

Human-Centered Design Methodology

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1. Introduction

At the conference Design Research in the Netherlands 1995, 10 years ago, our Design Methodology Group was introduced by Kees Dorst with the following sentences: *“The Delft faculty of Industrial Design Engineering has a five-person group working on Design Methodology. Organizationally this group is linked to the department of New Product Development, Section Innovation Management.”* One year later Nigel Cross left and the chair of Design Theory and Methodology remained vacant over the last 8 years. This situation has now changed; since 1st October 2004 Petra Badke-Schaub was appointed as Professor of Design Theory and Methodology in the department of Product Innovation Management in the now separate faculty of Industrial Design.

Thus, we want to take the opportunity to dedicate one part of the paper to our research intentions and to our future design research topics (see section 5). The paper starts with a short introductory discussion about the question of a shared understanding of design methodology in the design community. We then present a rough overview of the research of the group during the last years (see section 3) which was mainly related to the analysis of design processes. The fourth section refers to the question ‘how to get meaningful results,’ what are the research methods we are using and going to use in our future research projects (see section 4). Hence, the paper is divided into the following four parts:

1. Design Methodology: a ‘shared understanding’?
2. Studying design processes: what was our focus during the last four years?
3. Research methods: how to get meaningful results?
4. Human-centred Design Methodology: a research programme.

2. Design Methodology: a ‘shared understanding’?

If we accept that designing is not a purely intuitive artistic activity but can be taught, we need a body of knowledge which to a certain degree is proven to being relevant for the education of designing and for the support of the designer’s daily work. Thus, design methodology should integrate knowledge which is being developed, applied and evaluated in order to provide support in designing.

Analysing the current situation of design research, the situation gives reason for optimism, when we consider the growing amount of data and studies published in various scientific journals from researchers from different disciplines. The drawback of this situation is that most empirical results are highly restricted to the particular context - the validity of the data has mostly not been established beyond the specific situation in which the data are collected. Thus, we do not know how to combine results and how to transfer the results to other subjects

and situations. At the same time the number of methods, techniques, and design tools being developed is increasing and covers a broad field within and between disciplines.

But although different disciplines propose different approaches to designing in order to obtain optimum results there are similarities related to two issues:

- *General strategies, heuristics, operations* which may guarantee a successful result: The famous work by Descartes ‘Rules for the Direction of the Mind’ (‘Regulae ad directionem ingenii’, written 1628, published 1701) refers to some general rules such as the reduction of the complexity of problems. Descartes was convinced that in finding the proper method scientific progress would follow. Nowadays software design, engineering design, architecture as well as physics and many other disciplines recommend to plan your process, to subdivide complex design problems into sub-problems, to evaluate before decide and to proceed from general to particular, from abstract to concrete, and from important to less important.
- *A basic underlying structure* of the process which refers to the main requirements of a given task or problem: There are various models aiming at structuring the design process. A closer look at different procedural models (see for example French 1971; Pahl and Beitz 1984, 1996; Pahl, Beitz and Feldhusen 2004; Roozenburg and Eekels 1995; VDI 2221 1986) reveals a basic underlying structure which can be referred to the principles of the general problem solving theory (Dörner 1972, 1996) as well as to systems-engineering-theory (Hall 1962). The differences are mainly related to the degree of abstractness and generalisation, although newer revisions try to explicitly avoid rigid divisions between the phases and stress the flexibility of the designer (see for example Ehrlenspiel 1995; Lindemann 2004).

Of course, the underlying assumption is that designers following design methodology will perform better than designers who don’t. However, we also know from empirical studies that designers in practice rarely follow the basic principles, which methodology prescribes. And it is not necessarily true that their ways of working will lead to a negative design result (Günther and Ehrlenspiel 1999). Whereas if designers are using at least basic principles of design methodology, such as a detailed goal analysis, explicit divergent and then convergent solution search, detailed evaluation of solutions and reflection on the own action and thinking strategies they showed successful results.

Hence, the important question is: Which influences on the designer (and to what extent) do design methodology as a body of knowledge neglect? Which specific factors and constraints lead to different design processes and thus to different outcomes?

The consequence is that there is an essential need to know of how designers work and think, what particular problems may occur in a particular situation and which methods, tools and techniques might help in this situation.

