra words to describe what they mean. But later too, whenever a frame comes up the sentences become longer. For instance the frame John introduces above:

" yeah let’s get to the materials a bit I mean it looks like everything we’re looking at right now is wire form but actually a friend of mine em suggested a product that he would do an injection moulded rack that would kind of like fold down a couple of years ago and I was thinking yeah sounds interesting “.

Frame-ideas are put before the other designers in carefully worded proposals. The frame-owner tends to draw in his ‘audience’ by leaving things purposely vague, words his proposal as a question, and invites others to finish his half-finished sentences. The frame-ideas are thereby communicated with the other group members in a manner that is not just an explanation of an idea, but also a transfer of ownership. In the next quote, the words that are used to make the proposal vaguer are indicated in bold script.

I just think another there’s a kind of other class of solutions outside of our design problem and that’s that you could somehow use the external frame and wouldn’t need the rack maybe it’s some sorta like

I mm
I don’t know maybe
I (inaudible)
I yeah
I we’re assuming what the rack is right
I yeah I mean maybe yeah we’re assuming there is a rack I’m thinking maybe on the external frame there could be a little a little like er what do you call it um like er
I mm mm
I snapping clips or something that would allow you to
I just snap right on to
I yeah like cantilever it off the back of the bike
On the whole, we see very little convincing going on: group members in these teams are eager to explore ideas, and are bent upon picking up each others lines of thought. Designers use the vaguest communication (with open-ended sentences, and a careful and explorative choice of words) that is meant to convince the team members to follow one’s general ideas.

**How are reflections used to direct the framing or reframing of the team?**

In most moments of *reflection* of Fran, George and Harold (six in total) the team reflects on what they are doing at that moment. As an example we illustrate where the team is *naming* different features (00:43:00):

F frame to the bike frame to the bracket yeah cos
G if you set it all
F you’re at least two places attach it and then it still needs to OK now (inaudible)
G well maybe yeah maybe we should organise and think about in a sense yeah and issues like supporting a thirty pound pack on a cantilever how much bearing span do you think we need off of this tube and stuff like that and then do we have that much bearing span for every bike or do people like drop the seats way down .. if they do then maybe we have to go on some other attachment plan
H yeah I think we can count on this being here but they might wanna adjust if it were
G its gonna be different this is
H mmmm
F they’re really on a lot of things
G oh are they
H yeah because they all have to go to this clamp this clamp is standard

After having *named* “the bracket to the bike” and “the frame to the bracket”, George suggests to “organise and check” their current solution. Their next *move* is “checking the bearing span underneath the seat”.

Ivan, John and Kerry have similar moment of *reflection*, e.g. (00:49:03):

I that’s interesting yeah they said with it sticking up people couldn’t swing their
legs over the back
K yeah
J I mean I er
I something low lower is better
K I agree
I if I can make a general point
J OK
K I agree
J and we keep turning the focus on the back I mean sounds like or it seems like we might have already mentally eliminated
I the front
J the front (laugh)
K it tends to be em
I unless you can get them really low
K if you can get them low but then if you get them too low you start hitting things that are you’re driving by
I (inaudible) clearance
J we can we can sorta like cull some of our solution sets here a little bit because we know you realistically can’t put a full pack in here otherwise it's not gonna fly
I (inaudible) come out
J em
I its er inner diamond ...so that
J if it was a smaller article it would work but not if it’s something this size um ...
...and over the front does do people have any problems with mounting it up front? I kinda think it makes your steering harder cos you’re putting more

Ivan, John and Kerry are discussing ergonomical issues of the backpack, when they realise that they are constantly focussing on the back of the bike. They decide to evaluate all earlier generated locations, in order to make a valid decision on the location of the backpack on the bike. In these examples the teams notice that their current move does not have a desired result and they decide upon another move.

There are also moments of reflection that are aimed at a broader perspective. As an example we illustrate when Fran, George and Harold explore the frame “common theme’s between mountain bikes and touring bikes” (00:10:36):
H you have the person on it too and I dunno if there's something you can use with the person and the bike somehow .. but there's always a person there
G that's right
F that's a commonality
G yeah ........
F that's not so bad I'm tryin to think of a place that this fits
H but the idea is that it's packed alright yeah
G yes
H it's not just a store place for the backpack it's ...
H backpack and contents
G yeah and contents
F right right right yeah I mean it would have to be pretty darn skinny to fit
.....
G yeah it could be off to the side as a saddlebag thing but then you'd want tools so that you're balanced again
H yeah
G then you've just doubled your parts
H mm mm ........ well y'know the bag is necessarily neither like .. they both have wheels like so you can maybe if a
G well it looks like those bags are (inaudible) has a
F put a wheel on it (laugh)
H it actually has a split down the middle so it doesn't wanna be (chung ??) it hangs down and straddles
F (inaudible)
H aha hangs over ..we're starting with ideas here em .. is it like that
G yeah ........OK
F carry... so do you have to deal with the backpack you're already carrying
G well I think we need to clarify that
F OK

The team realises that they are generating ideas for locations of the backpack on the bike. This is not what they planned to do. The move does not fit the current frame and leads to rejection of that frame.

Ivan, John and Kerry have more of these moments of reflection. For example at 01:20:18, Ivan, John and Kerry are exploring the tray-idea. Then John says:

J so what we're doing right now though is we're coming up with like again
classifications of solutions of kind of all they're all either or things I mean like we wouldn't do the net and the shade and the snap in with the tray either or any one of those will probably

I yeah OK

Earlier the team had decided to systematically evaluate all their solutions so far. Now John realises they are generating new ones (the tray idea). This reflection leads to rejection of the tray-sub frame and returning to their earlier move “evaluating and integrating positions and joining concepts”.
Another example where reflection leads to repositioning in the Ivan, John and Kerry team is at 01:33:36:

X You have thirty minutes to the end of the session
K OK
J OK
I OK
J where are we supposed to be schedule wise we're supposed to be designing right
I yeah well that's what we're doing right
J and OK
I I think we should be done in about er
J well OK well we know we we like this tray idea right
I right
J and I guess if I had to express that someway I would I would see it as being something like er here's the front of the frame

The experimenter interrupts the design project by stating that they have thirty minutes left in the experiment. This triggers the team to choose the tray idea and they start to work out that as their concept. From this moment the idea of the tray is adopted and accepted as a new frame.

The last three examples show reflections, where the teams not only consider the current activity, but also the current frame. These reflections not only lead to new moves, but also to renewed consideration of the context.
What can frames contribute to the shared understanding of the product design content?

In the teams' design projects frames seem to have three functions. First of all frames serve as a guidance for activities and communication. Especially in the phase of understanding and exploring a problem, problem frames provide a good guide for activities. The absence of a problem frame means that a context for alternative ideas is lacking.

Secondly, frames serve as a guideline for the product design content. They provide a way to deal with the complex design task. For instance solution frames help the teams integrate the different issues in the design task into one solution.

Thirdly, by explicitly stating frames in a team a shared understanding is created. A shared understanding of the way the problem will be approached, and of the way the design content should be developed. Using, communicating and manipulating frames in design teams can therefore improve the creation of shared understanding between the team members.

Conclusion

Describing team designing as reflective practice

Applying the method of description onto two design team projects, indicated that the coding is reliable. However, there will always be differences in interpretation of data. These differences can be dealt with in an inter-coder discussion. In this way the differences can be detected, discussed and solved. This discussion must be aimed at better understanding of the data, in relation to the goal of the study.

The arbitration discussion has led to new definitions of naming and frames. The sole justification for awarding a name is when the named design content has a consequence for the following activities of the team. In other words: the name must have potential to become a frame. When a design team agrees on a formal order on a (sub) problem or (partial) solution to explore further on, then this ordered context for action is called a frame. The frame is an explicit context guiding further activities.
Full definition of the notions in reflective practice is still problematic. However, these descriptions seem to provide enough guidance for identifying and using the notions, such as frames.

**The reflective practice in design teams**

In the analysis of the design teams we have shown that frames are used by the design teams themselves. Frames are not only a way of observing design by researchers (something we can identify while observing design), but teams actively and explicitly use frames in the design project. In analysing the design problem, generating solutions and detailing the concept. During the detailing phase the frame is embedded in the design concept itself; the most important decisions are set by the choice of the concept.

The designers treat frames differently from other items in the design process.

