Ontwerpen is een proces, maar niet voor de ontwerpers. [dit proefschrift]

Ontwerponderzoekers moeten kiezen welk paradigma toe te passen, en deze keuze moet gebaseerd zijn op kennis over de aard van de specifieke ontwerpacativiteit die ze willen gaan bestuderen. [dit proefschrift]

Als het waar is dat ‘Protocol studies kunnen werken als Rorschach vlekken’ [Terry Purcell, bij de workshop Analysing Design Activity], dan hebben ontwerponderzoekers misschien alleen zichzelf onderzocht. [dit proefschrift]

De ontwerpmethodeologie is uniek in haar doelstelling om, tenminste op praktisch niveau, de ‘context of discovery’ [Kuhn] te belichten. Dit vakgebied verdient dan ook veel meer aandacht van de technische, sociale en de exacte wetenschappen.

Als beweerd kan worden over ontwerpers ‘dat er methode is in hun waanzin’ [Cross], dan beschrijft het RATIONAL PROBLEM SOLVING paradigma de ‘methode’, en verklaart het REFLECTIVE PRACTICE paradigma de redenen voor hun ‘waanzin’.

Kunst maken en ontwerpen zijn verwante activiteiten, die beide een reflectieve conversatie inhouden. Maar ontwerpers werken binnen gegeven ‘kaders’, en kwaliteit binnen ontwerpen is het vermogen dit kader om te vormen naar een interessant uitgangspunt voor het ontwerp. In de kunst maakt de kunstenaar zelf het kader.

‘Een methode in het rijk van de geest als een kruk. De ware denker loopt vrij’ [Bomans]. Een groot dilemma in het onderwijzen van ontwerpmethoden is dat men de kans loopt het gebruik van kruiken voor te schrijven aan mensen die ook vrij hadden kunnen lopen.

Cultureel gezien is dit proefschrift kenmerkend voor Nederland, voor het Calvinisme, en voor het eind van de twintigste eeuw; deze studie beweegt zich in het niemandsland tussen twee paradigma’s, en zoekt helderheid met het oog op de practische toepassingen van een theorie.

Bij misdrijven als zware mishandeling gaat in ons huidige rechtssysteem alle aandacht uit naar het beschermer van de rechten van de dader, en niet die van het slachtoffer.

Het World Wide Web is bezig uit te groeien tot een natuurgetrouwe kopie van de buitenwereld. Daardoor krijgt de mensheid een unieke kans zichzelf opnieuw te bezien.

In elke filosofie zit een punt waarop de filosoof aantoont dat het ‘filosoof zijn’ de enige zinnige bezigheid is. Dit versterkt het vermoeden dat filosofie een levenshouding is, en niet een wetenschap.

Het feit dat er zo weinig ontwerpers actief zijn in het ontwerponderzoek kan misschien begrepen worden aan de hand van Tom Lehrer’s uitspraak dat een filosoof iemand is die ‘zijn brood verdient door nuttig advies te geven aan mensen die gelukkiger zijn dan hijzelf’.

‘... wij proberen ... totaal helderheid te bereiken. Maar dit betekent dat het filosofische probleem ook totaal moet verdwijnen. De échte ontdekking is degene die mij in staat stelt te stoppen met filosoferen wanneer ik dat wil’ [Wittgenstein, PI 133]. In het ideale proefschrift zouden de onderzoeksvragen moeten worden opgelost en geëlimineerd, en de gedachten weer worden vrijgemaakt om nieuwe dingen te doen.
Designing is a process, but not to designers.

[This thesis]

Design researchers must choose which paradigm to use, and must base their selection on the nature of the specific design activity they are going to study.

[This thesis]

If 'Protocol studies can work as Rorschach blots' [Terry Purcell, at the workshop Analysing Design Activity], then design researchers may unconsciously have been observing themselves.

[This thesis]

Design methodology is unique in trying to clarify, at least at a practical level, the 'context of discovery' [Kuhn]. As such, it deserves more attention from the technical, the social and the exact sciences.

If it can be said of designers that 'there is method in their madness' [Cross], then the paradigm of rational problem solving describes the 'method', and the paradigm of reflective practice explains the reasons for their 'madness'.

Art and design are closely related activities, which both involve 'reflection-in-action'. But designers work within given 'frames', and quality in design is the ability to 'move' and transform these 'frames' into interesting ones. In art, the 'frames' are freely chosen by the artists themselves.

'A method in the realm of the mind can be compared to a crutch. The true thinker walks free' [Bomans]. A major dilemma in the teaching of design methods is that one runs the risk of imposing the use of crutches on people who would have been able to walk by themselves.

Culturally, this study is typical for Holland, for Calvinism, and for the end of the twentieth century, because it takes place in the no-man's land between two paradigms, seeking clarification for practical purposes.

After crimes like the 'causing of severe bodily harm', all official attention is devoted to defending the rights of the perpetrator, and not the rights of the victim.

The World Wide Web is becoming a faithful reflection of the outside world. Thus technology has provided humanity with a unique chance to get a fresh look at itself.

In every philosophy there is a point where the philosopher proves that 'being a philosopher' is the only thing worth doing. This feeds the suspicion that philosophy is an attitude to life, rather than a science.

The fact that there are few designers active in design research might be understood in the light of Tom Lehrer's remark that a philosopher is someone who 'makes a living by giving helpful advice to people who are happier than he is'.

'... we are aiming at complete clarity. But this simply means that the philosophical problems should completely disappear. The real discovery is the one that makes me capable of stopping philosophy when I want to' [Wittgenstein, PI 133].

The ideal thesis should resolve and eliminate its research questions, and release the mind to do new things.
DEScribing Design
A comparison of paradigms

PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft,
op gezag van de Rector Magnificus Prof. dr. ir. J. Blaauwendaal,
in het openbaar te verdedigen ten overstaan van een commissie,
door het College van Dekanen aangewezen,
op maandag 8 september 1997 te 10.30 uur

door Cornelis Hans DORST,
ingeneer industrieel ontwerpen
geboren te Rotterdam.
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DESCRIBING DESIGN - A COMPARISON OF PARADIGMS

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### BIOGRAPHICAL NOTE
PREFACE

In the field of design methodology a small community of researchers scattered all over the world investigates how designers work and builds models and methods to assist them. This is not easy because ‘design’ is a string of activities which can be both rational and intuitive, abstract and concrete, analytical and creative.

My interest in the way I myself worked as a designer led me to do an empirical study to describe the how designers reach integration in their designs. As I began the study, I noticed that many of the things I knew and saw to be important could not be expressed by design methodology. This naturally led me to question why this was the case: my focus of interest shifted to the fundamentals of design methodology itself. There I found that there are two fundamentally different ways of approaching design, formalized in the two paradigms of design methodology called ‘rational problem solving’ and ‘reflective practice’. The main research question my project shifted to an exploration which of these two approaches would more accurately describe design as experienced by designers.

A comparison of paradigms. And that is what this thesis is about.
So during the research project I stepped back from exploring and describing design to exploring the fundamentals of perceiving design. But although this thesis is quite theoretical, my goal is still that of a practising designer, namely: trying to get things (in this case: paradigms) to work, and trying to understand the design activity itself.

Reading paths

This book is a thesis to be defended before a Forum of distinguished design research specialists, and as such contains elaborate justifications and careful descriptions of every reasoning step in the project. These necessary elaborations may have rendered this thesis less readable than the average novel. The following reading paths may help you find your way through this thesis:

- For ‘the general reader’ I would recommend § 1•1, § 1•2 and the summary.
- For designers, most points of interest are in §1•3, § 2•4, §5•2•2, §5•2•3, § 6•3, Appendix II, III and the summary.
- For people interested in the research methodology of this project: § 1•3, Chapter 2, §3•2, and Chapter 6.
- People interested in the way the protocol analysis experiment was organized should read § 5•1 and Appendices I and II.

And I really hope that all of this book is interesting to design methodologists and others that study design; after all, it was written for them.
1

INTRODUCTION:

DESIGN METHODOLOGY AND DESIGN PRACTICE

The aim of this research project is to contribute to the development of a design methodology that addresses more of the issues of designing as it is experienced by practising designers. We will explore the properties of design methodology in describing design-as-experienced and develop proposals to improve this descriptive ability. This first chapter introduces the small academic field of design methodology for those readers who might be less familiar with it (§ 1.1), and the domain of this study - industrial design engineering (§ 1.2). The perceived mismatch between design practice, as it is experienced by designers, and the descriptions of design practice by design methodology are discussed in § 1.3.

1.1 DESIGN METHODOLOGY

Design methodology can be described by touching on its scope, ways of working and on the nature of design methods and techniques. Every description involves an interpretation of the subject, and this description of design methodology is already tainted by my views on what the science of design methodology is and could be. As such it already introduces some core thoughts and emphases that will eventually lead to the research questions in § 2.1.

1.1.1 SCOPE

Design Methodology has been defined as “the study of principles, practices and procedures of design” [Cross, 1984]. Its general goals are to enhance the efficiency and effectiveness of design activities and to develop design as a discipline by gathering, creating and critically discussing insights about design. Design methodology includes the development of formal models of design activities, from which methods, techniques and computer tools can then be derived. In doing this, it tries to be domain independent.
Design methodology is thus essentially teleological in nature: the knowledge and understanding acquired in studying design are not goals in themselves, but they should be translated into methods and techniques to be used both in designing and in design education. Design methodology can be a theoretical science when its insights are based upon (logical) models of the design process, it can also be an empirical science when it describes, models and explains real-life design activities. And design methodology can sometimes function as just a pseudo-scientific aid for design practice and education. ‘Pseudo-scientific’ in the sense that some of the knowledge in this field cannot be generalised and verified to the standards of ‘normal’ (positivistic) science. Design methodology is wedged somewhere between ‘pure science’ and ‘pure practice’. On the one hand its insights should be rigorous and well-researched in the scientific tradition, but on the other hand they should also be applicable in multi-faceted practical design situations. The demands thus imposed upon design methodology are often contradictory. Striking a balance between ‘practical relevance’ and ‘scientific rigour’ is a primary concern throughout the field, and is one of the main themes running through this thesis.

In the 30-odd years since the first papers on design methodology were published, design methodologists have explored a broad and varied terrain. An introductory tour of the field can be given by briefly touching upon the main subjects that are studied within design methodology:

- **Designers** - In studying design practice, methodologists have worked towards establishing a consensus about the thinking styles, abilities and personality traits that are critical for a successful designer [Cross,1990,1996-II] [Christiaans,1992]. In the past few years, attention has broadened to include the study of design teams as well as multidisciplinary groups doing design work [Tang,1989][Brereton,1996][Minneman,1991][Valkenburg,1996].

- **Design problems and solutions** - There is a small body of literature on the nature, structure and types of problems designers grapple with [Rowe,1987], [Lawson,1993]. The most rigorous analyses of practical design problems can be found in design automation and ‘design-Artificial Intelligence’ literature [Tzonis,1992].

- **Design processes** - Design processes have traditionally been the core subject of theoretical design methodology. There is an avalanche of literature on general problem solving models, descriptive and prescriptive models of the design process, process management, strategies and heuristics for design.
Recent textbooks by [Cross,1994][Ullman,1992][Ulrich,1995] and [Roozenburg,1995] provide an overview.

- **Design methods and techniques** - Based on the knowledge of design processes, a large number of methods and techniques have been developed for different phases of the design process. This was not a purely academic undertaking; several designers and companies have developed their own views about which methods should be used in their design practice [van Wierst,1992][Bos,1993]. The textbooks mentioned above also contain a treasury of design methods and techniques.

- **Computer aids** - A lot of design research has gone into the development of computer aided design systems, the computer simulation of designing and the building of communication tools for designers [Tovey,1992] [Scrivener,1992,1997][Mazijoglu,1996]. There is an ongoing struggle to lay the foundations for design-AI and expert systems [Tomiyama,1990] [Coyne,1996][Gero,1990]

- **Design education** - Some researchers have concentrated upon the special issues involved in teaching design: the structure of design courses, learning models, the measuring of design performance, the development of criteria for design quality, etc. [Christiaans,1993][Cross,1990,1994][Brereton,1993].

- **Design as a profession** - There has been a continuous interest in the design profession by the humanities, notably anthropology, sociology and history. These fields of study are gradually becoming an integral part of design methodology [Schön,1983][Bucciarelli,1987][de Wilde,1997].

In addition to these works on the core subjects of design, there is a body of work to provide the basis, ensure the development and guarantee the coherence of design methodology itself. Main topics of this meta-methodology are:

- **Nomological network** - A most valuable accomplishment of design methodology is the development of a conceptual framework that can serve as a basis for reflecting upon and explicitly discussing design [VDI,1985] [Pahl,1986][Rowe,1987].

- **Philosophy of design methodology** - Many have attempted to provide a philosophical basis of design methodology by comparing design and design methodology with science and scientific theory building. Points of focus are the logical form and status of design as a way of thinking, design ontology, design epistemology and design ethics [Simon,1992][Schön,1983].

- **History of design methodology** - Collective memory and reflection are fostered in papers and books like [Cross,1984,1992].
• **Research methods and techniques** - This is the research methodology of design methodology itself. Its subjects are the development of methods and techniques to conduct theoretical investigations, empirical studies and the discussion of the paradigms of design research [Coyne, 1991, 1995] [Stauffer, 1988] [Dorst, 1995]. This thesis also belongs to this last category.

1.1.2 **WAYS OF WORKING: THE PARADIGMS OF DESIGN METHODOLOGY**

As in any scientific undertaking, the basis of design methodology is formed by **paradigms** that define the domain and the subject to be studied. In doing this, these paradigms also define the methodologists’ perception of the scope, characteristics and ways of working of design methodology itself. The need for a more structured management of design processes in practice and in education led to the first papers on Design Methodology in the early 1960’s. Much of the early methodology was compiled by engineers who applied the same ‘systems thinking’ they had used in designing their products to analyse the design process itself. This led to the development of phase-models and flow-diagrams of the design process [Archer, 1965], and to attempts to rationalise and even automate the treatment of design problems [Alexander, 1964]. The technical, positivist background of these theories led to design being seen as a rational (or rationalisable) process. These papers were extremely optimistic about the level of systematisation that could be applied to design problems and processes, and to the effects that this would have on the quality of the resulting designs (see [Cross, 1984]). Design methodology became part of the sixties-drive to rethink the world. But the theoretical models from those times were rightly criticised for being overly rational, weak in the description of design processes, and, worst of all, impractical.

Criticism of these early models and methods came to a head in the late sixties/early seventies. The often heated debate of those times deepened the interest in the fundamentals of design theory, and the logical form and status of ‘design’ itself. Right from the beginnings of design methodology there has been a strong feeling that the act of designing is fundamentally different from other reasoning patterns, and that its scientific, educational and practical aspects should not be formalised by the same paradigms as other acts and thought processes [Lawson, 1990]. This crisis of confidence fostered a need for more detailed descriptions of the design activity, which led to the first in-depth empirical studies.
of designing. Attention was refocused from 'the design process' towards a broader view of design activities by incorporating other issues which concern designers and design problems.

The criticism was most strongly heard in Architecture, which caused architectural design methodology to move away from attempts to further detail the rational phase models and concentrate instead on the ill-structuredness [Rittel,1972] and creative aspects of architectural design activities. This criticism was also heard in the Engineering school of design methodology, but here it led to attempts to incorporate more theoretical knowledge of designers and design problems into the rational phase models of the design process (see also [Roozenburg,1991]). The theories introduced by Simon [1969] provided a framework for this.

He forged a link between classic design methodology and the problem-solving theories from computer science and psychology. Design methodology almost became a 'Science of the Artificial'. Simon's theories provided a model to describe designers and design problems within the paradigm of technical rationality, enormously extending the scope of design studies. They also finally provided a sound, rigorous basis for much of the existing knowledge in design methodology.

In Simon’s paradigm design is seen as a rational problem solving process, and this view has become the dominant influence shaping prescriptive and descriptive design methodology ever since. Most of the work done in design methodology today still follows the basic assumptions, the positivistic view of science, and the goals of this school of thought.

A radically different paradigm was proposed some fifteen years later by Donald Schön [Schön,1983], describing design as a reflective practice.

This constructionist theory was a reaction to the rational problem solving approach, and it attempted to address the blind spots and deficiencies Schön perceived in what by then had become mainstream design methodology.

1.1.3 THE NATURE OF DESIGN METHODS AND TECHNIQUES

The knowledge contained in design methods and techniques can be seen to be generated by two sources: insights about the character and basic structure of design are acquired by theoretical reflection, and knowledge about real-life design processes is (of course) gained from practice (see figure 1.1). These sources have not always played equal roles in the thinking about design: design methodology began as introspection by professional designers attempting to structure their design activities. This eventually lead to hypothetical design theories.
Scientific (logical) reflection on these theories then became the mainstay of design methodology; ‘consensus’-models of design have been developed [Roozenburg, 1991]. Right now the ‘learning cycle’ [Kolb, 1984] is being closed by an abundance of research projects in which the theories of design methodology are examined in the light of empirical studies of design practice [Hales, 1987][Blessing, 1994][Fricke, 1993][Cross, 1996][Frankenberger, 1996].

Any method for aiding design activities must contain statements about the dynamics of a design process, a model of the designer and a model of the structure of the design task. Design methods are based upon these ‘three dimensions of design activities’ (see figure 1.2, and [Dorst, 1995][Roozenburg, 1991]).

![Diagram](image1)

**Figure 1.1 - Design practice and design theory as the foundation of design methodology.**

![Diagram](image2)

**Figure 1.2 - The three dimensions of design activities.**
Two of these three dimensions are often ignored by current design theories. Classical design methodology is almost solely focused on enhancing the efficiency and effectiveness of design processes, to the exclusion of anything else. However, the recent empirical studies have led to the realisation that the basic elements of design methodology are design activities, not just processes. This means that we should refocus our attention towards the assumptions that current design theories implicitly contain on the other, the ‘design task’ and ‘designer’ dimensions. An example may clarify this point: ten years ago Pahl and Beitz published a classic and very influential phase model of design processes ([Pahl, 1986][VDI, 1985]), in which:

- the designer’s properties and limitations are described as far as the subject is supposed to be an inexhaustibly rational human being capable of processing all the information necessary to perform the design task.
- the structure of the design task is roughly captured in the general assumption that a design problem can be functionally subdivided into reasonably independent subproblems, and that the solution can be built up out of reasonably independent subsolutions.
- the resultant of this study is the Pahl and Beitz process model of design. design activities are captured in a phase-based chart of the design process.

In this Pahl and Beitz process model of design the ‘design task’ and ‘designer’ dimensions are treated as parameters, and the ‘process’-dimension is the sole focus of attention*. This severely limits the scope of the observations and descriptions which can be made using this model. These descriptive limitations in turn create the limits for the resulting process-model and design methods. In this study design methodology will be taken as a science that tries to address all three dimensions of designing.

1.2 INDUSTRIAL DESIGN ENGINEERING

Before going into the relationship between industrial design engineering practice and current methodology the reader should have an accurate image of the domain at hand, and the way its design methodology developed. This introduction also discusses the particular environment in which this study was done, the Faculty of Industrial Design Engineering at the Delft University of Technology.

* See § 6.1 for an extensive discussion of this point.
1•2•1 DEFINITION OF THE DOMAIN

A rather lengthy and abstract definition of the industrial design profession has been adopted by the International Council of Societies of Industrial Designers (ICSID), based on work by Maldonado [Maldonado, 1957]:

'Industrial Design is a creative activity whose aim is to determine the formal qualities of objects produced by industry. These formal qualities are not only external features but principally those structural and functional relationships which convert a system to a coherent unity both from the point of view of the producer and the user. Industrial design extends to embrace all the aspects of human environment which are conditioned by industrial production.'

The Faculty of Industrial Design Engineering uses a similar working definition of its domain:

'Industrial Design Engineering is the development of durables (mass-produced products) for people, based on the integration of interests of users, industry, society and environment.' [Buijs, 1997]

Some remarks and explanations:

- The 'objects produced by industry' mentioned by Maldonado are mainly consumer products, ranging from teaspoons to cars. There is some specialisation in industrial design, but most practitioners work on a large range of products. Products that I have worked on as an industrial design engineer include: a bicycle seat for children, stationery, hospital beds, medical equipment, caravans, a car interior, an ergonomical measuring device, spotlights, toys, reception desks, a whiteboard-system, etc., see the illustrations on the front and back cover of this book*.

- Maldonado describes industrial design as the building of a network of relationships between physical objects with formal qualities. Two things are deemed important: the resulting product should be coherent, and it should be seen to be coherent from different viewpoints - by the producer as well as the user. In other words, the demands of these stakeholders (see § 2•3) should be integrated in the designed product.

- Not only the producer and user are listed as interested parties: others, like the designer him/herself and society as a whole (moral responsibility) have to be taken into account.

- It is important to note the broadness and multidisciplinarity of industrial design problems in yet another sense: when a product is designed, technical, ergonomical, aesthetical- as well as business considerations have to be taken

* An example of an industrial design engineering problem is given in § 5•1, and the activities of experienced product designers working on this task are described in Appendix III.
into account. A product will have to function in all of these contexts.

- Because the products are meant for mass production, the economy of the designed product is extremely important. The number of parts and the material, production and assembly costs have to be minimised. Product development costs are high [Ulrich, 1995], so industrial design should be performed in a structured, controlled and dependable way.

- Industrial design problems are essentially of a practical nature. They can arise from more or less coincidental circumstances; for instance, changes in technological knowledge, the market or company policy. And they will have to be resolved in open and changing circumstances.

- The last sentence of Maldonado’s definition, delineating the scope of industrial design, sounds ambitious and even a little pompous. But in the last 25 years, people trained as industrial designers and industrial design engineers have gone beyond this, using their core design abilities for the development of organisations and services, the planning of cities, etc.

Industrial Design is a relatively young profession: surprisingly, the widespread training of professionals whose specific task is to design industrial products did not begin with the onset of industrial production at the time of the Industrial Revolution. Indeed, until 50 years ago, almost all products were designed by mechanical engineers, artists and architects who had strayed from their original disciplines. Industrial product design slowly emerged from these disciplines as a speciality, requiring specific skills and a different knowledge base. Industrial designers were initially cast as specialists who were needed to ‘give form’ to products that had already gone through technical development. Such industrial designers are being trained in art schools all over the world.

The Faculty of Industrial Design Engineering of the Delft University of Technology has been created with a different purpose: it does not aim at educating form-giving specialists, but it produces generalists capable of integrating the aspects of form, ergonomics, engineering and management sciences into their design projects. The phrase ‘Industrial Design Engineering’ was coined to express this more technical and functional orientation, compared to industrial design as it is taught in art schools. This Faculty has had a major influence on the Industrial Design profession and its methodology in The Netherlands. Its fresh approach to the industrial design profession and design education is receiving increasing attention from the international product design community. For a description of this Faculty, see [Smets, 1991][Buijs, 1997][de Wilde, 1997] (for a description of the
design research in this school, see [Dorst, 1995-IV]).
The domain of this thesis is industrial design engineering - but this does not
mean that the results will only be relevant to graduates from this one school.
Although this Faculty in Delft is one of the few teaching establishments explicitly
offering such a wide-ranging course, many product designers working in practice
do cover the same terrain.

1.2.2 THE METHODOLOGY OF INDUSTRIAL
DESIGN ENGINEERING

There is only a small body of literature dealing with the methodology of
industrial design engineering. A partial explanation for this is that product design
is such a young profession which has slowly spread from the art-school
environment to universities. And most of the ‘industrial design research’ that has
been done was focused on defining and putting together the knowledge base of
the field itself. Only in the last fifteen years or so have industrial design engineers
begun to reflect on themselves and their discipline as independent and different
from other disciplines.*

The methodology currently used in industrial design engineering is based upon
the rational problem solving paradigm. Most of the methods and techniques used
have been taken from the methodology of mechanical engineering, and then
adapted to industrial design engineering [Roozenburg, 1995]. These methods have
been successful in providing aids for the management of industrial design
engineering processes. Recently, more of the architectural methods have been
adopted, shifting attention to the creative, social and psychological aspects of
designing [Cross, 1996]. But again industrial design engineering is a young
profession, and its design methodology is still in its infancy. The adoption of
design theories from other domains has led to a situation in which factors that are
unique, or even critical, to industrial design engineering may have been ignored.

1.3 STANCE ON DESIGN
METHODOLOGY AND DESIGN
PRACTICE

The origin of this research project lies in my observation of a difference between
design activities as they are described in current design methodology, and the way
these design activities are experienced by designers. In this section, the issues that
constitute this difference are identified, based on introspection about my own

* There are some notable exceptions to this three-sentence history: one of the very
first design methodologists, Bruce Archer, was a product designer [Archer, 1965].
experiences as a teacher and practitioner of industrial design engineering. This section of the thesis is unashamedly subjective (kind of a manifesto), generating issues that are subsequently investigated in a theoretical analysis and in an empirical study. The aim is to develop a methodology for industrial design engineering that is more closely grounded in design practice, and to address previously ignored issues that are relevant to design practitioners.

1.3.1 THE DISTANCE BETWEEN DESIGN METHODOLOGY AND PRACTICE

As a practising industrial design engineer, one can't help but notice the inadequacies in the support current design methods provide for design practice. The methods are invaluable in structuring design processes, in practice and in education, and they do provide a structure for design courses, helping students to get the broad and difficult subject of design under control. But one also observes that they are not specific, detailed or clear enough to support the vast majority of decisions that designers have to make. There seems to be a considerable difference between design methodology as it is taught and used, and the problems experienced by designers.

Design methodologists have been criticised for being out of touch with design practice for quite some time. One of the early architectural design methodologists, Christopher Alexander, is on record as saying (in 1971) that

‘... <design methodologists> have definitely lost the motivation for making better buildings... there is so little in what is called ‘design methods’ that has anything useful to say about how to design buildings...’ [Cross, 1984]

The origins of this rift are unclear. It certainly is true that design methodologists have not gone out of their way to keep in touch with design practice, and the attendance rate of people ‘from industry’ to established design methodology conferences organised by bodies like the International Conference on Engineering Design and the American Society of Mechanical Engineers is also shockingly low. A partial explanation can be the overriding focus in industry on end results, rather than on the process by which results are achieved, and the inevitable difference in the level of abstraction between science and the real world. The general statements of design methodologists will never completely capture the specifics of the problems that confront a designer in industry. I will argue in this thesis that the rift between design methodologists and practising designers is not just due to this lack of communication, but that its cause
is more fundamental. The rift is a consequence of the fundamental difference between the way design is described within design methodology, and the ways in which designers experience their work. As Coyne [1995] has remarked:

There exists a gap between promise and fulfillment, between theory and pragmatic use, ...( ...)..... The reason for this gap lies not in some supposed inertia or antiscientific prejudice on the part of the designers, but in the lack of correspondence between models of the design process and the process itself as experienced by designers in their practice...

The aim of this research project is to develop a methodology for industrial design engineering that addresses more of the issues experienced by designers in their design practice. There are several reasons why this attention to the designer’s experiences is warranted:

- Weighing today’s design methodology on the balance of relevance versus rigour, Donald Schön remarked that the scales are heavily tipped towards the ‘rigorous’ side, to the cost of ‘relevance’ [Schön,1983]. This has led to a design methodology that has successfully proven itself to be a scientific undertaking, but that in the process has lost some of its relevance for the world of design. Design methodology, duty-bound to enhance the efficiency and effectiveness of design activities, has to take pains to be compatible with design practice. Therefore the subjects treated, the ways in which the subjects are abstracted and the scope of the research will have to harmonise with design practice to be at all useful.

- A further reason to concentrate on designers’ experiences is that the decisions designers take in their multi-step process of designing are ‘controlled’ by the perceptions of the designers themselves. So the experiences of designers working on a problem are an integral and vital part of design activities. The understanding of their design experiences is an indispensable ingredient for any real understanding of design activities.

1.3.2 INDUSTRIAL DESIGN ENGINEERING EXPERIENCES

But what does a practitioner experience when working on a typical industrial design task? To clarify this, I must rely on my own experiences as a designer and design teacher, supported by some literature. This hopefully suffices for a first orientation. The image of design practice that emerges through these six points will be put to the test in the empirical study.
Design situations: thrownness

First of all, a designer is not just working on an assignment, but he/she is thrown into a design situation. ‘Thrownness’ (in German: Geworfenheit) denotes the predicament of living in an unstable present, being in a situation, part of a situation, and not being in control of yourself and the situation [Heidegger, 1962]. This point was first raised in connection with design by Winograd and Flores. They use the activity ‘chairing a meeting’ to illustrate this notion:

‘When chairing a meeting, you are in a situation that:
- you cannot avoid acting (doing nothing is also an action).
- you cannot step back and reflect on your actions.
- the effects of actions cannot be predicted.
- you do not have a stable representation of the situation.
- every representation you have of ‘the situation’ is an interpretation.
- you cannot handle facts neutrally; you are creating the situation you are in.’ [Winograd, 1990]

This certainly applies to many everyday situations, including design. It also ties in with the descriptions of design tasks as being ‘wicked’ or ‘ill-structured’ [Rittel, 1984][Simon, 1973]. However, Winograd et al. are not using ‘thrownness’ to illustrate properties of design tasks, they are describing ‘being thrown’ as an integral part of the whole design situation.

The point to be made here is that when you are designing, you are inside a design process (thrown into the design situation), and not always in the position to consider it critically and rationally. Therefore, if you want to be in control of your design process, you must step out of the ‘designerly way of thinking’ [Cross, 1994], every now and then. Decisions pertaining the design process – the object of much of current design methodology – are thus not really part of normal design reasoning. Designers do consciously think about their design processes, but this requires them to ‘step out of their design situation’. These ‘jumps’ to a completely different level of thinking can easily be seen in any protocol of a designer at work (see § 5.3.1). If we take this standpoint, a design methodology that only treats the design process is very unsatisfactory indeed. It is bound to overlook much of the core design activity. But what is this core design activity, then?

The core design activity

As a designer, you are in a situation where you are continually faced with the challenge of your perceived design problem. You must decide about what kind
of action to take, and what the content of the action should be in this situation. 'What does this situation mean?' and 'What can/should I do in this situation?' are eternally recurring questions. By answering the second question you decide on an action, determining the process- and content-component of the following steps in a design process. In most cases, considerations linked to the content of the perceived design situation (your interpretations of a design problem or solution, your goals, your resources, motivation, your capacity to handle the task before you and your perceived options for the next step) will determine the process-component of the next step. From this perspective, the developing design process is a by-product of content-based decisions.

- **The primary question to be addressed by design methodology**

  In taking a decision to act in a concrete design situation, the central question designers face is:

  > 'If I am a designer with the following capabilities, and I am confronted with a design task with these characteristics, and I am working in this situation, and I have progressed to this particular point in the design process, then what should I do now?'

  In posing and answering this question the designer links the three 'dimensions of design' (see figure 1.2) in a rational or intuitive way. Really confronting this broad question within design methodology means exploring all three dimensions of designing as subjects of methodological research. (This is a broader view of design research than is commonly held within design methodology, which traditionally focuses only on the process of designing, and the general question 'What to do when designing?'.) The broadness of this central question will probably make it very hard for design methodologists to find patterns in the behaviour of designers, to pinpoint the variables that rule this behaviour and to make methods based on the interaction of these variables. This approach can only be fruitful if and when the study of the 'designer' and 'design task' dimensions of design activities has deepened our understanding of their structure, nature and behaviour.

- **Design tasks**

  Design methodology has always described the challenges set before designers as *design problems* (see [Cross, 1990] for instance). A consensus has emerged within design methodology that design problems are 'ill-structured' and 'wicked'. As a consequence these design problems are perceived to be too diverse for scientific analysis and generalisation. But it would be very valuable to develop systems to categorise these design problems: by discriminating
between design problems one could learn how different kinds of problems affect the ways designers work. So far no one has succeeded in making a stable taxonomy of these problems. Yet most methodologists would agree that designers, somehow, must use some form of implicit categorisation in addressing their design problems.

To obtain a sharper picture of what a designer is confronted with, I propose a slight shift in focus. As a designer, you are not just faced with a design problem, but with a **design task**, where a task is a combination of 'the design problem', the design situation, and a time component. I believe that this shift of focus is a sensible step, because the designer's interpretation of the situation (including the resources) and the time constraints heavily influences the way he/she is going to approach 'the design problem'. A design brief is interpreted in such a way that it becomes a manageable task within the given constraints. This interpretation of the design task is much clearer and more real to the designer than the rather academic 'design problem'.

- **Striving for coherence and integration: design as a balancing act**

One of the strongest impressions you have, as a product designer deeply immersed in a design task, is the feeling of performing a balancing act. All of the various aspects that have been identified in the definitions of industrial design have to be reconciled in the particular product you are working on. Some aspects will have priority over others, but several will be competing for attention simultaneously. The evolving design has to be cross-checked continually, to integrate all these aspects.*

This integration is a hard enough goal to attain in design practice, but the problem is severely aggravated by the need to simultaneously reach coherence in your design (see the definition by Maldonado in § 1.2.1). Coherence is far from being a formal scientific concept, and is even harder to describe than integration. It measures to what extent parts of a design are 'united by a relation in form or order' (dictionary definition in [Webster, 1953]). The need for coherence effectively limits the amount of compromise a designer can build into a design: too much would make it 'look like nothing', 'not a unity'. Both integration and coherence have been widely recognised by designers. They are recurring issues in the jury reports of the Annual Design Review of the prestigious journal Industrial Design [ID, May issues of 1958-1997]. Yet, integration and coherence have all but escaped attention within current design methodology.

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*This has been modeled in current design methodology as 'concentric development' (see for instance [Roozenburg, 1995]), but no methods or techniques have been developed for doing this effectively.*
• Experiential learning of design

In the product design schools that I know, there appears to be a remarkable two-way split in the way design is taught. On the one hand there are courses in Design Methodology, taking the form of lectures with some small exercises for learning techniques like project planning and brainstorming. On the other hand there are Design Courses, in which products are developed by students under the tutelage of (often) experienced designers. These design exercises are meant to develop the ‘design ability’ of the students [Cross, 1990]. This learning process is also partially devoted to the development of skills that have been previously taught (e.g. in Design Methods courses), by trying to apply them under guidance.

However, my experience is that the most important skills that are taught through experiential learning in these Design Courses are the ‘missing subjects’ of design methodology that have just been described:

* The student has to get used to being (thrown) into a design situation, and learn to be comfortable with the inherent stress and uncertainty of it. As Ted Happold, a structural engineer once said: ‘I have, perhaps, one real talent: that I don’t mind at all living in an area of total uncertainty’ [Cross, 1990] (actually, this must be a sobering thought for the people driving across the bridges he designed).

• In a design situation, the student has to learn which kinds of situations require which actions, ‘what to do when’. To a design tutor, this may be one of the hardest things to convey to students: what ‘situation characteristics’ does a designer react to and how does he/she react?

• The student must learn to deal with the design challenge in the light of his/her own limitations. Design problems are not stable, and are difficult to convert into realistic design tasks. Even very experienced designers struggle with this.

• Balancing and integrating a design has to be done anew with every design project. Experienced designers do display some structured behaviour in this respect, and the heuristics for this are often implicitly passed on to the students [Schön, 1983, 1987]. ‘Coherence’ can be even harder to teach, although this depends on the ideology, if any, in the design school. A clear and pervasive ideology helps to ‘frame’ the design problem, and supports the designer in making detail decisions.

• In addition, the student has to ‘learn how to learn’ in each design situation. Doing a project and learning from it at the same time requires

* The sheer importance of experiential learning in design education has lead some people to doubt the possibility of really teaching much of design at all [Best, 1992].
a dual-mode of thinking that is vital to the continuous development of a designer's abilities.

I hope that my methodological research into 'design as experienced by designers' will render explicit knowledge that can contribute to the teaching and learning of design. However, it could be that some of the core knowledge and high-level skills a designer needs will always remain beyond the reach of explicit design methodology. There probably are kinds of knowledge and skills that may only be mastered by experiential learning.

1.3.3 CONCLUSION

I hope to have demonstrated the mismatch between 'design methodology' and 'design-as-experienced' by discussing these six points. They are also a first foothold in the development of closer descriptions of design experiences. Possibly, not all of these issues can be addressed in a way that is up to the scientific standards adopted by today's design methodology community. We might encounter the basic limitations in the current viewpoints (paradigms) of methodology, and in the views of science and methodology of science that are implicit in these. But it is my strong conviction that there is a vast and relevant body of knowledge hidden within professional designers which can be made explicit, and that can be investigated rationally and systematically. After all, experienced industrial designers do cope with design situations and their associated problems every day. It is the task of design methodology to describe and explore the methods and heuristics these designers use to the full extent of what can be generalised and turned into explicit knowledge.
STUDYING THE PARADIGMS FOR DESCRIBING DESIGN

The research questions of this study are formulated in § 2.1, and the way in which these questions can be addressed is developed in § 2.2. The concept of integration, that is central to the description of design-as-experienced, will be introduced in § 2.3. The layout of the study is presented in § 2.4.

2.1 THE BASIC RESEARCH QUESTIONS

The starting point of this research project is the perceived rift between the way design is dealt with by design methodologists and the way designing is experienced by practising designers. The aim of this study is to develop a methodology for industrial design engineering that more effectively addresses design activities as they are experienced by practising designers. A first prerequisite for such a design methodology is the development of descriptions of design activities that more closely match the experiences of designers. To that end an empirical study will be performed to look into the properties of current design methodology in describing industrial design engineering activities. This should then provide us with clues to how the description of design activities can be improved.

I propose two basic questions that will guide this research. The first serves as a basis for the empirical part of this study, the second will inform the theoretical analysis and conclusions.

1. What are the properties of current design methodology in describing industrial design engineering activities?
2. How could this description be improved?

We will now define the elements contained in these research questions.
‘current design methodology’

The notion of ‘current design methodology’ was already discussed in § 1.1.2.
There, design methodology was described as evolving along two fundamentally different paradigms: the rational problem solving paradigm and the paradigm of reflective practice. To determine the fundamental 'descriptive properties' of design methodology as a whole, the 'descriptive properties' of its two basic paradigms will have to be explored and compared.