3. Studying design processes: what was our focus during the last four years?

As mentioned before there is a need for empirical studies which provide a deeper understanding of design. What is needed is to take a closer empirical look at what designers really do while designing. This look, however, shall be solidly grounded in theory again, taking into account aspects of normative design theories, theories of creativity and problem-solving and cognitive theories of human decision-making.

The past four years have seen the group focussing on aspects of the design process that were previously treated as parts of a whole. The dominant research approach of the group has long been that of protocol analysis deriving from the now famous Delft Protocol Workshops organised by Nigel Cross, Kees Dorst and Henri Christiaans (1994). This research methodology – essentially recording design activity and then analysing the concepts that are being used in that activity – has provided a strong and flexible foundation for the research during the past four years. It has provided a way of keeping the complexity of design processes while allowing researchers to focus on distinct elements that go to make up that activity. The research has also been more closely linked with design education in a number of projects. Research has included the following subjects which will be dealt with in more detail below:

- Reflective practice in design education.
- Sketching during idea generation in the design process.
- Discourse analysis of design processes.
- Ethical decision-making in design.

Reflective practice in designing

The work of Donald Schön (1983) and Larry Bucciarelli (1995) has been a key influence on the group's output for some years and there are now a number of projects using the theory of reflective practice in empirical studies within the group (see for example Kleinsmann and Valkenburg 2003; Valkenburg 2000). A project that was completed successfully in 2003 relating to reflective practice was VALiD – Video Assisted Learning in Design (McDonnell, Lloyd and Valkenburg 2004). This project used the technology of digital video to study the learning processes that are embedded within the design process. The idea was to let a team of designers film their own design process and edit a short film of the design process from the footage. During the process of watching their own footage, selecting 'important' bits during editing and compiling the edited film, there were a number of identifiable learning moments. The 're-experiencing' that the video allowed provided a number of interesting insights into the original process of design.

Sketching during idea generation in the design process

In a PhD thesis and a number of papers Remko van der Lugt (2001) has analysed at how sketching and the idea generation process are inter-linked. Using the method of protocol analysis a number of 'braindrawing' sessions by teams of designers were filmed and analysed using linkography (van der Lugt 2002). This research revealed how ideas deriving from visual information associated to, and built on, earlier ideas in the session. These insights have important consequences for the way of how brainstorming and braindrawing sessions should be used within the design process.

Discourse analysis of design processes

In several studies Peter Lloyd has focussed on the way that designers use words during the process of design. The data for these studies has ranged from a number of different sources including design practice (Lloyd and Busby 2001) to television programmes about the design process (Lloyd 2002) to commentary on the design process (Lloyd 2003). All studies however have critically examined the concepts and assumptions that designers use in designing. The studies emphasise the important role that rhetoric (the art of convincing) plays during even the most technical discussions in the design processes, and particularly the idea of storytelling.

Ethical decision-making in design

Following on from the studies of discourse has been research into the ethical nature of decision-making in design (Lloyd and Busby 2003). This has been looked at, not at the global level which is traditionally the case, but at the micro level in discussions and conversations that designers have with each other and the ethical assumptions that they use. Results have shown how closely ethical judgments in technical disciplines are related to aesthetic judgements and also how normative much of the discourse in design is.

Design conferences

The group has also organised two international conferences during the past four years. *Designing in Context: Design Thinking Research Symposium 5* (Lloyd and Christiaans 2001) looked at how the environment of design affects design activity. *The Changing Face of Design Education: The 2nd International Engineering and Product Design Education Conference* (Lloyd, Roozenburg, McMahon and Brodhurst 2004) brought together top design educators from around the world. Papers from both these conferences are available online (<http://www.io.tudelft.nl/iepde04/>).

4. Research methods: how to get meaningful results?

The choice for a particular research method depends on the aim of the study, the research question. Or to speak with Homans: “*People who write about methodology often forget that it is a matter of strategy, not of morals. There are neither good nor bad methods, but only methods that are more or less effective under particular circumstances in reaching objectives on the way to a distant goal.*” (Homans 1949).

Our primary focus is to understand designing as a human activity, involving cognitive and motivational processes. Therefore, from very early on the DM group as well as in research collaboration with the Institute of Theoretical Psychology, University Bamberg, the Department for product development of the TU Darmstadt and Munich have used and developed approaches for protocol analysis of design activity (Cross et al 1996). Protocol analysis was used to analyze verbal *and* non-verbal aspects of individual design processes (Günther and Ehrlenspiel 1999; Dorst & Dijkhuis 1995), of interactions of design teams (Stempfle and Badke-Schaub 2002) and of design behavior of teams in the laboratory (Valkenburg and Dorst 1998; Van der Lugt 2005) as well as in the design work environment context (Badke-Schaub and Frankenberger 1999).