We also identified moments of frame communication. This communication is characterised by long sentences and carefully worded proposals. The frame ideas are transferred to the other team members in a manner that is not just an explanation of ideas, but also a transfer of ownership. The ideas constitute an invitation to come in on the idea and play with it together with the originator of the communication. During this, there is very little convincing going on; group members are eager to explore ideas and are willing to pick up each other's lines of thought.

In the team design projects we identified two types of reflection. In some moments of reflection the teams reflect on current activities and decide upon the next activity. In other moments of reflection the teams consider a broader perspective and reflect on the current frame.
6 Improving team designing

Introduction

In order to improve team designing, we have to understand it. In order to understand we must be able to describe it. Therefore the empirical study had two goals. The first goal was to develop and evaluate a description method for describing team design activities. The second goal was to understand the nature of team designing by exploring design teams at work. Now the time has come to take stock of the results and draw conclusions. We will answer the two research questions of the empirical study, and indicate possible solutions to the problem statement of the research project.

How can we describe team design activities?
The first research question: “How can we describe team design activities?” focussed on a method for studying team designing. We adopted Donald Schön’s theory of reflective practice to develop a method of description for team design activities. A model for the reflective practice activities was developed, together with a notation system to process empirical data. With this method four team design projects were described. The method of description was evaluated, using both a multi-coder approach and an arbitration discussion of the data. In the first section we will answer this first research question by discussing reflective practice as a research method.

What can we learn from design teams at work?
The second research question: “What can we learn from design teams at work?” focussed on the insights to be gained. We observed team designing from the reflective practice viewpoint in order to gain an understanding of the nature of it. In the empirical studies two key areas of interest were investigated. The first area was the use of the four different reflective practice activities within the teams. The second area was the interaction between the reflective practice activities within the teams, to explore patterns in the team’s reflective practice strategies. In
the second section of this chapter we will discuss the insights into the nature of team designing that we gained from the empirical studies.

How can we improve team designing?
The answers to both of these factual questions will be used to discuss possibilities for improving team designing. This discussion will result in ideas and suggestions to improve team designing, and therefore in recommendations for the practice of design, design education, and further research. This will be described in the final section of this chapter.

Reflective Practice as a method of description for team design activities

The exploration of the reflective practice theory in chapter 2 also revealed criticisms and raised questions. In this section we will summarise and discuss the key findings on the method of description. We will do so by addressing the earlier stated criticisms on Schön’s work. Subsequently, we will conclude on reflective practice as a research method for describing team designing.

Summary and discussion of the key findings

Criticism 1: The inadequate empirical evidence for Schön’s ideas
Schön’s ideas are based upon empirical studies of professionals. His examples don’t show designers at work, performing reflection-in-action, but rather tutors reflecting on their students’ design work. These examples therefore show reflection-on-action (chapter 2, page 67). Our data on the other hand, concern design teams at work. We have shown that reflection-in-action occurs in some teams, while other teams work in a different way.

In the studies we identified reflective practices in two design projects. The teams ‘Tecc’ and ‘Ivan, John and Kerry’ design in a reflective practice manner. They name issues in the design task that require attention, and explicitly organise and choose these names. They explicitly frame their view on the problem, guided by
an appreciation of the design situation. This *framing* gives it coherence and sets a direction for action. Within this context they make *moves* to solve the design problem. As they spin their web of *moves*, their attitude towards the design task changes. Every now and then they *reflect* on these changes, deciding whether their *moves* are aimed in the desired direction and whether their current *frame* is satisfactory as guideline for further activities. By stating the directions they are going to take, they harmonise not only what they are doing in procedures but also what the content of that activity is. For instance when they decide to generate ideas, they explicitly set the direction for these ideas, such as ‘ideas for bridging the gap between the competition table and the basket’ (Tecc) or ‘ideas for positions of the backpack on the bike’ (Ivan, John and Kerry).

In the studies we also identified other ways of working within two design projects. Team ‘The Delft Pitchbulls’ *name* important issues in the design task that require attention. Within the project they continue to attend to all of them. They divide their attention over each issue and interrupt discussions that aim to focus on a subject. They are searching for solutions for these issues, but without generating many alternatives. The solutions they decide upon are not compared to others, or evaluated extensively. The team appears to adopt a wait-and-see attitude, omitting to take control and make things happen.

Team ‘Fran, George and Harold’ also deal with the design problem as a set of separate design issues. They start by looking for a solution for the first issue and then connect all other issues one by one as they progress into the project. This seems to work well in this project, although the concept in the end is not optimised as an integrated solution. It is only evaluated and optimised on the separate design issues.

The teams The Delft Pitchbulls and Fran, George and Harold are much more difficult to understand from a reflective practice point of view. This is remarkable, because, according to Schön all designing is reflective practice. It is difficult to point the finger at what exactly is happening within these teams. We described earlier the interruption mechanism that operated in The Delft Pitchbulls team. A feature of their communication is that every time one of the team members tried to focus their attention, another one brought up a different issue that is
'very important' and the team's discussion changed direction. Working in this way they do not effectively deal with any issue.
Fran, George and Harold, on the other hand, do work together purposefully. Bit by bit they construct their design out of all the separate issues that they encounter in the design problem. It is notable that the team does not take a critical attitude towards their activities, or towards the design result.

What is the result of all this? Of course there are not enough data to generalise these outcomes, but we have shown that not all designing is done in a reflective practice way.
It is remarkable that both teams that do use reflective practice make an extensive evaluation of their end results at the conclusion of their design projects. Tecc makes a list of the weak and strong points of their design, which is regularly quoted in their discussion with the expert judges. Ivan, John and Kerry extensively compare their design with a list of requirements that they themselves made. Fran, George and Harold as well as The Delft Pitchbulls don't seem to have this critical attitude towards their design activities.
A comparison of different ways of designing, among which the reflective practice manner, and their attending successes and results, would make an interesting follow up research.

Criticism 2: Schön's lack of precise terminology
Over the years Schön's work repeats a lot in explaining and illustrating his basic ideas, but the explanations do not progress far in providing more refined ideas or definitions. Sometimes Schön even fails to hold on to a consistent approach of his own concepts (chapter 2, page 67). Using Schön's defective definitions as a starting point, we developed a notation system for reflective practice. In an explorative empirical study we encountered problems that we tried to solve. These problems concern the precise definitions, which we specified from insights from coding and discussing different codings. These problems also concern interpretations the researchers have to decide upon.

For example, it is difficult to unambiguously define what a frame is. However, the discussion among the coders indicated that frames are not difficult to identify. It
can easily be agreed upon what the frames are that the teams used. Objectively defining frames is difficult, because frames depend on the specific situation and the design content in this situation. The frame is not only determined by this design content, but also by the way in which the team deals with this content. In team designing, we cannot recognise frames, but we can recognise framing.
In chapter 5 we showed an example where the teams Ivan, John and Kerry and Fran, George and Harold are doing similar things in the design project (see also page 185). Both teams name different issues they have to consider in the design project. Ivan, John and Kerry name ‘positions’, ‘joining techniques’, and ‘materials’. Fran, George and Harold name ‘the bracket to the bike’ and ‘the frame to the bracket’. After this naming-activity Ivan, John and Kerry continue by framing ‘joining technology, attaching pack to rack’ and focus on the exploration of that frame. Fran, George and Harold continue by checking the idea they generated earlier and connecting an attachment solution to it. In this example both teams name issues in the design task (even comparable issues). In one case this naming leads to framing of the problem, in the other case it leads to a move.

We found a way of identifying reflective practice. By focussing on design activities, we can picture the interaction between the design activity (process), the design task (content) and the designer(s). At the same time, this interaction hampers the operationaLising of the constructs within reflective practice. Defining general notions that are content- and activity- dependent is per definition impossible. The way of identifying these notions did provide clarity. Clarity on the reflective practice within design teams, but also on the reflective practice theory itself. This can form the basis of further research.

Criticism 3: Making reflective practice work
While there has been much theoretical speculation about Schön’s notions, surprisingly few researchers have set out to operationalise them (chapter 2, page 69). We made reflective practice work within the boundaries of its beliefs. The reflective practice way is, up till now, still the only way that is able to describe the developing design content within projects, while linking this content to the design process and designers. For studying team designing it gives a clear picture of the developing design progression.
We already indicated that this interaction also introduces problems. In this research project we developed a method to deal with these problems. We evaluated the method of description by processing the data with three different coders. Then we set up an arbitration discussion between the coders to identify and deal with the agreements and disagreements between the coders. This evaluation of the method of descriptions gave good reliability of the data processing among three coders. The initial disagreements in data processing among coders proved to be systematic, for example the way that a coder interpreted the coding of frames. By discussing these systematic differences and the arguments behind them in relation with the data, always led to shared understanding between the three coders. Eventually, all disagreements could be dealt with.