'descriptive properties'
To determine the descriptive properties of something as abstract and vague as a paradigm requires several steps:

- The first step is to translate the paradigm into a more concrete description method that is suited for description of design practice, while still representing the most important properties of the paradigm. Since we intend to evaluate current practices in design methodology, we should stay reasonably close to the description methods that have already been used in earlier methodological studies. In our case the construction of a description method is a process of condensation, more than invention.
- The second step is to translate the description method into a concrete encoding system for applying to the empirical data.
- The evaluation of this encoding system is then used to evaluate the description methods, which in turn will help to assess the paradigms.

'industrial design engineering activities'
Industrial design engineering activities in general cannot be studied. They are too diverse and wide-ranging in nature to even take a representative sample of them. The practical solution to this will be to perform an in-depth empirical study (using protocol analysis) of designers working on a 'typical' industrial design engineering task. In this empirical study the attainment of integration in design is singled out as the special subject.

'How could this description be improved?'
Based upon the empirical study and the theoretical analysis of the two paradigms, recommendations will be made to improve the methodological description and modelling of design.
2.2 RESEARCHING PARADIGMS FOR DESCRIBING DESIGN

2.2.1 THE STUDY OF PARADIGMS

Ever since its introduction into the theory of science, the word ‘paradigm’ has been heavily over-used, which has caused its meaning to erode. It is therefore important to precisely define the word in this study. A ‘paradigm’ has been defined rather ambiguously by Kuhn [1962] as a ‘model from which springs a particular coherent tradition of scientific research’.

This definition was later criticised and elaborated by Ritzer [1975]:

‘A paradigm is a fundamental image of subject matter within a science. It serves to define what should be studied, what questions should be asked, how they should be asked, and what rules should be followed in interpreting the answers obtained. The paradigm is the broadest unit of consensus within a science and serves to differentiate one scientific community from another. It subsumes, defines, and interrelates the exemplars, theories, methods and instruments that exist within it.’

This definition is fairly clear in itself, but it does little to help identify and describe paradigms that concern us now. There are three main problems with this definition:

- Paradigms can exist on many levels of abstraction.
- Paradigms do not come in a unified format.
- It is the a posteriori process of adopting a fundamental principle, theory or research project as a model that turns it into a paradigm.

The term ‘paradigm’ originates in the theory and history of science; thus a paradigm is essentially a historical and social construct. This means that it is difficult to state a set of stable a priori properties of paradigms. Instead, we will have to concentrate on the role a prospective paradigm plays in the dynamics of evolving thought patterns within a research community.

Paradigms are most clearly defined as the deeply rooted (and often implicit) accepted ways of working of a research community. When a shift of basic tenets occurs, it is often accompanied by what is called a ‘paradigmatic crisis’. In periods of ‘normal science’, a research community industriously works on detailing and expanding the knowledge that can be gained by working within the dominant paradigm (this is irreverently dubbed ‘puzzle-solving’ by Kuhn). When eventually a dominant paradigms is overpowered by others, the rise of this new paradigm
takes the form of an acrimonious period, (a crisis) in which competing schools of thought exist and fight each other. A new dominant paradigm emerges from this struggle. These are real revolutions:

‘...[the new paradigm’s] assimilation requires the reconstruction of prior knowledge and the re-evaluation of prior fact...’ [Kuhn, 1962].

Paradigms can thus be ‘discovered’ (postulated) by identifying a paradigmatic crisis, and then describing the prevailing thoughts when the dust has settled. This roundabout way of ‘discovering’ paradigms may have contributed to the over-use of the word. Scientists tend to experience ‘the present moment’ intensely, as an apparent a crisis compared to the past. In many sciences this results in an undercurrent of restless search for new fundamentals and the constant emergence of would-be paradigms. This continuing quest for re-invention is a largely healthy and informative phenomenon, but a truly new paradigm will only emerge when it resolves fundamental issues for a significant part of the scientific community. Kuhn initially proclaimed that paradigms are incommensurable, and denied that ‘competing paradigms can be measured against a yardstick of descriptive adequacy’ [Losee, 1993]. If this is the case then the comparison of paradigms we have set out to make in this study is impossible. But in the postscript to later versions of ‘The structure of scientific revolutions’ [1969], Kuhn allows the co-existence of different paradigms adopted by different groups of people in a research field and adds that there can also be people that act as ‘translators’ between these groups. This then does provide us with a basis for a careful comparison of the paradigms of design methodology in this study. *

This thesis is an empirical comparison of the two paradigms of design methodology: rational problem solving and reflective practice. This empirical comparison will be carefully prepared by constructing description methods and encoding systems as lower-level representatives of the paradigms, and by formulating theses that guide the exploration of the properties of the description methods. But in the end this comparison of paradigms will still be a matter of judgement. As Snodgrass [1992] pointed out:

‘The fit between the model and its referent is only approximate rather than precise, and an assessment of what constitutes an adequate approximation between the two systems is a matter of judging undefinable relations between the complex networks of interacting factors which operate within the total theoretical system..’

By carefully preparing, performing and reporting this empirical study, I hope to,
arrive at a more subtle, well-informed and balanced judgement of the properties and performance of the two paradigms. However, it will be seen from the empirical study that the evidence we can collect for this is rather circumstantial, anecdotal and indirect: there is no direct evidence that can be the basis of a clear and simple comparison. The empirical study is not designed to falsify hypotheses about the paradigms, or to reject one or the other of the paradigms as hopeless in describing design. The empirical study is just an exploration of the properties of the paradigms, in which we hope to discover how they perform in describing design-as-experienced.

2.2.2 ON DESCRIPTION METHODS

Paradigms, such as rational problem solving and reflective practice, are a mixture of concrete and abstract statements that cannot be tested empirically. To test them a description method for design has to be developed on the basis of each paradigm that faithfully mirrors its most important properties at a lower level of abstraction. Figure 2.1 outlines the steps of this process.

A description method is a part, a selection of a paradigm made with a specific goal in mind. So this 'translation' of the abstract paradigm into a more concrete description method, encoding system and data processing method is not unique. One and the same paradigm can be implemented in many different ways, which will limit the scope of the conclusions that can be drawn about the paradigm itself. In the next chapters we will carefully select the description methods in such a way that they enable us to study the relevant issues in this project.

For this thesis, the tests will concentrate on the ability of the description methods to capture the issues of design-as-experienced. The comparison of the rational problem solving and reflective practice paradigms will hopefully suggest improvements of the description of design-as-experienced. Our first research challenge is to develop description methods, encoding systems and data processing systems based on something as general as a paradigm. We must then find ways to translate the concrete empirical findings back into the extremely abstract level of the paradigms.
A fundamental problem of developing the description methods is that paradigms are teleological constructs, and as such they are not true or false. They can only be more or less suited to the goals for which they were made. For this they define their own unique sets of values. This uniqueness means that they cannot be compared to an 'absolute' standard, and they cannot even be directly compared to each other. Such a comparison could be very unfair, since one of the paradigms is bound to be judged on a number of criteria that it was not meant for. Here, the problem is solved by requiring of the paradigms a concrete description of an aspect of design that lies outside the explicit scope of each of them. Later we will choose integration for this role, as it is one of the key aspects of design—as-experienced.

For this thesis the description methods must function in a protocol study of practising industrial design engineers, who were videotaped while working on a short design task. The experiment was set up to make the design task and the conditions as realistic as possible within a laboratory environment. The ensuing design activities were captured on videotape, from which transcripts were made. The requests for information by the designers were recorded, and their sketches and drawings were collected. This is a fairly straightforward, broad and extremely detailed way of collecting raw data, which then requires careful processing and
interpretation. (The burden of scientific work is effectively shifted from the setting up of an experiment (that is not very well-aimed, and broad) to the handling of the data.) The links between the paradigms, the derived description methods and the encoding systems must be made with the utmost care.

The place of description methods in the scheme of this research project and the constraints this poses upon such a method has been outlined. But in addition to these 'external' criteria, there are a number of issues that determine the 'intrinsic' quality of a description method*. These criteria will guide the construction of the description methods in the next chapters.

- **Consistency.** For a description method to be of any value, it should be internally consistent. Logical flaws in the structure of the method could result in contradictions or systematic ambiguity in the use of the method.

- **Acceptable conclusions.** The conclusions that can be drawn using this system as a basis should be realistic. This may seem an unscientific criterion, and it could indeed be used maliciously in a circular justification ('just seeing what you want to see'). What I mean here can be illustrated by the study of Snoek [1990], a comparative protocol analysis of novice and expert neurologists making a diagnosis. The study was meant to uncover the differences between the methods of the two groups, but the analysis of the protocols in one of his earlier research layouts failed to show the apparent differences that he wanted to describe. The conclusion that novices and experts work in the same way is, of course, unacceptable.

- **Clarity of concepts.** The concepts used in the description method should be rigorous and clear, to prevent ambiguous conclusions.

- **Clarity of assumptions.** The assumptions underlying a method of description should be clear, reasonable (at least probable) and there should be as few assumptions as possible. Also, the consequences to the results of the empirical research should be outlined, and the ways in which they limit the scope and validity of the conclusions that are drawn from these results should be known. The assumptions should not limit the validity of the 'vital' conclusions of the study.

- **Clarity of goals.** It should be clear what the aims of the study are, so that the way assumptions have been handled can be critically considered by others.

- **Completeness.** The description method should cover the data in such a way that the relevant conclusions can indeed be drawn from this.

- **Ease of use & interrater-reliability.** The use of any description method

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* This list is a combination of the criteria used for the setting up of philosophical systems [Doorman, 1980][Kuhn, 1962] and those for making performance specifications in design [Roozenburg, 1991].
should be practical, and it should not depend unduly upon the identity of the person using it. The interrater-reliability should be high enough to give the results a sufficient degree of intersubjectivity. The amount of interpretation of the data involved in working with the description method should be small, or there should be explicit, strict and consistent rules for this interpretation.

2.2.3 INTEGRATION

The next item to be discussed is the focus of our design descriptions. We need a clear and simple focus because design activities are too diverse to be described 'generally' in any meaningful way. The whole of design methodology bears witness to the fact that many different approaches and subjects are possible and useful. My own attempt to focus empirical design research by organising a research workshop based on one concrete set of protocol data resulted in a set of papers that were still confusingly diverse [Dorst1995][Cross, 1996]. Such a kaleidoscopic view is interesting in its own right, but it does not help answer the specific questions of this thesis. The research setup requires further specification. We need to investigate a specific goal or subject within each paradigm. As this is an exploration of design-as-experienced, I selected one the design experiences that were listed in § 1.3.

Integration was chosen as the subject of this thesis, for a number of reasons:

- Integration is an important subject within the domain of industrial design engineering. It can be seen as the core of this profession, that according to its definition aims to 'embrace' and 'combine' different aspects of designing into an 'integrated' product. The ability to integrate is seen as one of the core abilities of industrial design engineers [Buijs, 1996].

- Integration has not yet been examined within design methodology. This is mildly surprising, but this is probably due to the fact that integration is, on the whole, less important in the two major domains of design methodology, Engineering and Architecture. This also weighs against choosing integration as the subject of a study which aims to include all design disciplines. But the fact that integration is less important does not mean that it is not relevant to those disciplines. It would certainly be a valuable contribution of this study if it could address this blind spot of current design methodology.

- The balancing of design aspects is something that pervades design decisions in concrete design situations. It is part of the experience of being a designer, 'thrown' into a design situation. Therefore integration is a good representative of the design experiences in general (as they were listed in § 1.3).
Integration has not yet been described in either of the paradigms. By concentrating on the ability of the paradigms to capture the integrative industrial design engineering activity we position them to compete on neutral territory (integration), with an impartial referee (closeness to design-as-experienced).

Integration as a design activity can be useful to design research because it connects the ‘content’ and ‘process’-components of design decisions. The study of integration could thus help bridge the divide between the general process knowledge of design methodologists and the more content oriented knowledge of practising designers.
Therefore the comparison of the two paradigms in design methodology will be based on the description of integration within industrial design engineering activities (see figure 2.2).

2·3 INTEGRATION: DEFINITION AND STRATEGIES

In this section the rather elusive concept of integration will be formally defined. Because integration is new within design methodology, a nomological network will be constructed and general strategies for reaching integration will be discussed.

2·3·1 DEFINITION OF INTEGRATION

There is a slight problem in defining integration for this study, which must be addressed before we can proceed: any definition of integration within design methodology will, of course, be based on one of the two paradigms that constitute design methodology. The dilemma is that it is necessary to define a concept, but we can only do this in terms of the paradigms that are to be investigated. For now, the rational problem solving paradigm is taken as a temporary vantage point to look at integration. The positivistic rational problem solving paradigm is definitely better suited for this task because it is well-known and accepted within the research community. The concept of integration must then be redefined before being used to scrutinise the descriptive properties of the reflective practice paradigm.

In his definition of industrial design Maldonado mentioned that the demands of different stakeholders (e.g. the producer, the user) must be integrated into the designed product. Also, he stated that industrial design problems require integration in another sense: when designing a product, technical, ergonomical, aesthetical- and business considerations must be taken into account. Already, these statements give an impression of what a definition of integration could be. But for the purposes of this study we must go one level deeper and try to define integration as a specific form of human activity, which can (hopefully) be observed in the empirical study.

Design activities are viewed throughout this study as the development of a network of decisions in a human mind, possibly with the help of some material tools (sketches can be seen as 'external short-term memory' [Ullman,1991,1992]).

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A product which results from design activities is therefore just the material reflection of a thought process. In other words, a product is a network of thought-out forms and properties, of objects and thought-out links between them which have been instilled with meaning. I would like to point out that in such a definition a 'product' is the total network of decisions that has been built up while designing, including the vast number of possibilities that were considered, but were in the end rejected, information processed but not directly used, the background theories that were used, etc. So the thought-construct 'product' is larger than what is normally seen as the direct outcome of a design activity. On the other hand, inadvertent properties or things that just happened to end up in the material product do not fall within the definition of thought-construct 'product', because they were not part of the thought process [Raaymakers, 1985]. Design thus becomes a thought process aimed at building a network of decisions that form the thought-construct 'product', which can be instantiated in the material world. The aim of industrial design engineering activities is to develop a product in which decisions were taken which link the elements of the problem or solution, adequate in all relevant contexts. This process of linking, while taking into account more than one context, is called integration.

A definition of integration:

someone is designing in an integrated manner when he/she displays a reasoning process building up a network of decisions concerning a topic (part of the problem or solution), while taking account of different contexts (distinct ways of looking at the problem or solution).

Figure 2.3 is an illustration of this. The process-states are shown at the top, the content-states (the corresponding effect on the thought-construct 'product') can be seen at the bottom. In the two steps of the design process one topic is looked at from two contexts. This results in a design decision about this topic that combines the viewpoints of the contexts: the two contexts are integrated in a decision about the topic.

This definition of integration is meant to be as close as possible to the common usage of the word in everyday practice. For this definition to be viable within the rational problem solving framework, the key concepts of 'topic' and 'context' will have to be defined within the rational problem solving paradigm. That will be done in § 3.2.2.
2.3.2 NOMOLOGICAL NETWORK

In a nomological network, a concept is described by defining its links to other concepts that are theoretically or practically close to it. In this section, the concept of integration as defined above will be contrasted with ten other concepts and theories that are conceptually near.

- **Integration versus combination**
  
  The word integration is sometimes used for the process of combining subsolutions or features in a design process. This kind of 'integration' (rather: 'combination') is illustrated in figure 2.4. In the two steps of this design process one context provides the viewpoint for the decisions about two topics. For instance, the technical 'integration' of mounting points for some printed circuit boards in the housing of a shaver. That kind of 'integration' is not under consideration here - this study deals exclusively with multi-viewpoint decisions concerning topics in design activities.
• **Integration versus product integrity**
  Our description of integration has very little to do with product integrity, as it is sometimes used: a metaphysical notion of ‘wholeness’ or ‘rightness’ in a product design [Clark, 1990] [Lewis, 1989]. There is a certain feeling of simplicity (‘unification’, if you want) to a well-integrated design, the feeling that nothing should or could have been done differently. And there probably is agreement among judges about the ‘integratedness’ of certain design solutions. But that is just because integration is a word for the number (and density) of conceptual links that have been made between the different parts of the design problem or solution, looking from different contexts. This case of perception does give ‘integration’ a certain holistic glow, some feeling of being the ‘essence’ of a designed object, the ‘product integrity’. But from the standpoint of the working designer, integration is just a goal to be reached by looking at topics from different contexts.

• **Integration as an activity versus integration as a quality of a design**
  Integration is defined above as an activity rather than as a quality of a designed object.
One could talk about the level of integration in a product, and in practice people do so, but that level of integration is not measurable on an objective scale. Perhaps it would be possible to rank products from less to more integrated, with a high level of agreement between the graders. But that is only an approximation of what you are really measuring, the topics that have been considered from different contexts. Determining the level of integration of a designed product in a scientifically acceptable and interesting way does not seem to be possible, at least not purely from looking at the end result of a design project. Integration can be more rigorously assessed when it is being done, when explicit multi-context views on topics are being developed. In this study we concentrate on getting more insight into the activities of designers, and avoid developing semi-objective measures for the end result of their exertions.

- **Integration versus coherence**
  Coherence could be described as the purposefulness or 'unity' of a design, it is a measure of the clarity of the designer’s goals and the consistency with which they were pursued (see § 1•3•2). It is - like integration - a goal that is important in the problem determination phase and the conceptual phase of the design process. In the problem determination phase the priorities for the design are exposed, negotiated or imposed by the designer. From then on, the designer will use certain strategies/heuristics to ensure the coherence of the design relative to these priorities, and to balance the different aspects that have to be 'reconciled' (integrated) in the design. The two goals are often at odds with each other: the need for integration can lead to compromises that potentially harm the coherence of a design.

- **Integration versus optimisation**
  Optimisation is the (incremental) improvement of an already existing product or design concept. Optimisation is generally used to describe the reasoning patterns that occur in redesign or in the embodiment phases of new design projects. Integration is also an (often incremental) improvement, but in contrast to optimisation it involves changes in context, the balancing of stakeholders or aspects. It can take place in all phases of the design process; the biggest leap in the ‘amount of integration’ is generally achieved in the conceptual phase.

- **Integration versus holistic problem solving**
  Integration is a very clear and specific design goal. It has to do with the links that have to be forged between parts of the design problem or solution.
This preoccupation with links does not necessarily mean that a person trying to make an integrated design has to consider the product as a whole throughout the process. It does mean that the designer should be aware that the product will in the end have to function as an undivided whole. Products stand in the world as ‘holistic’ objects, but this whole does not necessarily have to be reached by purely ‘holistic methods’.

- **Integration versus creative ideas**
  Integration is closely linked to the concept of ‘idea’. An idea, as the sudden occurrence of a ‘whole’ in what used to be a messy and ambiguous situation, can indeed be integrative in nature [Christiaans, 1991][Davies, 1987]. Integration can be attained by ideas, but that is not the only way. Most integration is very hard work (at least, for me it is), occasionally speeded up by ‘good’ (integrative) ideas.

- **Integration versus concurrent engineering**
  Concurrent engineering is a process management technique that seeks to structure the parallel development of different parts (however defined) of a design, the company organisation, marketing and production facilities. As such, it has to deal with the problems of attaining integration, maybe slightly more so than ‘traditional’, more linear ways of controlling and managing design projects. But theoretically speaking, the activity or process of integration will not be influenced by the order or parallelism of parts of a design project [Bos, 1993].

- **Integration versus feature modelling**
  Integration is not supported, and in most cases made a lot more difficult, by today’s Computer Aided Design systems. Some of the activities vital to attaining integration, like switching back and forth in the notes or drawings of a design, the assigning of value to different items of interest and the making of overviews over different (incommensurable) kinds of information, are decided weaknesses of computer tools in general. The mistaken use of the word and concept of ‘feature’ (namely, as a predefined and detachable part of a designed object) makes the more ‘intelligent’ CAD systems worse in facilitating integration than the simpler drawing packages.

- **Integration versus the structuring of a design problem**
  Design problems in general, and maybe industrial design problems in particular, do not have a strong and clear structure of themselves, but they can be thought of as being structurable in many ways [Cross, 1995]. These imposed structures can serve as tools which help a designer to get the design problem
under control in various stages of the design project. In the strategies of
designers these 'structures' of the design task must ultimately be combined in
an integrated solution. In integrating, the designer manipulates different ways
of structuring a design task. The structuring frameworks under consideration
here are 'universal particular' contexts, related to the aspects and stakeholders
that play a role in industrial design engineering, see § 3.2.2.

2.3.3 STRATEGIES FOR INTEGRATION

Our current definition of integration is static, in the sense that integration is
described as an activity, without describing how this activity can be carried out.
To trace the occurrence and handling of integration in a design activity, we need
to know how to recognise it. This means that we need have an idea of the way
the activity of integration works. What are the (strings of) activities that a designer
does, or needs to do, to achieve integration?

The first principle underlying any strategy for achieving integration has already
been named in § 1.3.2 as balance, or compensation: a designer, having
concentrated on a part of the design problem will have to compensate for the
inevitable limitations and bias in this initial treatment by making a second step
that is complementary to the first. For instance, if a part of the product has been
designed focusing on form the designer will have to compensate for this bias by at
least checking if the initial design idea is technically possible, producible,
ergonomic and that it is economically feasible. Little integration-loops like these
are made constantly while designing. Integration is not limited to only one level
of abstraction, phase of activity or time scale. It potentially pervades the whole
industrial design activity, from beginning to end. The second issue underlying
strategies for achieving integration is the management of information.
Designers face great difficulties while integrating because it involves the making
of a network of multiple interdependent links. Design problems are seldom
'additive'. Splitting them up into subproblems, solving these and 'adding'
(combining) the subsolutions does not yield an efficient and effective total
solution. The solutions to the subproblems must be developed more or less in
parallel, and brought together with the greatest care. The need to handle many
subproblems and to satisfy many factors in parallel puts a strain on the limited
information processing capacities of a designer. It is impossible to do this
simultaneously, so an intelligent way of getting to an acceptable solution must be
found. Strategies to attain this are based on limiting the amount of information to
be processed, reducing the number of conceptual links to be considered at any one time, and on the construction of a starting point for integrating design activities. Five general strategies for information-management in the design process have been identified in earlier empirical research into engineering design activities. The list below is mainly based on work by Norbert Dylla [1991]. To limit the amount of information that has to be processed at any one time, one could generally follow either one of two strategies:

- **Abstract -> concrete**
  Make an abstraction of the problem, and then descend concentrically to reality. This strategy is built on the assumption that there is such a central, abstract core to a design problem, or that one can be made. In ‘concentric development’ the designer, working on a design at a certain level of abstraction carefully deals with all aspects of the design problem or solution at that level before descending to a more concrete level.

- **Divide -> solve -> reconnect**
  Divide the problem, analyse and solve the subproblems and then reconnect the subsolutions, concentrating on the interfaces. This strategy depends on the design problem being both ‘divisible’ and ‘additive’. Some design problems can be divided, right from the start, into independent subproblems. This rarely happens in the particular field of industrial design engineering, but this is still an important strategy that is often used as a useful approximation of reality. It often is not that useful at the very general level where a designer identifies components and makes configurations. But it could be relevant in the embodiment phase of design activities. And if a design task is divisible and additive, the divide->solve->reconnect strategy is very strong indeed.

There are several strategies to limit the number of links between decisions that have to be considered at any one time:

- **Adopt -> adapt**
  Adopt an integrated solution structure, and then adapt the solution to the problem at hand. By adopting a general solution structure that approximately fits and then changing the details to really solve the particular design problem at hand one potentially saves a lot of work. However, there are dangers to this approach: unless one knows the solution structure-to-be-adopted very well, all kinds of unknown assumptions and decisions might creep into the design (often, when this strategy is used, the solution adopted is one that the designer him/herself has worked on before). When this strategy is applied without analysing the
design problem it can lead to an unconscious ‘jumping to conclusions’ that produces suboptimal designs or results in a lengthy process of solution-adaptation, in which cases work nor time is saved by using this strategy.

- **Prioritise -> solve -> adapt**
  This common strategy is based on the fact that integration is easier when done among factors of differing importance. If there is a dominant context, or one can be imposed, a core solution can be developed with this one context in mind. Most of the less-important contexts and their interdependencies can then be ignored. Once the core solution is constructed to satisfy the first priority, other parts of the developing design are adapted to fit this core solution.

A designer can be in a position that he/she has to create a **starting point** from which to propagate the integration.

- **Start -> correct**
  One could take a (random) starting point and compensate possible bias by taking other, complementary standpoints in turn. When there is no structure to a design task, and no clear priorities can be imposed, one has to let a design emerge that can be worked on with other strategies. The criticism of the concrete initial design will then assist in discovering what is important, where there is a conflict of requirements, etc. Jack Howe, an engineering designer, reported on this in an interview: ‘I draw something -even if it's “potty”, I draw it. The act of drawing seems to clarify my thoughts.’ [Cross,1990].

This strategy is, in fact, the opposite of the first one: the designer is working with concrete design solutions to get an image of more abstract design problems. Difficulties in the use of this strategy centre around the risk of tackling the design task from an unpromising angle, and a possibly inappropriate emphasis on some part of the problem or solution.

It should be noted that these design strategies are not ‘pretty’: design is pragmatic, messy and opportunistic (or dishonest, when ‘adopt’ becomes ‘steal’). The use of these strategies has a tendency to be ‘messy’ as well. In real life they will be used incompletely, at different levels of generality, at different phases in the development of the problem or solution, and more or less in parallel.

These kinds of strategies, that I have presented above as being tied to integration have been observed by many of the researchers doing protocol studies or looking at design activities by similar means [Blessing,1994][Fricke,1993]. They are central to design reasoning. They help attain integration, but they also serve a number of other goals. Some of them can be useful for reaching and maintaining coherence,
or for the general management and control of design activities. This very universality is one more reason one cannot easily identify the process-dimension of integration. Integration is tied up in strategies that also have a wider use, so patterns found in empirical data that reflect these strategies do not strictly guarantee that integration is taking place. The surest, and maybe the only way to identify integration is to check the occurrence of these strategies by looking at the content of what the designers are saying, and identify instances in which they can be seen to or explicitly report on balancing contexts. This explicit reflection on integration is most likely to take place when designers evaluate their progress towards a solution.

2.4 OUTLINE OF THE STUDY

The research layout that has emerged is mirrored in the structure of the thesis, see Figure 2.5.

![Diagram](image)

Figure 2.5 - The outline of this study.
In *chapter three* the paradigm of rational problem solving is introduced. Integration is defined within this paradigm. A description method of design as an integrative rational problem solving process is derived. Theses are formulated based on the description of design as an integrative rational problem solving activity. In *chapter four* the paradigm of reflective practice is treated in the same way. The empirical study is introduced in *chapter five*. The protocol analysis method is introduced, and its usefulness for studying design activities will be considered critically. The empirical study is described and commented upon in the light of recent developments in design methodology. Then an overview is given of the results of the empirical study. These results of looking at the integrative design activity with the help of the two description methods will be discussed in great detail. In *chapter six* conclusions are drawn on the descriptive performance of the two paradigms, and a model for handling design descriptions is proposed.
3  

DESIGN AS RATIONAL PROBLEM SOLVING

The rational problem solving paradigm is introduced in § 3•1. A description method for the integrative rational problem solving process is developed in § 3•2. Then, theses will be formulated (§ 3•3) that can be used to explore the descriptive abilities of the rational problem solving paradigm in the empirical study.

3•1 THE RATIONAL PROBLEM SOLVING PARADIGM

3•1•1 HISTORY

A brief history of design methodology has already been given in § 1•1. We take up the story in the late sixties, when the abstract and fundamental ‘analytical paradigm of design’ [Alexander, 1964] [Tzonis, 1992] was collapsing. It had proven to be unrealistic and failed to improve the efficiency and effectiveness of design processes. The more practice-based branch of design methodology (like the phase models of Archer and the VDI) was not directly affected by this collapse, but struggled with the fact that its theories only dealt with the design processes. Knowledge about the other ‘dimensions of design’ (see figure 1.2) was available and deemed important, but it could not be given a solid theoretical basis within this design methodology. Doubt also remained about the scientific status of these process models, though they were recognised as being both pragmatic and useful. Inspired introspection and rationalisation of practice does not necessarily lead to science - for that one needs a theoretical framework that guides the process of scientific abstraction through the steps of description, model making, theory-forming and (possibly) experimentation. This theoretical framework should be explicit and act as a safeguard against uncontrolled bias.

The rational problem solving theory, as introduced at that point in time by Simon, had by far the most impact on design methodology. It addressed the need for fundamentalisation while incorporating the theories and adopting the goals already present in the field. It contained new elements, as well as providing more
rigour to the existing thoughts about design.

- The rational problem solving theory incorporates more knowledge about all three dimensions of design. It contains statements about design processes (i.e. phase models and optimisation techniques), design problems (ill-structured in certain ways) and designers (as information processors, with certain cognitive limitations). Most importantly it contains statements about the way these three merge in the design activity (the problem solving theory).
- The rational problem solving theory also provides a theoretical basis for the emancipation of design (and design studies) as a profession, by placing it in the framework of the 'sciences of the artificial'.

By adopting these fundamentals, a design methodology emerged that could claim to be a veritable 'science of design'. And a science that although specific in some senses could use the positivistic outlook and methods that made it an unflinching member of the community of sciences. With the adoption of this paradigm a positivistic heritage has become firmly embedded in design methodology. Thus there was no 'paradigmatic revolution' needed for the general acceptance of these ideas. Design methodology, as a young discipline, had no such all-encompassing paradigm, it had (in Kuhn's terms) never seen a period of broadly accepted 'normal science'. The basis needed for that was finally provided by the rational problem solving approach. Since then the basic assumptions, goals and views of this paradigm have been so widely adopted that 'to do design research' is to work within this paradigm.

3.1.2 GENERAL PROBLEM SOLVING

The rational problem solving approach in design methodology is a combination of practice-based phase models of the design process, a model of the designer as an information processor from the field of cognitive psychology, and some thinking on the nature of design problems. The glue that holds these together and defines their connections is the theory of 'human problem solving'. The central paradigm or metaphor in this field is that problem solving can be described as

'..... the search for a solution through a vast maze of possibilities (within the problem space)... Successful problem solving involves searching the maze selectively and reducing it to manageable solutions.' [Simon, 1969]

These search processes have been studied through protocol analysis of subjects solving chess- and cryptarithmetic problems. They can be displayed and analysed in 'problem behaviour graphs' [Newell, 1972]. This approach has been developed in domains where problem solving involves mainly deductive and inductive
reasoning. Simon’s key contribution to design methodology was to state that the productive thought of design could be captured in the same positivistic framework.

3.1.3 THE RATIONAL PROBLEM SOLVING APPROACH TO DESIGN

Simon’s design theory will now be characterised by describing how it views designers, design tasks and design processes. This will be augmented by two points that characterise its approach to design science: the knowledge needed for designing and a model for the science of design (see Figure 3.1). This description is largely based upon direct quotes from the most influential source of the paradigm, ‘The Sciences of the Artificial’ [Simon, 1969, 1992].

![Rational Problem Solving Diagram]

Figure 3.1 – A summary of the rational problem solving paradigm
• Designers

Problem solvers are seen as ‘goal-seeking information processing systems’, operating in an objective and knowable reality. Simon explicitly states that his theory does not take into account the processes and results of human perception. The assumption is that

‘A man, viewed as a behaving system, is quite simple. The apparent complexity of his behaviour over time is largely a reflection of the complexity of the environment in which he finds himself... in studying an adaptive system (like man)... we can often predict behaviour from knowledge of the system’s goals and its outer environment, with only minimal assumptions about the inner environment.’

This has lead to an easy acceptance within this paradigm of design theories and methods that are (supposedly) independent of the detailed properties of the designer or designers they are meant to support.

• Design tasks

Problem solving theory is concerned with the ways in which people or artificial systems arrive at solutions to problems they encounter. This theory can be captured by four propositions:

• A few gross characteristics of the human Information Processing System are invariant over task and problem solver (see above).

• These characteristics are sufficient to determine that a task environment is represented as a problem space, and that problem solving takes place in a problem space (For a detailed definition of problem space, see §3•2•3).

• The structure of the task environment determines the possible structures of the problem space.

• The structure of the problem space determines the possible programs that can be used for problem solving. ’ (from: [Newell,1972])

If this theory is valid for design, design problem solving also takes place within a problem space that is structured by the structure of the task environment, which in its turn determines the ‘programs’ (strategies or methods) that can be used for designing. In a later paper Simon [1973] addressed some of the difficulties that might arise in applying the rational problem solving approach to design by defining design problems as ‘ill-structured problems’.

Ill-structured problems are to be tackled in an ‘immediate problem space’. This is a part of the total problem space which is deemed too large, ill-structured and ill-defined to be described. The immediate problem space is addressed and
put together by an (unspecified) ‘noticing and evoking mechanism’. The basic ‘design’ problem-solving process would be the same as in other kinds of problem solving.

The goal of a design process is to arrive at a solution that is ‘good enough’,

‘we satisfice by looking for alternatives in such a way that we can generally find an acceptable one after only moderate search.’

**Design processes**

Design processes are seen as search processes through the problem space. In ‘The Sciences of the Artificial’, Simon outlines the pattern of search in a problem that is ‘additive’. He remarks that the ‘validity requires some rather strong assumptions about the independence of the effects of the several actions on the several differences’. But he maintains that design problems are (to be) hierarchically organised, and the way to design a complex structure is to discover viable ways of decomposing it into subproblems, solving these and combining them to arrive at a new overall solution.

In problem-solving theory, a ‘good’ (most efficient) reasoning process is defined as the one that involves the shortest search path through the problem space. For ill-structured problems like design, the shortness of the search path is important, but there are a number of factors that could lengthen the search process while still being considered good design practice:

- It is widely accepted that one should take time to explore more than one view of the problem and solution.
- It is also good design practice to accumulate knowledge around an acceptable solution, which will aid its later modification and embodiment.

Apart from this, in a ‘satisficing’ process like design, the path-length measures are hard to use: the fact that there is no exact measure of goal attainment means that the length of the path cannot be measured either. So instead of this criterion, Simon states a number of concrete processes and issues that characterise a good, rigorous design process:

- search for and find ‘command variables’
- compute the optimum solution
- use means-ends analysis
- manage the resource allocation
- use schemes for guiding search
- tackle the design problem by hierarchical decomposition along functional lines
- display generate-test cycles throughout the design process
• manipulate alternative representations of the design problem and solution.

• **Design knowledge**

At the end of his book, Simon summarises his theory by itemising areas of design research that form the essential knowledge base for the education of designers:

' **The evaluation of designs:**
  • utility theory, statistical decision theory

**Computational methods:**
  • algorithms for choosing optimal alternatives (linear programming, control theory, dynamic programming)
  • algorithms and heuristics for choosing satisfactory alternatives

**Formal logic of design:**
  • imperative and declarative logic

**Search for alternatives**
  • heuristic search (factorisation and means-ends analysis)
  • allocation of resources for search

**Theory of structure and design organisation:**
  • hierarchic systems

**Representation of design problems**

• **Models for a science of design**

Searching for a model for the theory of design, Simon turns to

' a considerable area of design practice where standards of rigour and inference are as high as one could wish... optimization methods... The optimization problem is to find an admissible set of values of the command variables, compatible with the constraints, that maximize the utility function for the given values of the environmental parameters.'

A real science of design should be modelled on the natural sciences: it should be

' the discovery of a partially concealed pattern' in a rigorous and objective way. Design science could then become 'a body of intellectually tough, analytic, formalizable, partly empirical, and teachable doctrine about the design process... In the past, much, if not most, of what we knew about design... was intellectually soft, intuitive, informal, and cookbooky...’

Simon thus seeks to build a rigorous theory of design processes, with rather far-reaching assumptions about the properties of designers and design tasks.
3.1.4 A HIERARCHY OF PARADIGMS

The quotes above contain the fundamentals, the ontology and epistemology of the rational problem solving paradigm. But a paradigm can be defined at many levels of abstraction; it pervades a science from the very abstract to the very concrete. A paradigm is not a unified whole but consists of a number of theories, that show a 'family resemblance' [Wittgenstein, 1953]. Therefore, paradigms will to some extent escape definition: they can just be characterised by naming their fundamentals and main properties.

The rational problem solving paradigm will now be put in perspective by placing it in a hierarchy of paradigms that shows its position relative to more abstract theories. Later the paradigm will be extended in the opposite direction, when it must be implemented on a much lower level of abstraction for use in the empirical study.

The rational problem solving approach to designing has its roots in the paradigm of technical rationality. This paradigm considers problems to be solvable by 'rigorously applying general principles, standardised knowledge (based on rigorous scientific research) to concrete problems' [Schön, 1983]. This paradigm of technical rationality is based upon a general positivistic epistemology. Positivists hold that science is the only source of knowledge about the world, and that this objective knowledge of reality can be extended to control technology, human behaviour and society. The role of science within this paradigm is to discover how the phenomena of objective reality are related to each other, and what the laws of nature are [Andreski, 1974]. This hierarchy of paradigms is illustrated in Figure 3.2. Please note that the family tree of paradigms branches out, when going from top to bottom: the positivist epistemology has inspired many paradigms in different fields besides technical rationality paradigm that it resulted in for the technical sciences*. Likewise, the paradigm of technical rationality as it is applied to design has not only led to the rational problem solving paradigm, but has also provided the background for the purely process-oriented approaches like the 'systematic design models' that are most extensively used in Engineering [VDI, 1985] [Pahl, 1986].

* For instance, it lead to the development of neopositivism by the Vienna Circle [Kraft, 1968].
3.1.5 INFLUENCE OF THE RATIONAL PROBLEM SOLVING PARADIGM

Given that a paradigm is this rather diffuse pattern of thoughts in a scientific discipline, we must address the question which elements of the rational problem solving approach are worth considering a paradigm in this study, in the sense of having been a ‘dominant force’ in design science. This is then taken to be the kernel (a posteriori, in practice) of the rational problem solving paradigm. Well, the rational problem solving paradigm as paraphrased in § 3.1.3 has not, in this exact form, been a dominant force in design methodology. Some of its assumptions have not been generally accepted as realistic. There is a broad consensus that not all of design can be captured in factorial methods as are used in optimisation, and the interdependency of design subproblems usually prohibits the ‘addition’ of subsolutions. The crucial ‘noticing-and evoking mechanism’ [Newell,1972] which plays such a vital role in the theory’s applicability has not been specified further by Simon or by any other author. The same holds true for the elusive ‘structure of the design problem space’. The question is whether these clarifications can really be made without overstepping the bounds of the paradigm. And finally, no one has succeeded in describing the complex and productive design process using standard problem solving methods such as problem behaviour graphs.