One of the main challenges of using protocol analysis is to find meaningful ways to interpret the data. The main emphasis therefore is to create a categorization system relating to the research question. Furthermore the question arises how to divide the whole process into meaningful steps, sections or episodes. Traditional protocol analysis approaches segment the protocol based on time intervals. In analyzing design activity, we have developed alternative approaches for segmenting the data. Valkenburg and Dorst segmented the protocol in moves, which they then coded by means of a scheme based on Schön’s (1983) theory of reflective practice.

In his studies into the role of sketching in creative group meetings, Van der Lugt adapted linkography, a way of analyzing protocols of design activity developed by Goldschmidt (1996). Linkography is based on a structuralist approach, marking the links between moves, and then analyzing the resulting link structure. Goldschmidt’s analysis relies heavily on creating graphical models of the design process, which are then interpreted. Van der Lugt has included some basic statistical analysis of the resulting linkographs.

One of the key limitations of protocol analysis has been the large amounts of data that need to be considered, which limits the applicability outside of the studio. In order to collect and analyze complex observational data more easily, our group has recently purchased a software package for video analysis (Interact), <http://www.mangold.de/english/intooverview.htm>, which allows direct coding of video footage. This sidesteps the lengthy process of transcribing the videotapes. In addition, the software package allows for instant shifts back and forth between fragments, what is especially useful in research approaches like linkography, which requires looking for evidence for – or against links between moves. As the transcript itself seldom provides sufficient evidence for links, non-verbal behavior and the circumstances in which remarks were made become very important.

We intend to use this software package to include more statistical analysis of qualitative data, and to allow the analysis of more comprehensive design processes, ranging from quick laboratory-based design exercises to *in situ* analysis of design activity.

5. Human-centred Design Methodology: a research programme

Limitations of design methodology

Although we can state that the proposed procedural models of design methodology are useful, it seems necessary to analyse which modifications are necessary in order to adjust methodology to the designers' needs. Let us take a look at an example: Student teams had to design a mechanical concept for a sun planetarium in a one-day period. This sun planetarium should be able to visualise the way of the sun across the sky for different positions on the hemisphere as well as for different seasons. We have analysed these design processes in detail (Stempfle and Badke-Schaub 2002), but here we only want to illustrate the procedure of the solution finding of one group which is quite similar to group processes we analysed in the industrial context (Badke-Schaub and Frankenberger 1999). This group consisted of five persons with three of them being very active and dominant. Thus, lots of solution ideas were generated. However, as soon as a new solution idea was proposed, the team immediately decided on the fate of this solution idea. From a methodological perspective ideas should be first analysed and then evaluated. The reason is twofold: One is that a premature rejection may discard a good solution idea because it does not seem to fit the current constraints. A second reason is the premature adoption of a solution idea which proves problematic later on because a crucial constraint has been forgotten, facts have been ignored, etc. and only after a considerable time it may turn out that the solution does not work. What might be a reason for this analysis-avoiding-behaviour – knowing that the students have had a basic course in design methodology?

Firstly, we know that humans tend to reduce complexity in order to reduce cognitive load (for an overview see Bannert 2002). Thus, an early evaluation of solution ideas is what we call the 'natural thinking process,' which provides several immediate advantages: If all goes smoothly, a solution can be decided on very quickly what is time-saving compared to time-intensive evaluation techniques such as those proposed by design methodology.

Secondly, a quick solution will not threaten the self-efficacy because the problem seems to be solved easily. The more analysis takes place the more difficult a task usually appears, as the analysis brings up new points of uncertainty. Perceived difficulty of a task and the non-availability of solutions reduce one's feeling of competence and self-efficacy.

And thirdly, in quite a lot of situations this procedure yields successful results quickly, especially with simple problems; however, the more complex the problem is the more likely errors will occur.

This example highlights some major limitations of design methodology: Whereas the process the designer should follow is explicitly prescribed characteristics of the individual designer such as experience or cognitive overload is not referred to. This is also true for characteristics of the organisational environment such as time constraints, financial constraints, and constraints through multiple projects that must be treated simultaneously. These are reasons, which contribute to the situation that design methodology has not been as accepted in industry as one would expect.