In a research project with Mazijoglou and Scrivener, we contrasted two descriptions of design. Mazijoglou and Scrivener developed a method of description by inductive analysis that sought to make sense of the data [Mazijoglou and Scrivener 1996 and 1998]. Their aim was to minimise interpretation of the data in the data processing phase. We compared their description of the Ivan, John and Kerry team with the description according to reflective practice [Mazijoglou et al 2000]. This comparison shows that including subjective interpretation in data processing, as in the reflective practice research approach, delivers a way of giving meaning to data segmenting. Data segmenting according to objectively identifiable elements (‘discontinuities’ in Mazijoglou and Scrivener’s approach) provides an overview of these elements, but not per se an overview for the entire team protocol (‘chains’ in Mazijoglou and Scrivener’s approach). Reflective practice provides a clear picture of the entire team design process.

Qualitative research involves subjective interpretation by the researchers. These interpretations will always differ, inherent to the researcher’s interpretation of the world. Researchers need to find ways to deal with this interpretation in the development of research methods. They should not try to ignore or avoid subjective interpretation, but reliably include it in research. In this research project we used several observers to identify reflective practice in team designing. These observers were chosen carefully; they had to be able to understand design activities and the developing design content. These observers all watched the
team at work and then discussed their results. This method of multi-coding, combined with an arbitration discussion, proved to be a useful evaluation method to deal with the multiple, subjective interpretation of the coders.

Criticism 4: The paradox between generalisation and specification
To Schön, every designer and every design task is unique, but in the end he still describes the reflective practice process as a general view on designing (chapter 2, page 69). The uniqueness that Schön addresses is embedded in the design task from the viewpoint of the designer. In this research project we attempted to exclude the uniqueness from the viewpoint of the researcher. Different observers can identify the same issues in the design task, which makes reflective practice, as a research method, less individual and subjective.

Concerning the uniqueness of the situation and design task, we cannot make statements on the basis of four design projects. Observing two sets of two projects does raise questions that, we think, can be dealt with using the reflective practice approach to research (see the recommendations for further research on page 223).

Reflective practice as research method
In conclusion, we can say that the research project provides us with a detailed empirical investigation of examples of reflection-in-action. Evaluating the research method we learned to deal with Schön's heritage and attempted to develop a way to deal with subjective interpretation in qualitative research. We also extended reflective practice to design projects. Schön describes reflective practice as a local activity. Applying the method of reflective practice to an entire project also shows different patterns, which Schön does not deal with at all. It provides a good picture of what the teams are doing and how the design content progresses.

We must also admit that some results turned out differently than we expected them to. We could not completely validate the research method, in the sense that every coder would get the same results from data processing. We did, however, develop a way for dealing with differences in data processing, which we think, is of more use in this type of research. We can not provide clear definitions of the notions within the theory of reflective practice, but we did find a way to identify them in team designing. We can not prove the existence of reflective practice, but
we can raise the question whether reflective practice is always good designing. Looking at designing in-depth, the way we did in this research project, provides too few data to generalise conclusions for teams. A good exploration of the teams’ activities does provide a way of clarifying questions for further research.

We made reflective practice work as a research method, but we encountered the boundaries of its basic beliefs. To indicate the possibilities and impossibilities of the research method we will refer back to Dorst’s conclusions on reflective practice.

Dorst compared the ‘reflective practice’ paradigm with the ‘rational problem solving’ paradigm [Dorst 1997]. In his conclusions he indicates that: “... The design researcher must therefore choose to use either one of the paradigms as the basis from which to observe, describe, model and create methods for design...” This choice of the appropriate paradigm is, according to Dorst, a very complex problem and depends on three main factors: the goals of the research, the objects of study, and the subject of study. He indicated the appropriateness of using the paradigms for various goals, objects and subjects in a table. We will compare our results with his (see figure 35).

Concerning the goals of the research project, Dorst indicated that reflective practice is well suited for methods and techniques for design education and case study descriptions of design activities, and unsuitable for formal models or general prescriptive models. According to our findings, we have to agree. However, from the empirical findings, we also have a strong feeling that reflective practice can be more than just case study descriptions. Our four team examples indicate the ability of identifying reflective practice. This can be developed a step further for intervening in behaviour of design teams (by project managers or design tutors). We will elaborate on this after discussing the reflective practice within teams in the next section.

* Dorst defined a paradigm as ‘a fundamental image that... defines and interrelates the exemplars, theories, methods and instruments... within a science’. He stated that Design Methodology is founded on two fundamentally different paradigms. One is the ‘rational problem solving paradigm’, developed by Simon. (For a description of his basic beliefs see also our chapter 1, page 31). The other is the ‘reflective practice paradigm’, developed by Schön.
The goals of the research project can be:

- **formal models**
- **general prescriptive models or techniques**
- **methods and techniques for design education**
- **case study descriptions of design activities**

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Possible objects of study are:

- **design processes**
- **design persons/designing organisations**
- **design tasks/design problems**
- **the interaction of design process, person and task**

The subjects of study can be:

- **subjective or**
- **objective design activities**

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The appropriateness of using paradigms for design research [Dorst 1997, Figure 35 page 167], compared to the results of this research project.

Concerning the objects of study, Dorst indicated that reflective practice is well suited for design processes and design activity as a whole. Our observations support these findings. A reflective practice description of a team design project indicates what the team is doing.

Dorst also indicated that reflective practice is neutral for describing design persons and design tasks. In describing team design projects this is not totally true. In our descriptions of team designing, we succeeded to capture the 'team dimension' in the design project. This team dimension is an interpretation of the team’s attitude towards the design task.

Describing the designer’s attitude in observing individual designers requires an interpretation of the designer’s cognitive process. In team designing, we are able to observe the team’s communication processes. Communication is ‘natural behaviour’ of teams. Communication is also easier to trace than cognitive issues. Working
together in a team requires explicitly verbalising information in order to share. Through this communication it proved to be able to trace the frames used in the design project and the development of the design content.

The most important division between design activities that Dorst indicated is that between design activities involving objective or subjective interpretation. From our findings we agree that looking at subjective design activities can very well be done with reflective practice. We also want to stress that involving subjective interpretation in research projects requires the development of methods to deal with this interpretation.

We found other results than Dorst did, for studying team designing makes the research project differ slightly from a project studying individuals. Reflective practice is especially suitable for studying team interaction in design projects. It shows how a design team approaches the design task, what activities they take to solve it, and how they develop the design. By observing and analysing team design activities it is possible to look into the team’s design process and break open the ‘black box’ of the team members’ interaction.

**Insights into the nature of team designing**

In this section we will summarise and discuss the key findings of the empirical study concerning the reflective practices in the teams. We will look at the use of the four different reflective practice activities within the teams, and the interaction between the reflective practice activities within the teams, indicating patterns in the team’s reflective practice strategies. We will conclude on the insights gained from investigating the reflective practice within design teams.
Summary and discussion of the key findings

The reflective practice activities
The reflective practice theory provided a starting point for the research project. From Schön’s work we indicated that designers work by naming the relevant factors in the design situation, framing this situation in a certain way, making (experimental) moves toward a solution and reflecting on those moves (see chapter 2 and figure 36).

We looked at reflective practice in different situations, and now we will discuss how the teams deal with the four reflective practice activities. (We will only discuss the two teams that worked in a reflective practice way).

Tecc starts the design project by using names to divide the design task. Then the team chooses one of the names and makes that their frame for the moment. During the rest of the project Tecc keeps referring to earlier names as a stepping stone to create new frames.

Tecc uses six different frames sequentially during the design project. These frames originate from the different functions they have named early in the process (‘shooting the balls’, ‘collecting the balls’, and ‘driving the product’), but also from insights that the team gains while designing. The actual designing takes place as moves; when the team is really handling and changing the design content. Once the context for moving is set, by stating a frame, the moves work towards exploring the design task and challenging the chosen frame. Tecc reflects throughout the design project. Tecc’s reflection is initiated by evaluating what the team is doing in relation to the frame they are working in. A reflection can also be initiated by the design content. These moments of reflection always occur in relation to the current frame and the team’s progress in the design project.
Ivan, John and Kerry also explicitly use frames to approach the design task. Half an hour into the design assignment the team is generating (naming) frames for the design task; what they call ‘classifications’. Then they explore these different viewpoints on the design problem. They do this by exploring different frames and generating many alternatives, before integrating them into a total solution. Ivan, John and Kerry extensively explore four problem frames (“positions for the backpack”, “joining technology: pack to rack”, “joining technology: rack to bike”, and “materials”) before thinking about an integrated solution. This ‘frame less’ part of the design project is an interesting moment, where Ivan, John and Kerry try to evaluate all discovered potential solutions and try to integrate them into one design.