On the other hand, the rationalistic approach of this paradigm and many of its basic assumptions have been adopted by the design research community.
These fundamentals are mostly on the level of the paradigm of technical rationality (see figure 3.2). They are the common ground between this rational problem solving paradigm and the 'systematic design models- school' of design methodology. But still, Simon's theories are of particular interest to this thesis. They stand (almost) alone in their breadth as an attempt to make a science of design which captures the three dimensions of design and their interrelations, and to define the essence of designing itself. The books and papers by Simon have become the common ground that 'the design research community' continually quotes as the established basis of their approach to design research.

This thesis is a comparison of the descriptive properties of the two paradigms of design methodology, by employing an empirical study. The empirical study forces us to test a concrete guise of the rational problem solving paradigm and by doing so we are also testing the more abstract theories, general attitudes and epistemology which it contains. As it happens the conclusions of the empirical study will focus again on the general principles of technical rationality, rather than the details of rational problem solving. It turns out that this is the level at which the differences in the two paradigms can best be understood, and at which alternative approaches can be found to improve the methodological description of design activities.

The systematic design models (the phase-models of the design process, see figure 3.2) play a vital assisting role in this. They will be used to complement the rather general statements on 'design processes' in Simon's theory which are too vague for the purpose of the empirical study. This combining of the rational problem solving approach with the process models of design is common in the positivist branch of design methodology.

3.2 DESCRIBING DESIGN AS AN INTEGRATIVE RATIONAL PROBLEM SOLVING PROCESS

We will now develop a description method for design as an integrative rational problem solving process.

3.2.1 A DESCRIPTION METHOD

In literature, there is an abundance of empirical studies that are implicitly based upon the paradigms of technical rationality and rational problem solving. Some of

* As an illustration: in the two Research in Design Thinking workshops organized in 1992 and 1994 by the Delft Faculty of Industrial Design Engineering, visited by a fair cross-section of design researchers from Product Design, Engineering and Architecture, Simon was referred to more than anyone else: 31 direct references and goodness knows how many indirect ones in 32 papers.
the most rigorous studies are informed by the Pahl and Beitz [1986] model of the design process, which combines the paradigm of technical rationality with a strong systematic-phase-models orientation [Blessing, 1994][Fricke, 1993] [Hales, 1987]. Their description methods were directed at uncovering strategies and heuristics for the design process, and they do not capture the development of the product that is being designed. They are less suited for our present goal because a viable description method within the framework of rational problem solving should include both the process and content of the design activity. And we need descriptions of both the process and content of designing as a basis for describing integration.

The empirical study by McGinnis and Ullman [1992] reported in their paper ‘The evolution of commitments in the design of a component’ is very relevant to this thesis, because it subscribes completely to the rational problem solving approach to design and design methodology and it strives to get close to a description of the content as well as the process of design. They follow the development of one part of a product in a larger design task, describing the ‘product elements’ considered by the designer and the constraints that are imposed upon them. This most interesting study was done in a series of projects concentrating upon the uncovering and use of design histories. A summary:

*McGinnis and Ullman set out to study the development of one component of a machine throughout a four and a half hour design session. The aim is to trace and describe the way in which the machine component gets gradually more defined, by the accumulation of constraints on its form and function. This obliges them to look very closely at the empirical data, a ‘thinking-aloud’ protocol. They avoid making assumptions about the kinds of ‘design objects’ that are to be considered by consistently using the terms in which the designer refers to the design. This data-driven approach offers a simple, objective, straight-forward and rigorous way of following how a designer works.*

*The theory-driven part of the study is that they divide the ‘design objects’ thus found into ‘form features’ and ‘functional features’. The authors refer to their study as ‘bookkeeping of the design process’, and publish the raw data, as well as some conclusions on the development of description methods for design.*

Their study adheres to the assumptions of the rational problem solving paradigm:

- The designer is seen as an impassionate info-processing unit.
- No *a priori* structure for the design problem is supposed, and the study is not
aimed at finding such a structure. The detailed study of the ‘design object’ is used to arrive at process-oriented conclusions.

- The study aims at making a formal model of the design process
- The study is executed within the paradigm of technical rationality; it investigates how the design process works, and does not consider why the design decisions were taken the way they were.
- The study was conceived with a strong emphasis on attaining rigorous results. A rather atypical aspect of this study is that the generalizability of the conclusions has been sacrificed to a certain extent by not using a predefined list of ‘design objects’ classifying which issue the designer is tackling. This is agrees with the exploratory nature of the study, but is in direct contrast to the overwhelming use of a priori scoring categories in other empirical studies within the rational problem solving paradigm [Frickc, 1993][Blessing, 1994][Frankenberger, 1996].

The study has the potential to get closer to describing integration and the other aspects of design-as-experienced than other studies based on this paradigm, because the vital connection between process and content was conserved by concentrating upon the development of the object being designed. And the ‘resolution’ of this description method would be suitable for a protocol study of integration, too: it tackles design activities at the level of designer’s statements. Thus it avoids the tricky interpretation step required in making more general (retrospective) summaries, and it avoids going into the more detailed logical or semantic layout of the designer’s statements. Therefore, this study is used as a model for the development of a description method for describing integration within a rational problem solving framework.

3.2.2 THE DESCRIPTION OF INTEGRATION WITHIN THE RATIONAL PROBLEM SOLVING PARADIGM

An integrative design activity was defined as:

someone is designing in an integrated manner when he/she displays a reasoning process building up a network of decisions concerning a topic (part of the problem or solution), while taking account of different contexts (distinct ways of looking at the problem or solution).

The key concepts in this definition, ‘topics’ and ‘contexts’ must be described in more detail within the rational problem solving paradigm.

- **Topics** - Topics are the features of the problem or product a designer is working on, the subjects of the reasoning designers do when making a design.
In [McGinnis, 1992] a list was made of the topics considered by one engineering designer who was making a single product component. The length and diversity of the list is impressive. Designers tend to split up the design problem in different ways (defining features in several different contexts) and at a number of levels of detail. In this study I will attempt to at least pre-categorise the topics the designer deals with to achieve more rigour in the data encoding system.

- **Contexts** - The 'context', as we use it, is a 'way of looking', the 'view of the problem' at a stage in the reasoning process of a designer. As such it is closely associated with the 'problem space' as introduced by Newell and Simon [Newell, 1972], where they define a problem space as

  'A set of elements, \( U \), which are symbol structures, each representing a state of knowledge about the task

  - A set of operators, \( Q \), which are information processes, each producing a new state of knowledge from existing states of knowledge

  - An initial state of knowledge, \( \pi \), which is the knowledge about the task the problem solver has at the start of the problem solving.

  - A problem, which is posed by specifying a set of final, desired states \( G \), to be reached by applying operators from \( Q \).

  - The total knowledge available to a problem solver when he is in a given knowledge state, which includes:

    - temporary dynamic information created and used exclusively within a single knowledge state

    - the knowledge state itself

    - dynamic information about the task.

    - access information to the additional symbol structures held in Short Term Memory or External Memory (such as notes, sketches and drawings)

    - path information about how a given knowledge state was arrived at and what other actions were taken in this state if it has already been visited on prior occasions

    - access information to other knowledge states that have been reached previously and are now held in Long Term Memory or External Memory

    - reference information that is constant over the course of problem solving, available in Long Term Memory or External Memory'

* McGinnis and Ullman used the term 'product element' for this, but as designers deal not only with the product, but with a wide range of subjects, (they also reflect on the problem, their strategies, etc) the more general term 'topic' was adopted here.
This could be a good definition, in terms of knowledge content, of what I mean by the ‘context’ of a design consideration: a distinct and self-contained way of defining, looking at, operating upon, solving and evaluating a problem. But ‘context’ and ‘problem space’ are not quite the same, because the concepts differ in their uses. Newell and Simon assign one problem space to every problem, in which the whole of the solution process takes place. When considering the designing of a house, Simon remarks that:

‘...The design task is ill-structured...[thus (or because)]... The problem space is not defined in any meaningful way,...’ [Simon, 1973].

A context could then correspond with what Simon calls the ‘immediate problem space’, in which a designer works at a particular moment in time.

As such, the concept of integration implies that design problems, though they may be ill-structured, are coherently structurable from a number of different viewpoints (contexts). Therefore a context is a meaningful and coherent part of the total problem space of a particular problem, which still contains all the basic elements (problem states, goals, tools) of a general problem space as defined by Simon. For example:

Consider looking at a developing design from an aesthetical context only. That ‘context’ will determine the features seen, the goals to be attained and the tools that can be used. For aesthetics, these ‘tools’ include composition, texture, material, colour, rhythm, etc. And the goal might be a product which has a certain expression or harmony. Thus, the problem state is the measure to which the aesthetical goals are reached in the concept at hand.

Now, in order to be theoretically and practically useful, contexts have to be defined in such a way that they are independent, used by designers and generalizable across design tasks.

- **Independence of contexts** means that they should be separate worlds [Schön, 1984, 1988]. Independent contexts should be fundamentally different, and must be unconnected by categorical rules or laws. Continuing with the example above: It is not possible to make a direct theoretical and categorical link between the aesthetic context and the one dealing with the technical aspects of a design (which would give nonsensical categorical statements like ‘if you want your products to look aggressive, then you should use a gearbox’). The bottom line is that any product must function in a number of different, independent contexts - after all a product is a technical construction which also has aesthetic properties. The absence of any categorical connections
between contexts means that the designer has to create a new concrete union between elements of these contexts in the design of any product (in our example: the designer has to make sure that the product is well-constructed, but also has the right aesthetic expression). The connections that cannot be made on the abstract level of categorical statements have to be made on the concrete level of the product.

There have been numerous attempts to avoid this laborious integration process for every new product by connecting the contexts of design at a categorical level. But all of these led to design ideologies or ‘pseudo-theories’ that can never have a scientific status. For instance, in Kandinsky’s lectures at the Bauhaus he introduced theories of form and colour [Poling, 1986] [Roethel, 1977] in which he stated that squares are ‘naturally’ red, triangles yellow and circles blue. This is a valid statement by itself (everyone is free to choose) but it does not stand up under scientific scrutiny. Statements like these can be found in abundance, particularly statements that deal with aspects of aesthetics, form and formgiving. Van Doesburg [1919] explicitly claims a scientific, or at least ‘universal’ status for the theories of the De Stijl movement. These claims to universality and scientific status are based on a grave misunderstanding of the nature and status of art. The subjective categorical statements will not hold up indefinitely, and will ultimately be surpassed by others (they could be seen as the ‘paradigms of art’). But as such, these ideologies do help artists to define, clarify and defend their views and their ‘worlds’.

- **Contexts should be used as distinct ways of thinking by designers.**
  Contexts must be used, so they have to be attractive for designers as tools in their work. They must give some benefit by defining (part of) a design problem in such a way that it is coherent and easy to address. Thinking about the design problem from within one context must be easier to a designer than not using that context or working within a few contexts simultaneously.

- **Contexts should be generalizable across design problems.**
  The general definition of industrial design engineering already lists the contexts in which an industrial design product must fit. These are (1) the *aspects*, distinguishing between considerations of form, ergonomics, business and construction and (2) the *stakeholders*, these are the parties who are involved in a design project (the designer, the user, the manufacturer, society...). For our purpose these are called the ‘universal particular’ contexts.
The universal particular contexts that could feature in industrial design engineering are shown in figure 3.3. All of these contexts contain the complete set of knowledge, problem states, tools and goals relevant to their domain. Some of these contexts have previously been described. For instance, form and aesthetic has been described by Ashford as:

*Important concepts relevant to discussion on aesthetics are: (1) form and proportion, (2) visual balance, (3) clarity of form and expression, (4) colour, (5) rhythm, (6) surface texture, (7) unity*. (in: Lewis, 1989)

This description is a mixture of aesthetic goals (2, 3, 7) and the tools needed to reach these goals (1, 4, 5, 6). Other contexts have not been described before, but they are here effectively modelled on the disciplines that traditionally play a role in product development. They are classic divisions that are widely used in design education and practice. For the construction of our description method and encoding system we will assume that designers work within these universal particular contexts. Whether these contexts are actually used by designers is investigated in the empirical study.

Figure 3.3 - An overview of the universal particular contexts of industrial design engineering.

For a brief description of these aspects and stakeholders see Table 3.1.

This set of contexts for industrial design engineering is an open system; recently, these four aspects shown in Figure 3.3 are being joined by a fifth, 'environmental design'. In this book we will still use these four, because they were the only ones used by the designers in the empirical study, which dates back to 1992. If it were
repeated now, this aspect would undoubtedly play an important part in the
designer’s deliberations, and have to be treated accordingly in the description
method (for a study into this aspect, see [Bakker, 1995]).
Possible extra stakeholders that can be important include ‘society as a whole’,
‘other clients’, ‘non-users’, etc.

3.2.3 THE DESCRIPTION METHOD AND ENCODING SYSTEM

The description method now contains two categories to describe the content-
side of integrative design activities:
  • **Topics**, which are the parts of the design problem, the design solution or the
design process on which the designer is working.
  • **Contexts**, as the ‘universal particular’ viewpoints for considering a design
problem or solution.
The process-side of design activities can be described by the introduction of two
very general categories of description:
  • **Acts** are the activities a designer engages in at a particular moment. This could
be reading, thinking, asking for information, etc.
  • **Goals** are the aims towards which those acts are directed: gathering
information, generating ideas, building a concept, evaluating a design, etc.
This definition of goals corresponds to the phases of the design process,
because phases are generally defined by their goals, rather than the activities
they involve. We will borrow the labels for the subcategories of the encoding
system from the phase-models of systematic design.

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**User**
The prospective user has expectations, demands and wishes which the product must satisfy. The user will want certain benefits from interacting with the product, and to avoid negative side-effects of using it. These goals can range from the simple desire to open a can to the expression of status and personality. Knowledge about these goals can be gathered by consumer research, and by the empathy of the designer towards the user.

**Client**
The client is the prospective buyer of the product. This can be, but does not have to be, the same person as the user. In the case of the assignment that will be used in this empirical study we see that the client of the latter system to be designed is the Dutch railway company, while the users are both the travellers and the emptying/cleaning staff. Each player in this whole network of people will have his/her own demands and wishes concerning the product. Generally the client will concentrate on getting ‘value’ (user satisfaction) for money.
The strategies for obtaining ‘value’ range from simple face-value test of the product to the elaborate customer-testing of products (which is often the case in professional markets) to the participation of the customer in the product development process.
Company
A company has to use its resources to further both short term and long term goals. The tools available to management include product development, production development, human resource management and marketing.

The current and future resources the company has available (in time, money, knowledge, co-operation, people and machinery) and the experience and understanding of product development within the company are particularly relevant for product development. The resources and freedom of the designer depend upon this. Both the design project and the designed product will have to function within the company.

Designer
The contribution of the designer is controlled by his/her goals in the design project, and the role he/she can play in it. The goals of the design project, which generally are a specific combination of efficiency, effectiveness, speed and/or creativity are supplemented by the personal goals of the designer (such as self-expression, learning, and making a product that is something to be proud of). To achieve this, the designer can strategically use his/her resources, which include contacts, accumulated knowledge, money, time and negotiating skills.

Denys Lasdun, an architect, expressed his personal view on designers and designing: 'Our job is to give the client, on time and on cost, not what he wants, but what he never dreamed he wanted; and when he gets it, he recognizes it as something he wanted all the time.' (Cross, 1990)

Form & aesthetics
The aspect of aesthetics brings its own set of specific goals which focus around giving the product an expression that is appropriate to its essence and function. This can mean that the product should be balanced and pleasing, but it could also lead to wilder, more expressive forms. The personal preference of the designer plays an important role in the shaping of this aspect. The tools to achieve aesthetic goals include manipulating the product's form and proportion, colour, rhythm, surface texture, material and composition.

Ergonomics
Within the sphere of ergonomics, ease of use and the psychological closeness of the product to the human user ('the psychology of everyday things') are important aims. A specialist field has developed which provides designers with data on all aspects of man-product interaction: anthropometric, information processing, cybernetics, and product safety.

Technical
Technical goals include getting the product to function, elegance in construction, not using more resources than necessary and the clever use of existing parts and knowledge. The technical vocabulary includes the choice of materials, power source, construction (static and dynamic), mechanisms, electronics and computer science.

Business
In the business context the costs of the development project and the production costs of the design are the most important factors (please note that all other factors that deal with the business environment of a design project are captured more closely by the stakeholders-contexts).

| Table 3.1 The universal particular contexts of industrial design engineering |

These four are all the categories necessary for a simple description method for integration within the rational problem solving framework. These categories have been translated into an encoding system that is used to process our protocol data.
The precise subcategories of the protocol encoding system can be found in Appendix I. Making these subcategories involved the performance of a pre-test (see § 5.1). The major change in the system resulting from the pre-test was to add a fifth category, dubbed ‘auxiliary’ (for want of a better word). This category was used to collect activities in which a designer is only indirectly involved with the design task or solution, for instance when the designer considers products other than his/her own concept (a competitive product, for instance) or contemplates his/her design process, practice, etc.

To illustrate the way this description method and encoding system works, let us look at the encoded data from one short period of design activity (15 seconds). The code is: 03 02 05 35 00
(this means: act=03, goal=02, context=05, topic=35, auxiliary=00).

Which translates back into:

the designer is writing (act 03) a performance specification (goal 02), looking from the viewpoint of the users (context 05) at the location of the litter bin (topic 35) without comparing it to other products or thinking about the process.

I hope you agree that this one-sentence description potentially gives a fair representation of the content as well as the process of a design activity.

We must ensure that the description method still reflects the character of the rational problem solving paradigm. There should be a strong correspondence between the description method and Simon’s problem solving theories. Key assumptions of Simon’s work should have been incorporated, and the key concepts introduced by Simon should be contained in a protocol that was encoded in the above manner.

- **Knowledge states** could theoretically be captured in this description system, by combining the ‘context’ and ‘topic’ category.
- A **problem-behaviour graph** could also be constructed by combining these categories, and mapping these knowledge states cumulatively (see [Newell, 1972]).
- The **command variables** that Simon deems important for rigorous design methods (such as optimisation methods) could be approximated by analysing the recurrence of certain topics in episodes of the design process.
- The **phases of the design process** correspond with the goals-category in the encoding system.

More of Simon’s key concepts can be reconstructed from the encoded protocol.
data. Problems arise with some concepts that would require some textual analysis of the protocol, such as _constraints_, _utility function_ and _satisficing_. These problems arise from an ambiguity in Simon's theory on the status of textual analysis. The theoretical framework of the rational problem solving paradigm doesn't preclude the use of textual analysis, but stresses that the use of _a priori_ 'universal' categories is important for the generalisation of conclusions. In this study we will be conservative: textual analysis can be used only if it supports or is supported by the more rigorous data processing done with the encoding system. For example, the process of satisficing can only be recorded when it could be inferred from the transcribed protocol, and when the encoded data shows a recurring pattern of redefining (downgrading) the goals of the design activity while evaluating a design concept.

### 3.3 Rational Problem Solving in TheSES

We have developed a description method to capture integrative design activities within the paradigm of rational problem solving. We now concentrate on a further specification of the first research question from § 2.1, translating it into theses to guide the exploration of the descriptive value of the paradigm.

1. **Exploration of design-as-experienced**
   The most important criterion for a description of design is its ability to describe to design practice as experienced by designers. Integration was chosen to be the main focus of this study. However, this does not mean that the other five issues of design-as-experienced will be totally excluded from our investigation. Their occurrence and importance can to a certain extent be inferred from the data. Our first aim in the empirical study is to: _explore whether designers implicitly or explicitly refer to the phenomena of design-as-experienced._

2. **The actual existence of the concepts of the paradigms**
   A necessary condition for a description of design to serve as a basis for the development of design methods, is that the main concepts used in the description of design can indeed be found to correspond to concepts and processes in the real world [Snodgrass, 1992].
   Thesis:

   _Designers obviously engage in or report on manipulating the main concepts of the encoding system; topics and contexts are used by designers._
These concepts should also be unequivocally identifiable by the design researcher:

*Scoring on the encoding system will be reasonably straightforward.*
* Interrater reliability should be high, or the differences between raters can be resolved by mutual agreement.*

3• The occurrence of integration as defined by the paradigm

A further condition for a description of design to serve as a basis for the development of methods is that it must capture some of the dynamics of design activities as they are experienced by the designers. Integration has been singled out as the target phenomenon to be described in this study.

Thesis:

*Professional designers will display the compensating behaviour central to the strategies of integration (see § 2•2).*

4• Quality in design, according to the paradigm

The final condition is that a description of design, in order to serve as a basis for the development of (prescriptive) methods, should enable us to discern ‘good’ and ‘bad’ design activities.

Thesis:

*Simon states a number of concrete processes and issues that (to him) characterise a good, rigorous design process:*

- search for and find ‘command variables’
- compute the optimum solution,
- use means-ends analysis,
- manage the resource allocation
- use schemes for guiding search
- tackle his/her design problem by hierarchical decomposition along functional lines
- display generate-test cycles throughout the design process
- manipulate alternative representations of the design problem and solution.

*These strategies, processes and goals listed by Simon will be used more often in the design processes that lead to the designs graded ‘best’ by a panel of design experts.*
DESIGN AS REFLECTIVE PRACTICE

The paradigm of design as reflective practice will now be treated in the same manner as the rational problem solving paradigm of chapter 3. The paradigm is introduced (in § 4•1), and integration is described within this paradigm (§ 4•2). A description method for design as a reflection-in-action activity is constructed. Then, theses will be formulated that guide the exploration of the descriptive properties of the paradigm (§ 4•3).

4•1 THE PARADIGM OF REFLECTIVE PRACTICE

4•1•1 HISTORY

The paradigm of technical rationality (encompassing the rational problem solving paradigm and the systematic models of design) may have been the dominant methodological paradigm in design research in the seventies and early eighties, but it was not the only one. Especially in architecture, there was a feeling that a number of the most important aspects of design practice could not be captured or supported by this design methodology. There has been a string of isolated attempts to develop a methodology that addressed these shortcomings.

Most fundamental were the suggestions by Jones [1977] and Alexander [1971], who proposed an alternative view of design and methodology, based upon a phenomenologically inspired epistemology and ontology of science. In books like ‘The Timeless Way of Building’ [Alexander, 1979] architectural design is seen as a subjective and deeply human activity. The subjective knowledge humans attain through constructing their own realities is considered to be essentially personal and inherently non-generalisable. If categorical statements cannot be made about this knowledge, then general methods cannot exist. Their conclusion is that design education should be aimed at stimulating the personal development of the students, rather than infusing them with declarative knowledge and general design procedures. In forwarding these views Alexander and Jones alienated themselves from the design research community. Their position on the impossibility of arriving at general methods precluded incorporating this fundamentally different
perspective into design methodology. The impact of these views, which were seen as unproductive 'anti-theories', has been limited.

However, the doubts they expressed about design theories and methods are still valid today. In 1983 Donald Schön reopened the discussion about the fundamentals of design and design methodology when he published 'The Reflective Practitioner'. In this sociological study of the behaviour of 'professionals', Schön included what he calls a 'primer' for a new theory of design. The roots of this theory are close to the phenomenological epistemology of Alexander, but have been specified in such a way that some of the fundamental difficulties and limitations inherent in phenomenology have been side-stepped.

For example, in the classic phenomenological literature, personal introspection is seen as the only valid way of learning, which leads to the idea that only personal methods can exist [Husserl, 1982]. But Schön clearly wants to develop more general methods for design - which means that he must adopt a partly positivist stance towards the attainment of knowledge. Schön thus treads the difficult middle ground between positivism and phenomenology. The reflective practice paradigm is revolutionary because it proposes a novel way of considering design that is incommensurable with the traditional rational problem solving approach, while seeking to function in the same scientific environment and addressing some of the same goals as the rational problem solving paradigm.

This dual purpose may be one of the reasons for the theory's vagueness and inconsistency which surfaces later in this chapter. Because of these weaknesses the theory of reflective practice, though widely known throughout the design research community, has not been widely accepted and used. Despite this, there is a good reason to consider it a paradigm in this study: it is an alternative approach to design methodology at a very fundamental level. It is true that in the wider world of methodology not yet a paradigm, but it could contain the seeds for the development of one. Recently, attempts have been made to extend Schön's primer into a design theory, to apply it, and to address some of its limitations (by Schön [1988, 1992, 1994] and others like [Bucciarelli, 1987][Valkenburg, 1997]).

4.1.2 DESIGN AS REFLECTIVE PRACTICE

Schön's starting point is his feeling that the paradigm of technical rationality hampers the training of practitioners in the professions. He believes that the design-component of the professions is underestimated, and that the nature of human design activities is misunderstood. He shows that in the training programmes of professional schools that recognise design as a core activity, design
knowledge is defined in terms of generalities about design processes and declarative knowledge needed to solve design problems (see also [Christiaans, 1992]). No attention is paid to the structure of design tasks and the crucial problem of linking process and task in a concrete design situation. To Schön every design task is unique, a ‘universe of one’. Therefore, one of the basic problems for designers is to determine how such a single unique task should be approached. This problem has always been relegated to the ‘professional knowledge’ of experienced designers, and was not considered describable or generalisable in any meaningful way. However, this does not satisfy Schön; he calls this tackling of unique design tasks the essence, the artistry of design practice. He finds fault with the prevalent analytical framework for failing to describe these activities, and regrets that their solving therefore cannot be taught in the professional schools. To describe the undertaking of fundamentally unique tasks, Schön proposes an alternative view of design practice, based on the idea that ‘a kind of knowing is inherent in intelligent action’ [Schön, 1983, p. 50]. This ‘action-oriented’, often implicit knowledge cannot be described within the paradigm of technical rationality. But Schön insists that this kind of knowledge is vital for action-oriented professions like design. He does recognise, however, that this implicit ‘knowing-in-action’ is difficult to describe and convey to students. What can be thought about and taught is the explicit reflection that guides the development of one’s knowing-in-action habits. This he calls reflection-in-action.

Schön’s theory is based on a constructionist view of human perception and thought processes. Through the execution of ‘move-testing experiments’ (involving action and reflection), a designer is actively constructing a view of the world on the basis on his/her experiences. In this paradigm, the basic elements of design activities are actions, and the kernel of the design ability is to make intelligent decisions about those actions. The results of these experimental actions are scrutinised by the designer, who reacts to this new state of his/her own making. The final design is a result of this interaction. In this reflective conversation with the situation, designers work by naming the relevant factors in the situation, framing a problem in a certain way, making moves toward a solution and evaluating those moves. The frames are based on an underlying background theory, which corresponds with the designer’s view about design problems and his/her personal goals. This background theory is not subject to change within design projects. But it can change over time, slowly and in tune with the professional and personal development of the designer.
Schön contrasts this theory with the positivistic rational problem solving approach:

‘...The positivist epistemology of practice rests on three dichotomies. Given the separation of means from ends, instrumental problem solving can be seen as a technical procedure to be measured by its effectiveness in achieving a pre-established objective. Given the separation of research from practice, rigorous practice can be seen as an application to instrumental problems of research-based theories and techniques whose objectivity and generality derive from the method of controlled experiment. Given the separation of knowing from doing, action is only an implementation and a test of technical decisions.

In (the subject’s) reflective conversation, these dichotomies do not hold. For him, practice is research like. Means and ends are framed interdependently in the problem setting. And his inquiry is a transaction with the situation in which knowing and doing are inseparable...’[Schön, 1987, p.78]

In this quote, Schön criticises the paradigm of technical rationality for introducing analytical dichotomies that, in his view, do not have any counterparts in practice. As an alternative he proposes the categorisation of names, frames and moves. If this works, Schön may have made some progress towards the goals of this study: to make a description of design activities that corresponds closely to design activities as they are experienced by its practitioners. In ‘The Reflective Practitioner’ and its sequel, ‘Educating the Reflective Practitioner’ [Schön, 1987], the theory is illustrated by a thinking aloud protocol of an architectural design process. The well written description of this protocol sparks immediate, intuitive recognition by designers. It could be one of the most accurate descriptions in design literature of some of the main problems facing designers. The description is definitely much closer to the phenomenon of design than (most of) the more formal design methodology produced within the paradigm of technical rationality. But that is just its face value – we will have to see whether this paradigm of reflective practice can indeed lead to a deeper understanding of design and enhance design (teaching) methods.

Avoiding the positivistic dichotomies of technical rationality might bring design methodology closer to design practice, but there is a price to pay. Not imposing these dichotomies makes it much harder to analyse design activities, since we must then consider a complex mixture of analysis, design and planning-oriented actions (mental and physical) as the subject of study. Classic divisions in design methodology, like that between ‘design problem’ and ‘design solution’ cannot be
maintained within this paradigm. This may be true to life, but it is extremely difficult to handle analytically. To understand how Schön addresses this problem we have to re-examine the theory of science that lies behind the reflective practice paradigm. The difference between the rational problem-solving paradigm and the paradigm of reflective practice is so fundamental that it even extends to the very meaning of ‘scientific analysis’. In Schön’s terms, scientific analysis is emphatic, that is, aimed at gaining an understanding of the reasons behind a designer’s behaviour. The operative question is ‘why’, as well as ‘what’ and ‘how’. The theories and methods that Schön seeks to develop are of a different order than those which are derived within the paradigm of technical rationality. On the other hand, Schön clearly strives to capture, describe and explain the essence of reflection-in-action in a reasonably rigorous and generalisable framework.

The paradigm of design as reflective practice is summarised in figure 4.1. The categories and statements of the figure will now be treated in detail.

• **The designer**

  The paradigm of design as reflective practice is founded on the more general paradigm of constructionism (see § 4.1.3 and [Schön, 1987]).

  In constructionist epistemology, perception is a process of actively constructing a view of the world. An objective reality exists, but that reality only influences the world of the subject to a limited extent. The subject’s perception of the world, his/her goals in constructing this personal world and the situation in which this ‘imbuing with meaning’ takes place are important influences on the world under construction. Human behaviour cannot validly be described or understood without including this personal, constructed world-view.

• **Design tasks**

  One of the basic assumptions of the theory of technical rationality is that there is a definable design problem to start with. Schön remarks that

  ‘... Although Simon proposes to fill the gap between natural sciences and design practice with a science of design, his science can only be applied to well-formed problems already extracted from situations of practice...’

  Schön, on the other hand, does not make any assumptions about the design problem, ill-defined or not. The description of design as a reflective conversation concentrates on the structuring role of the designer, setting the task and outlining possible solutions all in one framing action. The strength of this framing action determines the amount of structure in the task.
In reflective practice design tasks may be analysed and subdivided in a number of different ways, and there is no \textit{a priori} way to determine which approach will be the more fruitful. Therefore, design task and solution are always and inherently developed together.

Schön thus ignores the possible structure that design tasks and solutions might have, although he gives a table of ‘Normative Design Domains’ in the analysis of the Quist-protocol of ‘The Reflective Practitioner’.

These ‘Normative Design Domains’ could provide a categorisation for the description of design tasks, but unfortunately these domains are not connected to the core theories of reflective practice, and they are never mentioned again. Schön’s failure to link the theories of reflective practice to a model of design tasks means that descriptions of design activities within this paradigm can not benefit from any structure that might be present in the design task.

- **Design process**

Designers do behave rationally, but they will do so by imposing a network of
names onto the design task and the design situation, and then frame the design task and solution. The designer’s perception of the design task and the design situation exerts an important influence on this process. The metaphor of the ‘reflective conversation’ describes a design activity as being controlled locally: people make moves and evaluate these on (among other things) the immediate problem solving value. The theory of reflective practice does not deal with higher level strategies, (comparable to the phases of rational problem solving), although it could easily be extended to contain them. A strategy could be seen as a (multiple) move, to be framed and evaluated like the single moves. 

The essence of Schön’s reflection-in-action mechanism is that designers are active in structuring the design task, and that they do not evaluate concepts, but that they evaluate their own actions in structuring and solving the design task. The unit of ‘doing design’ that is manipulated and evaluated by the designer is not a ‘topic’ or a ‘concept’ (the static descriptive terms used in rational problem solving), but is dynamic: an action, a move.

- **Design knowledge**

  According to Schön, general ‘scientific’ knowledge about strategies and methods for design has very limited use in design practice. The ‘essence’ or ‘artistry’ of design lies in the decision of when to do what, which strategies and methods to apply in which situation (see § 1•3). Every design situation is essentially unique, and requires such structuring decisions by the designer.

- **Example/Model**

  The philosophical basis of Schön’s theories, constructionism and (indirectly) phenomenology, are closely related to some branches of the humanities. Design is seen as an artistic and deeply human process, the understanding of which requires the conceptual framework and an approach to research that has been developed for the study of human activities.

**4•1•3 A HIERARCHY OF PARADIGMS**

Like the paradigm of rational problem solving, the paradigm of reflective practice is constructed using many theories at various levels. A sketch of the family tree of paradigms to which it belongs is shown in Figure 4.2.

The root of the reflective practice paradigm is not ‘positivism’, as was the case for the rational problem solving paradigm (see figure 3.2), but phenomenology. Therefore, there is no common philosophy which links the two paradigms of design methodology, not even at the most fundamental level. Phenomenology
studies the world as experienced by humans, while positivism is concerned with exactly the opposite, that is: the ‘objectivity reality’ that can be known through scientific research. Rigorous positivist research techniques should ensure that a carefully considered intersubjectivity is reached as an approximation of reality. Therefore, positivism explicitly ignores the direct human experience that is the object of phenomenology. Within phenomenology one can distinguish a number of schools which are based on differing views about the existence and status of an objective reality. Constructionism (and thus the paradigm of reflective practice) believes that people actively construct a view of reality based on their perceptions of objective reality. Idealism claims that objective reality does not exist, or that it is totally beyond observation, for both scientists and their subjects.

Phenomenology in its purest form also has been plagued by some esoteric assumptions and positions in Husserl’s original ideas. These included the definition of phenomenology as inherently non-teleological, and the adoption of introspection and self-observation as the only valid research technique. This has led to phenomenology being perceived more as an attitude to life or an area of interest than a philosophical or practical science [Varela, 1993]. Today’s hermeneutic phenomenology is more goal-directed. It allows other research techniques than just self-observation and introspection, and is cautiously aimed at general conclusions [van Manen, 1990][Coyne, 1995]. However, this rather one-dimensional classification is not a complete characterisation of Schön’s position. The linking of Schön’s paradigm to
phenomenology-based theories is valid for much of the philosophical content and background of his theories. And to a certain extent for the purposes for which he developed his theory. His core concepts (frame, move, etc.) reveal a phenomenological ancestry, although they are used in a more structuring way than you would find even in modern hermeneutic phenomenology. The ambiguity of Schön's position is betrayed in his treatment of his core concepts: he introduces them on a phenomenological footing, but then implicitly treats them as if they were generalisable across subjects and disciplines.

4.1.4 INFLUENCE OF THE REFLECTIVE PRACTICE PARADIGM

The theory of reflection-in-action did not originate in a large-scale paradigmatic crisis, and neither did it spark one off. The rational problem solving paradigm has always had its doubters, reformers and heretics, but their discontent never reached a crisis point, and their views never spawned a complete alternative. So when Schön's theory was published, and seemed to suddenly provide an alternative approach to studying design, it did not fall on very fertile ground. It has not been widely accepted as the new paradigm for describing design. There is broad consensus that the theory is interesting since it is fundamentally different from the rational problem solving approach, but that it is difficult to put to practical use. Schön developed a 'primer' for a new theory of design, and as such the basic theory of reflective practice is rather sketchy; the key concepts are vague and its uses are not totally clear. The problems we encounter in the next section in applying the theory and deriving a description method for integration within the reflective practice paradigm, can serve as an illustration of this. Another reason for its limited impact could be that, because the rational problem solving paradigm has been so dominant for so long, it came to define what design methodology is all about. As a consequence, possible dissenters to the common view (like Jones and Alexander) are constantly pushed out of design methodology and must find other ways of expressing their scientific interest and views about design (such processes have been described by Latour [1987]). The interpretation of design methodology as a human, rather than a natural or technical science and the emphasis on education may also have antagonised people in a field which has been traditionally concerned with the construction of formal models and prescriptive methods.
4.2 DESCRIBING DESIGN AS A REFLECTIVE CONVERSATION

4.2.1 TOWARDS A DESCRIPTION METHOD

In his various publications Schön has outlined a new approach to design and design methodology, but he has not produced a well-rounded theory that can be applied directly in these fields. This section is an attempt to describe, detail and, where necessary, extend his theories to arrive at a description method for the empirical study. The mechanics of reflection-in-action will be described in more detail, the nature of the reflective conversation will be specified. Finally we will explore what constitutes ‘good’ reflective design practice.

The mechanism of reflection-in-action

Schön’s theory does not include any sweeping statements about complete design processes or episodes, but presents a ‘mechanism of design’, which describes design activities at a much more detailed level. As such, it is comparable to the ‘basic design cycle’ of analysis-synthesis-simulation-evaluation that lies at the heart of the technical-rationalist approach [Roozenburg, 1991-II, 1995].

![Diagram of reflective practice cycle]

Figure 4.3 – The basic cycle of reflective practice.

Reflection-in-action is a process of naming, framing, making moves and evaluating them (see Figure 4.3). In the naming step the objects to be considered in the design situation are selected and named. In the framing step these named entities are put into a context, and an overall perspective on the design task is constructed. In making a move the designer takes an experimental action based on the naming and framing of the design task, and this action is then evaluated. The evaluation leads to either satisfaction, the making of new moves, or the reframing of the problem. The evaluation could also lead to a complete reconsidering of the designer’s view of the design task,
causing the designer to start naming new entities in the design situation. There are three general criteria that are used in the move-evaluation step:

- Coherence: is this move well-directed in the light of the goal of the design activity, and is it consistent with earlier moves?
- Accordance with the performance specification: is this move within the bounds of an acceptable solution to the design problem?
- The problem-solving value: has this move succeeded in reducing the problems, or has it led to more serious problems?

A complete design project consists of many of these reflective practice loops.

When we compare the reflective practice mechanism with its positivist counterpart, which is the basic design cycle (Figure 4.4), we see that all the design activities in the basic design cycle are also present in the mechanism of reflective design, but that they are grouped differently.