A research programme

These objections are not new; thus, the question arises: how can we encounter these limitations in a future research programme? We define designing as a form of complex problem solving in an environment with numerous influences which are interconnected. Thus, in order to understand designing and to come up with fruitful support, there needs to be a general framework of design theory. Hence, we need to ‘identify’ this network of designing. That means design research has to encompass the various fields related to:

- the characteristics of the given task or problem,
- the individual designer,
- the designer in the team, group or project context,
- the organizational context,
- the design process,
- and the product as the result (see Figure 1) of this interplay.

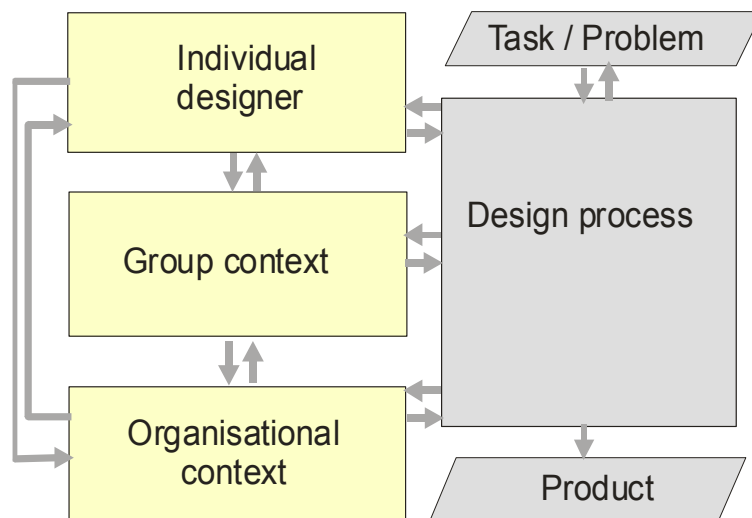


Figure 1: Network of designing.

The outline of a research program, filling in this network of designing with content, offers various possibilities (see Figure 2); and of course there exists already a body of knowledge related to the different fields - however this knowledge is fragmented and spread over different disciplines.

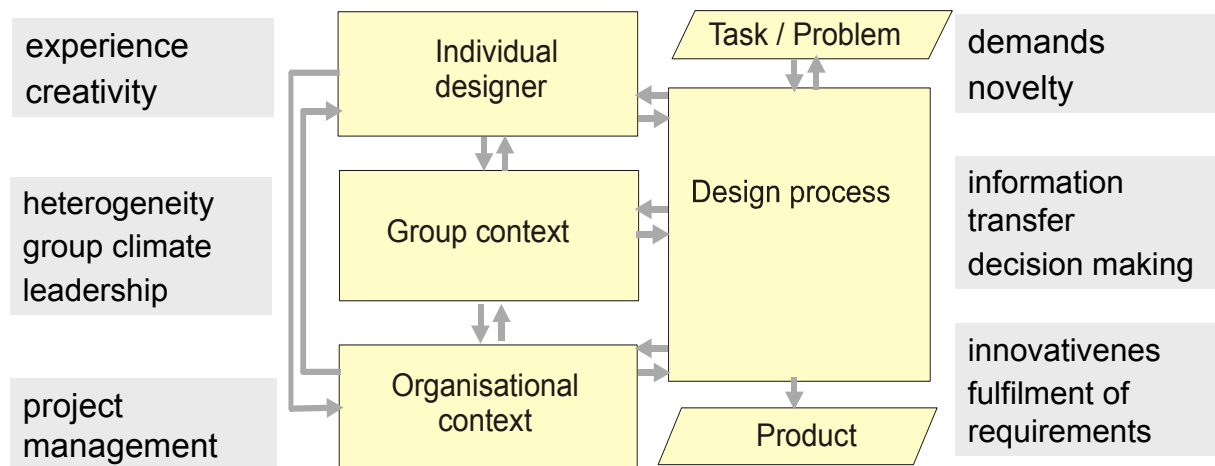


Figure 2: Network of designing with examples.