During the design project, in some moments of reflection Ivan, John and Kerry reflect on what they are doing at that specific moment. There are also reflections that are aimed at a broader perspective, where the team not only considers the current activity, but also the current frame. These reflections not only lead to new moves, but also to the reconsideration of the context (reframe).

In the analysis of the teams’ reflective practice we indicated that the teams name different issues in the design task. The team members pass these names over to each other and then decide upon a focus within the design problem. They do so by framing a view of the problem or the solution.

The actual designing takes place as moves; when the team is really handling and changing the design content. Moves outside frames appear to lack a shared goal. This lack makes it difficult to aim the team’s discussion. During the ‘frame less’ period of Ivan John and Kerry, they do agree on a procedure; evaluating earlier generated solutions. Even then the team has difficulties in aiming their discussion. While discussing earlier solutions, they come up with new ones (among which the tray-idea). The team reflects on this (“What we’re doing right now is again generating classifications for solutions”), and returns to the evaluation of solutions.

Frames are important elements for they improve the team’s moves, and therefore the team’s designing.

The two teams that design in a reflective practice manner both end up with an integrated concept. We expected frames to be important in tasks that require
subjective interpretation. Now they also seem to aid integration in the end product.

The development of frames, both stating a frame and modifying or rejecting it again, is important in building an understanding of the design task and its solution. This is guided by the mechanism of framing, reflecting and reframing. Therefore, reflection is crucial in designing. Only by reflecting on its design activities can a team of designers rationally make a decision to start a new activity or to reframe their approach towards the problem. Reflections are used to guide the progress and the quality of the design project.

Reflective practice strategies

All four activities can be found in the observed team design projects. All observed team design activities can be indicated as one of the four reflective practice activities. Applying the detailed mechanism of naming, framing, moving and reflecting onto a total design project also reveals patterns and large-scale strategies. Schön completely missed this for he described reflective practice as a locally controlled activity. The teams' descriptions are not just a flow of separate activities; patterns occur in the reflective practice of the teams.

It is interesting to notice that frames mostly end with a moment of reflection, where the team closes the current series of activities and moves on to the next (see figure 37). If necessary by reframing the problem. Such a mechanism indicates an underlying learning process, where the team creates an understanding of what they are doing and how the design content is developing. The exploration of the frame is concluded by reflection and so is the learning cycle within.

Not only frames help in this 'learning process'. Also conscious reflection on what the team is doing and where it gets them in solving the design problem, builds this knowledge and understanding of the design task. Regular reflecting in the project seems to be a precondition for reflective practice. We already indicated the pattern of reflections ending frames. In the empirical study we also identified
moments of reflection in a sequence of moves (see figure 38). Every now and then, the teams look critically at what they are doing, and then decide how to proceed.

Another pattern in the reflective practices of the teams is the development of frames throughout the project (see figure 39). Teams Tecc and Ivan, John and Kerry use different views of the problem to explore it. These views are generated early in the design project (naming). Following the development of these frames in the project traces the progression of the design content, as well as the understanding the team builds of their design task. The frames we identified in the empirical study are of a very practical and concrete nature. Tecc views the design problem as ‘shooting the balls’, ‘getting the balls into the basket’, and ‘simple and integrated solution’. The first two frames concern a part of the design problem, whereas the third frame indicates a view of the problem.

Ivan, John and Kerry explore three views of the design problem: ‘positions’, ‘joining techniques’ (divided in joining techniques ‘pack to rack’ and ‘rack to bike’), and ‘materials’. Although these frames may seem to be parts of the design problem, the team is really generating ideas for the whole solution, but from the viewpoint of the set frame. The frames derive from an extensive analysis on the design problem and are changed by insights the team gains in the design project.

In Ivan, John and Kerry’s design project we also identified sub frames (see figure 40). The team uses ideas, like “a leg that attatches right to the external frame”, or a “a little fold away trailer”, not as solutions to the overall problem, but as “spring boards” to explore a frame’s design possibilities. The occurrence of these sub frames (ideas for further exploration) does not seem to be random.
The ideas appear at the beginning of frames that seem difficult to approach. The team is looking for a way to deal with 'joining technology' or 'materials', which seem very abstract issues. Especially compared to the generation of ideas for 'positions'. They solve this by introducing a concrete idea to explore. The idea is subjected to discussion about the issues of the frame ('joining', and therefore ergonomical issues, and 'materials'), and in doing so they explore the frame itself.

There is a similar sort of moment in Tecc's design project where the bulldozer-idea, noticed and picked up by the whole team, has a major influence on the course of the project. When Tecc has set the frame 'collecting the balls', they are generating ideas for integrating collecting the balls in the chosen shooting concept. After generating ideas for five minutes, they decide that this will give them too complex a product. In the moment of reflection, while looking for a way to proceed, the idea of a bulldozer comes up. The exploration of the bulldozer idea makes them realise that they have to keep their product really simple and integrated. With this notion in mind they reframe their approach to the problem.

The bulldozer exploration is a very odd activity in Tecc's design process. The idea does not fit their earlier way of working (which was very structured), nor their earlier ideas (which were about functions of the product). However, all team members participate in the discussion of this idea. Imagining how the
bulldozer will collect the balls and just throw them all at once in the direction of the basket. Maybe one or two balls will hit; some may even score for the other side. The idea of the bulldozer seems to function as a stepping stone to discover what is of importance in the design problem, namely keeping the product very simple.

**Reflective practice as a view of team designing**

We investigated reflective practice in teams. We stated earlier that teamwork requires social interaction and communication on the part of the team members. This implies the challenge to synchronise their thoughts and activities to achieve a design: communication on the content related aspects of the design task. These content related aspects are difficult to define at the beginning of the project; they constantly develop during the design project and every single team member has a specific subjective interpretation of these aspects (see chapter 1).

Looking at the four reflective practice design activities it seems that **naming** and **moving** in teams work towards diversity of thoughts, whereas **framing** and **reflecting** aim for convergence of thoughts. Because **frames** and **reflections** are explicitly stated, they also aid the sharing of these thoughts within the team. Especially while **framing** and **reflecting** the team is creating shared understanding of the design task (**frame**) or the direction to take (**reflecting**).

**Framing** is an important tool to deal with the complex task of designing. **Frames** help to define the problem or solution as specific views, and therefore manageable parts. As a team activity **framing** also helps to focus the teams' attention. By explicitly verbalising **frames**, thoughts and interpretations of the design task are passed on and harmonised.

In the empirical study we saw that **frames** are used by the design teams themselves. **Frames** are not only a way of observing design by researchers (something we can identify while observing design). But teams actively and explicitly use **frames** in the design project. The designers also treat **frames** in a different manner than they do other items in the design process, as for instance ideas or information. This use of **frames** can be seen in two ways. First of all **frames** create a view that guides the following activities in a design process. In this way they provide a way
of dealing with the complex design task. Secondly, *frames* can serve as a social construct. By explicitly stating *frames* in a team a shared understanding is created. A shared understanding of the way the problem will be approached, and of the way the design content should be developed. Using and manipulating *frames* in design teams can therefore improve the creation of shared understanding between the team members.

*Reflection* plays a crucial role in the challenging and setting of *frames*. *Reflection* is also an important activity in learning. Kolb has located the concept of *reflection* in a sequence of activities of learning from practice (see figure 41).

Kolb's learning cycle starts with concrete experiences we have in daily practice. Reflective observation of those experiences can lead to satisfaction, which provides no drive for learning. If the *reflection* does not lead to satisfaction, we have to think of a new plan; abstract conceptualisation. Testing this plan, active experimentation, leads to new concrete experiences [Kolb 1984], see also [Buijs and Valkenburg 2000].

![Kolb's experiential learning cycle](image)

Kolb applies the cycle to a wide range of situations. He does not say very much about the process of *reflection*, he only attempts to locate it in experiential learning.

Looking for the underlying learning process in reflective practice, we can try to fit it in the learning cycle (see figure 42). According to Schön a designer starts by *naming* the objects in the problem, *framing* them in some way, and making
moves to solve the problem. Only if these moves cause a surprise, the designer will reflect on his activities. This reflection can lead to the making of new moves, or the reframing of the problem.