![Diagram of design cycle and reflective practice mechanism](image)

**Figure 4.4 - The correspondence between the elements of the basic design cycle (above) and the mechanism of reflective practice (below).**

The *naming* and *framing* steps correspond mainly to the analysis step in the basic design cycle, though they also involve the construction of starting points for the synthesis-step. ‘Making a *move*’ is a combination of synthesis and simulation. The *evaluation* steps that are part of both mechanisms differ in character: in the basic design cycle, the design concept is evaluated on criteria derived from the problem statement and the performance specification, while in reflective practice, the design action, move, is judged on its effectiveness.

**The form of reflective conversations**

Schön used the metaphor of a ‘reflective conversation with the situation’ to describe the whole design process which results when using the mechanism of reflection-in-action. When making a move, the designer *speaks to the design*
situation, observes and evaluates the results of his/her actions (the back talk of the situation). This conversational metaphor was introduced by Schön because it captures both the interactive nature of the reflective design mechanism and the 'satisficing' (or: negotiating) nature of design activities. A designer tries moves and observes the results knowing that not everything is possible, and that the completed design will be a 'negotiated settlement' between the designer and the design task. However, reflective conversations in design are not quite comparable to normal conversations between two people:

- As a conversation, reflective practice design follows a proposal>action>result>evaluation format in which the proposal and the result are possibly of a different character. The result does not directly or exclusively concern the quality of the proposal (move or frame) that is being tested. The proposal is a goal-directed thought, and the result is a new design situation of a much more general nature. This new design situation then needs to be re-interpreted by the designer.

- The move-testing experiments a designer performs in a reflective conversation are basically sequential in nature, trying one thing after another in a string of moves. The resulting response is basically cumulative. What the designer observes is the result of all earlier moves and frames, and of influences he/she may not even be aware of.

- The proposing actions should be performed to be both effective and efficient; the 'back talk of the situation' only concerns the effectiveness of the solution. The efficiency of the move and the sequence of moves must be ensured in a separate step, when the designer explicitly considers the planning and process of the design project.

- The frames and moves are guided by the ideals and preferences of the designer, and so will the evaluation of their results. Reflective design conversations are thus potentially circular and self-fulfilling. That is not really a problem, as long as the designer compares his/her frames and moves with the frames of the other stakeholders that must be satisfied.

On 'good' and 'bad' in reflective conversations

Schön's goal in introducing the mechanism of reflective practice and the concept of reflective conversations is to improve education for practitioners on the key point of adapting one's skills to the unique problems of design practice. However, the mechanism of reflective practice and the concept of reflective conversation are only descriptive models. To improve design theory and education we need to make a transition from this pure description to
prescription. We need explicit statements about what a reflective conversation should consist of. Schön does not systematically address this point, but throughout ‘Educating the Reflective Practitioner’ there are some statements about what a ‘good’ reflective practitioner should be, and what characterises a good reflective conversation:

- In a good reflective conversation, the designer will oscillate between the whole and the parts of the problem or solution.
- In a good reflective conversation there will be a gradual shift from the from tentative adoption of a move or frame to the eventual commitment of the designer.
- A good reflective practitioner will compile a wide ranging repertoire of examples to be used as moves or frames in future projects.
- A good reflective practitioner will be fluent in the construction and use of ‘virtual worlds’ (sketching and modelling).
- A good reflective practitioner will ‘experiment rigorously when he strives to make the situation conform to his view of it while remaining open to evidence of his failure to do so.’

4.2.2 THE DESCRIPTION OF INTEGRATION WITHIN THE PARADIGM OF REFLECTIVE PRACTICE

In § 2.3, integration was defined within the rational problem solving paradigm: ‘someone is designing in an integrated manner when he/she displays a reasoning process building up a network of decisions concerning a topic, while taking account of different contexts.’ This definition was possible and valid because the conceptual framework of rational problem solving provides the meaning for the terms ‘topic’ and ‘context’, and these terms are assumed to be valid tools for describing design activities (this assumption must be verified in the empirical study). But these terms are meaningless when we consider integration from within Schön’s theory of reflective practice. There, the design process is described in a wholly different conceptual base consisting of names, frames and moves. Therefore, integration must be redefined in terms of the concepts from the paradigm of reflective practice.

Definition of integration

Within reflective practice the ‘objects’ of the designer’s decisions are not the topics (part of the problem or solution) but the moves a designer makes or considers making. These moves are not considered in different contexts, but they are related to different frames imposed upon the design problem.
Therefore **frame** takes the place of **context** as the natural unit of considering the problem.

To construct a new definition of integration within reflective practice we can substitute these translations of the concepts. The definition of integration then becomes:

> someone is designing in an integrated manner when he/she displays a reasoning process in which the moves (design actions) are made while taking account of different frames (distinct ways of looking imposed upon the design task and solution).

Figure 4.5 is an illustration of this. The process of integration is shown at the top of the figure, the content (what is happening to the product) can be seen at the bottom. In the two steps of this design process a move is made within one frame, and the result of this move is looked at within a different frame. This results in a design decision about the move that combines the viewpoints of the two frames: the two frames are thus effectively integrated in this decision. This definition contains the essence of integration, and is potentially useful. But a number of questions arise when we compare this definition with the general definition of integration in chapter 2. These issues must be addressed before the definition is used to develop the description method.

![Diagram](image)

**Figure 4.5 - Integration within the paradigm of reflective practice**
The exchange of key concepts to preserve a close analogy in the two definitions has changed the meaning of 'integration': the words *topic* and *move* are not equivalent, although their function in the two paradigms is analogous. The same is true for *context* and *frame*.

The rational problem solving definition of integration describes how decisions about the product are taken from different viewpoints. In reflective practice we are involved with the actions a designer takes and the frames that define the subjects to be handled and way they are to be handled.

If we define integration as the connecting of action-decisions, we should realise that these connections can already be defined within the frames. The process of the integration of moves can take place within the current design project, or it might have happened already as the frame was constructed. Integrated moves are then implicit in the frame.

We did not encounter these kinds of *a priori* integration in the rational problem solving paradigm because the counterparts of frames, universal contexts, were constructed to be independent and unintegrated. The frames of reflective practice are not constructed by the researcher, but are imposed by the designers. As such, they could be 'messy' and replete with internal and external connections of an integrative nature. Frames that are pre-integrated are sure to occur in most design activities. This leaves us with the research problem that this pre-integration cannot be traced or analysed in an empirical study— it does not occur 'live' in the design project being studied. It could possibly be traced by dissecting a frame, but such an analysis would require a more detailed insight in the components and structure of a frame than we currently have. It is possible that in some cases, pre-integration will be referred to explicitly by the designer, and that it may also appear in the encoded data. But it is impossible to trace this form of integration completely and dependably. Therefore, the more 'explicit' integration which is made anew in the design process will be the focus of this study.

Thus integration as defined in chapter 2 and integration as defined above are not quite the same phenomenon. They are two different perspectives on integration. It is not surprising that integration cannot be 'transported' from one paradigm to the other without changing some of its meaning. In general, this fundamental shift of attention and meaning is one of the characteristics of the differences between paradigms in any field. In this case, the theory of reflective practice has a blind spot for 'objective' categories like topics and contexts, and the theory of rational problem solving has no way of dealing
with the more experiential and action-based categories of moves and frames.

**Strategies for integration**

The principle underlying any strategy for integration (as identified in § 2.3.3) is that of balance, or compensation: a designer, having concentrated on a part of the design problem must compensate for the limitations and bias of this initial treatment by taking a second step that is complementary to the first. This could also be true for the integration of decisions about moves, analogous to the integration of decisions about topics. However, finding this integration in an empirical study and distilling strategies from it might be more difficult than in the case of integrative rational problem solving activities. The definitions of moves and frames are much less clear-cut than those of topics and contexts: the identification and precise connotation of a frame (its core meaning, its scope, the associations connected to it) can only be gathered from an in-depth study of its use. A ‘frame’ can only be defined *a posteriori* and on the basis of an interpretation of the contents of the design activity.

In § 2.3.3 five strategies for integration were presented, which were effectively based on reducing the information overload that is associated with integration. This information overload issue is acknowledged by Schön: when dealing with the implication-based reasoning of designers, he observes that

> ‘Even he (Quist, the expert-designer) cannot hold in mind an indefinitely expanding web (of design implications). At some point, he must move from a ‘What if?’ to a decision with binding implications for further moves’ [Schön, 1983, p.100]

The five general strategies can also apply to the integration of moves within a reflective conversation. But they will be difficult to distinguish because of the implicitness of frames and the pre-integration that could already be contained within them. For our purpose, the most certain and possibly the only way to identify integration is to analyse the contents of what the designers are saying, and identify instances in which they obviously engage in, or explicitly report, on balancing moves or frames.

**4.2.3 THE DESCRIPTION METHOD AND ENCODING SYSTEM**

The categories constituting the description method for integration within the paradigm of reflective practice are only *names, moves* and *frames*. Because these can only be described *a posteriori*, in the words of the designers
themselves, it is not possible to construct an *a priori* encoding system as was done for the rational problem solving paradigm. The only thing that can be done in preparation for the empirical study is to ensure that there is a consistent identifying principle and notation for them.

- The *names* can be identified as bits of the information, the design task or the developing design that the designers stress as being important (see [Schön, 1994]).
- The *moves* can be characterised by describing the process (verb) and content (noun) of the design activity, such as ‘designing a lid’.
- A natural and uniform way of expressing *frames* is as the last part of the sentence: ‘the designer is treating the design task AS IF...’. For instance: ‘the designer is treating the task as if he must repair the substandard ergonomic performance of the current product’.

A trial experiment showed that names, frames and moves can be identified without great difficulty. Unearthing internal integration within moves and frames is more difficult. It (inevitably) involves some degree of interpretation by the researcher.

4.3 REFLECTIVE DESIGN PRACTICE IN THESSES

The first research question from § 2.1 can now be specified further and made into theses to guide the exploration of the descriptive abilities of the paradigms in the empirical study. The theses presented here are directly analogous to those made in § 3.3 for the rational problem solving paradigm.

5. The realism of the concepts of the paradigm

*Designers obviously engage in or explicitly report on manipulating the main concepts of the encoding system; the names, frames and moves a designer uses can be determined. The use of the encoding system should be reasonably straightforward. Interrater reliability will be high, or a consensus should be attainable on the differences between raters.*

6. The occurrence of integration as defined by the paradigm

*Professional designers will display the compensating behaviour essential to the strategies of integration.*

7. Quality in design, according to the paradigm

*Schön has listed some properties of good reflective practice:*

- *In a good reflective conversation, the designer will oscillate between*
the whole and the parts of the problem or solution.

- In a good reflective conversation there will be a gradual shift from the tentative adoption of a move or frame to the eventual commitment of the designer.

- A good reflective practitioner will compile a wide ranging repertoire of examples to be used as moves or frames in future projects.

- A good reflective practitioner will be fluent in the construction and use ‘virtual worlds’ (sketching and modelling).

- A good reflective practitioner will ‘experiment rigorously when he strives to make the situation conform to his view of it while remaining open to evidence of his failure to do so.’

These strategies will be used more often in the design processes that lead to the designs graded best by a panel of design specialists.
5

EMPIRICAL STUDY

The empirical basis of this research project consists of a protocol study of nine experienced designers working on a small design task in a laboratory setting. The empirical research design is explained in § 5.1. A sample of the results is presented in § 5.2, and the theses that were developed on the basis of the paradigms of rational problem solving and reflective practice are addressed in § 5.3. Conclusions are drawn in § 5.4.

5.1 THE EXPERIMENT

Protocol analysis is not uncontested within design research, and some of its possibilities and limitations are discussed here. Those issues provide the rationale for the setting of the experiment.

5.1.1 PROTOCOL ANALYSIS

An extensive range of research methods has been developed or adopted for the analysis of design activities. Techniques for empirical investigation include (participant) observation, interviews and the ethnographic description of design teams.

To study detailed design reasoning as it occurs, one can investigate (1) the accounts of exchanges between subjects, i.e. the communication between members of a design team (2) retrospective verbal accounts, i.e. asking someone to recall what he/she was thinking recently, and (3) concurrent verbal accounts of individual designers (i.e. protocol analysis). Of all these, the latter has been used the most and has received the most attention in recent years. Protocol analysis is the tracing of design activities by recording the verbal accounts given by designers. The idea is to examine what is going on inside people’s heads by asking them to verbalise what they are thinking. Luckily, people find it relatively straightforward to ‘think aloud’. Protocol analysis is regarded as the most likely method to bring out into the open the detailed cognitive activities of designers. As Ericsson and Simon [1993] claim, in their standard work on protocol analysis:
'There is a dramatic increase in the amount of behaviour that can be observed when a subject is performing a task while thinking aloud compared to the same subject working under silent conditions. A brief instruction to think aloud usually suffices to bring about this major change in observable behaviour.'

This promise of data about the detailed activities of designers was the reason that thinking-aloud protocol analysis was chosen as the empirical research technique for this study.

The analysis of think-aloud protocols emerged as a method of psychological research in the 1920s, and from the beginning it was a useful method of seeking insight about problem solving. Thinking-aloud protocol analyses were used by de Groot [1965] in his studies of chess playing, and by Newell and Simon [1972] in their studies of cryptarithmetic and rational problem solving. The first protocol study of designers was that by Eastman [1970], who studied architects. It was not until the late-1980s that protocol studies of engineering design began to appear, and since then studies in that domain have increased rapidly. A significant improvement in protocol techniques has been achieved recently by concentrating on team design activity (by [Tang, 1989][Minneman, 1991, 1993][Cross, 1996-II]). The verbal exchanges between the members of a team who are engaged in a joint task provide data indicative of the cognitive activities that are being undertaken by the team members. In team situations, the most significant design steps must be brought into the open for discussion and to reach a shared understanding among the team members. The industrial design domain has only been studied relatively little through protocol analysis [Ballay, 1987][Christiaans, 1992, 1992-II], prior to this study and the 'Delft Protocols Workshop' [Cross, 1996].

The use of thinking-aloud protocol analysis in design research has always been problematic: it is obvious that even under ideal circumstances not all of the designer’s thoughts are captured. Designers do not necessarily always know what is going on inside their own heads, let alone have the ability to verbalise it. They might report what they believe they are thinking, what they want to communicate to the researcher, what they think the researcher wants to hear, or what they were thinking recently.

The adoption of protocol analysis as a research technique for design can be seen as an effort on the part of design methodologists to find a rigorous form for their detailed study of design activities. Protocol analysis is somewhere between the 'hard' experimental methods of the natural sciences and the 'weaker' observational
methods of the social sciences. In the last decade the number of protocol studies in design has grown and the complexity of the tasks has increased (up to the analysis of several-day protocols of team designing [Frankenberger, 1996]). However, because of their disparate and independent nature it is not possible to draw general comparisons between protocols, nor even to reach agreement about general procedures or standards for such studies. Real discussions about the protocol analysis methodology and on the results of the design studies are few and far between. In 1994 the Delft Protocols Workshop was devised by myself to force a concentration on the research methodology of protocol analysis. In this workshop 20 groups of researchers analysed two videotapes and transcribed protocols that were provided by the organisers, and discussed their findings. The critical treatment of protocol analysis in this study is a reflection of those discussions (publications include [Cross 1996][Dorst, 1995, 1995-V]).

The workshop’s methodological discussions are of particular relevance because the data which was used in the workshop was collected in the same manner as the data in this study. Thus the workshop discussions are a critique, by the Research Forum (in terms of [de Groot, 1961]) on the methodology of this protocol study. This gives a unique platform for reflection upon this empirical study - and it also causes some regret about a few of the decisions made as this particular experiment was set up (this experiment predated the workshop by two years).

The major disadvantages of using thinking-aloud protocols to study design activities are:

- There could be unintended effects from verbalisation, which could cause changes in the designer’s behaviour or their cognitive performance. This did not seem to be a problem for most of the designers in this study, but we can never be quite sure.
- What the designer reports may well be incomplete accounts of his/her cognitive activity. Not all ‘modes of thinking’ can be easily captured by protocol analysis. In some episodes designers tended to slow down in their verbalisation, perhaps indicating that the possibly more ‘pictorial’ way of thinking prevailed over their urge to verbalise (this was shown by [Lloyd, 1995]). This was tolerated because we did not want to force the designers into thinking verbally or to recall them to the experimental situation the whole time. But the spells of silence mean that the data is uncontrollably incomplete in some episodes of the protocols, and the places where their ‘verbal rate’ drops are particularly suspect.
Another associated issue is the use of objects, drawings and gestures in the
design activity. These are hard to capture, and even harder to interpret because
of their ambiguity. Harrison and Minneman [1996] have done pioneering
work in analysing these issues.

- There are also side-effects of the experimental situation: the designer is
isolated from his/her normal working environment, and has to solve a design
problem with limited means in a very short time. The reason for this artificial
arrangement is that we attempted to capture all design activities from the
moment a designer gets the brief to when he/she decides on the concept.
This experimental situation caused some designers to complain about the
circumstances, about not being able to work in a ‘normal’ way. In those
instances our eagerness to ensure the rigour of the research layout may have
compromised the relevance of the research findings.

- The subject may inadvertently give irrelevant accounts, for instance reporting
thoughts that are parallel to those that are actually being employed in the
design task. In the protocols of this study some designers tend to launch into
‘mini lectures on design’, or comment on the artificiality of the laboratory
situation. It is difficult to fathom whether they then restart their designing at
the point they left off, or whether other cognitive processes have continued
beneath the surface.

5.1.2 RESEARCH DESIGN

This empirical study involved a pretest, followed by the main experiment and
then a separate study to measure the ‘quality’ of the resulting designs.

The pretest

Students from the Faculty of Industrial Design Engineering of the Delft
University of Technology were the subjects of the pretest. They were selected
on two levels of expertise, and on having a representative spread of grades for
their design courses. In all, ten second-year students and ten final-year students
performed the design task individually. This study is reported in detail in the
PhD thesis of my close colleague Henri Christiaans [1992], and in a number
The conclusions of the pretest were that the design assignment worked well,
and that the experimental situation did not seem to unduly influence the
performance of the design students. Most of the students liked the challenge
that was put before them, and jumped right in. It didn't take them much time
to start concentrating. The concentration level was maintained well for the first two hours, but then began to flag in almost all of them. The students testified that they had worked as they would have done normally, and did not feel as if they were in an examination situation (although the ones that did not do so well clearly felt the eyes upon them now and then). The information given to them seemed adequate, and of realistic vagueness. Some were disappointed that the information cards contained little in the way of 'pre-cut' decisions or structure. The limited time available to them was a source of complaints (mainly from the students who didn't do so well). About a quarter of the students finished well within the time limit. These results gave no reason to change the research format for the main experiment. Different time intervals for scoring on the rational problem solving encoding system were also tested on these student protocols. A fifteen second interval turned out to be satisfactory: designers hardly ever changed their activity (acts, goals, contexts or topics) twice within such an interval.

The experiment

For this study we selected nine designers with five or more years of experience (the minimum was five years and the maximum was twenty). The chosen subjects were all working in design consultancies, which is important because the assignment is modelled on design consultancy practice. The designers had a wide variety of backgrounds, from university to art academy to mechanical engineering at a vocational level. They were selected and approached by a non-participant in the research project. They were only rewarded with a small book voucher.

The assignment was to create one or more concepts for a 'litter disposal system' in a new Dutch train. This problem is typical as far as industrial design engineering is concerned, in that it calls for the integration of ergonomics, construction, engineering, formgiving and business aspects. The design brief outlined the problem, introduced the stakeholders and defined the designers' position. A special condition in the experiment was the manner in which information was provided to the designers. All the necessary information was prepared for them on information cards, with one specific topic on each card. Topics included interviews with the client, technical information about materials and production techniques, or a survey of train passengers. If a designer wanted to know something, he asked the experimenter (who was sitting at the same table), who would then hand him the appropriate card. This was done to ensure a quick but natural flow of information. The information
on the cards was presented as if it had come from different natural sources: from textbooks, from shops, catalogues and from the different stakeholders who were presented in the design brief. As a result, the information cards contained natural amounts of vagueness and inconsistency. The number and types of cards subjects asked for was noted. If the information was not available on the cards, or if the question related to a detail of a card, the experimenter answered the question. Because the experimenter did not have a background in design, he was connected by headphones to a second experimenter who was familiar with the assignment. This experimenter ‘2’ was sitting in an adjacent room where he could see and hear the subject (see figure 5.1).

![Image](image.png)

**Figure 5.1 - The experimental situation**

The designers were requested to think aloud as they were solving the design problem. The design session was preceded by a short training exercise, to help them become accustomed to thinking aloud. The instructions read out loud by the experimenter, were:

> 'What is a designer doing when performing a design task? What is he/she thinking about? What kind of decisions are made? What information is needed to solve (sub-)problems? These are the questions in our study. As an experienced designer you can give us an understanding of designing. Presently you will be offered a design task, similar to the ones you’re familiar with in your design practice. We want to know how you design. Therefore, we ask your permission to videotape this session.'
Because we want to understand what you are thinking during the task, I also ask you to think aloud. Most important is that you continuously speak what you think, from the very beginning of the task. Act as if you are talking in yourself, but in such a way that I can hear you. I can imagine that it feels odd. In order to get used to thinking aloud, I will give you a small problem which has nothing to do with the design task. Try to solve this problem while thinking aloud. Do the same while reading the instructions: as if you’re talking with yourself.’

The pre-task used was the classic cryptarithmetic DONALD + GERALD = ROBERT puzzle, extensively used and analysed by Newell and Simon [1972]. While solving this problem, the designers were continuously encouraged to think aloud. After 10 minutes they were asked to stop. Then the following instructions were read out loud by the experimenter:

‘Now I offer you the design brief. As I said, it’s similar to a problem you could encounter in design practice. Only the time is limited now: just 2.5 hours.
In a normal design project a substantial part of the time would be spent gathering information, reviewing the relevant present product domain etc. In order to save time we’ve developed a solution for the information accessing problem. We’ve put all the information that you could need, in a normal situation, in a card-tray. Information on the design task, the client, the user, and on all kinds of visualisations, but also details from text-books: information on engineering, ergonomics, form theory and styling, business aspects etc. This information is at your disposal, provided that you ask for it. If you do request it then I will recovered the information, which may take some time, so please keep working while I’m looking for it.
Again, don’t be reserved in asking for information, because it may contribute to the quality of the result. We are interested in what information a designer uses. So, ask for everything you think you need or look for in a normal situation. To summarise, work like you are used to, but continue to verbalise throughout whether you are reading information, sketching or thinking. Otherwise we don’t know what is going on in your mind. Occasionally, I will remind you to keep thinking aloud.
My role is to act as a source of information, and a reminder for you to keep thinking aloud. I don’t want to influence you at all. Don’t mind what I am doing. I won’t persistently remind you of the time; after 2.5 hours I will ask you to stop working. Do not mind me. If you want to take a break, do it. You can leave the room for a short period.’
The design brief was then given to the designer. The time allotted to them was 2.5 hours. During this period designers were encouraged to think aloud only if intervals of silence lasted for more than 30 seconds. Remarks like ‘What are you thinking now’, or ‘I’d like to hear what you are thinking’ were used. After the design session, there was a brief interview to determine the motivation and attitude of the designer towards the test situation and his/her own design. The verbal reports and sketches were recorded by two movable video cameras in the corners of the room; one pointing down at the designer to capture sketching and drawing behaviour, and one to take a general picture (see Figure 5.1).

A copy of the design brief can be found in Figure 5.2

**DESIGN BRIEF**

- **The Company**
  Lemmens Inc. is a producer of plastic bins and buckets. There are 40 employees in the factory, working with 10 injection-moulding machines, an assembly line and a small toolmaking facility. Most of the products made are injection-moulded: small special series are made by vacuum moulding or rotomoulding (done by Ten Cate Rotomoulding). Lemmens has a small own assortment, aimed at professional users, and supply buckets to for instance Curver PC (comparable to Tupperware) in Oosterhout. The company wants increase its own assortment and reduce its supplying activities.

- **This assignment**
  The NS (Dutch Railways) is working on a number of new trains for the nineties, including a new local, the SM90. This will be a totally new design, with an increased passenger capacity attained by putting five (2+3) chairs in a row. Because of the growing number of travellers they are also thinking about a new litter-disposal system (now: bin + emptying device) for the passenger compartment.
  The producer of the current bins has made a new design, but the railway company is not very enthusiastic about it.

As a result, they started a small inquiry into the functioning of the current
litter disposal system: the kinds of litter were determined, and passengers and litter collectors were asked to comment on it. Then the railways decided to invite Lemmens Inc., among others, to come up with a better concept. There has been a meeting between the manager of Lemmens Inc., Mr. Kouwenhoven, and the leader of the project within the NS, Mr. Van Dalen. Lemmens Inc. sees this project as a chance to give it a higher profile within the market.

That is why you, an external designer, are asked to make one or more proposals. Tomorrow you will have a meeting where your proposals will be discussed:
- principle solution
- general embodiment (materials, construction)
- idea behind the form
- 1:1 sketch views
- cost estimation

Good Luck!

Figure 5.2 - The design brief.

The choice and precise wording of the design task is a crucial part of protocol analysis research. Researchers spend a lot of time, care and effort to produce a design assignment that will be appropriate for their research purposes. But there is very little theory, or even descriptions of the considerations that led researchers towards their choice of a specific task. Ericsson and Simon [1972] also observed this:

‘...if the purpose of obtaining verbal reports is mainly to generate hypotheses and ideas, investigators need not concern themselves with the methodological questions about data collection. As a result, there is little published literature on such issues...’

To aid the development of knowledge on this important methodological point, we will now briefly run through the choices involved in setting this design task and the reasoning that led to its final formulation (the design task and the information system are treated in much more detail in Appendix II).

Developing the task

The design task was meant to be challenging, realistic, appropriate for the
subjects, not too large, feasible in the time available and within the sphere of knowledge of the researchers (see also [Dorst, 1996]).

- The designers were challenged to work on a litter disposal system for a new train. They were given the basic idea in rather abstract terms: a 'disposal system' involves products, as well as a design of the logistics. The word 'disposal system' was used so as not to bias them towards a litter-bin-type idea right away. In the comments about a preliminary design (available in the information cards) they were encouraged not to focus on the litter-bin idea (although it was not prohibited either). Thus, they were lured into uncharted territory. The assignment was left very vague as to the special features the new product should have: there were some problems with the old one, but the reason for this assignment to arise was not that the old one was chronically malfunctioning or outdated. It was more that the building of a new train opened up the possibility for a new litter system. The priorities and scope of the design task had to be determined by the designers themselves. The set target price was high enough so they would not worry about price in this conceptual stage. The task was presented as a new design problem with the opportunity to make something 'nice' and surprising.

- 'Realism' here means that the assignment and all the information came from real life, and that the designers were put in a realistic situation. What was offered to the designers was a company problem, to be interpreted and turned into a design problem. The precise problem statement and the performance specification had to be derived from the assignment and the information that was available on request. The designer was cast as being in a design firm, with only a few hours to spend on getting his/her act together for a meeting. There was some realistic vagueness and ambiguity in the information, and some (near-)contradictions in the viewpoints of the different stakeholders.

- This is the kind of problem that would be common in a small design consultancy. The time pressure (a few hours to come up with some concept as a starting point for client discussions) is also typical. The designers were chosen for their allround design abilities, and their experience with this kind of challenge. They were basically asked to do something in which they had already displayed competence. The introduced product idea was novel enough to assure that they would not have experience with anything quite like it before.

- The problem was limited in size by making it easy to relate to - the designers themselves are train passengers, every now and then. The information load was
limited by the conciseness of the information cards, and by providing
information on a comparable product (the preliminary design).
This preliminary design, and its evaluation, characterise the companies and
their view of the project much better than the statements from the design
brief itself. The evaluation of this preliminary design explicitly points to factors
that are important in the design. It serves as the necessary link between the
rather abstract description of the companies and the product idea, and the very
concrete problems to be solved in designing such a product.

- The last section of the assignment sets the scene for the designer's activities;
  he or she is asked to produce some concept at a level detailed enough to serve
  as the basis for a worthwhile discussion. This is a trick sentence, allowing
designers who get stuck in the problem analysis phase to see the analysis itself
as a good result of the design session. When these designers were asked if they
were satisfied, they would say things like 'at least I exposed the basic problems
involved' or 'I would need some company feedback on this before I would go
on making a concept'. Therefore the wording of the assignment evokes a fairly
concrete image of what the designer is expected to produce, but also reassures
them that a basic (satisficing) level of ideas and problem analysis can easily be
reached within the 2.5 hour limit.

- I have been involved in the development of a litter bin, so I already had a clear
overview of the issues involved, the kinds of solutions that would probably be
generated, etc. The Dutch Railways kindly provided most of the basic material
for the information system, including technical drawings of trains and the
existing litter system.

The interrater reliability

The interrater reliability of both paradigms' encoding systems was
doublechecked by having five different people encode parts of the protocols:

- one experienced design researcher encoded all the data and corrected the
data set by going through all of it twice. In the second round about 10% of
all the codes needed to be corrected, mainly because of subtleties in the
interpretation of the categories that had emerged during the first round of
scoring.

- another experienced design researcher encoded 90 minutes of one protocol.

- one design researcher and two final year design students each encoded 4
  random 10-minute samples of the protocols.

So all the data was encoded and corrected, and about 210 of the 1350 minutes
of protocols was double checked by different raters (15% of the data).
The effect measurement

The design concepts of all designers (see Figure 5.3) were sketched in a similar format (see the figures in appendix III). The quality of these concepts was then assessed by five design teachers from the faculty of Industrial Design Engineering, all of whom are also practising designers.

The procedure was as follows:

- First the assignment was read and some of the relevant information was shown to them in an abbreviated form. The judges could ask questions for further clarification.
- Then slides of all the concepts were shown in random order for 15 seconds, accompanied by a one-sentence summary to explain the way each of them works.
- The first scoring category was briefly introduced, and all the design concepts were again shown for 15 seconds in random order. Each judge graded the concepts individually in this category. The scoring categories were: creativity, forming, technical aspects, ergonomics and business aspects (in random order).
- In the last run-through, the judges were asked to give a total judgement of the concepts.
- They were then interviewed collectively about their experiences in this judging process.

This rather laborious multi-step procedure enabled us to analyse the rationale behind the judging behaviour and to test the consistency between raters. As it turned out, the 'ergonomics' judgement correlated most heavily with the 'total judgement', but none of the categories were of overriding importance (see table 5.1). This was confirmed by the factor analysis: the aspect of ergonomics correlated 0.95 with the main factor of the factor analysis, good for 43.4% of the variance of the data. The even distribution shown in table 5.1 is precisely what was aimed at in the formulation of this design task: it was supposed to be a typical, all-round industrial design engineering task. The primary goal of the assignment was to make sure that the handling of the litter system is better than that of the current product. The perceived need to balance aspects was built into the design task to invite integrative behaviour.
Figure 5.3 - Sketches of all nine designs
Table 5.1 - Correlations between the ratings of the design concepts on different categories and the total judgement of the design judges.

The interrater reliability was determined by computing the alpha-coefficient for the agreement between the judges [Nunnally, 1967] [Christiaans, 1992]. The alpha-coefficient for the relevant measure in this study, the total judgement, was a very reasonable 0.71. The alpha coefficients computed with deletion of a judge's scores range from 0.78 to 0.56.

An overview of the scores by aspect and design can be found in Table 5.2. The concepts of designers 3 and 4 clearly stand out as the best on most aspects. Design concepts 7 and 1 are consistently bad on all aspects. Design concept 8 was considered the worst on all criteria, except creativity. Indeed it is rather far-fetched, ugly, difficult to make and use but it is decidedly new, and 'different'.

Figure 5.4 shows that concept 8 is an exception to the general trend: on the whole, the more creative designs were considered better in the total judgement (correlation: 0.32, but this rises to 0.8 when concept 8 is omitted).

It was clear from the interview after the judging session that this method of grading designs is not particularly judge-friendly: they complained about the sheer number of slides they had to look at (84), and felt that they were pushed into gut-reactions by the limited time available. On the other hand, the whole session took about 30 minutes, which they felt to be fairly long. We tried several alternative procedures to solve these obvious problems - but the introduction of a brief sketching session for the judges led to a strong bias towards concepts that looked like their own ideas, and showing the slides for a longer period did not lead to more (or less) consistent judgements.
<table>
<thead>
<tr>
<th></th>
<th>total judgement</th>
<th>ergonomics</th>
<th>construction (technical aspects)</th>
<th>formgiving and aesthetics</th>
<th>business aspects</th>
<th>creativity</th>
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<tr>
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<td>3.8</td>
<td>4.2</td>
<td>6.4</td>
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<td>4.6</td>
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<td>6.2</td>
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<td>4.8</td>
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<tr>
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<td>6.6</td>
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<td>6.6</td>
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<td>7.6</td>
</tr>
<tr>
<td>design 4</td>
<td>7.0</td>
<td>7.2</td>
<td>7.0</td>
<td>8.4</td>
<td>7.8</td>
<td>6.4</td>
</tr>
<tr>
<td>design 5</td>
<td>4.8</td>
<td>6.6</td>
<td>6.4</td>
<td>5.0</td>
<td>6.4</td>
<td>5.2</td>
</tr>
<tr>
<td>design 6</td>
<td>5.6</td>
<td>4.6</td>
<td>6.4</td>
<td>6.6</td>
<td>5.6</td>
<td>5.0</td>
</tr>
<tr>
<td>design 7</td>
<td>3.8</td>
<td>6.0</td>
<td>7.2</td>
<td>2.6</td>
<td>4.8</td>
<td>3.2</td>
</tr>
<tr>
<td>design 8</td>
<td>3.4</td>
<td>3.8</td>
<td>5.0</td>
<td>4.8</td>
<td>5.0</td>
<td>6.8</td>
</tr>
<tr>
<td>design 9</td>
<td>5.4</td>
<td>4.8</td>
<td>6.6</td>
<td>6.0</td>
<td>6.8</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Table 5.2 - Overview of the mean scores (on a one to ten scale)

![Figure 5.4 - Scattergram for the means of 'total judgement' and 'creativity'](image_url)

Figure 5.4 - Scattergram for the means of 'total judgement' and 'creativity'
5.2 RESULTS

5.2.1 THE DATA

The raw data generated by this protocol study is nine 2.5-hour videotapes and about 400 pages of transcribed protocol. The data was processed in both encoding systems. For the rational problem solving paradigm this resulted in 27,000 data points on a 90-category encoding system. The paradigm of reflective practice representation entails 9 tables with about 900 entries. For the purposes of this study only a small part of this avalanche of data will be used.

The section of the design projects that is particularly relevant for this study runs from the (supposed) end of information gathering to the point where the basic design concept is fixed. We can expect this section to be an episode full of integrating behaviour. So most of our attention will be focused on this phase of the protocols, which is easily distinguished from the other phases:

- The designers generally report their intention to quit the information gathering phase which precedes the concept development (although they may not do so right away). They indicate this by sorting and/or summarising the information. Also, as they progress into ‘pure’ concept building, they tend to sit back and refocus their attention to what they see as the main issues.

- At the end of that conceptual phase designers can be seen to fix their main concept. They stop redefining the design task and solution to avoid problem areas in their design, and start to tackle the detailed problems directly. Their whole physical attitude changes at this point: instead of sitting back or moving around, they start leaning forward and become absorbed in confronting these issues.

These changes in behaviour were seen in all of the protocols. A 40 minute protocol sample of the highest-scoring designer’s conceptual phase can be found in the next section. Most of the quotes used as illustrations in this chapter are also taken from this protocol – the transcript is included to provide the context for these quotes. The graphs that represent the rational problem solving description of this sample protocol can be found in § 5.2.3, the table that captures the reflective practice description is presented in § 5.2.4.

The summaries of all nine protocols can be found in Appendix III.

5.2.2 TRANSCRIPT OF A PROTOCOL

This section of transcribed protocol runs from minutes 51 to 93 of designer 4’s
design project. It includes most of the concept-development the designer performs, and the analysis of this data will be used throughout this chapter as an example of the designer's integrative activities. The reader should be warned that this is a translation of a Dutch protocol, and that the faithful translation of a transcribed protocol is nearly impossible. A designer who is thinking aloud expresses his thoughts in ambiguous words and phrases which can hardly be translated into their English equivalents. The translated texts are not very dependable: much of the subtleties of the designer's language are lost in this translation process. Therefore, the presented transcript has limited value outside the context of this study. These translation problems did not effect the data processing in this study, since that was all done in Dutch. The protocol transcript has been illustrated with the designer's sketches, which are presented to you at the appropriate moments in the protocol. This designer was left-handed, so please note that the sequence of sketches on each sheet runs from right to left.

At the moment we join this design process, most of the relevant information has been assembled by the designer, and he has tentatively combined some items of information. To complete the information phase, the designer sorts the information cards, and recalls their contents.

(time: 51)

I think I have enough information to work with now...
I'm going to sort it...
Mr Lemmens, he will certainly choose injection moulding...
that is his core business at this moment...
he has two vacuum moulding machines...
something has already been said about that...
'small series are made by vacuum moulding or rotomoulding'...

(time: 52)

but I don't think we are dealing with small series here...
This is about 5600 times 10...
56000 as a minimum...
could be 75000...
or 80...
almost...
okay..Are there possibilities to integrate the bin in the wall of the new train...
Do you know anything about that?...
How the new train is put together.

(time: 53)

EXPERIMENTER: 'I've got information on the construction of the walls of the current train.'
Not of the new train?...
And do you know if there is a difference between the two? Is it the same?
'EXPERIMENTER: yes'
Ok, then it's useful to have...
Is this all?...
Functioning of the current bins...

(time: 54)

Procedure...
Survey...
I'm looking at the train wall construction now...
There's a wall here that...
Looks like an internal wall...
The folding seats suggest an end compartment...
but that isn't right...
there's a window over there...

(time: 55)

The current bin...
where did that go...
here...
The first thing that comes to mind now in connection to the litter bin is that...
It would, and I'm thinking about the aircraft industry, where they don't empty and clean the bins inside the cabin. But to lift the whole thing out and replace it by another...
the problem is if you want to do the same in trains, that you have to fixate things better than in aircraft. Because in aeroplanes it is not-done to demolish the bins like after a soccer game. Because you are in a more controlled situation...

(time: 56)

You can't leave during the journey...
That's different in trains...
So there is less control in trains...
And the amount of staff...
So everything that can be disassembled is disassembled...
I've got some own information from the Railways on this...
I know the problem to a certain extent...
It is well known that everything that can be unscrewed will be unscrewed...
That's why we have to keep the assembly-points out of sight...
Or we have to use tools that the passengers are unlikely to carry...
Well-known solution is the triangular key that the Railways use...
The thing should have a certain rigidity...
That strikes me when you consider vandalism...