In order to attain and combine meaningful information which allows deriving support for designers we propose an integrated research approach (see Figure 3) which is based on three interrelated columns:

1. The theoretical column: theories and theoretical concepts provide the starting point for design research. Theoretical concepts can be of different nature such as design theory (Andreaasen and Hein 1987; Hubka and Eder 1992; Roozenburg 2002a, 200b) naturalistic decision making (Zsombok and Klein 1997) or cognitive theories (Schaub 1999), depending on the focus of the research question. Of course, a theoretical framework has to integrate proven concepts and has to be adjusted again and again by the empirical data.
2. The empirical column: empirical studies aim at evaluating hypotheses about the thinking and acting processes of designers. As the thinking and acting processes are being changed under specific conditions such as the situation of being part of a teams or working in a specific working environment, these conditions as basic research fields have to be part of empirical analyses. Thereby it is not possible to generate a complete study with all variables included, nor is it possible to investigate each research question in reality. However, a validation of the results has to be set in context, with designers in practice.
3. The application column: the focus on the application of methods includes the adaptation of existing methods as well as the development of new methods to come up with a designer-oriented methodology which supports the designer in his way of designing. Methods not based on theory are less useful because we do not know why they work—and under which circumstances they would probably fail.

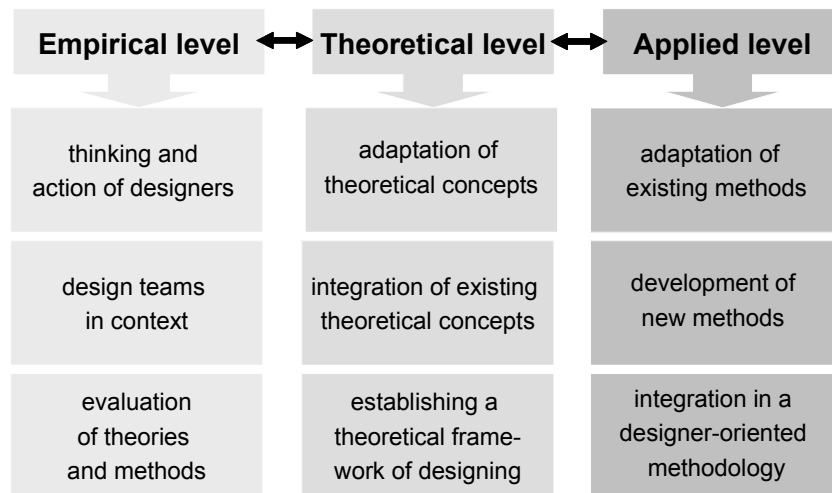


Figure 3: An integrated research approach: synchronisation of theory, empiricism and application in design research.

Attempting to start with this research program while building on our research and experience of the past years we have set up a first research project ‘Mental models in design teams’ which tries to combine the investigation of individual cognition in the social context. In this project we intend to take a closer look at the development and exchange of mental models in groups in so far that we are interested in the question, how do ‘mental models’ as individual unique constructions develop during designing? Research conducted in cognitive psychology has provided some results that illustrate how mental models establish strategies of thinking under varying conditions. Referring to the practice of designing as cooperative and often as a multidisciplinary activity raises questions related to design activity as informational exchange between team members’ representations. How do design teams establish common mental models and how do design teams integrate different mental models? When and how do design teams modify mental models? These findings could provide the basis for a method which supports design groups to be aware of their mental models and to support the adequate use of mental models.

Table 1: Research Questions: Mental models in design teams.

Focus	Question
Individual	How do mental models as individual unique constructions develop during designing?
Group	How do design teams establish common mental models?
	How do design teams integrate different mental models?
	When and how do design teams modify mental models?
Organizational context	How efficient is the use of a guideline supporting the adequate use of mental models in design practice?

Another subject that we see as an interesting addition on the issue of the development of mental models is related to fixation and the ways how experienced designers store their knowledge about solutions and solution principles and how they use it.

Is the output always a variation of former solutions – and if– when is fixation helpful and when and or how get the designer rid of previous material out of his current thinking? What kind of material is especially prone to fixation, which less?

Of course, there are further research topics which would be of major interest but these two ideas may answer the purpose of illustration.

6. Conclusion

In this paper we have tried to reveal basic problems of design methodology. As a consequence we have presented a generalized research program and ideas within this framework which should overcome the most important limitation of design methodology, the missing link to the ‘human’ characteristics of designing. Based on the fact that the basic principles of design methodology offer essential support for designers we build upon this framework but focus on the human aspect which is so far neglected in all methodological approaches. Thus, this program reflects a continuity of the former research although it addresses a substantial new dimension: the designer as human being and a pleading for a human-centered design methodology.