![Diagram](image)

**Figure 42** Reflective practice as a learning process.

In our empirical study we identified two types of reflection. In some reflections the team reflects on what they are doing at that moment. They notice that their current move does not have a desired result and they decide upon another move. We also indicated reflections that are aimed for a broader perspective, where the teams not only consider the current activity, but also the current frame. These reflections not only lead to new moves, but also to the reconsideration of the context (reframe).

Kolb indicates that reflection should always take place with consideration of the broader perspective, in order to be able to learn from it. Our data show that only reflections, considering the current frame lead to major reframes. In order to learn in designing and to build an understanding of the design problem, this type of reflection is necessary.

According to Schön, reflection-in-action only occurs in situations where the activity yields unexpected consequences (the surprise). We will discuss the surprise moments we noticed in the research project. In the Petra-Quist example, Petra missed the surprise; she got stuck and just did
not know what to do. Quist, hearing the problem for the first time, was able to react and reflect on the problem:

1 Petra is stuck
2 Quist reframes the problem

In the project of Tecc we indicated that the development of the 'bulldozer idea' can be seen as a surprise. In this process:

1 Tecc is stuck
2 They think of something completely different (the bulldozer)
3 They explore and evaluate the bulldozer
4 They use the outcome to reframe the problem

The sub frames that Ivan, John and Kerry use, have a similar function in the design process:

1 Ivan, John and Kerry start a new frame, which is difficult and abstract (for instance on materials)
2 They think of something completely different; a concrete idea (the fold away trailer)
3 They explore and evaluate the fold away trailer
4 They use the outcome to deal with the difficult frame.

We see that Petra and Tecc use the surprise to get out of the problem (a negative impulse). Ivan, John and Kerry use the surprise to deal with a problem in a positive way. Anyway, these surprises have a function in reflective practice.

Looking at reflective practice in design teams indicated interesting issues in the team’s processes. We discussed the use of frames as tools to pass on thoughts on the product design content in teams, as well as tools to deal with the complex task of designing. We put reflective practice in the perspective of experiential learning, and in doing so set conditions for the reflection activity. Finally, we discussed the potential value of surprises for solving problems the teams encounter in the design process.

These issues are interesting, because of their possibilities for intervening in the design activities of design teams by project managers or design tutors. Improving reflective practice can be done, among other ways, by intervening in the teams’ activities. Now we can formulate recommendations for improving team designing.
Improving team designing

The problem statement of this research project was:

**How can project managers manage the design contents of their product design project while at the same time achieve a shared understanding of this content among project team members?**

This research project is only a first step in the investigation of team designing in the real world. Some accomplishments turned out differently from what we expected them to and guided subsequent steps in the research project. Therefore the results do not deliver the exactly sufficient know-how for direct application in the practice of product design. The findings concerning reflective practice force us to investigate the usefulness of the theory further, before we may be able to develop practical tools and guidelines for project managers. As a result this research project ends with more recommendations for further research than it does on applications. That is not what it was originally meant to do.

However, we are not left completely empty-handed. Reflective practice provides us with insights into issues in designing that could not be attended to earlier. It provides us with a way of communicating, as well as a language to communicate, about issues in design that we were not able to ‘capture’ before. Intuitively accepting that working in a reflective practice manner delivers better results and learning processes, we can formulate recommendations for the improvement of design in a reflective practice manner.

**Recommendations for the practice of design**

From a reflective practice view we can define new roles for the project manager:

**Frame coach**

*Frames* provide a way of approaching the problem, as well as a way of harmonising thoughts and developing a shared aim as guide for activities. Projects that require a lot of integration seem to benefit from the use of *frames*. We also indicated that
frames seem to aid integration in the end product. This could be explained by the fact that experimenting in frames and experimenting with different frames increase the understanding of the design task. Therefore it enables the consideration of different views within this task.

We indicated frames as an approach towards the whole problem. But we also identified sub frames, as an approach towards the current frame. There may also be frames for entire projects, used in some sort of metaphorical way and over longer periods of times. In multidisciplinary design projects it is even be more important to consider the task from different views. It enables specialists to bring in their knowledge in a way that it supports the entire design. Experimenting with different frames, generating alternative frames, and enabling team members to bring in their specialist knowledge can be done by coaching the generating and use of frames by the project manager.

The project manager as a frame coach also sets requirements for the project manager, concerning his knowledge. The project manager must be able to understand what the frames are within the team. He must be able to estimate the usefulness of the frame, and to encourage the team in experimenting with frames. Therefore the choice of the project manager must, among other characteristics, be based on his knowledge on the content of the task; his ability to play with frames.

Reflection guard
Critical consideration of the activities within the team plays a crucial role in designing. Reflecting seems to be a repeating pattern within the team’s project. To stimulate this pattern the project manager can introduce moments of reflection at set times in the project. Initiating a pattern of reflections may enable the team to adopt reflection as ‘natural behaviour’.

Another way of stimulating reflection is the introduction of surprises. Surprises force the team to reflect in order to react on the surprise. Surprises may be questions or ideas. They may even be ‘random’. From literature on creativity we can learn that ‘random stimuli’ enable creativity [Buijs and Valkenburg 2000]. In a similar way surprises can be studied for design.
Major reframes in designing require reflections that consider the team's activities in the perspective of the current frame. The project manager must also guard this 'level of reflection'.

Move helper
Designers have a repertoire of moves; including for instance generating ideas, working out ideas in detail, evaluating ideas, and sketching ideas. These can be expected to be the skills of the designer, and therefore the team members in the project. How to implement these skills or when to do what, may be enabled by the project manager. He can also stimulate the team to experiment; try out different moves, spin a web of moves, evaluate moves, and estimate the consequences of moves.
Frames guide further activities and therefore moves. Frames can improve the result of moves, and therefore the designing. Frames seem to have an amount of value in the creation or initiation of moves. Coaching frames is therefore also an important role in helping to improve moves.

A lot of questions remain about how to improve team design practice. Especially in design projects in the real world it is interesting to know how to organise projects and teams to be able to work effectively with frames. In what way should frames be used, or what is good experimenting with and within frames? These are just some examples of remaining questions for further research.

Recommendations for design education
“...The paradox of learning a really new competence is that a student cannot at first understand what he needs to learn, can learn it only by educating himself, and can educate himself only by beginning to do what he does not yet understand...” [Schön 1987a, page 157]. That is why Schön said: “Designing is learnable, coachable, but not teachable...” [Schön 1987a, page 157]. We do not totally agree with this. Reflective practice provides a context for addressing issues in designing that are ignored in other methods of designing. Explicitly stating them and giving them attention will help to communicate on this important part of the design activity.
In current design education, students are taught design processes and techniques. In design exercises they then have to practice designing. Design tutors coach the students in their design projects and facilitate the learning processes within. The design processes that are taught deal with only part of designing as practised. They indicate different phases in the design process and provide a way to manage and plan the design project. Designing, however, is also about trying to understand the design problem; interpreting what the nature of the design task is, how to approach it and what a good solution to the question is. This is determined to a large extent by the designer’s interpretation; he has to make choices depending on what he believes matters most and from which viewpoint he should consider the design. We regret that such an important aspect of designing is left to the artistry of the design tutor and of the design student.

This research project showed that this part of designing could very well be indicated with reflective practice. Looking at design as reflective practice provides a clear picture of the designer’s attitude towards the problem. We also think that reflective practice can be taught and coached better.

Teaching reflective practice
Making students aware of insights from reflective practice is the first step in teaching them to apply it. Presently, students are taught about ‘Programs of Requirements’ and ‘Morphological Charts’, but not about, for instance, ‘Frames’. Providing students (and tutors) with a language to communicate about the difficult and subjective issues within design projects, can help them to understand this part of designing.

Reflective practice descriptions provide a clear picture of design projects. These pictures can be used to describe projects afterwards (as in this research project), but also projects that are on-going. These pictures can be made from the students’ own design projects, but also from projects of designers in the real world. Explicitly addressing reflective practice in design, in student’s work as well as in case studies, can provide students with a ‘repertoire’ of reflective practice experiences. A repertoire that includes different ways of framing problems, of making choices in different design situations, of dealing with surprises, or of possible outcomes of reflections. A repertoire that can help elicit tacit learning experiences of a delicate part of designing.
Coaching reflective practice
Current design exercises aim for 'learning by doing'. In his work Schön referred to 'learning by doing and coaching'. Coaching students is very important to facilitate the student's designing as well as the underlying learning process. From a reflective practice view the role of the design tutor can be defined:

- Teaching the student to reflect: challenge frames and moves within the design project.
- Inviting the student to use and develop different frames for the problem situation; provide alternative frames, alternative moves, and indicate consequences of moves.
- Making sure the student goes through the entire learning cycle.
- Teaching the student to make use of surprises; even impart the sensitivity for surprises.