(time: 57)
All kinds of things are demolished, but the bins are mostly left intact...
I remember that from the interviews...
No, that was under ‘functioning’...
Let's see...
Where did we get that remark...
Oh no, it was MrVan Dalen after all...
‘Mostly concentrated on the covers of the seats, the windows and the walls’...
And then mainly the walls in the end compartments...

(time: 58)
Integration in the walls was seen as an interesting option by MrVan Dalen...
But I don’t feel that I’ve got a very clear picture of the walls on the basis of this information...
That’s not the case...
EXPERIMENTER: ‘you could ask me’...
Can I ask you?...
Well, that’s what I’ll do...
Because there is a...
Let’s look at the current situation...
There we have tables under the windows...
And then there’s a bin under that table...
Under that, near your feet, there is this curb...
That contains the heating...
The bin is above that...

(time: 59)
My question is how the wall behind the bin...
How that is constructed...
Because well we’ve got the skin of the train...
that is panelled on the inside...
with some construction in between...
How should I picture that?...
EXPERIMENTER: Steel tubes...
And there is some kind of isolation between the two layers?..
EXPERIMENTER: Yes...
How much space do I have?...
EXPERIMENTER: The total wall thickness is 9 centimetres...
I'll note that down...
And I don't think that 9 cm is enough to let the whole bin sink into the wall...

(time: 60)

Just had a flash...
Would it be good to make separate bins?...
Because we have several different types of litter...
We've got the dry litter...
I would say paper bins...
Because lots of newspapers and magazines are left in trains...
I can imagine that you make a bin in which you can put newspapers and magazines, that kind of stuff...
That bin should be made in such a way that you can't put coffee cups and other stuff in there... That's a problem...
Because people are bored...
That happens in trains...
They tend to start trying things that weren't supposed to happen...

(time: 61)

But it would be a nice...
Well, there's a number of things crossing my mind now...
First, there's the Railways...
The Railways provide a mode of transport that is environmentally friendly...
That is still being used as an argument in favour...
And it would be a nice marketing ploy to expand that idea into litter collection...
With litter I mean...
That the litter collection in trains could help that identity...
The environmentally friendly railways...
Then there would be in trains, where a lot of paper is thrown away, because that is the main kind of litter...
We could design the bins in such a way that we create a compartment where the newspapers can be put in...

(time: 62)

So we...
I don't know how it will find it's way in the rest of the litter processing...
But it would be nice if we could keep this paper separate from the rest of the litter...
Because that means that we have a bin that will not pose a number of problems in maintenance...
If I look at the current bin...
Then there is stench...
And it's too small...
It being too small is mainly because...
because it is full of newspapers and that kind of stuff...
It would be possible...
Because the newspapers are 40% if I remember...
Yes, 40% of the total litter is newspapers...
Almost half...
It would be so good to remove that beforehand...
It is dry litter...
It doesn't cause any visible dirt in the bins...

(time: 63)

It isn't wet, or any of that...
It would be nice if we could make a simple compartment on the bin where people can just stick in their newspaper...
You don't use the bin as much...
You need less volume in the bin...
What was the mean filling...
70 to 85 %...
Of which 40% newspapers...
That is an option anyhow...
To make such a newspaper bin...
And it has another advantage...
You see that newspapers and magazines are read by several passengers...
So if you don't put him in the same container with the coffee cups and the cans.....
That the newspapers will remain clean...
And can be used again...

(time: 64)

Now they stay on the table in the morning...
To leave them for the use of the next passenger...
I think the newspapers and magazines are also most of the stray litter...
I can't really tell from this information card...
I think I heard that somewhere...
See if I can find it in the interview with Van Dalen...
Then it will probably...
Yes, the newspapers also block the emptying help...
They are a nuisance...
Lots of stray litter on the luggage racks...

(time: 65)

What is on the luggage racks, ...
As far as I know in trains,...
But now I'm only using my own experience...
There are newspapers and magazines on the racks...
I would like to start with the division between newspapers and other litter...
I'll put down that 40% of the litter is newspapers...
That means that the other bin can be smaller in size...
However wonderful...
That is an important thing...
I think it...

(time: 66)

It is now at a height that is felt to be uncomfortable by everyone...
So we have to see whether we can find a better position...
Positioning...
For filling up and emptying, so to speak...
I think we have to try to get the bin as much against the wall as is possible..
The trains are, as some people said,..
Though not many...
Well, still 8%,..
That bump their knees on the bins...
That's a nuisance...
If we can avoid that we should...
So it would be nice to get the bin flatter against the wall...
And Mr Van Dalen also said...
I think this has to do with his remark that he likes the integration of the bin in the wall so much...

(time: 67)

You try to gain as much space as you can in the passenger compartment...
So let's say...
Has to stick out as little as possible...
Let's see...
Yes, and then there's stench...
And the filthy lid...
That filthy lid is brought up by almost 30%...
Yes, 28...
We have to find something for that...
Important...
Then we have more problems...
That it is too small, of course...

(time: 68)
This is also in my litter separation...
With the newspapers etc.
That includes the size...
Total size...
Then we have summarised in four points now...
The cleaners that would have to bend over so much...
Dark in the trains...
Too fast in flipping over...
That is the flipping over of the bins...
Sometimes...

(time: 69)
The liquids in the bin splashes...
Turn over...
splashing of the liquids...
Yes, I'm putting it all together now...
Then you've got the newspapers...
Ok...
I think that the separate collection of paper is all that's feasible...
Because other separations will be too complicated...
Do you know whether the Railways is interested in the separation of litter in paper and other litter?...

(time: 70)
EXPERIMENTER: That has not been discussed...
That has not been discussed...
Yea...
But if I bring up the subject, can I then get an answer from the Railways?...
In this way?...
EXPERIMENTER: You can raise the subject tomorrow...
Right... And then we're presenting the concepts...
That means we'll have to work now...
I will look back to the current bin...
Because I want to see how far that sticks into the compartment...
The exact measures...

(time: 71)

I don’t think...
I’m making a drawing of the bin...
And I’m putting in the measures...
The total size of the product as it is...
Because I have some views here...
And I’m making a 3D sketch...
This is the height...
Section...
And the lid...
247...
And there is some depth to it...

![Figure 5.5 - A sketch of the current bin.](image)

(time: 72)

Of 141 plus the brace...
With some distance between the two...
Right...
Let’s look...
I’ve got a 3B here...
And another one...
Would you have a another crayon?...
No...
Well the idea was to make the thing as flat as possible...
To reduce the depth...
Because of the space...
Then I'm taking the current position...
There isn't much space...
And when two chairs are facing each other it's ok...

(time: 73)

And not where the chairs are behind each other...
There the space is limited...
There is also a problem of the bins being under the tables now...
That there is a problem with the height of the bins...
You can't put them very high...
The integration of the table that was mentioned by Mr.,
the plastics producer...
Can't remember his name... Kouwenhoven... Yes, Kouwenhoven...
That sounds better than it is...
At this moment...

(time: 74)
The lid, that's a problem...
Because it is a filthy lid...
That is always filthy...
That you have to lift...
Then you have to fill it...
And you have to drop the lid...
So you have a lot of contact with the lid...
And a lot of dirt passes that lid...
There's a number of things that pass my mind...
There is a side issue that I'm thinking about...
Whether we can integrate the bins in the chairs, in some way...
That is not good for the space...
Do we have information on the chairs in the trains?...
The benches?...
EXPERIMENTER: There is some info on the SM90-card...
That is not much...
But do we have an exploded view?...
They don't know what chair to put in there, I think...
EXPERIMENTER: This prototype has been approved, in principle...

(time: 75)

This is an approved prototype?... Right... So that means... They are on some sort of console, if I see that right...
EXPERIMENTER: That is purely for the presentation...
EXPERIMENTER: In reality the chair will be put on a tube frame...
Is it known who developed these chairs?...
EXPERIMENTER: Yes...
That is known...
Because it could...
I would like to...
If this has been approved...
Is it being produced?...
Are they going to produce it? Did they decide yet?...
EXPERIMENTER: they are making a test series...
They are making a test series...
Let's say...
I don't need to...
I'm not going to start all of that, before I know what I want to do...
But is just to check...
To integrate the bin in the wall...

(time: 76)
The more I look, the more I doubt...
Anyway...
I'll wait with this...
It doesn't seem wrong in that bin, the litter, to separate the newspapers and the other litter... That means you have a bin, with some kind of second bin next to it...
In any case some narrow second compartment...
And it would be broad again...

(time: 77)
They want paper there...
This marker dries slowly...
That's one thing...
And the second problem is that we have a lid...
That is experienced as being very filthy...
Things in there...
I'm watching whether there is a third...
My coffee is getting cold, that's what I'm really thinking now...
I'm looking what's important for the shape...
Because the position...
Let’s put it this way...
I have an idea how to build up this bin...
No, how I am going to put it together...
I’ve got a litter part and a paper part...
The paper part can be fairly open...
That shouldn’t have a bottom to it, or...
So you can see that it isn’t suited for litter...
And on the other side you have the litter bin...
That should preferably be closed because of the stench and that kind of thing...
You can make a number of configurations of the litter bin and the paper bin...

And we can put the paper in the back or up front...
We’ve got a possibility of course where we put the litter behind the paper...
And we can put them side-by-side...

![Figure 5.6 - Possible configurations of the two bins](image)

We could put them on top of each other...
Although I can’t see that leading to a practical solution...
I’ll put them in here very small...
Paper and litter or the other way round...
Other things to think about...
How we are going to open this...
I’d better draw a side view now...
We’ve got the bin...
And there is a lid on top of that...
And the lid is raised...
(time: 81)

And to empty the whole bin topples forward...
Where did that go...
Hinges on a...
That doesn't really matter...
I can imagine we use other solutions...
Because the lid is in contact with the dirt, the lid will be filthy...
When the bin is too full the lid will remain open leaning against the top of the litter...
That's what makes it so dirty...
At least that's my interpretation...
And the spilling of liquids etc...

![Diagram](image)

Figure 5.7 - Design concepts for the lid.

(time: 82)

On top of the lid...
Before it is pushed in...
Another possibility would be to...
Keep the lid fixed...
And to get the bin forward for filling...
What is the advantage?...
The advantage is that we can fix a handle to the bin...
To open and close it...
And that part is not close to the dirty opening...
Problem is that when the bin is too full, it will remain open...
Because the lid will be against the litter that is sticking out.

(time: 83)

I think that the Railways will not be enthusiastic about that...
No lid doesn't seem wise...
A number of reasons...
Because things will get smelly in summer...
In winter it is also very hot in trains...
We can think of another solution to the lid...
Because we have to make sure that people don’t have to touch the lid...
I think that is important...
People should not get near to the dirty opening...
There are solutions that can be found for that...
But it should be very simple...

(time: 84)

What I’m trying to look at now is...
Whether there are other solutions to open and close the bin...
Than a lid that moves up, with a hinge at the back...
Or the pulling out of the bin...
Third possibility...
And that is variation on a theme...
To slide the lid back...
There you also have the problem that when the bin is too full, the lid won’t fit anymore... What’s an interesting option, is the prudent lifting of the lid, or the moving down of the litter bin...

(time: 85)

Let’s see if we have more flavours...
It really is difficult to say what I’m thinking now...
What I’m doing now is looking to and fro between these alternatives and see if there is a fifth...
And that is almost impossible to put into words...
That is the hard thing about design...
There are so many processes going on simultaneously... That is hard to put one of them into words...
Because that means that I can’t do other...
You tend to do thing simultaneously...
Because while I’m looking at this solution I’m thinking at the back of my brain about the paper of course...
Because what are the repercussions of this for the paper...

(time: 86)

I think that especially the combination...
The combination of paper bin and the lid is going to limit the possibilities...
That is what I’m thinking about...
At this moment...
You’re not always thinking very consciously...
It is more like you have a puzzle and you are puzzling with a number of pieces to see which pieces fit...
That is more an empirical than a reasoning activity...
Because I want to try to make the product as flat as possible...
There I can get into trouble...
Because the less depth, the more chance that the coffee cups will fall alongside or that it goes wrong...

(time: 87)
So I am kind of stuck...
I don't hear any complaints about the size of the opening of the bin...
With the users...
The bin as a whole is too small...
If you make it deeper, the problem would be solved...
Difficult to reach...
That means that the reachability by the passengers, that's what I'm thinking about, whether that has to do with the number of bins that is in the train...
For instance if you are on the aisle...
That you have to reach between two passengers towards the bin...

(time: 88)
Do you know anything about that?...
EXPERIMENTER: No...
That is not known...
Because when you're sitting next to the window the reachability is no real problem I guess... It's mainly the people on the aisles that have a problem there...
And that is only made worse when you put three chair next to each other...
Has that been researched, by the Railways?...
About the effects?...
EXPERIMENTER: No...
No...
Because that would point towards, especially if you are going to work in several rows, to provide more smaller bins...
That is not easy...
Because then the aisles will be narrower...

(time: 89)
The space between the chairs is hardly enough as it is...
You really can't put anything in there...
Or you would have to work under the chairs...
And then you're very low...
Which is a problem for the cleaners...
There are a number of issues now...
And that is quite separate from what I put to paper...
That is a combination of factors really...
What I just mentioned...
The reachability of the bin...
The reachability the cleaners talk about is probably based on the height of the bin...

(time: 90)
That is why they complain about their backs...
That could be dealt with by a good emptying help...
Because I think the reachability for the passengers has mainly to do with the distance from seat to bin...
I think that when you’re close to the window, there’s no problem...
As soon as the distance increases, you get problems...
How many passengers complain about the reachability?...
That is 22%...
That is a lot...
So there is a problem now...
Would it be possible to attach some kind of bin to the chair...
Near the feet...
On positions that are far from the window...
And what do we think then...
What kind of bins...

(time: 91)
The chair pops up again...
I’m not very...
From the design I would rather put it in the walls...
Against the walls like that...
Firstly for the cleaning...
To limit the amount of bins...
And to limit the number of types of bins...
Because when you attach them to the chairs...
Then you get there different bins from the ones that are on the walls...
You have the problem that the chair has been approved as a design...
And there is nothing integrated in the design...
I suppose the designers will have designed an ashtray in there but no litter storage...
That might be know...
Do you have information about the chairs?...
Does that exist?...
EXPERIMENTER: No... Not at all?

(time: 92)

Can I get an interview with the designer of these chairs?...
EXPERIMENTER: No...
Not...
Have things been decided yet?...
Yes, the chairs are on a frame...
That is known...
That will be kind of like with the current chairs...
I'm dropping the chairs because of time pressure...
I'm going to work on the walls...
Because I'll surely go over my time limit...
The filthy lid is a problem...
We have to make a provision for that...
I'm going to get the newspapers out of the litter...

(time: 93)

I think this is a good chance to do something with the litter...
I can argue why I'm proposing that...
It's 40% of all the litter...

The designer now begins to sketch the bin, and gradually details the design.
In the end, he produces three main drawings of the concept: a presentation-view (Figure 5.8), a drawing to explain how the bin works (Figure 5.9), and an exploded view that shows the plastic parts to be made and their relative positions (Figure 5.10).
Figure 5.8 - Presentation drawing

Figure 5.9 - How the bin works

Figure 5.10 - Exploded view of the litter bin
5.2.3 RATIONAL PROBLEM SOLVING DESCRIPTION

To complete the rational problem solving description of this design project, the video tape was played several times and then codes were assigned to every fifteen-second interval of design activity. The encoding system can be found appendix I. The graphic representation of this data is included in this section: the five graphs represent a picture through time of the designer's acts (Figure 5.11), the goals that underlie these actions (Figure 5.12), the contexts from which the designer operates (Figure 5.13), the topics that are being addressed (Figure 5.14), and the possible reference to topics and contexts outside the direct scope of this design project (Figure 5.15).

These graphic representations give an overview of the design project and allow us to distinguish some patterns in the designer's behaviour. Parts of these graphs will also be used in the next section to explore the rational problem solving description of integration in design. The time interval marked on the horizontal axis corresponds with the section of this protocol that was transcribed and translated in the last section.

Figure 5.11 - The acts of designer 4 throughout the design project.
Figure 5.12 - The goals of designer 4 in this design project

Figure 5.13 - The contexts designer 4 works in.
Figure 5.14 - The topics addressed by designer 4.

Figure 5.15 - The auxiliary topics addressed by the designer.
Some general patterns were observed in the rational problem solving graphs of all subjects:

- In the *acts* graphs we see that there is very little writing going on: most designers do not take the time to make an explicit performance specification. They shift immediately from thinking and reading to thinking and drawing. We can also see that the designers oscillate very quickly between thinking and other actions, especially in concept development.

- In the *goals* category we see that time management plays a minor role in these design protocols, although most designers looked at their watch periodically (typically every 20 minutes or so). All of the higher scoring designers took a break in the last half of their allotted time. In the protocols of the higher scoring designers we also see more oscillation between defining the task and concept development.

- In *contexts* we find that the contexts are spread equally between ‘stakeholders’ and the ‘aspects’, with the stakeholder contexts concentrated at the beginning of the design process (information- and concept phases) while the embodiment phase almost exclusively contained aspects. Apparently, the early stages of a design project are dedicated to processing the statements of the stakeholders, and the later stages are dedicated to detailing a core solution that can be viewed from different aspects.

- For the *topics* we observe a shift from stakeholders and general problem subcategories to the general solution, and then to the attributes of their concept design. Most designers saw this assignment as a request for pure concept development, and did not work on the detailing of the product.

- In the *auxiliary* category we find a striking number of references to the current product, especially in the information and the concept building stages: on average 12.1% of design time.
5.2.4 REFLECTIVE PRACTICE DESCRIPTION

For the reflective practice description of this same protocol, see Table 5.3.

<table>
<thead>
<tr>
<th>TIME</th>
<th>NAME</th>
<th>FRAME</th>
<th>MOVE</th>
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</thead>
<tbody>
<tr>
<td>01</td>
<td>production: vacuum forming</td>
<td>reads the assignment</td>
<td>makes an inventory of the important issues in the assignment</td>
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<td>02</td>
<td>&amp; roto moulding</td>
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<td>03</td>
<td>tools &amp; current litter system</td>
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<td>makes an inventory of problems with current bin</td>
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<td>04</td>
<td>type of train</td>
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<td>combines information on the contents of the bin and customer complaints</td>
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<tr>
<td>05</td>
<td>Lemmens' philosophy</td>
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<td>explores the width of the assignment</td>
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<td>06</td>
<td>interviews Mr Kouwenhoven,</td>
<td></td>
<td>makes an inventory of the problems of the cleaners</td>
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<td>Mr van Dalen</td>
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<td>combines the information and states priorities</td>
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<td>Lemmens as producer current bin</td>
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<td>gathers arguments pro and con</td>
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<td>integration bin in walls</td>
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<td>makes inventory of space in train and of construction of train walls</td>
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<td>the opinion of the Railways</td>
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<td>to stick into the passenger compartment as little as possible</td>
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<td>lid &amp; stench problems</td>
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<td>integration of bin in walls</td>
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<table>
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<th>TIME</th>
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<tr>
<td>77</td>
<td></td>
<td>separate bins for different kinds of litter, integrated in wall</td>
<td>summarizes</td>
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<td>experiments with different configurations</td>
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<td>explores possibilities for opening the bin</td>
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<td>considers having no lid</td>
<td>weighs the arguments for and against the bins in the walls or the chairs</td>
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<td>lifting of the lid, lowering the bin</td>
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<td>separate bins for different kinds of litter, and make the product as thin as possible</td>
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<td>size of the mouth of the bin</td>
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<td><strong>CHOICE:</strong> separate bins for different kinds of litter, and: the bins in the walls</td>
<td>explores different configurations of newspaper bin and litter bin</td>
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<td>93</td>
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<td>considers materials</td>
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<td>considers opening of the bin</td>
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<td>considers emptying of the bin</td>
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<td>considers integration in train wall</td>
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</tbody>
</table>

Table 5.3 - The reflective practice description of the protocol of designer 4.

The section of the table between rows 52 and 93 corresponds with the protocol transcript in § 5.2.2
When we look at all nine protocols we can conclude that using the concepts names, frames and moves is suitable for summarising the activities of the designer: in fact, the descriptions of the design projects in terms of the frames comes surprisingly close to 'neutral' summaries that were made of the protocols early on in the study to create an overview of their content (see Appendix III). We observe that many of the same 'names' are expressed by all subjects, although they vary slightly in their wording and strongly in their importance. We also see the designers use many of the same frames and moves, although they seemed to think that they were very original. They all had the idea of creating a special bin for newspapers, and they all considered this a unique and brilliant idea.

5.3 DISCUSSION

Performing this empirical study has been fascinating to me as a designer; the comparison of these designers' activities to my own design experiences and approach is extremely instructive. But in this thesis we must concentrate on the exploration of the paradigm-related theses that were developed in § 3.3 and § 4.3.

5.3.1 ON THE DATA

To help us explore these theses we now have three kinds of empirical data at our disposal:

- **The statements of the designers.** This is robust data, in the sense that there is a direct relation between their statements and their design behaviour. But this data is also anecdotal; designers can be quoted as reporting something, but the statements of different designers cannot easily be compared or processed.

- **Indirect data.** I.e. what can be observed by viewing the tapes and transcribed protocols in the manners of the paradigms. The encoding systems are aimed at providing the overview necessary to distinguish patterns and make comparisons between the protocols.

- **MetaData.** The experiences of looking in the manner of the description methods plays a major role in the evaluation of the paradigms. The interrater reliability, normally used to ensure the validity of the data (every encoder is seen as a measuring instrument, and their scores should match) is used in this study as an approximate measure of the difficulties in the use of the encoding system.

The exploratory theses that were formulated earlier each need evidence supplied
by a mixture of these three kinds of data to be supported, rejected, criticised or qualified.

5.3.2 **EMPirical Evidence for Design-as-Experienced**

The first and most general aim of this study is to explore whether designers implicitly or explicitly refer to the phenomena of design-as-experienced. The list of phenomena that detail design-as-experienced contains a number of philosophical or theoretical points that cannot be tested directly in an empirical study. These points have more to do with how outside observers view designing and less with the activity of designing itself. However, we can investigate whether these points reflect design experiences. The empirical evidence to look for is statements in which designers explicitly mention these phenomena or display the behaviour that is associated with them.

- **Design situations: thrownness and the core design activity**

  *Thrownness* describes designing as a state in which the designer is *inside* a design project, and not always able to reflect critically and rationally upon the project. Within this core activity the designer is continually faced with the design task, on the level of content. To plan and control the design project the designer must step out of this ‘core design activity’.

  Of all the phenomena associated with design-as-experienced, this is the most abstract, and thus the hardest to capture empirically. ‘Thrownness’ is a philosophical concept, not an empirical entity, and we really cannot expect designers to think about this explicitly (Heidegger is not an easy read for designers, and the word ‘thrownness’ itself is not in everyday use). However, some circumstantial evidence can be found which indicates the designer’s feeling that the design activity is a situation or a state, rather than a process.

- The designers were working in a very concentrated manner, flushed, clearly challenged by the content of the design task. All but one of them forgot that they were talking aloud and did so fluently, not even stopping when Experimenter 1 had to leave the room for a moment. This state of total concentration where the designer ‘lived’ in the world of the design task can be seen most clearly in the moments of transition into and out of this state. For instance, in the episodes in which their concentration is interrupted or breaks down. An example from the sample transcript (§ 5.2.2):

  (time: 077) Designer is generating alternatives for the relative
placement of the litter bin and the newspaper bin, and has considered putting them behind each other, or next to each other. He ponders other possible solutions, but can’t think of any. At this moment he seems to snap out of his design state, stretches his back, looks around, remarks that the marker that was provided is slow in drying, skips to a different subproblem (the fact that the bin is perceived to be filthy), skips back to the placement problem again within 10 seconds, and becomes silent. The test leader urges him to think aloud after about 20 seconds. He says: ‘My coffee is getting cold, that’s what I’m thinking’. And then resumes the course of the argument at full speed.

This phenomenon of snapping out of the ‘core design activity’ and waking up to the outside world could correspond with Heidegger’s thesis of being situated (‘thrown’ or ‘caught’) in the virtual world of the design situation.

• Being in a state of thrownness implies that you are not able, at that moment, to critically consider the process of designing. In the protocols we see that the core design activity seems to be quite distinct from process management, and has its own momentum: there are numerous instances in which the designer, trying to manage his activities, states his intention to do something, but fails to follow through.

For instance, in §5•2•2 the designer states: (time: 51) ‘I think I have enough information to work with now...’ but then launches into another ten minutes of information gathering.

Later on in the same project, something similar occurs. In the 74th minute, the designer has the idea to integrate the bin in the chair, looks for information on the chairs, doesn’t find any, and then chooses not to pursue that idea any further. But his concept development leads him to the chair idea again in the 91st minute. He then requests the same information: apparently he has a very limited overview of his design activity.

The notion of thrownness can possibly help explain the rather striking observation (in the rational problem solving analysis of these protocols) that designers who spent more time on process management produced designs of lower quality. Some designers were observed to have breakdowns of concentration, engagement and commitment and filled those episodes of disengagement with unproductive ‘mini lectures on design’ or process control remarks. Those projects exhibit more progress management than progress.
For instance, if we compare the protocols of the highest scoring designers (4 and 3) with the lowest scoring designers (7 and 8), we see that the number of management and planning episodes (and the time spent in them) correlates negatively with the quality of the end result (see Table 5.4). The correlation between process management/planning time and the quality of the design concept across all subjects is -.45. The correlation of the auxiliary category 'reflection on their own way of working' (another favourite subject when the designer doesn’t know what to do) versus concept quality is -.36. Designers that do not fixate on managing their design process so much but focus on the core design activity clearly do better.

<table>
<thead>
<tr>
<th>designer 4 (high-scoring)</th>
<th>number of episodes in which the designer plans/manages his process</th>
<th>percentage of time spent in planning/managing the design process</th>
<th>mean score of the resulting designs (Tms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>designer 3</td>
<td>18</td>
<td>8.0 %</td>
<td>6.6</td>
</tr>
<tr>
<td>designer 6</td>
<td>6</td>
<td>6.3 %</td>
<td>5.6</td>
</tr>
<tr>
<td>designer 9</td>
<td>13</td>
<td>5.0 %</td>
<td>5.4</td>
</tr>
<tr>
<td>designer 5</td>
<td>16</td>
<td>6.2 %</td>
<td>4.8</td>
</tr>
<tr>
<td>designer 2</td>
<td>24</td>
<td>8.3 %</td>
<td>4.6</td>
</tr>
<tr>
<td>designer 1</td>
<td>14</td>
<td>4.3 %</td>
<td>3.8</td>
</tr>
<tr>
<td>designer 7</td>
<td>26</td>
<td>16 %</td>
<td>3.8</td>
</tr>
<tr>
<td>designer 8 (lowest-scoring)</td>
<td>27</td>
<td>8.7 %</td>
<td>3.4</td>
</tr>
<tr>
<td>mean of all subjects</td>
<td>17</td>
<td>7.1 %</td>
<td></td>
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</tbody>
</table>

Table 5.4 - Management and planning episodes of the designers.

- 'When to do what' and design tasks
  In § 1.3 it was argued that in a concrete design situation a designer acts according to the task (= problem + situation + time) that he/she constructs and perceives. In addressing this task the designer asks the central question: 'When should I do what?'. We indeed observed that our designers did not treat the design assignment as an objective entity ('The Design Problem'). All the designers interpreted the assignment quite differently, in awareness of their own design environment, resources and capabilities. This design task manipulation is an almost constant process, but there were episodes in which this modification of the design task (especially tailoring it to the 2.5 hours available) was particularly clear.
  An example from design project 4:
(time: 07) ‘Now I have a problem, and that is that I’ve only got 2.5 hours. So I can’t do a number of things...That is very clear... If I start interviewing these people...And that is very important... For a design assignment... Then that will take time

(time: 19) From the assignment I gathered that we have to deal exclusively with the litter bin...I will check that now, just to be sure...they talk about a litter SYSTEM ... means we’ll also have to deal with the carrying of the litter out of the train...’

The design task had grown again, and this became a bit of a problem. The designer asked for more information and translated this ‘carrying out of the train’ into:

(time: 22) ‘I’ll note down that this is about the litter bin and emptying help...’

Later on, the design task was reduced again by ignoring the design of an emptying help, and adopting the current solution for this part of the system. Some time later the task was explicitly reduced again by letting go of a possibly complicated idea whether to combine the litter bin and the chair:

(time: 92) ‘... I’ll drop the chair idea because of time pressure...’

The designer thus decides ‘when to do what’ on the basis of his perceived and constructed design task, which includes the design problem, his design situation and the time available.

To arrive at a clear view of the design task is one of a designer’s main goals in the early stages of any design project. When we look through all the protocols, we can see that the designers used different strategies to organise the assignment. Some began by deciding whether the process should be one of design or redesign, others focused on which stakeholder should have priority in this project: the company, the Railways, the passengers or the cleaners. Some of the designers also explicitly arranged their design task to be new and challenging. They used a variety of techniques to ensure this newness, such as searching for technical, behavioural or cultural factors that were not addressed in the design of the current product. An example of such an episode can be found in the protocol of designer 3 (one of the highest scoring designers):

In the 26th minute, the designer has the idea of doing away with the litter bins all together, and just make a hole in the floor of the train. He then asks whether or not such an idea would be outside the scope of the assignment, saying he likes to manipulate assignments, because they are
often too narrow. Then he realises that there is already a litter system in a
train, namely the toilets. He asks for some information about that, and is
genuinely shocked to hear that they are just a hole in the train floor,
which opens onto the rails. He finds this an ugly, primitive, and very
backward solution, and adopts a new goal, namely to change this also.
He starts designing a special litter container, which sucks in all the litter
and compresses it. After some sketching he asks to confer with the Dutch
Railways about his interpretation of the design assignment. (See also the
summary of designer 3 in Appendix III).

But in the end, most of the designers concluded that the problems of this
product lay in its handling by passengers and cleaners, and so they begin to
work on a limited, mainly ergonomical problem. This myriad of different paths
and interpretations of the design task were constructed on the basis of an
assignment that seems fairly narrow to start with (see Appendix II and III, and
[Dorst, 1996]).

- **Striving for coherence: design as a balancing act**

  The designers strive towards coherence can easily be identified in all of the
  protocols. Some designers managed to weave coherence into the design
  concept right away; the integration strategy of priority > solve > adapt seems to
  be very suited for this. Other designers dealt with the coherence of their
design concept in a separate design episode.

  Some examples from the design protocol of § 5.2.1:

  The designer has developed a provisional form for the litter bin, and
  starts thinking about the newspaper bin)

  *(time: 120) 'I think we have to make a kind of bar for the newspapers...
  They (the company) can bend tubes... But that would be nasty for the
  unity of the product...*

  *(time: 132) We should make that stand out, the handle of the bin... Yes,
  you are trying to make this relationship of forms within the product...
  The question is where... And how... the total product doesn’t look very
  sophisticated now... I should try to do something with the total shape...’*

- **Learning in design**

  It is very hard to determine how much a designer learns while he’s working,
especially in the rather restricted design projects of an empirical study like this
one. An indirect and very inexact measure for the extent to which design is a
learning process is the amount of time these designers spent on comparing the
present task with their earlier projects and other products they had already
developed. Obviously, designers will refer back to the projects that they have learned from in the past. We cannot measure how much they learn, but we can observe them utilising the knowledge gained from their earlier projects.

<table>
<thead>
<tr>
<th>referring to their experiences with an earlier project</th>
<th>mean % of time (across all subjects)</th>
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<tbody>
<tr>
<td>referring to a product that they made</td>
<td>2.5%</td>
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</table>

Table 5.5 - References by designers to earlier project and products

In all, designers spent about three percent of design time on these references (see Table 5.5). Which is quite considerable when you remember that they are under pressure to produce a design, and do not have time for unproductive reflections. It is possible that if they had been given more time this figure would be higher still.

5.3.3 THE REALISM OF THE CONCEPTS OF THE PARADIGMS

The next thesis (a combination of rational problem solving thesis no 2 and reflective practice thesis no 5 (see § 3.3 and § 4.3)) deals with the actual existence of the main concepts used to describe design activity:

*Designers can be seen and quoted as manipulating the main concepts of the encoding system; designers will use contexts, frames and moves (from rational problem solving and from reflective practice, respectively).*

These concepts should also be unequivocally identifiable by the design researcher:

*Scoring on the encoding system should be reasonably straightforward.*

*Interrater reliability will be high, or a consensus will be attainable on the differences between raters.*

A quick answer to the first question is that the terms in which the rational problem solving contexts are formulated were not explicitly used by the designers. However, when checking the design protocols against the descriptions of the contexts as they were presented in table 3.1 one can observe them implicitly manipulating these viewpoints. An example from appendix § 5.2.1:

*(time: 74) 'The lid, that's a problem... Because it is a filthy lid... That is always filthy... That you have to lift... Then you have to fill it... And you have to drop the lid... So you have a lot of contact with the lid... And a lot of dirt passes that lid...'*

The designer is clearly putting himself in the position of the passenger, the
user of the bin. In one case this behaviour went as far as mimicking a female passenger's voice, and later mimicking a vandal maliciously trying to molest the concept design (which seemed quite gratifying to the designer). The contexts are not always as clear as in this example. In this study the people scoring the protocols were given instructions to only report a context when it could be established beyond any reasonable doubt, and report a 'neutral' when they were not quite sure. In the end, contexts could be identified with a considerable measure of success: a context was reported in 37.8% of all time intervals of all protocols (minimum: 27.1% maximum: 50.0%). There is no correlation between the percentage of contexts identified and the quality of the resulting of the designs. In some episodes the contexts turned out to be particularly hard to score, such as when the designer was concerned with the handling of the litter bin: often, it was not clear whether the designer was taking the standpoint of a stakeholder ('cleaners', 'passengers') or as the aspect 'ergonomics'. In such cases a 'neutral' was given to be on the safe side. This decision was adopted because the text produced in a thinking aloud protocol study is rather sketchy, and in these circumstances it is dangerous to rely only on a single word to score a context.

These problems did not occur while scoring design as reflective practice: the frames a designer used were clear statements that were processed in this description method in the designer's own words. There was no difficulty with implicitness or imprecise wording (see the next section). But still, frames were not easy to identify: the problem was that only the use of a phrase identifies it as a frame. So frames could only be scored after some laborious sifting through the data. 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. In principle, the reflective practice encoding is very dependable because little interpretation is required to make the description. The designer's words are taken as the descriptors of the designer's actions. But the lack of subcategorization within the frame and move categories and the use of the designer's own terms made this data very hard to subsequently interpret and process. The data interpretation which in the case of rational problem solving was done while scoring the protocols was in the case of reflective practice postponed to the later data processing.

The interrater reliability was used to check whether the encoding systems could be used dependably. Difficulties raters have in identifying the concepts of the
encoding systems should result in more differences between their scores.
In the pretest-experiment the results of this interrater reliability test did not look
very promising for the rational problem solving encoding system.
The subcategories, which had been defined at some length, were found to be still
too ambiguous for the subtle task of scoring these protocols. They had to be
specified further and to be accompanied by an extensive how-to-encode manual
(partially included in Appendix I). The encoding was followed by an arbitrating
discussion between the encoders, which resolved almost all of their differences
(this method was reported earlier by Purcell [1996]).
The match between the data and the encoding system had been the main
concern in creating the encoding system. The goal was to make an encoding
system that would limit the task of the encoder to identification, rather than
interpretation of the data. For rational problem solving this resulted in a system
that has a high number of concrete, specific subcategories (see Appendix I).
But still, there were major problems in linking the terms in which the designers
worked to the terms of the encoding system. Some parts of the protocol had to
be looked at many times to try to understand the exact connotation of a term a
designer used. The term used for describing the object which was being designed
(‘the litter bin’ or ‘the litter system’) was particularly hard to interpret: the
connotation of this term develops dramatically throughout the design project.
The whole design project can be seen as the manipulation and definition of this
one central ‘concept’. For instance, designer 3 developed a design concept in
which the opening of the litter bin was positioned under the train windows, and
the litter was stored in a central compartment under the railway carriage. It was
only after working with this design concept for half an hour that he realised that
he was developing a ‘chute’ instead of a ‘bin’. The meaning of the word ‘bin’ had
thus been temporarily extended to include his chute-and-central-storage design
concept. Other design projects show similar changes of connotation in the words
used to describe the design task and solution. This is a problem when we try to
study design activities by focusing mainly on the language a designer uses.

Resolving the raters’ conflicting scores could sometimes only be accomplished by
recording a more neutral score. Certain categories served as receptacles for
scoring difficulties in ambiguous sections of the protocols. This ought to be kept
in mind when looking at the graphs in § 5.2.3; the topics 30 (the product in
terms of general problems and solutions) and 50 (the litter bin as a whole) are in
the most part an honest reflection of the level of generality at which the designer

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worked. But part of the high incidence of these scores can be attributed to an inability to score the designer’s actions in more detailed subcategories.

A most interesting result in the use of this encoding system and description method was the spread of the interrater reliability through the phases of the design projects. The number of differences in scores between raters rose in the concept building phase, where the changing connotations of the words are sometimes hard to follow. Scoring in the information and embodiment phases of the projects was relatively easy, and did not lead to nearly as many discussions as in the conceptual phase. In the information phase the designer largely adopted the terms of the assignment and the information that was provided. The connotations of the words designers used began to change after they processed the information. In the embodiment phase the connotations were made precise again by a designer’s detailed discussion of the components of the product. This could be observed in three projects that reached this stage in this limited design experiment. The designers that didn’t quite reach this phase all ended by summarising the design problem as they saw it and their design concept, for presentation purposes. By doing this they also clarified the terms they used.

The encoding system of design as reflective practice was tested in the same manner. The arbitrating discussions between the scorers focused on the information phase, when there were questions about whether some statements should be treated as a name or a frame. The problem is that names and frames are often introduced in the same manner, but their use is different. In naming something the concept is introduced into the design reasoning; when this new name is cast as a dominant influence, and the designer works with it for a while, it can also be called a frame. But when does one identify something as ‘a dominant influence?’ Schön’s theory does not provide a clear answer to this dilemma, which makes the reflective practice description of the information phase very problematic. The discussions between the raters could not really be brought to a satisfactory conclusion.

In contrast to these difficulties, there was complete agreement between researchers on the scoring of the conceptual phase, which is the episode we wish to capture in this study. The frames were introduced quite explicitly by the designers, and the moves were clearly used to experiment and explore within these frames. In the conceptual phase Schön’s description fitted very well. The interplay between names, frames and moves provides us with a rich picture of the design activity. Both the information phase and the embodiment phase are
not described very well within this paradigm: the information phase is only a list of names, the embodiment phase only a list of moves. Apparently it is the concept of ‘frames’, and their interplay with names and moves that provide us with some understanding of what is happening in the design project. We will return to this issue in the next section, when we consider the reflective practice description of integration in the conceptual design phase.

5.3.4 THE OCCURRENCE OF INTEGRATION AS DEFINED BY THE PARADIGM

The most concrete test for the descriptive abilities of the paradigms is the thesis:

Professional designers will display the compensating behaviour central to the strategies of integration.

Many instances of this compensating behaviour can be found in the protocols. An extensive example is found in the description of protocol 4 in terms of the rational problem solving paradigm, see Figure 5.16. From the topics graph we can see that the topic the designer was occupied with hardly changed between the 53th and the 83rd minute. He was working extensively on the ‘general principle/layout of the product’, with some occasional references to the environment in which the litter bin would have to function. Meanwhile, the contexts can be seen to have varied, so there could be integration in this episode (see the definition of integration in §3.2). In the episode the designer came up with some ideas about the basic configuration of the product, taking the separation of litter and newspapers as the starting point. He then checked how the properties of his general layout worked towards solving the other problems that he had identified earlier (like the accessibility of the bin for passengers and cleaners). In the contexts graph we can follow the alternating behaviour between the different contexts, starting with the technical context when he double-checked information about the train walls and then progressing to the requirements of the passengers. He then stepped back a little to contemplate his position relative to the other stakeholders and thought about what the Railway company would think of his ideas. Returning to the design, he kept alternating between the passengers, the cleaners, and occasionally the Railways.

Please note that the certain identification of an integration pattern within these graphs is only possible with the help of the protocol text. The graphs provide insufficient information to distinguish which sections of the protocol should be seen as connected, as an episode - we need some description of the links between the scores of the time segments.
Figure 5.16 - The contexts and the topics used by the fourth designer
When we compare the above description of integration with its description in reflective practice, it turns out that the identification of integration is much easier in the reflective practice paradigm, precisely because this data processing method conserves the links between the designer's statements. For the reflective practice analysis of this same slice of protocol, see Table 5.6.

<table>
<thead>
<tr>
<th>TIME</th>
<th>NAME</th>
<th>FRAME</th>
<th>MOVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>52</td>
<td></td>
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<td>53</td>
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<td></td>
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<tr>
<td>54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td></td>
<td>replacing bins instead of cleaning them</td>
<td>gathers arguments pro and con</td>
</tr>
<tr>
<td>56</td>
<td>vandalism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>57</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>58</td>
<td></td>
<td>integration bin in walls</td>
<td>makes inventory of space in train and of construction of train walls</td>
</tr>
<tr>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>the opinion of the Railways</td>
<td></td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>information on litter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>64</td>
<td></td>
<td>separate bins for different kinds of litter</td>
<td>gathers arguments in favour</td>
</tr>
<tr>
<td>65</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>66</td>
<td></td>
<td>to stick into the passenger compartment as little as possible</td>
<td>experiments with the position of the bin</td>
</tr>
<tr>
<td>67</td>
<td>lid &amp; stench problems</td>
<td></td>
<td></td>
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<tr>
<td>68</td>
<td></td>
<td></td>
<td></td>
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<td>69</td>
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<td>70</td>
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<tr>
<td>71</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>height of bin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>73</td>
<td>lid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>74</td>
<td>integration of bin in chair</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>integration of bin in walls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>77</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>78</td>
<td></td>
<td>separate bins for different kinds of litter, integrated in wall</td>
<td>summarizes</td>
</tr>
<tr>
<td>79</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>lid design</td>
<td></td>
<td>experiments with different configurations</td>
</tr>
<tr>
<td>81</td>
<td></td>
<td></td>
<td>explores possibilities for opening the bin</td>
</tr>
</tbody>
</table>

136
<table>
<thead>
<tr>
<th>TIME</th>
<th>NAME</th>
<th>FRAME</th>
<th>MOVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>82</td>
<td>bin hinging forward</td>
<td>separate bins for different kinds of litter, and make the product as thin as possible</td>
<td>makes an inventory of problems</td>
</tr>
<tr>
<td>83</td>
<td>considers having no lid</td>
<td></td>
<td>weighs the arguments for and against the bins in the walls or the chairs</td>
</tr>
<tr>
<td>84</td>
<td>lifting of the lid, lowering the bin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>87</td>
<td>size of the mouth of the bin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>88</td>
<td>reachability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>89</td>
<td>more smaller bins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>91</td>
<td></td>
<td>CHOICE: separate bins for different kinds of litter, and: the bins in the walls</td>
<td></td>
</tr>
<tr>
<td>92</td>
<td></td>
<td></td>
<td>explores different configurations of newspaper bin and litter bin</td>
</tr>
<tr>
<td>93</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.6 – The reflective practice description of part of the protocol of designer 4.

This representation shows us that the design concept is based on an idea in the sixtieth minute: to make separate bins for different kinds of litter. This becomes the frame that dominates the ensuing design episode, in which the idea is tested and developed. Subjects used earlier in the design project as 'important names', are now used in moves that are integrated in the developing design concept within this frame. These moves include making proposals for problems like the placement of the bin and the working conditions of the cleaners. Gradually all the important issues that were named in the information phase of the project (see Table 5.3) were integrated into the developing design. At specific intervals the frame is modified to integrate major design decisions. For instance, in the ninetieth minute the position of the new product is finally fixed: it will be placed under the train windows.

The integration between frames, that was defined in § 4.2.2 and explained in figure 4.5, happened only a few times in the section of protocol we are concerned with: at the 78th and 85th minute, the problems of 'separating the litter bin and the paper bin', 'opening of the bin' and 'making the product as thin as possible' became the focus of a design episode that lasted several minutes. The solutions that sprang from this work were then integrated in the main solution.
This reflective-practice description of these integration steps is a good representation of the reasoning going on within the design project. The interplay between names, frames and moves provides a description of behaviour as well as uncovering some of the structure behind the designer’s actions. It captures what the designer is working on (in his own words), and how he is dealing with the subject. The rational problem solving analysis only describes the categories of topics and contexts the designer is working within, and it seems unspecific in comparison.

Table 5.7 shows an overview of the integrative strategies used by the designers in the development of the basic product concept.

<table>
<thead>
<tr>
<th>designer 1</th>
<th>abstract &gt; concrete</th>
<th>divide &gt; solve &gt; reconnect</th>
<th>adopt &gt; adapt</th>
<th>prioritise &gt; solve &gt; adapt</th>
<th>start &gt; correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>designer 2</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>designer 3</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>designer 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>designer 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>designer 6</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>designer 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>designer 8</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>designer 9</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.7 – The integration strategies of the designers

The results of the integration steps are clearly visible in the design concepts of the subjects, so we can expect some correspondence between the quality of this step and the quality of the completed designs. Both of the highest scoring subjects (3 and 4) used the prioritise>solve>adopt strategy while the lowest scoring subjects used other strategies. However, it would be a mistake to conclude that the other strategies are inferior: when we look at the protocol of designer 8, who used the adopt>adapt strategy, we get the impression that it just takes longer to arrive at a solution in this way. The design that was being developed when his time expired was not much different from, and certainly not inferior to, the designs of the others. The designer who used the start>correct strategy did so because he failed to get a real grip on the problem. The lack of clear priorities resulted in the tendency of all his ideas and concepts to gravitate towards the current litter bin. This was very frustrating to the subject, and caused him to stop after two hours.
Unfortunately, the main problem in identifying integration (which was mentioned in § 2•3) still remains: integration patterns take place incompletely, at different levels of generality, at different phases in the development of the problem or solution, and more or less in parallel. Neither of the paradigms goes far enough in helping us to unravel the design activities in such a way that we can compare the occurrence of integration in the protocols, and determine its extent and quality. And it should be stressed that examples of most of these strategies can be found in all of the protocols, in different places and at different levels of detail. For instance, when we take designer 4 again (see § 5•2), we observe:

- **Abstract -> concrete**
  
  *(time: 23)* 'That is to map the whole path the litter takes…'

- **Divide -> solve -> reconnect**
  
  *(time: 109)* 'We have to make an extension for the newspapers... That can be a simple element... just a few fingers... I'm going to leave that open…'

  The designer left this ‘solution’ for what it was, and progressed by determining how far the bin could be sunk into the wall of the train. Then he tackled the form of the bin, and quickly focused on the handle the passengers would use to pull the bin out of the wall. He came up with a provisional solution to that subproblem, and said:

  *(time: 119)* 'As I said before... Some kind of fingers to grab the stuff (newspapers)...

  *(time: 120)* The newspapers... The problem is that this is prone to be vandalised... You break them... They won't like that... A solution like that... Ok... I didn't specify them yet... I think we have to make a kind of bar for the newspapers... They can bend tubes... But that would be nasty for the unity of the product...

  *(time: 123)* I am working on the bin the whole time... But I will have to find a combination…'

  And he began working on the product as a whole again.

- **Adopt -> adapt**
  
  *(time: 55)* 'It would, and I'm thinking about the aircraft industry, where they don't empty and clean the bins inside the cabin. But to lift the whole thing out and replace it by another... the problem is if you want to do the same in trains, that you have to fixate things better than in aircraft... Because in aeroplanes it not-done to demolish the bins after a soccer game... Because you are in a more controlled situation…'


- **Prioritise -> solve -> adapt**

  This is the most utilised integration strategy for this designer (see Appendix III). It is interesting to point out that the subject worked from the outset towards using this strategy, by continually looking for priorities within the given information:

  *(time: 27)* ‘So it is very hard to make a hierarchy of the complaints the cleaners have ... The problem is that the people who work with this have the priority above the people that are higher in the organisation...’

- **Start -> correct**

  This, the least structured of the strategies, could not be found in this protocol.

The importance of integration in design practice can be illustrated by considering the project of our fifth designer. He made a near-catastrophic mistake in the integration of the product. As it happens, most designers had episodes when one of the stakeholders (most often: the emptiers and the cleaners of the bins) was forgotten for a while. The sudden realisation of this shocked the designer and led them to reconsider some of the design decisions that had been taken in the blissful period of forgetfulness. An extreme and tragic example of when this realisation came too late is displayed in the rational problem solving graphs of Figure 5.17.

![Graph showing various aspects for different stakeholders over time](image-url)

**Figure 5.17 - The contexts of designer 5.**
This designer, at some point during his analysis, framed the design task as an ambitious: every passenger should be able to throw away his/her litter without rising from the seat, and there should be separate bins for newspapers and other litter. He went on to develop a concept in which there are one or two bins hanging from every chair – one for newspapers, and one for other litter. He did not consider the problems the cleaners might have until point (1) in the protocol. At that moment he realised that his design made the cleaner’s problems a lot worse (more bins, spread rather evenly throughout the passenger compartment). Reconsidering his core idea would have meant starting all over again. As can be seen in the topics graph he reacted by thinking up and detailing a rather incredible emptying cart (see Figure 5.17) which is much too complicated, if at all possible.

When did he go wrong? It can not to be seen from the graphs, but the video shows that the vital information passed through his hands at moment (2). But he skipped it, and only started to evaluate his concept very late in the process.
This example of misintegration also illustrates a promising way of processing the data of the two encoding systems: the 'objective' patterns found in the rational problem solving graphs can be better understood in the light of the reflective practice frames they correspond to. And possible explanations for these frames can only be generated by detailed analysis of the protocol tapes themselves. Interviews and data on the earlier work of the designer could serve to identify some of the reasons behind the design behaviour.

5.3.5 QUALITY IN DESIGN, ACCORDING TO THE PARADIGMS

The core publications of both paradigms contain some statements about what 'good design practice' should be. They characterise in yet another way the motivation in developing these paradigms. It is interesting to investigate whether these statements match the behaviour of our expert designers.

This point is addressed by studying the design activities of the designers who came up with the best and the worst design solutions. The two design projects that led to the best design proposals should match the recommendations associated with the paradigms, and or at least they should correspond better with these suggestions than the two projects that led to the lowest scoring designs.

This is, of course, a very weak logical link, made even weaker because we cannot say that there is a one-to-one relationship between the quality of a design activity and that of its result. We can assume that better design activities enhance the product quality, and that an incompetent design performance will lead to an
inferior product concept. The design projects of the highest scoring designers look more fluent, balanced and more knowledgeable than those of the others. But this cannot be proven here; fluency and balance are very far from being scientific terms. For this thesis, the ‘concept quality’ is taken as the measuring rod for design performance merely because it is the best we can do at this moment. Let us first consider the design project features that Simon lists as characteristic for ‘good design practice’ within the rational problem solving paradigm:

- **search for and find ‘command variables’**
  Both high-scoring designers tended to work with subproblems, rather than basic variables. Early on in the design project, these subproblems were tied to the stakeholders and defined in their terms. Later on in the design project, when a concept had emerged, the subproblems (frames) tended to be more product related. The worst designers displayed the same behaviour. The notion of ‘command variables’ as introduced by Simon, was not adopted within design methodology, and it looks as though the design research community was right in ignoring it: command variables were not used by any of the designers.

- **compute the optimum solution**
  Consequently, there was no computation of anything like the optimal solution in the design projects of the best designers: they did not work with variables that would enable such a computation, and they were more interested in satisficing than in optimising.

- **use means-ends analysis**
  The best two projects show no sign of using any method for analysis or synthesis. The analysis was guided (in subject and in the order in which these were addressed) by the information system, with periodic overviews and checks if the designer’s knowledge was complete. The designers did use means-end-analysis, when we take this in a wider, metaphoric sense: all designers compared what they had done with the general goals of their design project.

- **manage the resource allocation**
  Both ‘good’ designers explicitly managed their most precious commodity, time, very well. They did not make an explicit planning, like some of the other designers, but they explicitly considered the time they had left at certain points in the design project, and they adapted their goals and strategies to that situation. Two examples from §5.2:

  *(time: 92) ‘I will discard the idea (to combine the litter bin and the*
chair) because of the time pressure... It (the bin) will be on the walls...
Otherwise I'm not going to make it within the time limit.'
(time: 104) (rereading the assignment) 'We work until 12??.. So we won't
make it anyhow... Ok... Then lets take some big steps...'

The worst designers spent much more, rather than less, time on process
management (see § 5.1)

- **use schemes for guiding search**
  The designers give the impression of using some implicit conceptual structure
  or checklist while searching for and addressing the information. There is no
  apparent use of systematic methods for searching the solution space.
  They seemed to rely on a broad and opportunistic approach.

- **tackle the design problem by hierarchical decomposition along
  functional lines**
  In the two best projects, we can find no evidence of any central problem
  decomposition along functional lines. The subproblems were defined as
  outlined above (first item of this list). This problem decomposition can in
  some cases lead to a subproblem-definition that happened to be the same as a
  product function. But this seems more of an accident than a conscious act by
  the designer, let alone a systematic way of working.

- **display generate-test cycles throughout the design process**
  This point is hard to address because it is not quite clear what Simon means
  by generate-test. Designers do not generate a lot of different solutions or
  alternative routes through the solution space, and consequently we do not see
  them evaluating-and-testing alternatives. In the example from § 5.2, there are
  two episodes in which a number of possible solutions to a subproblem were
  generated in quick succession. In these and other instances where multiple
  solutions were generated, they were usually not treated as equal solutions to a
  problem, but as an incrementally improving list of solutions.
  On the other hand, the very detailed cognitive processes designers go through
can be captured in small problem solving cycles like the 'basic design cycle'
[Roozenburg, 1991-II, 1995], that involve generate-test steps. The designers
that came up with the lower scoring solutions displayed less rigour in their
general thought patterns, addressing many problems without really solving
them, or solving them without putting these solutions to the test (see the
example of misintegration in the protocol of designer 7, that was exposed in
the last section).
• manipulate alternative representations of the design problem and solution.
  Designers fluently used the spoken word, written text, 2D and 3D drawings, exploded views, mime and gestures, often in combination with each other. Designer 4, for example, simulated the 'tipping over' of the old litter bin by rotating a drawing of it. Others made gestures as if they are passengers sitting next to the central alley who have to reach over sideways (across someone's lap) to throw away their coffee cup.
  To summarise, we can safely say that the elements of Simon's theory that have been adopted within design research are largely confirmed in this study, although the designers worked in less analytical and less systematic ways than the rational problems solving theory promotes. However, we must also conclude that Simon's design features are of such a general nature that they do not really provide a basis to distinguish between good and bad design practice.

Schön too has listed some properties of good reflective practice:

• In a good reflective conversation, the designer will oscillate between the whole and the parts of the problem or solution.
  This property is largely supported by the best design projects. However, the amount of oscillation varies considerably between the protocols. In the protocol of designer 4, there are three clear episodes in which the whole of the problem and solution was critically considered. There were many episodes in which the same awareness was addressed by defining a subproblem, solving it, and connecting the subsolution to the existing concept, and dwelling for a second on the character of the interface.

• There will be a gradual shift from the tentative adoption of a move or frame to the eventual commitment of the designer.
  This was clear in the best design projects. For instance the protocol example in § 5•2; the frame that was established in the 60th minute was examined quite thoroughly and was confirmed as the basis of the embodiment of the product only in the 93th minute, because of time pressure.
  In the earlier example of incomplete integration by designer 5, the initial frame ('every passenger should be able to throw away his/her newspapers and other litter in separate bins, without rising from the seat') was embraced far too quickly, without a complete check for the other stakeholders' possibly conflicting demands.
• A good reflective practitioner will compile a wide ranging repertoire of examples to be used as moves or frames in future projects.  
This point has already been confirmed in § 5.3.2. The designers that produced the best design concepts did rely on knowledge gained from their earlier design projects.

• A good reflective practitioner will be fluent in the construction and use of ‘virtual worlds’ (sketching and modelling the future situation the product will be in).
This has also been treated above. All of the designers were more than proficient in sketching.

• A good reflective practitioner will ‘experiment rigorously when he strives to make the situation conform to his view of it while remaining open to evidence of his failure to do so.’
The designers clearly struggled with this. Because of the limited time available for this design project, they tended to stick with their first task frame, or to give up before the 2.5 hours had expired.
  
  Designer 7, for example, got stranded in a task frame that was quite similar to the current litter bin. He tried to escape from this design by repeated brainstorming sessions. He generated some quite imaginative solutions and interesting analogies, but when he started to turn them into a complete design concept they all turned into something close to the current bin. After two hours he felt unable to generate more concepts or to reframe the problem, so he gave up.

  In general, there was very little reframing of the task in these protocols.
  
  With the noted exception of one of the better designers (no 3) who reframed the design task quite radically after about 30 minutes.

The features that Schön lists as being characteristics of good reflective design practice are also largely supported by the data from this study. But as was the case with the rational problem solving paradigm, these are very general points that do not help us distinguish between ‘good’ and ‘bad’ design practice. And it should be emphasised that these features are not, as was the case with the other paradigm, directly linked to the core concepts of the paradigm itself: they appear to have been derived from design practice, and merely to be phrased using the concepts of the reflective practice paradigm. As such, they cannot be used to determine the quality of the paradigm itself.
5.4 CONCLUSIONS OF THE EMPIRICAL STUDY

In this empirical study we investigated the first research question of § 2.1. The exploration of the description methods that were developed on the basis of the paradigms has brought us closer to discovering what the properties of current design methodology are in describing (integrative) design activities. An analysis of the protocols has provided ample evidence for supporting our introspective account of design-as-experienced as it was introduced in § 1.3. We have also found that the concepts the paradigms present for describing design activities are realistic, in the sense that designers implicitly used and sometimes explicitly named them. But the use of the encoding systems was harder than expected, and the difficulties varied over the phases of the design projects. Integration as defined by the paradigms could be found in the empirical study, but the picture of the same integration activity in the two paradigms was quite different. It turned out that the concept of quality in design, as defined in each paradigm, is very general and does not correlate strongly with the differences between design projects that were found in the study.

5.4.1 DESCRIBING DESIGN AS A RATIONAL PROBLEM SOLVING ACTIVITY

For the description of design as a rational problem solving activity the empirical study leads to the following conclusions:

- On the whole, the scoring on this encoding system was more difficult than one might expect. The interrater conflicts were easiest to resolve in the information- and embodiment phases, where the description method for describing design provided us with a good overview of the issues a designer deals with. In the conceptual phase, however, applying the encoding system required more interpretation by the researcher. The difficulty in the conceptual phase was caused by the ambiguity in the terms designers use; the main concepts of the design task and solution were constantly instilled with subtly different meanings, which could not be captured in our ‘objective’ encoding system. This caused the rational problem solving description of the conceptual phase to become somewhat arbitrary.

- The description of design as a rational problem solving activity focuses on the process-component of design activities. The ‘topics’ category, combined with the acts and goals, gave us some idea of the reasons behind the designers’
actions and the eventual course of the design process. But for a real understanding of what the designer is doing we need a description of the missing links between design steps. These links could only be reconstructed on the basis of textual analysis.

- Integration patterns could be found in the scoring of the protocols. It was possible to trace integrative design activities in this way, although it was difficult to identify the boundaries of the design episodes.

5.4.2 DESCRIBING DESIGN AS REFLECTIVE PRACTICE

- The description of design as a reflective practice works particularly well in the conceptual phase of a design project, where the designer proposed and experimented with problem/solution structures. The analysis showed how the frames and provisional solutions were manipulated until a satisfying combination was constructed. In contrast, the description of the information phase is very uncertain and sketchy. The lack of a clear frame leads to a description that does not express much of the actual structure of the design activity and fails to capture the rationale behind all the consecutive moves.
- The description method for capturing design as a reflective practice tries to preserve the links between design process, task and designer. We find concepts like ‘frames’ very interesting and most valuable. Unfortunately, the treatment of design as a reflective practice lacks the clarity and rigour which was achieved by the rational problem solving paradigm.
- The weakness of the underlying theory and its notion of what is ‘good’ design practice makes it very difficult to draw any general conclusions from this description of design, or to develop methods that are based on such a description.

5.4.3 OVERALL CONCLUSIONS OF THE EMPIRICAL STUDY

These extensive analyses have enabled us to get a glimpse of design as it is experienced by practising designers. Comparing the performance of the paradigms’ description methods leads to three closely interrelated points of interest:

- Activities like integration, in which the process and content of design activities are intricately combined, can be described to some extent by using the rational problem solving paradigm, and they can be more precisely
understood using the reflective practice paradigm. So there are differences in the levels of understanding of design practice which can be reached on the basis of the paradigms.

- There are differences in the descriptive capabilities of the paradigms in the various phases of a design project. Rational problem solving descriptions seem to work best in the information phase, while the conceptual phase can best be described from the perspective of reflective practice.

- The changing and subjective connotations of words in the conceptual phase was found to be a major issue which determined the lack of reliability in scoring based on the rational problem solving paradigm. The changing and subjective connotations of words were not problematic when describing design as reflective practice.

These conclusions and other findings from the empirical study suggest to us that the strengths and weaknesses of the two paradigms could be complementary; they could supplement each other if they could be combined in a meaningful way. In chapter 6 the possibilities for such a combination will be investigated in a deeper theoretical analysis of the paradigms. A dual-mode model of design and design methodology will be developed in which the two paradigms are combined.

5.4.4 ON PROTOCOL ANALYSIS AS A METHOD FOR STUDYING DESIGN ACTIVITIES

In this study, the use of protocol analysis as a research method for studying design activities has proven to be a mixed blessing:

- The protocol experiment was constructed in such a way that we would capture 'all of design': the designers received their design assignment at the beginning of the tape, and had to deliver their design concept at the end. This led to design projects that were rather compressed: there was no time for incubation, reframing or for deeper contemplation. Even a minor inefficiency on the part of the designer in addressing the design task led to considerable time pressure at the end of the project. There was very little time to learn from mistakes or to go through several iterations between task and solution. In our zeal to capture 'all of design' we inadvertently set up the experiment in such a way that we missed these interesting aspects of design behaviour.

- The multidisciplinary 1994 protocols workshop [Cross, 1996][Dorst, 1995, 1995-V] demonstrated that different kinds of analysis did call for very different kinds of protocol data. Protocol analysis is not the 'neutral', or 'universal' research technique into cognitive processes it is sometimes made out to be.
Protocol analysis turned out to be a very specific research technique, which captures some aspects of design activity in great detail, but misses many others. It can only be used successfully in a specific study when the theoretical background of the wider research project is clear and the limitations of this technique in capturing certain aspects of design activities are taken into account.

- The amount of interpretation needed to draw conclusions from the detailed protocol data is comparatively large, so there is a very real danger that as Terry Purcell commented, 'protocol tapes can work as Rorschach-blots'.

The conclusion of the protocols research workshop was that protocol analysis as a research technique for design had been 'validated', with these qualifications. Further development of the research methodology should focus on ways to increase the 'relevance' of the protocol gathering without losing the 'rigour' of this technique. Better results could be obtained by combining protocol studies with other research techniques (such as observations and interviews).
COMPARING PARADIGMS FOR DESCRIBING DESIGN

The empirical study provided some insight into the properties of current design methodology in describing industrial design engineering activities. In this last chapter we will concentrate on the second research question by investigating how the description of design activities could be improved. We will perform a theoretical comparison between the paradigms based on their differences as found in the empirical study (§ 6.1). This leads us to the development of a dual-mode model of design and design methodology (§ 6.2). The conclusions of this thesis will be formulated in § 6.3, and in the epilogue (§ 6.4) ideas are developed for further research.

6.1 A THEORETICAL COMPARISON OF THE PARADIGMS

In the empirical study, three key areas of difference between the paradigms were identified: (1) differences in the type of understanding of design activities that can be reached on the basis of the paradigms, (2) differences in the descriptive capabilities of the paradigms in the phases of a design project, and (3) differences in the ability of the paradigms to cope with the changing and subjective connotations of words in the conceptual phase (see § 5.4.3). These differences highlight the descriptive properties of the two paradigms of design methodology. But these isolated issues do not directly provide a basis for addressing the second research question. To ‘improve the description of design activities within design methodology’ requires a deeper understanding of the precise and fundamental differences between the paradigms. We will now embark upon a brief theoretical comparison of the two paradigms, in which we seek to explain the key differences discovered in the empirical study. We will address the first conclusion of the empirical study by investigating the nature of abstraction in the paradigms, then we will address the others by considering the epistemologies of the two paradigms.
6.1.1 Abstraction in the Two Paradigms

In design methodology, as in any science, theories are formed by abstracting from the messy details of everyday life. The two paradigms of design methodology differ fundamentally in the way they abstract from design reality (see §3.1 and §4.1). Two aspects of this process are treated here: deciding which variables are to be dependent or independent (what is abstracted?), and the levels of abstraction.

In a research project some variables are singled out for study, while others are assumed to be constant, represented in a simple model, or just deemed unimportant and thus ignored. The variables that are singled out are 'dependent' variables, the ones that are varied to study their impact are the 'independent' variables, and those that are constant are 'parameters' [Baarda, 1995]. For instance, in the empirical study of this thesis project, the drawing tools were not considered an object for study, so this parameter was kept constant by giving all designers the same tools.

In any study of design, there are three general 'dimensions' to a design situation, which can be chosen to be dependent or independent variables, or parameters (see Figure 6.1). In the rational problem solving paradigm 'the designer' is a parameter, and is replaced by a simple model in which the designer becomes an information processing system. Such a substitution limits the understanding that can result from a description of design within this paradigm and limits the scope of the conclusions that can be drawn. The substituted model defines the concepts and relationships that can be used in the explanation of an observed phenomenon. If, for instance, aspects like the designer's motivation are kept outside the model of the designer (as is done in rational problem solving) there can be no statements about this although a failing motivation might clearly influence a design project that is being studied.

Figure 6.1 - The three dimensions of design activities
The rational problem solving paradigm not only takes 'the designer' as a parameter, but also the 'design task', which is only described as being ill-defined. All attention is thus focused on the design process, the dependent variable (but: dependent of what?). The design process is modelled in great detail, and methods and techniques are developed for this. The focus is the discovery of patterns in the design processes, which are then tentatively traced to their sources. These sources can include only limited (and exploratory) statements about the designer or the design task. In defence of these models, it must be said that design activities can of course be abstracted in this manner, and there are good reasons to do so. It becomes possible to make methods and techniques for design processes that are independent from the properties of design tasks, and function independently from who is/are designing (at least, in theory).

In reflective practice there is no clear choice for selecting the designer, the design task or the design process as an independent variable or parameter. This paradigm focuses on understanding the linkages between these three, using notions like 'frames' that span the three dimensions. After all, a frame is defined as a personal, task-related view that guides the steps in a design process. As a consequence, studies within this paradigm can result in conclusions about all three aspects: the education and (personal) development of the designer, the interpretation of design tasks and the nature of detailed design processes. However, this also implies that any conclusions drawn on the basis of a study within this paradigm are not readily applicable to other designers or design tasks. This approach leads to 'case study' descriptions as instructive examples that demonstrate how designers work. To extend the scope of the conclusions that can be based upon this paradigm, models should be developed that generalise knowledge about the properties of designers and design tasks. There is no reason to suppose that this cannot be done: this knowledge exists in everyday design practice. It is the essence of the largely implicit 'professional knowledge' of experienced designers. Designers react sensibly to different task situations, and experienced design tutors recognise the working styles of their students. There is very little literature in which attempts are made to make this knowledge more explicit, and to generalise and systematise it. The work of Rowe [1987] in architecture is a notable exception. Outside academia, this knowledge is sometimes expressed by design practitioners: for instance in the work of the cartoonist McCloud [1994], and the screenwriter Field [1984]. Field produced a wonderfully detailed how-to book for the design of Hollywood movie scripts, based on a very clear perception of design processes,

\* In the empirical studies based on this paradigm, the designer seems to be treated as an independent variable, because this dimension is varied by using different designers as subjects. However, there is a strong emphasis on generalisation rather than on the interaction between the independent and dependent variables; the differences between the designers is effectively abstracted from.
the role and capacities of the screenwriter, the dramatic structure of a screenplay and the circumstances under which screenwriters work.

Both the rational problem solving paradigm and the paradigm of reflective practice take design processes as their dependent variable (as one of three dependent variables, in the case of reflective practice). The design processes are the main object of study, and both paradigms aim to improve this dimension of design practice. This need not be the case for methodologies in general. For instance, an alternative methodology could concentrate on the designer’s personal development as a dependent variable. Schön touches briefly upon this idea (the shift in ‘underlying background theories’), but does not pursue it in any detail. It has been explored recently by Bryan Lawson in his interviews of outstanding architects [Lawson, 1993, 1994], and by Edmonds and Candy [1997].

The levels of abstraction involved in developing design methods are modelled in Figure 6.2, where the process of abstraction is shown as an activity that removes us from reality at (t1), and allows us (by choosing parameters and independent variables) to develop models and theories about the dependent variables. After this, a reverse process follows, that of concretisation, in which these abstract models and theories are re-applied to reality at (t2). In this application the factors of influence that were taken as parameters or independent variables must be taken into account again. (The latter process is often ‘forgotten’ within the scientific community. There are many interesting models and theories that do not have the impact they deserve because this concretisation step is missing.)

![Figure 6.2 - Abstraction and concretisation](image-url)
When we apply this to the two paradigms of design methodology we can see that they differ not only in their choice of dependent/independent variables, but also in their levels of abstraction. In rational problem solving, abstract models and theories of design processes are developed, but the concretisation of these theories for design practice is largely ignored. Schön has criticised the high level of abstraction involved in the rational problem solving approach to design. He argues that design as a situated activity should be studied at a much lower level of abstraction, and should take into account a much wider range of influencing factors. This criticism is somewhat unfair: the absence of concretisation in rational problem solving does not mean that it could not be made concrete.

These differences in the way design is abstracted from and the levels of this abstraction do explain the differences in the kinds of understanding of design activities that were found in the empirical study. The rational problem solving description, which is based on design processes as the one dependent variable, can only try to distinguish patterns in design processes. The paradigm of reflective practice casts design process, design task and the designer as dependent variables, and thus it has a bigger and more diverse set of variables with which to describe and build an understanding of the integrative design activity. These differences also render the paradigms quite incompatible, and make it impossible to merge the two paradigms or to ‘translate’ the terms of one paradigm into the other. For instance, a ‘problem statement’ within rational problem solving is a rather formal description of the goal of the design activity, written down in a certain format and subject to negotiation with the client. Within reflective practice, the counterpart of the ‘problem statement’ is a possibly implicit frame containing the (subjective) goal of the design activity. Thus the concept of ‘problem statement’ softens to embrace the situation-dependent and person-dependent nature of a design activity, and becomes unsuitable as a basis for the general process methods that are the objects of positivist design methodology.

But the paradigms could clearly enrich each other: the perceived lack of concretisation of the rational problems solving paradigm could be complemented by making connections with the wider range of dependent variables that a reflective practice description of design tries to take into account. Thus, both paradigms could be united to work towards their shared goal of developing knowledge and methods for designing.

We should be aware, though, that the concept of ‘method’ is defined in quite
different ways in the two paradigms. In rational problem solving (and other paradigms in the positivistic tradition), a 'method' is a general pattern of behaviour that is considered relevant for a particular phase in the design process. This method can be based on empirical research, on theoretical models or the logical consideration of design processes. A method is 'valid' when it is independent of the precise problem or the identity of the acting subject. The paradigm of reflective practice does not lead to the development of general methods in this sense. Its primary aim is to describe design activities very precisely, and to encourage designers to be aware of what they are doing. On the other hand, viewing design as reflection-in-action does lead to guidelines for designers. Since design steps are always inherently tied to 'unique situations' and the 'abilities of the designer', advice or methods to support those steps will inevitably mirror this dependency. The application of such methods requires an amount of interpretation that would not be tolerable within a positivistic framework. For design methodologists working within the rational problem solving paradigm the methods that result from reflection-in-action will look 'sloppy', not 'intellectually tough' [Simon, 1992] and of very little use. Conversely, to adherents of the reflective practice paradigm, the methods that emerge from rational problem solving look too general since they do not address the wider (task-and-person dependent) design activity.

6.1.2 THE EPISTEMOLOGIES OF THE TWO PARADIGMS

In the epistemology of a theory or paradigm the origins, nature, methods and limits of knowledge are defined.

The rational problem solving paradigm is based upon positivistic epistemology, and the paradigm of reflective action is phenomenological in nature. Positivism and phenomenology are on opposite sides of the spectrum: subjectivity and the human experience (phenomenology) is contrasted to a view of the world as a separate reality that can be described objectively (positivism) (see § 3.1.4 and § 4.1.4). The conflict between these opposing views is one of the basic issues in Western philosophy (see [Coyne, 1991][Varela, 1991]). Over the centuries a number of attempts have been made to bridge this gap - but none of these attempts has generally been recognised as successful. We will not try nor pretend to resolve this dilemma here. However, some relatively recent developments in philosophy and cognitive science could be useful when dealing with this dilemma in the specific case of design methodology.
To understand the epistemologies of the two paradigms of design methodology, we must concentrate on the basic difference between positivism and phenomenology. These differ quite strongly in the way subject (the acting person) and object (the outside world) are related, see Figure 6.3.

![Diagram of Models of positivist and phenomenological epistemology](image)

**Figure 6.3 - Models of positivist and phenomenological epistemology.**

Positivism claims that a person lives in an objective world which can be known through his/her senses; the sensory data is then structured by an internal processing system. This structuring system interprets the data by using basic *a priori* categories. To know the objective world, a person should study it carefully and dispassionately, preferably with scientific methods (see [Outhwaite, 1994]). In phenomenology the person is not static, but an emotive social being with a history and an environment which heavily influences the person's construction of reality. And the subject is influenced (and in the end 'formed') by what he/she perceives. Therefore, person (often called subject) and object are inextricably connected (see [van Manen, 1990], [Merleau Ponty, 1992]).

These same simplistic schemes can be used to describe and contrast the epistemologies of the two paradigms of design methodology, see Figure 6.4.

![Diagram of The epistemologies of the two paradigms for describing design](image)

**Figure 6.4 - The epistemologies of the two paradigms for describing design.**

* These models are gross simplifications of the real perceptual processes, about which there are a number of competing theories. The only thing these models seek to express here is the presence of perception and interpretation as an object of study within the phenomenological framework, and the basic interdependency between person and object in this framework. (In this and the following figures the person is represented by a hexagon, the object by a square, the action by an arrow, and a feedback action by a double arrow. Remarks to specify the actions are added in grey ellipses.)
The arrows in these figures represent the processes of perception. In positivistic paradigms like rational problem solving there is an objective world on which the designer acts. Perception is a process 'in which facts about the world are (sometimes inaccurately) registered in our thoughts and feelings' [Winograd, 1990]. In the phenomenological approach this awareness is attained in a two-way (multi-step) process of 'bringing expectations to bear upon a situation' [Coyne, 1991]. This perception involves interpretation as a structuring act. Some of the 'frames' with which reality is structured are general a priori categories (like Kant's 'space' and 'time') while others may be detailed and personal subjective frames such as those described within the reflective practice paradigm. Through the act of interpretation the perceptual knowledge base of the subject (the gallery of frames) is changed, 'especially when an initial structuring act breaks down and a renewed observation has to take place’ [Coyne, 1991]. This difference in the epistemologies of the two paradigms thus explains the differences in the way the changing and subjective connotations of words in the conceptual phase were handled in the empirical study. The paradigm of reflective practice naturally takes the design task and solution as they are perceived by the designer as the starting point of its representation, while the rational problem solving paradigm takes them to be objective (or rather: it has the tendency to objectify them in the subsequent analysis).

In §6.2.1 we will use these theoretical analyses to address to the third issue raised by the empirical study, the differences in the descriptive abilities of the paradigms in various phases of a design project.

6.1.3 CONCLUSION

From these theoretical investigations we must conclude that the two paradigms are on opposite sides of a fundamental divide in the philosophical field of epistemology. They are also quite incompatible in the way they abstract from design reality and construct models and methods for designing. Fortunately the differences are such that they could possibly complement each other, if a framework could be created in which they both can function. The challenge is not to emphasise the differences but to explore whether these differences can be overcome; whether some modus vivendi could be found in which the paradigms could complement each other.