Frames can be very well identified in design projects. We have shown the identification of frames in observations of design teams at work. However, frames can also be identified in discussions with designers (or design students) of their work. By asking very simple questions as "What do you think is important in this design problem?" the current frames of the designer can be traced. After identifying the current frame, also other possible frames can be discussed.

In tutoring product design students in their final project, I try to trace the students' framing of the problem and make this frame clear for the student. This provides the student with an insight into what he is doing, as well as making him aware of possible alternatives. Clearly knowing what is happening makes it easier to adjust, reconsider, or think of alternative approaches. In complex design problems, alternative frames can also be used to divide the problem in manageable parts without losing the relationship between these parts.

For example in the design of a baby carrier for use on bikes [Van Leeuwen 1999], frames were generated that viewed the problem as:
A The location of the product on the bike, concerning issues as safety and mobility.
B The safety of the baby, concerning issues as falling of the bike, rocking and bumping.
C Handling the baby, concerning issues as transportation before and after
cycling and stability of the bike while standing.

D Support of the baby, concerning ergonomical issues of the baby and the parent.

Each of these four ways of framing the problem provided a way of exploring issues and generating possibilities (see figure 43). Each possibility delivers a complete design, optimised from one point of view. Exploring the different frames increased the student's understanding of the problem and helped her to make choices for the final design, which had to be optimised from all frames.

Incorporating a reflective practice way of working in design education will give rise to new questions. To address these questions, an educational research program on coaching and learning by doing could be set up. The School of Industrial
Design Engineering at the Delft University of Technology is the largest school on product design in the world (with over 1800 students). If anywhere, there an educational research on designing is suited.

**Recommendations for further research**

This research project started out as a study of team designing. The results from looking at team designing as reflective practice also made it into a study of designing.

The premise of this research project was the theory of reflective practice. Observing practitioners at work was the basis of this theory and Schön indicated that it reflects the artistry of designing. However, in this research project we found that reflective practice is not the only way of designing. Other varieties of designing also occur. Our data also show that teams that do work in a reflective practice manner seem to perform better. Their solutions seem to be better thought out and evaluated, which resulted in a higher level of integration of the design. The teams' understanding of the design task, gained through the underlying learning process, also seems better. This calls for an investigation into the use and success of a reflective practice way of designing.

Also, as we studied product design teams questions have come up whether reflective practice is also current in other design fields, such as architecture or engineering design.

Reflective practice also enables us to study these design fields in more detail. Design Methodology deals mostly with general methods and theories, concerning every design field. Applying these general methods and theories to a specific situation often poses problems for the designer(s). Applying the reflective practice method is a way of addressing some of these problems, for instance the development of *frames*. However, these problems depend on the content of the design problem and on the specific situation. Further research should therefore take place within the different design fields.

Scientists in the field of management should also extend their research towards the areas where management knowledge is used. We indicated the relationship of project management and the content of what is managed. Researchers of the management of team design projects should extend their investigations towards designing.
Looking back on this research project, keeping in mind what we know now, our results can be combined with insights from literature on teams. Now that we know the importance of *frames* and *reflection* in team designing, we can try to improve our understanding by taking into account, for instance, the maturity of teams (group development stages), leadership roles or languages in a team. It is to be expected that these aspects can influence the skills of *framing* and *reflecting* in the team (see also chapter 5 in [Buijs and Valkenburg 2000]).

Much can be learned from empirical studies of designing. In this research project we studied design teams in special settings (competition and experiment). For future research on reflective practice, we should include examining team designing as a professional performance.

Studying design as it is experienced requires the development of research methods that are able to ‘capture’ the complex interplay of variables in real life settings. Design researchers are already looking into this direction by introducing research methods from other disciplines into the study of design, such as ethnographic research (see the special issue of Design Studies [Jagodzinski et al 2000]).

Describing product design projects as reflective practice provides a good way of observing, for it provides structure in the design project (with the design activities *naming, framing, moving, and reflecting*), without prestructuring variables concerning the designers and the design contents of the project. The descriptions of the team’s projects are very inspirational. We can follow the course of these projects. In this research project we have only observed design teams afterwards. We could question the need for further (video) observation on this detailed level.

Research into the reflective practice of design teams can easily be done while the design teams are at work, applying research methods as interviewing.

Focussing on designing as it is experienced by practitioners remains necessary to provide insights and improve designing. Initiatives such as the conferences on ‘CoDesigning’ [Scrivener et al 2000] and the forthcoming ‘Designing in context’ (Lloyd and Christiaans 2000) are valuable for they indicate the importance of studying design as it is experienced in the real world.
Reflective practice is a way of working. It can be applied to a wide range of situations. I have shown its application in designing, teaching and doing research. In this research project I have set my own frame time and again. I have tried to challenge your frame. I hope to have given you enough surprises to reframe your thoughts. The reflection, however, is really up to you.
The Reflective Practice in product design teams

Current practice in product development is becoming more and more complex, because of increasing integration of required knowledge and communication. In order to efficiently organise this process product development teams have lately come to the fore. This shift from design as an individual activity towards design as a team activity has produced new aspects in the design process. The design team has to communicate and interact. Project managers face problems concerning synchronisation and harmonisation of the design content within teams.

Recent literature on design indicates a shift from studies on design processes towards studies on design in its constantly changing context. Recent empirical studies reveal insights into the complexity of co-operation in design. However they merely indicate the problems, without offering tools or guidelines to improve the content related communication within teams. The problem statement of this research project is: How can project managers manage the design contents of their product design project while at the same time achieve a shared understanding of this content among the project team members?

What can we learn from looking at design teams? To gain insight into the nature of team designing we will observe design teams at work, after which these observations will have to be analysed. A method will have to be developed that enables us to describe team designing.

Therefore, this research project will look for an answer to two research questions:
- How can we describe team design activities?
- What can we learn from design teams at work?

We have chosen the theory developed by Donald Schön. He considers designing as a reflective practice. By focussing on design activities, this theory looks at who (the designer), does (the design process) what (the design task). In this way this theory maintains the complex integrative character of designing and therefore
seems well suited to our purpose.

Schön's basic assumption is that the designer determines his position in the design situation. By interpreting the design situation in his own subjective way, the designer creates a context for further activities. By constantly considering his activities and their implications, the designer can adjust the activities, or adjust his interpretation of the situation. From Schön's descriptions of this process of reflective practice, we created a schematic representation of the four reflective practice activities: designers work by naming the relevant factors in the design situation, framing this situation in a certain way, making moves toward a solution and reflecting on those moves.

In this research project two empirical studies will be executed. In the first empirical study we will explore the method of description as well as the reflective practice of the design teams. In the second study the method of description will be validated and the reflective practice of the design teams will be studied in closer detail.

How can we describe team design activity?

To answer the question: "How can we describe team design activity?" we have developed a research method that gives us the means to study team designing. Applying the model of reflective practice requires the development of a method of description to process observations of team designing. Processing these data, they are first divided up into segments and subsequently these segments are coded according to our method of description. This requires the four reflective practice activities (naming, framing, moving, and reflecting) to be differentiated and identified.

If we take Schön's theory as a guideline we find that the definitions of the four reflective practice activities are weak. Defining the four reflective practice activities is difficult, however it is possible to identify and differentiate them in team designing.

In the second study we validated the method of description. We found a way to deal with subjective interpretation of different coders in data processing. At first different coders process these data independently of each other. Then the differences in results will be made explicit in an arbitration discussion.
This proved to be a useful evaluation method to reliably deal with subjective interpretations in data processing.

The answers to this research question show that reflective practice as a research method works. They also show that not all designing is done in a reflective practice way. The teams that do work in this way seem to perform better. Better in the sense that the team learns more within the design project and that the end result has a higher level of integration. Finally the descriptions of design projects give a good overview of how the team works during a project and how the design content develops within a project.

What can we learn from design teams at work?

Our second research question: “What can we learn from design teams at work?” asks after the nature of team designing. We are interested in the creation of a shared understanding of the design content within teams and will use reflective practice as a supporting concept to study team designing.