When looking for inspiration to attain this modus vivendi we find that the basic split in design methodology has its counterpart in many other fields of enquiry. For example, in psychology the debate between adherents of the positivist
approach (behaviourists) and the more phenomenological approach has been raging for the last forty years. This debate has been a major formative influence in the field of psychology as a whole, and has inspired many insights into the nature of studying human beings. Such a debate is regrettably absent in design methodology.

In philosophy, the positivist epistemology has been under attack for decades by philosophers who criticise Western thought for being overly mechanistic and inherently non-human. Holists like Pirsig [1974], phenomenologists like Varela [1991], van Manen [1990] and New-Mystics like Maturana [1984] have tried in various ways to re-integrate the human aspect into scientific thinking. Various fields have benefited from these discussions, in particular cognitive psychology:

'... Cognitive science stands at the crossroads where the natural sciences and the human sciences meet. Cognitive science is therefore Janus-faced, for it looks down both roads at once: one of its faces is turned to nature and sees cognitive processes as behaviour. The other is turned toward the human world and sees cognition as experience...'[Varela,1991]

A central theme in many of these approaches is the overthrow of the subject-object divide introduced by Descartes. Unfortunately these overarching theories tend to be too general for use in a practical teleological science like design methodology. They are having an impact on the development of more ‘human’ artificial intelligence [Winograd,1990] and they provide a rich human-sciences basis for the design of interactive media [Rijken,1994].

Within design methodology, Coyne and Snodgrass [1991,1992,1995, 1995-II] have also attempted to overcome the fundamental differences in epistemologies by challenging Descartes ‘dual knowledge thesis’. They claim that all human action can be described in a hermeneutical framework. In this approach, all knowledge is obtained by a process of interpretation, by bringing expectations to bear upon a situation. These expectations are inherently subjective, in the sense of being dependent on the earlier experiences of the subject. Their arguments open up the potential scope of design research to include more hermeneutical models and metaphors. However, their extremely interesting philosophical treatment of models in design methodology does not lead to conclusions that can help us in our current predicament. In the end, the differences between positivism and hermeneutics are stressed rather than resolved.

Intersubjectivist philosophers like Habermas and Gadamer have approached the problem of the two epistemologies from a slightly different angle. They do not
seek to contrast or integrate the two epistemologies, but they try to make a make a productive connection between them. Habermas does this by distinguishing different types of human perception and knowledge acquisition [Habermas, 1986]: (1) *Sensoric experiences* are intended to gather knowledge about things, properties and processes. The meaning of the sensory data is constructed (‘constituted’) on the basis of perception *a priori* like those introduced by Kant. (2) *Communicative experiences* are aimed at understanding (‘Verständigung’), leading, through a process of communication, to the meaning of what is being considered. An example could be reading a book: this process should in Habermas’s view not be described as a relationship between a subject and a physical reality, but as a process of communication and the gradual evolution of understanding (in fact, a ‘reflective conversation’). This process of communication can take place in a number of different contexts, with differing goals. It can, for instance, be performed with an ‘objectivating attitude’, in which an understanding of the world is constructed as if it were objective (almost as if it were a sensoric, rather than a communicative experience). Habermas thus preserves the basic epistemological differences between the paradigms, but distinguishes different aspects of reality in which the two epistemologies are more clearly expressed.

The treatment of knowledge acquisition as a human activity is also central in the work of Gadamer. He defines the basic operation in the acquisition of knowledge as *interpretation*, and claims that this is a dualistic activity: it is both a *‘revealing of what the thing itself already points to’* and *‘an attribution of value to something’* [Gadamer, 1986 (p 68)]. The ‘revealing of what the thing itself already points to’ could be called *‘objective interpretation’*. This is the case when something outside (say, a piece of information) impresses its meaning upon the observer. The ‘attribution of value to something’ could be called *‘subjective interpretation’*. This means that the subject, in an act of will, impresses meaning and value upon something.

This dualistic concept of interpretation will be our basis for building a dual-mode model of design research in which the two paradigms can be used together towards the common goal of describing, understanding and supporting design activities.
6.2 A DUAL-MODE MODEL OF DESIGN AND DESIGN METHODOLOGY

The conclusions of the empirical study and the theoretical investigation will now be combined to construct a model of design and design research which connects the two paradigms of design methodology. A model will be developed to combine all the strong points of the paradigms of rational problem solving and reflective practice, and which will provide greater clarity regarding the use of these paradigms in the study of design activities.

6.2.1 A DUAL-MODE MODEL OF DESIGN

Habermas’s idea that different modes of human perception correspond to different aspects of reality could provide us with a common ground between the two paradigms. The two types of design descriptions that were discerned in the analysis of the paradigm epistemologies (see Figure 6.4) could actually be a reflection of two kinds of design activities. These are most easily defined by the two modes of interpretation that were central to Gadamer’s description of knowledge acquisition:

- **The activities in which ‘objective interpretation’ plays an important role.**
  
  The designer observes and analyses the (objective) design problem, which is then transformed into a solution by a process of synthesis. This solution is again observed, analysed and evaluated.

- **Design activities that involve ‘subjective interpretation’.**
  
  In interpreting a design task, the designer assigns value to certain aspects of the situation. The designer ‘constructs’ the current task, and his/her subsequent behaviour is, in turn, is influenced by it.

This distinction between different modes of interpretation corresponds with our observations in the empirical study. It clearly played an important role in the episodes in which the designer determined the design problem and explores the freedom he has to produce innovative solutions. To obtain this information he first needed to interpret the statements of the stakeholders. We observed the designer’s struggle to both understand and to assign value to the statements. For example, in the design project of designer 4:

(time: 10) *‘Well, that Mr Lemmens sees a chance to get a higher profile in the market... The question is whether Mr Lemmens has an image of his company...An identity he wants to express in the market...Whether there have been product in the past, that he made, of which he thinks that they*
express his identity...
(time: 11) I would like to know... I always try to find out what he is aiming at... what keeps him awake at night...’
Later, in a different part of the information, he stumbled across a partial answer to this in a statement by the owner of Lemmens:(time: 48) (it turns out that the product Lemmens is looking for is) ...‘something modern with some good ideas behind it’... to which the designer comments rather wistfully: ‘that is why they are not a Curver ...’ (Curver is a competitor and is considered to be a high-quality firm) he then showed signs of disappointment and took the major decision not to bother with ‘Mr Lemmens’, and instead concentrate on the client, the Railways. The objective information in the stakeholder interview upset his initial subjective view of Lemmens as a possibly ambitious and able company. He turns away from Lemmens because he wanted to set his own goals and needed this freedom to produce an innovative design.
These distinct design activities of course correspond with the two paradigms of design methodology (compare Figures 6.4 and 6.5). The theories of Habermas and Gadamer were presented in the last section to pinpoint the differences in the epistemologies of the two paradigms. The design activities in which ‘objective interpretation’ plays a major role are described well by the rational problem solving paradigm. Activities that involve ‘subjective interpretation’ are most easily described by the paradigm of reflective practice (with the concept of frames again playing a pivotal role).
Which type of interpretation is dominant varies through the phases of design activity, and across design situations. This explains the differences which were found in the empirical study as to the performance of the paradigms in the various phases of design activity: in the information phase of a design project most of the design activity involves ‘objective interpretation’, so it is best described by the rational problem solving paradigm. The conceptual phase of a design project, which is a more subjective design activity, is best described by the paradigm of reflective practice.
The decision whether a part of a design activity will involve ‘objective’ or ‘subjective’ interpretation rests with the designer working on the design task. There are a number of influences on this interpretive behaviour of the designer:

- Design is an activity that is aimed at solving a problem for the outside world (increasing turnover and profit for the company, for instance). On the other hand, it is also a ‘creative’ process, underconstrained in the sense of giving the designer a certain measure of freedom. Inasmuch as a certain design project is a problem solving process for the outside world, it needs to be controlled and the design decisions must be justified to the stakeholders. In that case there is an emphasis to objectify the goals and decisions in the design project, to effectively eliminate the implicitness and elements of ‘subjective interpretation’ from the design activities (as in Habermas’s description of communicative experiences that can seek to mimic the sensoric ones). Any perception and problem interpretation must then be made explicit and becomes a subject of negotiation between the designer and the stakeholders. Through this process of negotiating, design becomes a more or less ‘objective’ process, in which problem statements, programmes of requirements, ideas and design concepts are still made rather ‘subjectively’ and implicitly, but in the end are presented explicitly and evaluated in order to settle them and make them real objects in the world. This results in an explicitly controlled pattern of objective design activity which can be described accurately using a positivist approach like the paradigm of rational problem solving. ‘Objectivity’ of the steps in a design process and of the terms used to describe it can thus be considered an artificial construction by the designer(s) for special purposes.
• 'Subjective interpretation' can become very important in a design project (or phase) where the design task is ill-structured. In such a case, subjective structuring is the only way to make sense of the task. Structuring of the task can be achieved by imposing personal goals of the designer onto the design task or by subjectively choosing priorities. In design there is no particular pressure to minimise the subjective interpretation of a design task and its solution: the dominant goal in design is to produce a good design, on cost and on time. A designer thus has the privilege and the problem of working in both an 'objective' and a 'subjective' mode.

• Where a certain design project gives (or demands) freedom of choice to the designer, he/she has to depend on their own interpretation and perception of the problem to produce a result. Then design is essentially a subjective activity, which can be best described in terms of reflective practice. This is particularly true in the conceptual phase of almost any design process, but this subjective approach could extend over whole design processes.

• Looking back at the protocols of this empirical study, designers were seen to spend quite some time at the beginning to consider what kind of problem they had to deal with. They did this in terms of the constraints of the problem which imposed on their freedom to define their own goals. The freedom depended partly on the assignment that they were given, and partly on their personal style: some designers seemed more at ease with an 'objectivist' approach to design problems, others are more comfortable imposing influential frames on the project right from the beginning (Examples can be found in Appendix III: designer 7 seeks objectivity, designer 3 is extremely subjective in his approach).

• The choice to use subjective or objective interpretation is also a personal one, possibly influenced by the designer's cultural background and training. In the empirical study there are several instances of designers who, having come to an analogous point in their design project, differ in their choice of whether to analyse and seek further information or to start posing priorities on the basis of their current knowledge.

• Group- or organisational design processes tend to require a large number of objectifying statements and arguments [Valkenburg, 1996] to keep everyone on track. This is even more extreme in multidisciplinary teams, where the basic level of shared understanding necessary for the completion of the job (based upon identical interpretations of the design task and situation) is more difficult to achieve.
• When a designer follows a procedure (a method or technique), there is no fresh interpretation of the design situation until the procedure is finished or breaks down. In episodes of a design project where there are few procedures, there are many more possibilities for the new, subjective interpretation of design task and design situation. In routine or redesign work there are many procedures, which decreases the importance of subjective (re-)interpretation of design task and situation.

By adopting the idea of discerning distinct kinds of design activities, the goal of this study has shifted from the attempt to create a bridge between the paradigms of design to clarifying which parts of design reality belong within each of the two paradigms.

6.2.2 A DUAL-MODE MODEL OF DESIGN METHODOLOGY

The empirical study led us to distinguish between two significantly different kinds of design activity which can be associated with the two paradigms for design research. ‘Objective interpretation’ can be described within the positivist rational problem solving paradigm, while ‘subjective interpretation’ is observed when looking at design as if it were a ‘subjective’ reflective practice activity. 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 question of which paradigm to use arises at the beginning of a research effort, when the design methodologist must decide which interpretation of the many-faceted object of ‘design’ will serve him/her best to attain the goals of their research. This choice has been illustrated in Figure 6.6. The two familiar diagrams again represent the rational problem solving and reflective practice approaches to design. It should be clear that a designer and the design researcher make similar choices; the choice of the design researcher - which paradigm is appropriate in this study - depends on the kind of design activity that is being studied.

The choice which paradigm is appropriate in design research depends on the earlier choice of the designer as to which kind of design activity to engage in.
Figure 6.6 - The dual-mode model of design methodology

The choice of the appropriate paradigm is a very complex problem. But generally speaking, the appropriateness of the using of a paradigm depends on three main factors:

- **The goals of the research.**
  The possible goals of any design research project are: the construction of formal models of design, the construction of general prescriptive methods and techniques, making methods and techniques for design education, and making case-study descriptions of design activities.

- **The objects of study.**
  These include the three dimensions of design activities: design processes, individual designers or organisations, and design task (plus combinations of these three).

- **The subject, the kind of design activity that is to be studied.**
  The most important division between design activities which was discussed in the previous sections is that between design activities involving objective or subjective interpretation.

The performance of the paradigms concerning these factors is summarised in Figure 6.7. Each research project has its own set of goals, objects and subjects of study. The idea is that those research projects in which a paradigm is used on its strengths (the plusses in Figure 6.7) will, on the whole, give the least paradigmatic trouble. The figure also shows that the combination of goals, objects and subjects can easily lead to contradictory demands.
The **goals** of the research project can be:
- formal models
- general prescriptive methods or techniques
- methods and techniques for design education
- case-study descriptions of design activities.

Possible **objects** of the study are:
- design processes
- design persons/designing organisations
- design tasks/design problems
- the interaction of design process, person and task
  (design activity as a whole).

The **subjects** of study can be:
- subjective or
- objective design activities.

Figure 6.7 - The appropriateness of using the paradigms for various goals, objects of study and subjects. (The ‘+’ indicates that the paradigm is well-suited for this, ‘0’ indicates neutral behaviour while a ‘-’ indicates unsuitability for this goal, object or subject of study)

Problems that can arise from using the paradigms of design research for purposes for which they are less suited can be clarified by an example we have used earlier from classic design methodology literature:

*McGinnis and Ullman [McGinnis, 1992] report on a study into the development of one component of a machine throughout a four and a half hour design session. The goal of the study is to develop a research method for conceptual design. They follow the way in which a machine component gets gradually more defined in a real-life design process (captured in a thinking-aloud protocol.). They avoid making assumptions on the kinds of ‘design objects’ (parts and features) that are to be observed by consistently adopting the terms in which the designer himself refers to the design. This approach offers a simple, objective, straightforward and rigorous way of following the designer’s activity. They list the parts and features named by the designer. That list turns out to be surprisingly long, with many words that have subtly different connotations. The list has no apparent structure. The authors refer to their results as just a ‘bookkeeping of the design process’. Further conclusions do not seem possible.*
When we attempt to explain this study in terms of the dual-mode model of design research (Figures 6.6 and 6.7), we find that they studied the development of a design component in the 'subjective' conceptual design activity while using the rigorous, positivist rational problem solving paradigm. They were thus studying a subjective interpretative design activity from within a paradigm that is not appropriate for capturing subjective interpretation. They could not, therefore, capture any of the rationale of what was happening in this design activity, and their data does not contribute to the understanding of what occurs in this particular protocol.

In this particular case it is the subjective character of the research data that frustrates our understanding of what is happening. If they had chosen a different design project, or a phase of design activity where the design task is effectively well-structured, the subjectivity of the interpretation steps could have been ignored or bypassed without misrepresenting the design activities that were observed. Many research projects show similar difficulties: most design researchers want to develop a deeper understanding of the conceptual phase of an innovative design project, while using the rigorous, but ultimately unsuitable, rational problem solving paradigm.

However, it should be restated that this model is a gross simplification of complex design reality; both categories of design activity will almost always be present simultaneously in design episodes. Design activities can then be described within both paradigms, and our empirical study has shown that design methodology could benefit from this.

6.3 CONCLUSIONS

We set out to explore the properties of the two current paradigms of design methodology in their ability to describe design as it is experienced by practising designers. An empirical study was carried out to explore the descriptions of integration within the two paradigms. We have demonstrated that both paradigms deliver relevant descriptions of design-as-experienced, as well as of the integrative behaviour of industrial designers. But they do so in very different and quite incompatible ways. The description of design within design methodology could be improved by a deeper understanding of the properties and limitations of the paradigms. This deeper understanding has been pursued through a study of the epistemologies of the two paradigms, and a comparison of the abstractions the
paradigms make of reality. This led us to the conclusion that the properties and limitations of each of the two paradigms are such that they could be used in combination. A further comparison of the two paradigms led to the development of a dual-mode model of design and design methodology, in which we have attempted to specify the appropriate uses of the two paradigms. This model was effectively summed up in Figures 6.6 and 6.7. Some further conclusions can be drawn for design methodology, design education and practice.

6.3.1 CONCLUSIONS FOR DESIGN METHODOLOGY

The study showed that the different ways in which the paradigms look at design reality and abstract from it could well complement each other. To achieve a more accurate description of design-as-experienced, we combined the two paradigms of design methodology in a dual-mode model of design and design methodology. ‘Interpretation’* is the central design related concept which divided, and could also connect the two paradigms.

This dual-mode model is no grand unified theory of design, but what does emerge is a clearer view of the choices design methodologists have to make when they try to capture design. Design methodologists should be aware that in every new research project they must choose which paradigm is the most appropriate. In doing so, they interpret design. Within the dominant rational problem solving tradition of design methodology this question never arises: legitimate goals of the design researcher are to make objective, general, formal models and prescriptive methods of design, and the only way to reach this goal is to work within the positivist paradigm. We have demonstrated that this is a limiting assumption: ‘subjective interpretation’ is involved in almost all design projects, especially in the development of the design concept.

The dual-mode model is an attempt to help design methodology to represent more accurately the object of study; design activities are partly subjective and partly objective, and design methodology should recognise this. The model is also an effort to improve the relevance of design research by bringing it closer to understanding design-as-experienced while conserving its rigour. We defined the model in such a way that the strengths of the paradigms could be combined, and their weaknesses could be offset by the other.

In order to extend the rational problem solving models of design into a more precise description and understanding of conceptual design activity, design methodology will have to adopt some of the fundamentals and approaches of the more ‘subjective’ reflective practice paradigm. This subjective, interpretative mode

* A dual-mode notion of interpretation, as introduced by Gadamer
of designing is undoubtedly more difficult to describe, model and make methods for than the objective mode. Still, it covers a very important part of design practice. The theory of reflective practice as it now stands is admittedly weak and fuzzy, and the research methodology behind it is such that it will always lead to less rigorous insights (if only because of the large number of dependent variables involved). But the methods that can be made on the basis of these ‘weak’ insights could be implemented, and then tested in rigorous experiments. Design methodology could thus develop into a rigorous, experimental science.

Some ideas about models and methods that emerge from this more accurate description of design-as-experienced are explored in the recommendations for further research. A central theme is that the more subjective aspects of design-as-experienced are potentially captured by the as yet little used paradigm of reflective practice. We hope this study provides an impetus to the use and further development of the reflective practice paradigm.

Finally, it should be stressed here that the dual-mode model of design and design methodology is meant to be a basis for a discussion within design methodology on the use and combination of the two paradigms. The linking and signposting of the two roads of design methodology only covers the application of the models of design that are the methodological core of the paradigms. The research methodologies of the paradigms, and the kinds of methods and techniques that could be developed have not been connected. As it stands, the model is preliminary, and needs further research. But I believe that it could be developed much further, and that, through discussion with designers and design researchers, it could become a subtle and valuable tool for the study of design.

6.3.2 CONCLUSIONS FOR DESIGN EDUCATION

The empirical study of this thesis concurs with Schön’s criticism of positivist design education as being unable to teach students the art of design interpretation. Design education requires the approaches of both paradigms: students should be taught to address design tasks in an ‘objective’ way, by teaching them the use of project planning, concept analysis and evaluation. But they also have to learn how to behave in the more ‘subjective’ interpretation-laden phases of design. The paradigm of reflective practice has provided us with a language to talk about the ways in which designers address concrete design situations, and thus about the application (‘concretisation’, see § 6.2) of the process-models of design.
In the development of an educational programme for design the two paradigms should be combined. It is important to realise that the paradigms differ not only in their research methodologies, but also in their educational methodologies. While rational problem solving concentrates on teaching design, reflective practice concentrates on learning and reflection. The paradigms apply to different phases in the learning cycle [Kolb, 1984], and therefore require quite different modes of learning behaviour from the students. Although both the subjective and objective elements in design are already implicitly part of design education (see § 1.3), their explicit combination could lead to an educational practice that is both more efficient and more effective. Improvements could be made in particular by setting definite targets for the broad but rather inefficient method of experiential learning, that is used in design courses: the reflective practice view of design could help us define the precise areas where it can best be used, and the concrete skills we need to convey to the students. The role of a design tutor can be defined within the reflective practice paradigm, too:

- A design tutor should help the students reflect on their designing so that they learn how to frame their design tasks.
- A design tutor should help the students learn how to explore and to experiment within their approach to a design task.
- And thirdly, the tutor should stimulate the development of the student’s intuition for ‘when to do what’ (by letting them share in the tutor’s own design experiences, e.g. by giving examples).

A more stable basis for design education could also lead to the explicit and more systematic treatment of difficult subjects like the personality traits of the designer (e.g. tolerance for uncertainty, communicativeness), the ‘artistry’ of design, the development of frames and background theories*, and the treatment of coherence and integration. But what should be stressed above all is the teaching of design as an activity that involves intense, continuous learning.

6.3.3 CONCLUSIONS FOR DESIGN PRACTICE

Design can be understood as consisting of a combination of ‘objective’ and ‘subjective’ interpretive activities. Both modes of designing could be studied and supported in their own ways, based upon the two paradigms of design methodology. The recognition of this distinction between the two kinds of design activities and a clearer view of the strengths and weaknesses of the research paradigms could play an important role in stimulating more accurate descriptions

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* The reflective practice paradigm could provide the theoretical backdrop for research into the origins of frames and background theories, and for methods to develop these. These issues are currently addressed in a most interesting study into the role of ‘vision’ in design [Hekker, 1997].
of design activities, eventually bringing design methodology closer to design as it is experienced in practice. This study was only a first step, and as such it does not contain much that is directly applicable in design practice. The problems we encountered as we tried to describe design-as-experienced forced us to consider the roots of design methodology. As a result this study has turned out to be more theoretical than it was originally meant to be. The most practical achievements stemming from this theoretical basis are yet to come. I hope to pursue the ‘conclusions for design practice’ in the coming years. For now, most of the ‘conclusions’ for design practice are expectations, filed as recommendations for further research in the next section.

6.4 EPILOGUE

6.4.1 RECOMMENDATIONS FOR FURTHER RESEARCH

This study has of course generated more questions than it answered. I would like to draw your attention to some of the most urgent new questions that emerged.

- Extensive work is being done on the rational problem solving paradigm, including empirical studies into its prescriptive properties. [Frankenberger, 1996]. These studies are very valuable in the light of this thesis. They are beginning to address some of the outstanding issues, including the detailed description and understanding of the quality of design activities, and the reassessment of some of the assumptions that underlie this paradigm, especially its abstractions of designer and design tasks. The models and theories that have been developed under this paradigm are being concretised (see Figure 6.1) on the basis of this empirical work.

- A firm conclusion of this study is that these efforts should be combined with work on the paradigm of reflective practice. Taking interpretation (‘frame’) and action (‘move’) as the means for understanding design better approximates the activity of design as experienced by designers. This would put a very extended and systematised version of Schöns theory in a very good position for possible application in design practice and education. In his paradigm of design as reflective practice Schöns has tried to construct an action-oriented theory that stands somewhere in the quicksand between positivism and phenomenology. This has led to an interesting description of design activities which is fraught with inconsistencies and vagueness. In the near future we need better definitions of the terms used to describe design in a subjective,
action-oriented fashion. A linguistic basis for the identification of frames is being developed [Trousse, 1996] and together with a taxonomy of frames this could lead to the more systematic description of design activities. These descriptions could then inform our further consideration of design as reflective practice.

- There are some subjects that may become tractable as a result of refocusing design methodology from the design process towards the broader study of design activities. For instance, the description of the design task used in our empirical study, and its solution (see appendix II) has shown that these matters can be described (design tasks may be ‘ill-structured’, but they are not devoid of any structure whatsoever), and that much insight can be gained by doing so.

- General trends in empirical design research show a justified shift from the study of individual designers towards the study of design group activity, both mono- and multidisciplinary. The observations of these studies are both more relevant to design practice and more rigorous in the methodological sense (they do not involve an artificial prompt to ‘think aloud’). The introduction of the extra dimension of social interaction has until now frustrated the development of new insights in the ‘classic’ design methodological sense. But once this factor is under control we can expect valuable results from these studies. The study of Valkenburg [1996] is an interesting investigation into group design activity, using the reflective practice paradigm.

- Much precision can be gained by studying design in its natural habitat, the workplace. This does require a dramatic shift in research methodology, towards an almost ethnographic approach [Lloyd, 1996] [Bucciarelli, 1994] which is quite alien to most design methodologists. The combination of this research with laboratory experiments and experiments in education should provide an exciting mixture of rigour and relevance. However, for design research to develop in this direction, it is necessary to diminish the workload of researchers: empirical methods like protocol analysis are extremely time-consuming. And things will get worse if we try to tackle longitudinal studies of real life design in such a way. The fact that the frame-and-move description of design activities was brief and some ways more reliable than the rational problem solving approach provides yet another argument for extending the theory of design to include reflective practice.

- Design methodology should cooperate closely with the design community. This could lead to phenomenological descriptions of design that are very useful at this stage in the development of design sciences, and open up new
subjects for study, like the professional development of a designer and the role that reflection on design plays in this. It could give the cooperating designers more tools to reflect on the fundamentals of their working style and on the industrial design profession. Where such cooperations exist, or where design and design research are united in one person, they prove to be very useful [Ullman, 1991].

- Design methodology should address the practice of design in a rapidly changing world: learning on the job is becoming more important than the teaching of knowledge. This challenge concerns the fundamentals of methodology: stimulating the learning of design requires a deeper understanding of what design is and how to address design-as-experienced.

- In my professional practice as a management consultant, I have found that much of the knowledge attained in studying design could be successfully applied in other fields as well. In the field of design methodology a consensus has grown about the conceptual framework of design which is very valuable for any discipline in which material or immaterial objects are created and produced. Some people from the social sciences have already used design methodology as a model to approach their own constructive activities (i.e. to design a social structure or an educational program [Visscher, 1996][Visscher-Voerman, 1996]).

- On a philosophical level, design methodology is of great interest because it describes and tries to cope with ‘the context of discovery’, as opposed to the well-documented ‘context of justification’. The context of discovery has always been deemed important (e.g. by [Polya, 1945][Kuhn, 1962][Outhwaite, 1994] and others) but very little effort has been made to study it. The available literature is on the level of intuitive statements of practitioner’s experiences. Design methodologists could supplement these descriptions with elements of both the rational problem solving and reflective practice approaches, and with the connection between the two.

- The preliminary model that was developed in this thesis could also be applied in other fields: today there are many domains in which the choice between positivistic and phenomenological paradigms is relevant. It is clear from this list that there still is a lot of work to do in this line of investigation. But this is the end of our current effort:

'All explanations end somewhere' [Wittgenstein, 1953].
6.4.2 CLOSING REMARKS

The conclusions a reader might draw from this study will be personal, depending on the presuppositions and standpoints the reader had to start with. Personally, I have been impressed with the value of the rational problem solving paradigm that I had grown to be extremely sceptical of. But it has its limits, and I hope to have clarified them. The recommendations for further research focus heavily on the reflective practice paradigm, because I believe it is highly undervalued. I hope to have been successful in promoting the case for subjectivity, and have given it a place in the study of design. I am sure that a subjective paradigm could be developed to takes its rightful place as an equal to the paradigm of rational problem solving. Design methodology would be all the richer for it.

In studying the different paradigms and presenting the dual-mode model of design and design research, I do hope to have contributed to the improvement of communication and sparked a new fundamental discussion in design methodology.

Finally, I should say that in this research project, as in many others, the framing was the problem - which always gives the impression that it could have been done much quicker. But on the crooked path that I took I have experienced the length and breadth of design methodology, and on the way I have picked up a much closer understanding of design. This study served its purpose for me, I hope this book will somehow be enlightening and inspiring for others.

6.4.2 ACKNOWLEDGEMENTS

It makes me happy to think about the friends and colleagues I have worked with. This is the place to thank all of you, and to realise how many you are, and how important you are, and that I can't name you all. Just to mention a few:

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support through all these years came from many colleagues at the faculty of industrial design engineering, Hanny, Jan, Willem, Sandra, Anneke, (and many many more), thank you for putting up with me.

Somehow, the fields of design and design methodology seems to attract many nice people. Thanks to my research colleagues, the participants to the Delft Protocols Workshop: they were wonderful as co-authors of that event, and they encouraged me to recuperate and finish this work in the end. Thanks also to the excellent designers that gave hours of their valuable time to be the subjects in my experiments. I want to thank my designer-colleagues from Van Dijk/Eger/Associates, GBO and Bos IDC for the opportunity and the pleasure to work with them, their trust and for their friendship. Jeroen, Jacques, Erwin, Ton, René, Boy, Marius: let's keep on working together. Dick Rijken has been a great inspirator and good friend - our interminable discussions did much to widen the scope of my thinking.

And at the home front, I had the best brother in the world to help me in troubled times. 'Almost twins', and I'm proud of that. But, however, therefore, it has been perfectionist' Phyllis that corrected the ways in which I wrote my English. My parents, thank you for thinking of me and looking after me. And Paulien, well, I just don't know what to say. Words fail me.
## APPENDIX I ENCODING SYSTEM

### I.1 ENCODING SYSTEM FOR THE DESCRIPTION OF DESIGN AS A RATIONAL PROBLEM SOLVING ACTIVITY

**Category 1: ACTS**

- ask information 01
- read 02
- write 03
- think 04
- sketch/draw 05
- model 06
- take a break 07
- sort/get things 08

**Category 2: GOALS**

- none 00
- determine the problem 01
- make performance specification 02
- generate concepts 03
- build concept 04
- make an evaluation, decide 05
- prepare presentation 06
- manage process (policy & strategy) 07
- make an overview 08
- model 09

**Category 3: CONTEXTS**

- none 00
- neutral 01
- stakeholders
  - the company 02
  - the railways 03
  - the designer 04
  - the passengers 05
  - the cleaners 06
- aspects
  - ergonomics 07
  - construction (technical aspects) 08
  - form 09
  - business 10
Category 4: TOPICS

the brief, the problem as such

the project:

the company (Lemmens):
  - policy
  - resources
  - position (role in the project)

the Dutch Railway company:
  - policy
  - resources
  - position (role in the project)

the designer:
  - goals (ideals)
  - resources (planning)
  - position (role in the project)

the environment (of both the project and the product):

physical environment of the product
procedures in the train-cleaning process
competition/patents
the garbage
passenger behaviour
cleaner behaviour
norms/rules/laws

the product:

in terms of basic problems/solutions:
  - general principle/layout
  - use
  - put in/get out garbage
  - maintenance
  - size and form
  - location
  - materials
  - production method
  - costs & price
  - safety/fire resistance
  - safety/vandalism
  - filth problems
  - the sorting/processing of garbage
  - series/investment
  - repercussions for train

in terms of physical parts:
  - bin as a whole
  - bin
  - lid
  - emptying mechanism
- interface with train 54
- emptying help 55
other, possible physical parts of the litter system:
- collecting cart 56
- newspaper holder 57
- ashtray 58
- bin on wall 59
- table 60
- container 61
- product graphics, ads 62

Category 5: AUXILIARY TOPICS

reference products
- current product 01
- the new proposal 02
- analogous product (in whatever way) 03
- analogous project 04
- earlier project done by the designer 05
- idea of Lemmens 06
- idea of the Railways 07
- comparing concepts 08

reflection:
- on design in general 10
- on project management 11
- on design problems 12
- on the experimental situation 13
- on the information 14
- on the designer's own way of working 15

I•2 SOME RULES FOR THE USE OF THIS ENCODING SYSTEM

General rules
• If a subject is treating different issues within a fifteen-second encoding interval, the activity that took up the most time during that interval is considered to be representative for the whole fifteen seconds.
• Exceptions: if a subject is treating an issue at length, and switches to a side issue and back within the fifteen-second encoding interval, the time spent on the side issue being 3–7 seconds, then the side issue is considered typical. This rule has the advantage of marking the small switches in attention to be expected in an integrative process. It does cloud up the exact times spent on the issues, however.
• Planning activity by the designer is scored as 04 07 04 17 00 (thinking, with the aim of managing the process, from the standpoint of the designer, considering his resources)
Rules by category

About acts:
- A by-rule in the case of activities is that the ‘thinking’ activity is considered non-dominant, in the sense that the subject is supposed to be thinking all the time, but will only be scored as such when he/she doesn’t display any other activity, such as writing, reading, sketching, etc.
- The activity ‘model’ includes the making of gestures, for instance mimicking passenger behaviour.

About goals:
- The category ‘generate concepts’ was set up to mark spells in the process where the subjects sit down and list a number of possible solutions. ‘Build concept’, on the other hand, is the gradual emergence of a concept from a more continuous reasoning pattern.
- The same goes for ‘make an evaluation, decide’: it marks distinct evaluation phases, as opposed to more gradual evaluation and decision-making processes displayed when developing the concept.
- The goal of ‘prepare presentation’ sometimes occurs at the end of the design process; the subject has stopped changing the concept, but makes some more elaborate drawings/pieces of text to explain the features of the design.

About contexts:
- A context can only be scored when the goals, tools and way of defining the problem or product clearly and consistently point toward it. The error of ‘putting down neutral by mistake’ is preferred to the error of ‘wrongly assigning a context’.
- The ‘business context’ is an almost empty category: the subjects tend to consider these things in the ‘stakeholder’-mode. Only cost-calculations are neutral in the sense of not serving a specific stakeholder’s goals, and should be scored as belonging to the ‘business context’.

About topics:
- The ‘resources’ that can be scored for the company, the railways and the designer are the time and tools (money, people, machines) available to these stakeholders in the project. For the designer, these are the resources available in the experiment, so this category is scored when the designer plans his way through the 2.5 hours available to him.
- The ‘environment’ is everything that influences the problem or product and can’t be changed by the designer. So the ‘passenger behaviour’ in this category is not the designed use of the bin, but the things passengers will do that the designer can’t influence (example from the protocols: ‘people will be lazy, and not prepared to stand up to throw away their stuff’).
- ‘The product, in terms of basic problems/solutions’-category was put together of the problems the designer would have to solve, the things he would have to determine in the course of the design process. The terms in which they are worded demonstrate the ‘shadiness’ of this area: some of them are problem-related, others solution-related terms, and a few can be used to describe both.
- The product ‘in terms of physical parts’ is a category reserved for the detail design of the litter system. The design decisions taken in this phase are clearly based on earlier decisions which parts to use and what their configuration is going to be.

About auxiliary topics:
- These are topics that do not have any direct bearing on the problem, and/or are not part of the concept resulting from the design process. They are reflections upon design and design processes, or upon reference products.
APPENDIX II THE DESIGN TASK

II.1 THE DESIGN ASSIGNMENT

The design assignment will now be introduced and discussed section-by-section. The most probable interpretations and conclusions will be discussed briefly.

DESIGN ASSIGNMENT

• The Company
Lemmens Inc. is a producer of plastic bins and buckets. There are 40 employees in the factory, divided over 10 injection-moulding machines, an assembly line and a small toolmaking facility. Most of the products made are injection-moulded: small special series are made by vacuum moulding or rotomoulding (done by Ten Cate Rotomoulding). Lemmens has a small own assortment, aimed at professional users, and supply buckets to for instance Curver PC (comparable to Tupperware) in Oosterhout. The company wants increase its own assortment and reduce its supplying activities.

• The company doesn’t sound very promising: a small firm, mainly working as a supplier. This could mean, in the worst case: no previous experience with product development, little technical and product knowledge within the firm, probably little to invest and very likely no marketing capabilities to speak of.

• The production capacity is small, and not very specialised. But one would need more information on that. Injection moulding has a lot of possibilities, of course.

• The small professional assortment gives some hope on at least some business-to-business marketing capacity.

• This looks like a classic case of a supplier wanting to become independent. This often doesn’t succeed, because they don’t have the marketing skills, and have to start competing with their own clients (Curver PC, in this case) [Smulders, 1996].

• This assignment
The NS (Dutch Railways) is working on a number of new trains for the nineties, including a new local, the SM90. This will be a totally new design, with an increased passenger capacity attained by putting five (2+3) chairs in a row.

Because of the growing number of travellers they are also thinking about a new litter-disposal system (now: bin + emptying device) for the passenger compartment.

• This means that the designer should focus on working for the railway company, and make sure that the resulting product can be made by Lemmens. But the railway company has the problem, and it should be solved specifically for these people.

• Designers in Holland know that the railway company is very bureaucratic, and pretty conservative in its views. A lot of designers would like to have the NS amongst their clients, but everyone knows that it is not an easy company to work for.

• The prompt for the assignment is pretty indirect: they are designing a new train with increased capacity, and more passengers mean more litter. But how much? The difference
cannot be that big...

- Try to recollect what those bins look like. And where they are positioned. In trying this, most people remember sitting in a rather cramped train seat, with their knees up against the litter bin hanging under the little table.
- What could an ‘emptying device’ look like?

The producer of the current bins has made a new design, but the railway company is not very enthusiastic about it.

As a result, they started a small inquiry into the functioning of the current litter-disposal system: the kinds of litter were determined, and passengers and litter-collectors were asked to comment on it.

- This is absolutely vital information: if one could get hold of this new design, and of the evaluation by the railway company, one would have some very concrete evidence on the scope of the assignment, the hidden agenda of the railways, etc. Information that would take a lot of time and energy to gather for yourself (practically the only way to get it is to make design proposals and to get comments on them - having the preliminary design and its evaluation would save the designer some precious iterations)
- The inquiries could provide very useful information. And because the inquiries were performed by the client, the Railway Company, this is data that cannot be ignored. They provide a backdrop to the whole design project.

Then the railways decided to invite Lemmens Inc., among others, to come up with a better concept. There has been a meeting between the manager of Lemmens Inc., Mr. Kouwenhoven, and the leader of the project within the NS, Mr. Van Dalen. Lemmens Inc. sees this project as a chance to give it a higher profile within the market.

- How many others are there? who are they? The fact that the Railway Company has invited several firms to develop ideas probably means that they are not paying for this stage of the product development. Which brings us back to the question how much Lemmens will be able to invest in such a risky situation. Bigger firms have an advantage.
- It is important to get the minutes of that meeting between Kouwenhoven and Van Dalen. They would help enormously in determining the roles of those parties in the product development project.
- What is the exact rationale for Lemmens to join in this pitch? It hardly helps them to become independent of single large clients, although the client in this case is also the user.