In the exploration of the teams’ reflective practice we see that the teams name different issues within the design task. The team members pass these names to each other and then decide upon a focus within the design problem. They do so by framing a view on the problem or the solution. The actual designing takes place through moves, when the team is changing the design content. Moves outside frames appeared to lack a shared goal. This lack of a shared goal makes it difficult to focus the team’s discussions. Reflection is crucial in designing. Only by reflecting on its design activities can a team of designers rationally decide to start a new activity or to reframe their approach towards the problem.

In the second empirical study the moments of framing and reflecting are studied in more detail, looking at the communication within the teams in these moments. In this study we saw that teams actively and explicitly use frames in the design project. The development of frames, both stating a frame and modifying or rejecting it again, is important in creating understanding of the design problem and it’s solution. Frames can be used in two different ways. First of all frames create a view that guides the next activities in a design process. In this way
they provide a way of dealing with the complex design task. Secondly, frames can serve as a social construct. By explicitly discussing frames in a team, shared understanding is created. A shared understanding of the way the problem will be approached, and of the way the design content should be developed. Using and playing with frames in design teams can therefore improve the creation of shared understanding between the team members.

Reflection plays a crucial role in the challenging and setting of frames. In our empirical study we identified two types of reflection. In some reflections the team reflects on what they are doing at that moment. They notice that their current move does not have a desired result and they decide upon another move. We also identified reflections that are aimed at a broader perspective, where the teams not only consider the current activity, but also the current frame. These reflections not only lead to new moves, but also to the reconsideration of the context (reframe). Reflections are used to guide the progress and the quality of the design project. Looking at team designing from a reflective practice point of view reveals the underlying learning process going on within the teams.

Conclusion

Applying reflective practice as research method provides us with a detailed empirical investigation on examples of team designing. Evaluating the research method we learned to deal with Schön's legacy and developed a way to deal with subjective interpretation in qualitative research.

Schön describes reflective practice as an individual, limited activity. We extended reflective practice to include design projects, performed by teams. Applying the method of reflective practice to an entire project also shows different patterns of how a team approaches a problem and how the design content progresses.

Some results turned out differently than we expected them to. We could not completely validate the research method, in the sense that every coder would get the same results from data processing. We did, however, develop a way for dealing with differences in data processing, which is of more use in this type of research. We can not provide clear definitions of the notions within the theory of reflective practice, but we did find a way to observe and identify them in the practice of team designing. Finally the results indicate that not all designing is
reflective practice, as Schön indicates.

**Recommendations**

From a reflective practice view we can now define new roles for the design project manager. The team’s progress and the quality of the design content can be managed by the project manager as a *frame* coach, *reflection* guard, or *move* helper. These roles can also be given to design tutors in design education. The results of this research project do not deliver the exact know how for direct application in the practice of product design. We think the theory and her usefulness should be investigated further. Only then we can develop practical tools and guidelines.

The empirical studies show that reflective practice is a useful method of description for team designing and that the teams work in a reflective practice way. However, a lot is still to be investigated:

- This research project was supposed to be a study into team designing. The results from looking at team designing as reflective practice also made it a study into designing. We studies product design teams and questions arise whether this way of designing also occurs in other design disciplines, such as architecture of engineering design.
- The reflective practice view indicates problems that designers encounter in specific situations. These problems, for instance concerning the development of *frames*, depend on the design problem and the specific situation. Further research should extent into these problems and go into the different design disciplines.
- This can also be applied to management science. We indicated the relationship of project management and the content of what is managed. Researchers should extend their interest towards the disciplines where management knowledge is used. Researchers on the management of team design projects should therefore extend their interest towards the content of the design project.
- In this research project we indicated important notions in team designing, e.g. *frames* and *reflections*. Now we can integrate this know how with insights from literature on teams. For instance what is the influence of group development of leadership style on the reflective practice of the teams?
• Much can be learned from empirical studies of designing. In this research project we studied design teams in special settings (competition and experiment). Future research should extend to team designing in the real world. Studying design as it is experienced requires the development of research methods that are able to 'capture' the complex interplay of variables in real life settings. Design researchers are developing in this direction, for instance by introducing research methods from other disciplines into the study of design.

We hope that the results of this research project will contribute to the reconsideration of current frames for designing, design education and design research. However, reflection is also in this crucial.
De reflectieve manier van werken in productontwikkelingsteams

De huidige productontwikkelingspraktijk wordt complexer door de toenemende integratie van benodigde kennis en communicatie. Om dit goed te kunnen organiseren worden steeds vaker projectteams ingezet. Deze verschuiving in de productontwikkeling van een individuele naar een teamactiviteit brengt nieuwe aspecten met zich mee in ontwerpprocessen. Projectmanagers krijgen bijvoorbeeld te maken met problemen op het gebied van synchroniseren en coördineren van de ontwerptaak tussen teamleden.

Recente literatuur over ontwerpen geeft een verschuiving aan van het bestuderen van ontwerpprocessen naar het bestuderen van ontwerpen in zijn natuurlijke omgeving. Een omgeving die continu verandert en het ontwerpen beïnvloedt. Deze empirische studies geven meer en meer inzicht in de complexiteit van samenwerken in productontwerpen. De meeste studies geven helaas alleen (nog) de problemen hiervan aan, zonder aan te geven hoe de samenwerking en communicatie in teams verbeterd kan worden. De probleemstelling van dit onderzoek is: Hoe kunnen projectmanagers hun productontwerpprojecten zo besturen dat zij met hun teamleden een gezamenlijk beeld creëren van de ontwerphinhoud?

Wat kunnen we leren van ontwerpteams? Om daar inzicht in te verkrijgen zullen teams die aan het werk zijn geobserveerd worden, waarna de waarnemingen worden geanalyseerd. Daartoe zal een methode ontwikkeld worden, die het mogelijk maakt om ontwerpen in teamverband te beschrijven. Het onderzoeksp project zoekt dus antwoord op twee onderzoeksvragen:
- Hoe kunnen we teamontwerpen beschrijven?
- Wat kunnen we leren van ontwerpteams aan het werk?

Als uitgangspunt voor de beschrijvingsmethode is de theorie van Donald Schön gekozen. Hij beschouwt ontwerpen als een reflecterende manier van werken ('reflective practice'). Door ontwerppractiviteiten centraal te stellen wordt gekeken naar wie (de ontwerper), wat (de ontwerptaak), hoe (het ontwerpproces) doet. Daarm
mee behoudt deze manier van kijken naar ontwerpen het complexe integrale aspect van ontwerpen en lijkt daarmee zeer geschikt voor ons doel. Schön's uitgangspunt is dat de ontwerper zelf zijn positie in de ontwerpsituatie bepaalt. De ontwerper interpreteert de opdracht op zijn eigen, subjectieve manier en creëert daarmee een context voor verdere activiteiten. Door deze activiteiten en hun gevolgen voortdurend aan een kritische beschouwing te onderwerpen, kan de ontwerper zijn gedrag of zijn interpretatie aanpassen.

Met Schön's beschrijvingen van dit proces van reflectief werken als uitgangspunt, hebben wij een model gemaakt van de vier activiteiten in de reflectieve werkwijze: ontwerpers ontwerpen door de relevante aspecten in de ontwerpsituatie te benoe- men ('naming'). Zij creëren een kader, van waaruit zij de situatie zullen benaderen ('framing'). Vervolgens gaan ze doen; binnen het kader ontwerpen zij een oplos- sing ('moving'). Vervolgens reflecteren ('reflecting') zij op dit doen.

In het onderzoeksproject worden twee empirische studies uitgevoerd. In de eerste studie wordt de beschrijvingsmethode geëxploréerd, evenals de reflectieve werkwijze van de teams. In de tweede studie wordt de beschrijvingsmethode gevalideerd en de reflectieve werkwijze van de teams meer in detail bestudeerd.

Hoe kunnen we teamontwerpen beschrijven?

Voor de vraag 'Hoe kunnen we teamontwerpen beschrijven?' hebben we de onderzoeksmethode die ons de mogelijkheid moet geven te bestuderen ontwikkeld. Toepassen van het model van reflectief werken vereist de ontwikkeling van een beschrijvingsmethode waarmee teamobservaties verwerkt kunnen worden. Bij deze data verwerking wordt de data eerst verdeeld in segmenten en vervolgens worden deze segmenten gecodeerd volgens de beschrijvingsmethode. Voor de data verwerking moeten de vier activiteiten (benoemen, inkaderen, doen en reflecteren) daarom onderscheiden en geïdentificeerd worden. Vanuit Schön's werk is het moeilijk de vier activiteiten van reflectief eenduidig te definiëren. In de studie blijkt echter dat ze wel geïdentificeerd kunnen worden in teamontwerp

pen.

In de tweede studie is de beschrijvingsmethode gevalideerd. We hebben een manier ontwikkeld die de gelegenheid biedt om te gaan met subjectieve interpretatie van verschillende codeerders in data verwerking. Verschillende codeerders
verwerken de data eerst onafhankelijk. Vervolgens worden in een geleide discussie de verschillende beschrijvingen en verschillen daartussen expliciet gemaakt en besproken. Dit blijkt een goede evaluatie methode om verschillende subjectieve interpretaties te kunnen behandelen in data verwerking.

De resultaten met betrekking tot deze onderzoeksvraag geven aan dat reflectief werken als methode operationaliseerbaar is. Uit de resultaten blijkt ook dat niet alle teams ontwerpen op een reflectieve manier. De teams die wel op een reflectieve manier werken lijken het beter te doen. Beter in de zin van een beter leerproces in het ontwerpproject en in de zin van een beter geïntegreerde oplossing als resultaat. Tenslotte geven de beschrijvingen van ontwerpprojecten op deze manier ook een goed overzicht van wat het team doet gedurende het project en hoe de ontwerpinhoud zich binnen het project ontwikkelt.

Wat kunnen we leren van ontwerpteams aan het werk?

Bij de tweede onderzoeksvraag "Wat kunnen we leren van ontwerpteams aan het werk?" bestuderen we de aard van teamontwerpen. We zijn geïnteresseerd in de wijze waarop het team een gezamenlijk beeld opbouwt over de inhoud van het project. We gebruiken de reflectieve manier van werken als een manier van kijken naar teamontwerpen.


In de tweede empirische studie zijn daarom de momenten waarop de teams kaderen en reflecteren gedetailleerder onderzocht, door te kijken naar de communicatie in het team op deze momenten. In deze studie zien we dat de teams zelf actief
en expliciet gebruik maken van *kaders* in het ontwerpproject. Het verkennen en ontwikkelen van verschillende *kaders*, zowel het vaststellen van een *kader* als de aanpassing of verwerping ervan, blijkt belangrijk te zijn in het opbouwen van een (gezamenlijk) begrip van de ontwerpopdracht en de mogelijke oplossingen. De gebruikte *kaders* hebben dan twee doelen. Ten eerste vormt een *kader* een manier om het probleem aan te pakken en daarmee creëert het een context om verder te *doen*. Een complexe ontwerpopdracht kan daarmee hanteerbaar gemaakt worden. Ten tweede hebben de *kaders* een sociaal doel. Door expliciet te discussiëren over *kaders* creëert het team een gezamenlijk beeld. Een beeld over hoe het probleem benaderd moet worden en wat er gedaan moet worden. Het gebruiken en spelen met verschillende *kaders* in ontwerpteams kan daarom het creëren van een gezamenlijk beeld tussen teamleden verbeteren.

*Reflectie* speelt een belangrijke rol bij het uitdagen en het vaststellen van *kaders*. In de empirische studie hebben we twee soorten *reflecties* onderscheiden. In sommige *reflectiemomenten* *reflecteert* het team op wat ze op dat moment aan het *doen* zijn. Ze merken op dat hun huidige manier van *doen* niet het gewenste resultaat oplevert en besluiten iets anders te gaan *doen*. We zien ook *reflectiemomenten*, waarin het team niet alleen *reflecteert* op wat ze *doen*, maar dat ook in relatie zien tot het gestelde *kader*. Deze *reflecties* leiden niet alleen tot andere activiteiten, maar ook tot het heroverwegen van de context daarvan (*herkaderen*). *Reflecties* worden zo gebruikt om de voortgang en de kwaliteit van het ontwerpproject te sturen. Op deze manier kijken naar team ontwerpen geeft inzicht in een onderliggende leerproces binnen het team.

**Conclusies**

Het toepassen van *reflectief werken* als beschrijvingsmethode levert zeer gedetailleerde beschrijvingen op van team ontweractiviteiten. Bij het evalueren van de onderzoeksmethode hebben we leren omgaan met Schön's gedachtengoed en een methode ontwikkeld om om te gaan met subjectieve interpretatie in kwalitatief onderzoek.

Schön beschrijft reflectief werken als een individuele, kortdurende activiteit. Wij hebben *reflectief werken* uitgebreid naar projecten, uitgevoerd door teams. Toepassen op ontwerpprojecten geeft ook inzicht in de aanpak van het gehele probleem en de ontwikkeling van de ontwerpinhoud. Het levert een duidelijk, visueel beeld
op van wat het team aan het doen is en hoe het ontwerp daarin ontstaat.

Sommige dingen in dit onderzoek bleken anders te zijn dan we hadden verwacht. Zo bleek het niet mogelijk te zijn de beschrijvingsmethode zodanig te valideren dat iedere codeerder altijd dezelfde beslissing neemt bij het verwerken van de data. Wel hebben we een methode ontwikkeld om op een betrouwbare manier met verschillen tussen codeerders om te gaan. Dat is, naar onze mening, veel zinvoller in onderzoek. Het blijkt ook niet mogelijk om de gebruikte begrippen in de reflectieve manier van werken (benoemen, inkaderen, doen en reflecteren) eenduidig te definiëren, maar we hebben wel een manier ontwikkeld om deze begrippen te observeren en te identificeren in ontwerpleiders die aan het werk zijn. Tenslotte geeft de data aan dat niet al het ontwerpen reflectief werken is, zoals Schön beweert.

Aanbevelingen
Vanuit de inzichten die verkregen zijn door de reflectieve manier van werken in teams te bestuderen kunnen we nieuwe rollen definiëren voor een projectmanag-

Uit de empirische studies blijkt dat reflectief werken een goede beschrijvingsmethode oplevert voor teamontwerpen en dat de teams op een reflectieve manier werken. Natuurlijk blijft er veel verder te onderzoeken:

- Dit onderzoeksproject is uiteindelijk ook een onderzoek naar ontwerpen geworden. De resultaten van het bestuderen van ontwerpleiders vanuit het oogpunt van reflectief werken, wekken nieuwsgierigheid naar de mogelijke toepassing ervan in andere ontwerpdisciplines.
- Deze manier van kijken geeft inzicht in problemen, die ontwerpers hebben in specifieke situaties. Deze problemen, bijvoorbeeld bij het omgaan met kaders,
zijn afhankelijk van het ontwerpprobleem en de specifieke situatie. Verder onderzoek zou hier verder op door moeten gaan, waarmee het zich kan verdiepen in de verschillende ontwerpdisciplines.

- Deze verdieping geldt ook voor de management wetenschappen. In dit onderzoek hebben we de relatie aangegeven tussen projectmanagement en de inhoud die gemanaged wordt. Onderzoekers op het gebied van management zullen zich ook moeten verdiepen in de disciplines waar de bedrijfskundige kennis wordt toegepast. Dus onderzoekers op het gebied van management van ontwerpprocessen zullen hun interesse moeten uitbreiden naar de inhoud van de ontwerpprojecten.

- We hebben in dit onderzoek een aantal belangrijke issues in teamontwerpen aangegeven, waaronder kaders en reflectiemomenten. Nu kunnen we deze kennis integreren met inzichten vanuit de literatuur over teams. Wat is bijvoorbeeld de invloed van de groepsontwikkeling of leiderschapsstijl op de reflectieve manier van werken in de teams?

- We kunnen erg veel leren van empirische studies van ontwerpen. Maar om meer te weten te komen over ontwerpen in zijn complexe en veranderlijke omgeving zal het ook in die omgeving bestudeerd moeten worden. In onze empirische studies hebben we teams onderzocht in speciale situaties (een ontwerp wedstrijd en een experiment). Vervolgonderzoek zal uitgebreid moeten worden naar ontwerpteams in de praktijk. Het bestuderen van ontwerpen in de werkelijkheid noodzaakt dan ook tot de ontwikkeling van onderzoeksmethoden waarin het mogelijk is om het complexe samenspel van variabelen te vangen die in praktijksituaties een rol spelen. Op dit moment zijn onderzoekers al op zoek naar dergelijke methoden, ook vanuit andere disciplines. Deze zullen dan specifiek toegepast moeten worden op het complexe proces van ontwerpen.

We hopen dat de resultaten van dit onderzoek bijdragen aan het heroverwegen van de huidige kaders voor ontwerpen, ontwerponderwijs en ontwerponderzoek. Maar reflectie is ook hierin cruciaal.


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