On the other hand, the product could be very visible, and give Lemmens a lot of publicity.

That is why you, an external designer, are asked to make one or more proposals. Tomorrow you will have a meeting where your proposals will be discussed:
- principal solution
- general embodiment (materials, construction)
- idea behind the form
- 1:1 sketch, side and front views
- cost estimation

Good Luck!
• The list of required results is impressive. But the task to make a first problem and solution-analysis of this assignment, good enough to be a basis for the discussion tomorrow is not impossible.

• It is clear that Lemmens does need a simple, well thought-out product idea in order to have any chance at all. The quality of the design idea will have to do the trick, because Lemmens Inc. as such has very little to recommend it. This fact, combined with the general impression that the railway company is very conservative in outlook, makes for a tricky design assignment. On the other hand, a good idea might be picked up by the railway company whether it can be made by Lemmens or not - the designer has some interest in making something special and challenging, without dwelling too much on the fate of Lemmens.

## II.2 THE INFORMATION SYSTEM

Some of the main cards from the information system will be introduced here in abbreviated form. The information is in italics.

- *A sketch of the new train (SM90)*

- *Some sketches of the interior of the new train (SM90)*

- For this, some futuristic sketches were used, giving very little concrete information on the definitive layout. This was done to avoid that the designer would focus too much on the form (blending in with the environment), instead of on the basic problems of the litter removal system.

- *An ergonomic sketch of the current trains*

- With the indication that the internal measures of a carriage would not be much different from those of the SM 90 (except, of course, for the extra chair on one side of the aisle).

- *Technical drawings and exploded views of the current litter system*

- The exploded view was given when the designer just needed to bring back to mind how the litter bins look. The technical drawings gave the measures of the bin, enabling the computation of its volume.

- *Inquiry into the use of the current system - the opinion of the passengers*

  - too small: 48%
  - filthy: 32%
  - filthy lid: 28%
  - hard to reach: 22%
  - stench: 15%

- Size and filth are cast as the main problems for passengers. But to let the bin grow in size means that the location will have to change, too. It cannot be made larger in its current location without hindering the passengers. A natural next question is what kinds of litter take up most of the bin volume.

- *Inquiry into the use of the current system - complaints of the litter collectors*
Interview with some 'litter collectors'
- lots of trash on the luggage racks
- they have to bend over a lot when emptying the bins
- the litter sometimes spills over while emptying (in particular when liquids are involved)
- newspapers get stuck in the 'emptying help'

The bins are cleaned once every ten days, with a wet cloth

- The problem of newspaper removal pops up twice in this interview report: as an unspecified kind of trash on the luggage racks and as getting stuck in the 'emptying help'. They are thus brought to the attention for special treatment, somehow.
- Back aches are a serious problem, especially with the current labour regulations.

But bringing the mouth of the litter bin (in the current position) higher cannot be the solution; there hardly is room for that, and it would increase the stench problem.

- contents of the litter bins
  - cups & cans 30%
  - peels 10%
  - newspapers 40%
  - small pieces of paper (wrappings) 15%

- Newspapers take up most room. This means that they are a definite candidate for separate treatment.

- The opinion of the Dutch Railway Company (NS)

About the current litter system:
positive points:
- sturdy
- reusable in all trains/interchangeable
- reasonably quick to empty
- emptying help works well
- timeless design (has been in use for 25 years)

negative points:
- the bins are expensive (about $90 all in)
- they are smallish for the current numbers of travellers (and they can't be emptied more often, at intermediate stops)
- they can produce stench (although they should be wiped every day)
- the bins are heavy (4.6 kg)
- the emptying and cleaning of the bins is labour intensive, and costs a lot.

The new design proposal didn't provide enough improvements. That's why the NS launched this open assignment to a number of companies.

About the new system:
- should be suitable for intercity trains and local s
- possible series: about 5600 (individual units)/ year, for 10 to 15 years
- it is still possible to integrate the letter system into the sidewalk of the railway carriage (the project leader did like this aspect of the new design proposal of the current producer)
- about vandalism: vandalism is mainly aimed at the upholstery of the seats, the windows and the walls
• The arguments in favour and against the current litter system are pretty weak. The project
doesn't seem to have a high priority with the railway company.
• Size of the bin and cost of litter removal are obvious targets for improvements.
• The target of remaining below the $90 gives plenty of room to make something fancy.
• The remark that the new litter system is also for intercity trains, and the positive
appreciation of the interchangeability possibly change the assignment. The freedom of the
designer would be severely limited if the new design should be built into different types of
trains (so structural solutions based on one train are out), and be downwardly compatible
with the current system. These remarks have rightly been ignored by most designers: they
indirectly determine the product, but are not 'hard' enough to rely on.
• The possible series is small for injection-moulded products, but not too small. It can be done,
if the investments are kept low by using a simple mould.
• Integrating in the wall seems to have the backing of the client, and could give some freedom
to increase the production volume of the litter-system.

About the company: Lemmens Inc.
- they supply plastic bins, etc., to companies like Curver (Vippeware-like Dutch company).
- they have 40 personnel, of which 27 work in production
- machines: 10 injection-moulding machines, 2 vacuum-moulding machines.

About this assignment:
- they see this assignment as a good chance to get on their feet as an independent producer (they refer
to Bummens, and the litter bin of Bas Pruyser (a well-known design in Holland))
- they are prepared to invest up to $50,000
- reason for hiring an external designer: 'it should be something modern, with some good ideas behind it'

• The investment of only $50,000 is very bad news. It falls far short of what the designer
needs for product development and moulds, tests, etc. When the designer subsequently
asked the test leader if this figure was a real upper limit, it was said no, it could be higher
if the idea was good enough.
• The last remark reinforces the impression that the company is not very professional in its
attitude towards product development.

II.3 AN EXPLORATION OF POSSIBLE ROUTES AND SOLUTIONS

The structure of this design problem and the possible solutions will now be discussed to give a better
idea of the options that were open to the designers. The design activities as described in chapter 5
and Appendix III should be seen in the light of the concrete possibilities for actions (in process and
content) the designers had. Here we will list the main design issues, and explore the most probable
design decisions.
To set the scene: the designer has read the assignment, and just finished the first round of information
collection, clarifying just a few points. There is a clear but fairly general view of what has to be
developed. Right from the start, there are two ways of tackling this problem, each with its own
entries. One way of tackling the problem leads to a redesign of the current product (but conserving
the principle of the litter bin and its location), the other leads to the development of a litter system
(e.g. chutes that lead to a central compartment that can be emptied once a week)
REDESIGN

The mostly implicit and unconscious choice for the redesign path could be triggered by a concentration on the problems the passengers have with the current litter bin. This invites a way of thinking that is aimed at improving those few weak spots in the old design, inadvertently taking the principle of designing a bin-based system for granted.

There are good reasons for taking on the problem as a champion of passenger comfort: passengers are the end-users and pay for the facilities. The fact that designers only know these products as passengers, and thus can easily place themselves in their position, could also play a part. And apart from this, there are some valid reasons for looking at a redesign of the bins: a bin-based system could be compatible with the current one, investments could be low, and the risks to the designer minimal.

**Size.** Size has been named by the passengers as one of the main problems. A solution is to realise that newspapers make up the single biggest kind of litter; all designers get the idea to split the litter into ‘newspapers’ and ‘other’. This means that the litter bin can remain the same size, even become a little smaller, and that a special newspaper holder has to be developed. The size of the current bin and the redesigned bin is heavily constrained by the geometry of the location where it is placed.

**Location.** Almost everyone remembers the current litter bin as being inconveniently placed, and starts immediately generating alternative locations for litter storage. All possible locations are enumerated (huger-lower-left-right-under the chairs, on the ceiling, etc.) and a few are selected for further consideration.

**Handling.** With some possible variations in size and location in mind, the ergonomics of the handling of the product comes in as a deciding factor. There are two approaches, now:

1. If one takes the passengers’ point of view, and designs for the ease of throwing away, the current position of the bin (centrally placed under the window) comes out as the best – though not ideal. When these bins are combined with smaller ones placed in the aisles (or in the armrests of the chairs that are close to the aisle), most problems of geometry and reachability can be solved. Some designers reserve the armrests for newspapers, others for general litter.

2. If one considers the handling of the litter by the litter collectors as important as or even more important than passenger comfort, the problem becomes a lot harder. Choosing a bin in the current position would mean that the collectors would still have to go into each four-seater and two-seater, reach down with the emptying help and flip over the bin. Awkward and time-consuming. Making more bins, like in (1), makes things worse. This problem cannot be solved, but the adverse effects of the central placing of the bin can be reduced by changing the emptying motion, or placing it a little higher. A good solution for the storage of newspapers would be at the end of the carriage.

**Other.** There are some minor conceptual problems that do not necessarily influence the layout of the product, but are important enough to be included in this description:

- Litter gathered in the bin has to be taken away – either in large litter bags carried by the litter collectors, or in some kind of cart.
- The separate collection of newspapers should result in them being taken away separately too.
- The complex logistics of this are just outside the scope of this design exercise, but if a collection cart has been designed, the interface to the other processing units should be specified.
- Odour is one of the main problems of the current product, but it can be solved easily by providing a lid. Designing a handy, well-fitting lid is not that easy, though.
- The current product - a cast aluminium bin - is quite strong. A plastic bin has to be sturdy too, but will also have to be easily replaced easily when broken, because it remains vulnerable. A simple steel frame could be a good support. A special problem is fire resistance. Some plastics
are reasonably fire retardant, but the new design will be inferior to the old one in this respect.

- The cheaper plastics that are a logical choice here do not make very strong integrated hinges. If sturdiness is important, the hinges should be of metal.
- The total series in which the bin is scheduled to be made is just enough to take to injection moulding, providing the mould is kept simple. Which means that there are few restrictions on the form of the product. But simple geometric forms are in order, with wedge shapes for easy release from the mould.

The redesign path described here is the most reasonable design task interpretation: the level-headed way towards a design solution.

NEW SYSTEM DEVELOPMENT

This design problem, process and result become totally different if one takes the general litter disposal in trains as the challenge.

Kind of product. Trains can be kept clean in many ways: by avoiding most of the litter (stop serving soft drinks on service carts), by having some kind of vacuum-cleaning installation with inlets for your rubble, by having chutes leading to a central rubbish tank, by making a conveyor belt along the sides of the compartment, etc. All these rather elaborate solutions could be economical if they substantially reduce the labour costs connected with the current system, if they are environmentally sound and/or so futuristic that they could serve as a marketing tool.

The most tangible advantage of reducing the labour costs can really only be reached by making a system that collects the garbage in a central tank, or integrating the emptying of the bins and the carrying off of the litter by making litter compartments that can be opened (automatically) from the outside of the train. On closer scrutiny, the central-compartment solution turns out to be problematic and expensive, especially the transportation of the litter to the collection-compartment. The opening to the outside-option isn’t easy either, but it is the best bet for someone who has pledged to design something radically different and interesting for the railway company.

Litter removal. For this option to be at all realistic, information has to be gathered on the precise procedure of litter removal, and it has to be redesigned. Could the emptying-device be a cart on a platform, or should it be a stationary unit along the rails, with the train driving by slowly? The cart on the platform is by far the easiest solution

Location. For ease of throwing away and emptying, the best location is under the window.

The compartment can be neatly built into the train wall

Form/size. The size of the opening can be determined by measuring the kinds of litter that will have to pass through there. Likewise, the size of the litter storage can be calculated.

NON- CONCEPTUAL ISSUES IN THE DESIGN TASK

- Solving the aesthetic problems of the form of the litter system has been a minor influence on the main-issue decisions. Most of the bins designed will be fairly plain: there is not much information on the train interior the product should fit into, so a ‘neutral’ form is the best choice. Fancy forms and materials are out, because the series are small to start with, the producing company probably couldn’t handle them, and the time for the assignment is way too short to go into those.
- Most designers will not arrive at a precise choice of materials. They will however have seen to it that the decisions on the main issues have landed them with parts that can be made, and be strong and stiff enough, with the kinds of materials they have in mind.
- The same goes for production methods. They will have made sure not to make a design that is
critical on these points. This is partly brought about by the time constraints. A choice for novel or high-tech production methods would increase the risk of ending up with a concept that is not feasible.

- **Safety issues** will also be discussed in a passive, checking manner at this point in the design project.

**RADICALLY DIFFERENT DESIGNS**

The two long strains of reasoning set up above seem to lead inevitably to one (type of) solution. There are some other possibilities, though, arising from different views of the design problem.

- **different scenario.** In all ideas described so far, there has been the assumption that you either have many small storage units (bins) to be emptied one by one, or one big compartment to which the litter is transported after disposal.
  
  But there are other possibilities, integrating the emptying and cleaning of the bins, or the emptying of the bins and the transportation of the litter to the outside of the railway carriage. This could be done with a flexible plastic belt with small litter bins attached to it, that runs on the side of the train under the windows. To empty the bins, the belt can be pulled out of the train (and rolled up, bins and all). The same action puts an identical belt into position.

- **different system border.** The problem can also be solved by changing the properties of one of the problem elements. For instance reducing the problem by compacting the litter, so that the disposal system wouldn’t have to be emptied that often (saving the all-important labour costs). The problem can also be expanded, also annexing more resources for solving it. The emptying of the litter bins could be combined with the cleaning of the whole train, or the litter system could be expanded to emptying the toilets.

- **different ideals.** The adoption of a strong ideal could change the problem altogether. A high priority to environmental care would result in the splitting up of the litter into multiple categories, like glass, aluminium, plastics and paper.

There might be still other possibilities, maverick solutions that could even be radically better. We will never be quite sure.
APPENDIX III

SUMMARY OF THE PROTOCOL DATA

In this appendix the activities of the nine designers are described, in process and content. The appendix ends with the graphs of the designers' activities, that resulted from the rational problem solving analysis.

DESIGNER 1

00 - 10 reads the brief, and starts gathering further info about the company - pictures it vividly - reflects on his normal way of working in this phase and then starts doing it

11 - 20 critically considers the interview with Lemmens, draws conclusions as to the size, policy and abilities of the company

21 - 30 starts gathering info about the company (rotomoulding activities, their contacts in the transportation business), about the SM 90, the current and new bins, and the research into the performance of the current bin

31 - 40 looks into the wishes of the NS, considers the new design with the possibilities for integration in the wall, goes over to vandalism (note: structured by the structure of the interview)

41 - 50 seeks information on vandalism, and norms for interiors - sorts his information cards, and goes on to ask deeper questions about the form sketches given - then looks at other bins from the info, and starts looking for comparable situations in planes - compares the stencil problem with that in an earlier project

51 - 60 says he will take a functional approach, and looks for selling points, accessories - reads about the train interior, and the opinions of passengers and cleaners - identifies some of the most important points (without writing them down) - works by comparing

61 - 70 makes a list of four main problem areas: size, stench, reachability and dirtiness - starts sketching different general layouts ('archetypes'), differing in form, and the possibility of a separate newspaper clip/tray/bin

71 - 80 evaluates his proposals for the different possible layouts - keeps his choice open - sketches a possible way of flipping the bin upwards, that would make it easier to reach - looks at the stencil problem - proposes to go and talk to the NS about chute-like solutions - looks at the dirtiness problem, says you should have a sleek, simple form to avoid gathering dirt

81 - 90 goes on with checking the info (NS, Lemmen), also looking for possible selling points - looks back at his principal solutions, (says integration is important) and using this as a basis, sketches a bin (concept A) that is totally integrated in the wall (by extending the wall into the compartment) lists the advantages of such a bin

91 - 100 extends concept A a little bit, (airco) then goes on to concept 2, taking the split collection of garbage as a starting point - evaluates his first sketch comparing it to concept A (too big a change, NS?) - further simplifies it into a normal bin with a curved top

101 - 110 makes the third concept, in which he lets the bin swing up to make it easier to empty - opts for a free-swinging arm - evaluates the concepts - kills no1 because Lemmens isn't up to it, and combines no 2 & 3 - starts with the embodiment; talks briefly about form, then production technique

111 - 120 starting with the detail-design, addressing a number of issues in quick succession: the
material and production technique, vandalism (misuse), form (fitting in interior), size

121 - 130 embodiment, working on purely technical aspects like the choice of materials and method of making - develops two alternatives for the latter, and goes back to Lemmens for a policy decision on this - remarks that the concept is similar to the current product, but wants to get the newness in the details and the greater possibilities for integration - then goes on to determine the approximate size of the bin, and goes back in the info to see how big the current one is

131 - 140 determines the shape of the lid, with its newspaper-carrying function - then draws side views of the bin, and fills in the details of the construction - (a covered snap - mechanism to hold the bin in place) - starts drawing the plastic parts

141 - 150 dealing with the problem whether to fasten the lid to the bin or to the wall of the train - chooses the latter solution.

CONCEPT I

![Concept Image]

Figure III.1 - The concept of designer 1

DESIGNER 2

00 - 10 considers the company, is enthusiastic about its possibilities - considers the NS a good client - wants to know what is wrong with the current system - reflects on the need for a garbage system, and immediately proceeds to make a comparison between the features of the current and a future system - generates all the information himself

11 - 20 says that the integration of bin, ashtray and table would be attractive, then proceeds to think about location, drawing the train interior (generates this quickly) decides in favour of the current placing, revokes the decision, then considers the problem of reachability

21 - 30 sketches some locations, to seek out the best reachability - makes a provisional performance specification, split in technical and functional terms - thinks about a modular system (bin, ashtray, table), and considers a beltway - dismisses this, because of stench (!) - sketches possible placings of bins, considers using more, smaller ones - ponders and rejects making a redesign, goes on to look for possible locations

31 - 40 decides to look farther than a redesign - starts generating false information about the emptying help - is stopped by the experimenter, and given info - asks information about train interiors - finds it confusing, less face-to-face than he counted on
41 - 50 considers making a removable bin, for easier cleaning - gathers info about the cleaning procedure - jumps back to the location, generates three concepts, keeps working on the third, hanging the bin on the chair - brings up the idea of one bin, with different possible placings

51 - 60 considers at length the different possible placings of the bin: on the wall, on the chair and free-standing - opts for a combination: on the wall (for reasons of feasibility) and on the side of the chair - gathers info about the chair

61 - 70 gives a justification for his placing of the bins, (reaching, emptying, legroom), compares briefly with current product, then sketches the bin in position in coach and face-to-face seat layout - thinks of connecting it to the floor, for greater strength - wants to take into consideration the opinions of designers of the train interior

71 - 80 sketches a bin on the side of the chair, triangular (inspired by the chair) wonders about the size, asks info about the contents of the bins - worries about blocking access to the chairs by using a triangular shape

81 - 90 finds the triangular form smallish, and starts drawing a parallelogram - draws two coupled bins, finds this an interesting possibility - (wants to keep investment low) - considers ways of opening the lid - reflects on the importance of aesthetics in the quality assessment of the traveller, perceives a trend toward more integration - returns to the opening of the bin - wants to make a model in foam, but doesn’t

91 - 100 wants to make the form more rounded, friendly - considers the mould costs and chooses a material (on the basis of production method and fire resistance) - looks for clues to guide his form decisions - hesitates whether to choose for integration of bin, ashtray and table, (pro: trend of integration, cleaner look, con: more complex problem, and less flexible) or to keep them separate - chooses the last, but wants to design them all within one style -

101 - 110 considers the possibility of making a ‘product family’ - would like to do more work on these different possibilities (family vs. integration), but feels forced to a choice, given the time - his ideology, of a quiet, well balanced train environment, would lead to a choice for integration - chooses for separation, because he sees enough functional problems in the bin alone - lists aspect he didn’t cover yet - starts to work on emptying - quickly generates a form and way of fastening and flipping - goes over his three ways of emptying developed earlier - rechooses flipping - details the construction

111 - 120 works on the details of the construction - decides which way to open the lid - then concentrates on the size, first computing the volume of the current bin - wants to use the opening to sift the garbage, with the can diameter as a critical measure - decides to maintain the volume of 7 - 5 litres

121 - 130 now concentrates on the bin as it can be placed, on the wall of the train - sketches it, and starts making concepts for the table and the ashtray

131 - 140 studies the measurements of the current train interior - realises he will need a mirrored version - reconsiders the layout of the wall-bin, and the detailed placing/height of the bin - regrets not to be able to make a small ergonomic study - wants to make a model, so starts to determine the form of the bin, holding the size constant - starts to determine the slant of the form, with aesthetic tranquility as a criterion -

141 - 150 chooses 30 degrees, starts making a one to one scale drawing then a scale drawing - criticises his angle, says it should be in harmony with the chair
DESIGNER 3

00 - 10 reads the assignment, starts asking info about the location and size of current bin, emptying procedure and contents of the bin - starts proposing solutions right away ("bigger bin") - remark: makes inferences about what information to expect before asking for it

11 - 20 quickly generates a lot of ideas, solutions for the subproblems he is considering at that moment - information is asked to clarify the problem, and extend the ideas, such as: split garbage collection, split level bin, push pedal bin, combine with ashtray, collecting tubes under the train, emptying from the outside

21 - 30 gathers info in a humdrum way, "to get a general idea" - concentrates on the handling and organisation of the garbage collecting - concentrates on atmosphere - keeps on developing ideas: bin between and under chairs, instead of luggage racks. removable bins - starts reflecting on the 'main problem': reachability versus ease of emptying - then comes up with the idea of a hole in the floor

31 - 40 asks whether or not such an idea would be outside the scope of the assignment - says he likes to change assignments, because they are often too narrow - wants to work on a system of separate bins, and on a connected system - realises that there already is a garbage system in a train, the toilets - is shocked to hear about it being just a hole in the train floor - finds this very backward - thinks of a special garbage compartment, that all the garbage is sucked into and compressed - tries to estimate the labour costs of the current system, per lifetime of a carriage - jumps to what plastics Lemmens uses - starts investigating what kinds of garbage could be collected separately

41 - 50 wants to confer with the NS - three possibilities: central collection, separate different kinds of garbage, or give passengers an individual bin - gets the info of Lemmens and NS, focuses on the latter - bumps into the existence of an emptying help - reads that he can integrate things in the wall of the train, and immediately chooses for separate garbage collection - gathers info on the construction of the wall, starts sketching the situation -

51 - 60 sketches, pauses for coffee, gets a phone call, returns to sketching, three openings for paper, cans, and other litter - is content with being environmentally sound - checks that the product is interesting for Lemmens to make - considers the alterations that have to be made in the train - works his way through a number of requirements
realises that he is initialising a whole chain of separate garbage processing - decides to flip the bin from above - looks at the relative amounts of garbage, to determine the size of the compartments - needs to confer with the NS whether to split the garbage in three or four kinds (glass separate) - considers fire resistance, thinks it will not be important

wants to talk to the NS, starts to prepare a presentation of his current ideas, the choice before which he stands

writes down the alternatives: all garbage together, split up in two or four different kinds - and alternative placings : centrally, per chair, per compartment, per window - writes down the pro's and con's - then goes over to the starting points for the design

considers at great length size and form of the different kinds of litter, looks how much room there is in the trainwall, determines the size of the bin - considers if you could cut back on the frequency of emptying

enlarges the size of the can-compartment - would like to talk to a cleaner, to analyse the problems - still doubts the practicality of having different compartments - runs into the 40 % newspapers - considers the possibility of making a newspaper bin, central in the carriage - pauses, and starts detailing the design

goes through the consequences of his earlier decisions - sees some technical problems in the insulation of the train, the outside advertising, what to do on the side of the train that is not near a platform, what to do with a double-decker - says he would like to speak with the designers of the NS - thinks of emptying automatically - plans - would like to know the labour costs of the current system

tries to figure out how much the NS would invest - alters the form a little, in case the bin would be too narrow - then works on the lid - draws the bin, considers the form (shining, körperfreundlich)

details the design: a lock, considers whether it will be a target for vandals, an ad on the hatch at the outside of the train, a special emptying cart - sees a problem in the non-universality of the concept (what to do with old trains?) - makes a summary of his reasoning leading up to the decision to split garbage (doubt?)

finishes his summary, and confers with experimenter about what to do next - quits.

Figure III.3 - The concept of designer 3
DESIGNER 4

00 - 10 makes list of things to know about the design problem: ability of the company current product performance of current product priorities of Lemmens (identity) and NS

11 - 20 looks at the problems of passengers and cleaners, trying to filter out the subproblems (location as important) and the priorities for the designer (finding out the why behind the complaints) suddenly realises that he doesn't know the scope of the problem: goes back to the brief

21 - 30 identifies the scope of the brief by picturing the complete cycle of the garbage, getting an overview of the practical problems, identifies those that can be solved in this design, then identifies the collectors as the most important stakeholders, and takes the decision to champion their cause -

31 - 40 investigates the possibilities and goals of Lemmens and the NS, confirming his view of the problem, gathers info about the new train

41 - 50 looks at the emptying procedure, sketches for the new interior, checks the most important statements by Lemmens and NS looks at layout of current train - identifies location as one of the main problems

51 - 60 wants to 'get going', decides on production technique, considers the wish of NS for integration in wall of train (extra info), compares the (garbage collecting) situation in a train with that in a plane, talks about vandalism, sorts his info and starts generating ideas

61 - 70 investigates his idea for the separation of garbage, and the newspaper bin - considers the problem of location, and the possibilities for integration in the wall of the train makes a list: separation newspapers/other refuse positioning for filling & emptying intrude into the cabin as little as possible dirty lid flip over?

71 - 80 thinks about incorporating the bin in the chair, but sees problems with the reachability, then - draws different configurations of newspaper bin and litter bin, different ways of opening a lid

81 - 90 generates possible ways of putting the lid on the bin encounters more and more problems (geometry of the opening, the number of bins in a carriage), reformulating old ones - (re location: the collectors are complaining about the height, the passengers about the distance to the chair)

91 - 100 considers building a bin in the chair (easy to reach) but rejected as too time consuming - approves the idea of a separate newspaper bin - considers the different configurations drawn earlier, and adopts the placing next to the litter bin - makes a first sketch of a wire structure - considers different ways of emptying

101 - 110 sketches the bin at a more detailed level, muses about the form of the newspaper rack, whether or not to let the lid move - decides on he flipping mechanism for the bin (with built-in stop), a problem also connected to the emptying device

111 - 120 talks about ways to let the form express the use of the bin, proposes to build the bin 4cm into the wall of the train - works on the dimensioning of the bin - sees a problem in the newspaper rack: maybe this open structure should be made out of metal

121 - 130 sketches, mainly solving details of form - details the newspaper bin

131 - 140 details the form in a number of drawings - not content with the way it is going: 'too weak' - makes a link to the form of the chair - changes from integration of the two bins to making a clear distinction - sketches a detail of the hinge
141 - 150 goes on with the detailing of the form, in side views, and makes an exploded view for the shapes of the plastic parts.

Figure III.4 - The concept of designer 4

DESIGNER 5

00 - 10 designer reads the assignment, tells he has worked for the NS, generates info about the emptying device, begins to structure the problem by aspects: technical functioning, atmosphere, functioning and fitness for use - doesn't want to concentrate on the bin, but to step back and see if there are underlying problems - when ticking off his standard list of factors, he runs into the fire-resistance of the product, tells about a train that caught fire because of a smouldering trashcan, and says he would like to go back to Lemmens, and advise them (as a maker of plastic bins) to stop with the assignment - but then he immediately starts to look for ways out of this dilemma

11 - 20 determines his own role in the process: making a concept, of a system - generates info about the cleaning of the trains, and checks that - possible solution for fire-problem: be quick in the removal of the litter gathers info about the contents, use and cleaning procedure

21 - 30 asks info about the emptying/cleaning procedure, and about the layout and measures of the train - suspects that because of needing more bins, and more problems with the reaching, he will have to look for a new location (not on the wall)

31 - 40 tries to establish the extent of the problem: calculates the volume of the bin per passenger, etc. - gathers info about the interior of the new train - idea: newspapers separately - idea: incorporate something in the chair - asks about the provisions for smokers (apparently still worrying about the fire problem)

41 - 50 collects info about the assignment: interviews - starts to set up a global performance specification, first concentrating on the passenger - calculates the minimal size of a bin without newspapers - decides to make two concepts: one with a separate newspaper bin, the other without

51 - 60 evaluates his two principle solutions, extends his performance specification, (for this,
rereading of a lot of the information) asking if the NS has already taken decisions on certain points - If not, he defers his own judgement, e.g. saying that he will make a bin that can be incorporated in the chair or hung on the wall - goes over to technical aspects in his performance specification, listing them

61 - 70 finishes his performance specification with some technical points about the cleaning procedure - starts building concepts - starts drawing, making an underlay of the layout of the train - determines where passengers could easily dispose garbage: back of seats, sides, armrest of chair

71 - 80 lists possible locations for bins - draws side and top view of train interior - idea: face-to-face: one central bin, coach: backside of chair, and: newspaper bin in the armrests - evaluates the product: how attractive for Lemmens? are there plastics that are sufficiently fire-resistant?

81 - 90 gathers info about the fire-resistance of plastics - decides to use a metal bin, possibly with a plastic outer skin - makes a resume of his ideas, considers making an additional bigger bin for the end of each compartment - starts 'brainstorming' on a more detailed level (embodiment) - starts to draw a side view of the chair, approximately to scale - worries about available space

91 - 100 draws side views of the bins, to get the volumes and location under control

101 - 110 summarises his ideas, by comparing with the current bin - reads in the brief what he was asked to produce - realises that he didn't solve any problems for the collectors - begins to think up a large emptying device/collection unit, to service three bins at a time - realises he hasn't solved the emptying of the newspaper bins, either

111 - 120 quickly details a folding cart as collection device - then details the newspaper holder a little bit more

121 - 130 makes a summary of his ideas.

Figure III.5 - The concept of designer 5
DESIGNER 6

00 - 10 asks an enormous amount of information - tries to get behind the need for a new bin: what was wrong with the old one? ridicules van Dalen's remark about the weight of the bins - considers the difference between intercity trains and locals: seems important, but can't figure out the repercussions - looks critically at the new design, focuses on the remark about integration in the wall of the train - then looks at the passengers' complaints, 'looking for priorities'

11 - 20 scans through the information: sketches of the train-interior, the chairs (has the mistaken view that the current bins hang from the chairs), the kinds of litter, the cleaning and emptying procedure - sees the back of the chair as a good point make a bin, and stops a while after he reads about the 40% newspapers (idea??)

21 - 30 muses about the efficiency of the cleaning procedure, ponders taking the newspapers separately, looks at the emptying of the new proposal, finds it cumbersome, starts to look into the location of the current bin, discusses the problems connected with a separate newspaper bin: how do you keep people from throwing in other stuff?

31 - 40 says aluminium is vandal-proof, plastics are not: bad news for Lemmens - sees the face-to-face seat layout as presenting problems: a lot of garbage, and no back of a chair to hang a bin on - considers armrests, but they would become too wide - looks back at the contents of the bins, considers the volume of a newspaper

41 - 50 talks about the problems with newspapers, that can easily fill up the bin (tries this out) designs a banana -like shape, integrated in the wall - problem: newspapers - decides that even when there is a special newspaper bin, the 'universal' bin has to be big enough to contain newspapers - comes up with the idea of putting two diagonally -shaped bins (that can be coupled) on the aisle-side of the chairs - sees an aesthetical problem, but defers that considers the size of a badly stuffed newspaper, then the locations where you would like to put litter - idea of a newspaper clip, to be placed at various points - comments on the intractability of the NS's plans for closed luggage racks - decides to keep the newspapers separate - there could be a metal inner-bin; the plastic part would then be just visual, with the NS-logo on there

61 - 70 is working on the detailing of the design, chooses material (PP) and production technique (injection moulding, rotomoulding) - about the newspaper clip: he is afraid his employer didn't ask for that, so considers it an extra - then integrates the clip into the side of the bin, which makes the inner bin more complicated - looks at possibilities for integration in the side of the train

71 - 80 deals with integration of the bin in the wall of the train - looks back at the assignment, for what he has to deliver - then starts making an estimation of mould costs: fl 230000 investment - goes back to his employer to see if this is feasible

81 - 90 talks about the idea of Lemmens, to combine the bin and the table, lists the drawbacks - triggered by his idea about keeping the current emptying device, looks at the card of the collectors, sees if he can do anything about their complaints - looks back at the assignment, starts a detailed cost estimation

91 - 100 making the cost estimation - chooses materials and production techniques on the way

101 - 110 price: fl 55, but the investments are high - asks about the kind of contract Lemmens has with NS (can it be broken after a year?) - says he wants a drawing board, to start with the embodiment - tells he would work with foam-models now, and make a sketch, to scale, in
side views, and then a drawing to measure - thinks that wouldn't change anything in the current design; just a lot of small problems to solve

111 - 120 talks about the way forward in this design process: to talk with the people doing the general interior design of the train, to determine the precise form - the technical details are solvable, 'just a question of doing it' - explains how he would present the design to the firm and the NS.

CONCEPT VI

Figure III.6 - The concept of designer 6

DESIGNER 7

00 - 10 reads the brief at length (2x), writes down the most important points makes a checklist of the information he wants, and of the output asked for - (worries a bit about the form) - starts asking info

11 - 20 collects the information cards - says he would normally have prepared himself in the acquisition stage, feels like jumping in the middle of a problem - makes a list of activities, plans his time

21 - 30 reads the information, starting with the interviews with Lemmens and NS, using those for leading him through the rest of the info - writes the info down as a performance specification, with own critical remarks, positively worded - expresses the wish to talk to Lemmens and NS - quite suddenly, ideas pop up - writes them down, but goes on with the info

31 - 40 finishes first draft performance specification, looks critically at the new proposal, computes the total costs, draws section of the train

41 - 50 reads the information of the passengers, cleaners and the content of the bin - writes it down in a requirement-like form, gets some ideas while doing this (newspapers separately) - wraps up the information phase by looking through his notes, and trying to picture the situation - sees the different kinds of garbage as a problem

51 - 60 chooses production technique, discusses his idea of separate newspaper collection - goes through his performance specification, with an injection - moulded bin with a separate newspaper compartment in mind - determines the kinds of garbage (to get an idea of the size of the opening) starts sketching on this, configurations
generates ideas about stench avoidance: using the airco to clean the air, making a lid - looks into the info, informs about the % of seats that are placed in rows - starts to detail the form of the lid, and makes remarks about how he would like the complete product to look.

considers the problem of making a lid that needn't be touched, generates simple alternatives - then connects this problem to the flipping of the bin, decides to consider the bin itself, looks at the size of the current prod -

describes the bin in general terms, finds this very close to current product - not content - works on the design, mainly from the side of the cleaners - recapitulates his general ideas - makes simple configurations of bin and newspaper compartment - wants to make a choice, but isn't content - says that he didn't solve the lid problem, either - says it is a hard problem. 

talks about the form and colour of the bin, leafs through sketches, discovers cleaning as a problem - starts to make an underlay, side-view of the train - sees no use for placing the bin at a different location (note: the first time he mentions location!)

justifies his choice for the current location, sketches a proposal on the underlay, estimates the size, talks about the way to empty it - then sits back and says he's stuck, didn't have a really good idea yet, isn't content with what he has, feels a qualm about taking his pencil - is content with his analysis, although it may be a bit too thorough, and says he does have a number of points he would like to discuss with his employer - is pretty sure that, given the limitations, he didn't overlook any great possibilities - calls his proposal conventional.

not content with his ideas, goes back to the emptying - refers to an earlier project of his, and chooses to take the whole bin off - adjusts planning, because the old one wasn't feasible any more - then refers to a car - garbage disposal system he knows (with a bag), sketches it, and then goes on to sketch a new layout for the bin, from there goes on to a side view of a combination bin-newspaper basket, thinks it too wide, and sketches a bin with two baskets at the side.

considers the size, form and practicality of a newspaper bucket, and possible alternative placings - then stops, leafs through ideas, chooses the one he worked on and starts refining it, again on the size and form of the newspaper bucket.

Figure III.7 - 'The concept of designer 7'
131 - 140 sees the fact that the cleaners would have to end to empty the newspaper bin as a serious worsening of the concept - and a higher, upright newspaper bin would be harder to empty because newspapers would tend to get stuck - starts to wonder if the separate collection of newspapers is such a good idea - explains the problem (it increases the work for the collectors) and said he would quit at this point, and go back to the NS to get a decision on this.

**DESIGNER 8**

00 - 10 reads the assignment quickly and critically, and starts recording his ‘first thoughts’ about form, atmosphere (public transport), plastics for this kind of product, vandalism, the role of the product for Lemmens - is totally form-driven in this - associates the assignment with squares, or half circles - refers to the bin by Kartel, as an elegant gesture - then jots down the main functions of the bin: placing, filling, emptying, cleaning

11 - 20 considers location - first looks for general priorities to guide him, doesn’t find them - sketches different possible layouts of the train - compares location -problem to planes, buses, trains in US - generates eight possible placings of the bin

21 - 30 considers the kinds of trash (generates all the info himself), wants to hide the garbage from smell and view, because he hates it himself - about form: doesn’t like the normal products of the railways, and wants to make something different (less boring, etc., a gem) about emptying and cleaning: has to be done efficiently, good working conditions, considers vacuum cleaner-like thing (refers to French dog-shit removal thingy) - wonders whether you have to clean the thing real good – then asks if the NS made a performance specification, lacking that, he asks for the new proposed bin

31 - 40 looks at the new design, no clear conclusions – summarises, looking for newness to help the image of the new train, thinks to find that in the location and in the passenger interaction of the new bin – prepares to make concepts, plans – takes location first: under the window, a banana-shaped bin, flatter and thinner than the current one, bended to avoid looking into it – is not enthralled; too close to the current bin

41 - 50 draws a bin that is split at the top, to strengthen the gesture - draws a few more, then considers taking the backside of the chair as a starting point - rejects it, because it wouldn’t work in a face-to-face layout - then considers a location under the chair, sketches, decides that it would be best on the side, wants to limit the impact on the chair - talks about a bag, instead of a bin

51 - 60 considers different possibilities for placing a bin at head-height: first looks at the sketches for new train interiors, thinks the layout will remain the same as now, but likes the freedom there is to think about such things – draws bins on top of the chair, hanging from the ceiling, in the window - checks the attractiveness for Lemmens of these ideas - stops is attracted to the idea of a central collecting bin, because train are already cluttered - could be emptied from the outside - but keeps to his list and starts sketching on a bin between the chairs - makes an elongated, small bin that fits the shape of the seat; but: hard to empty, the bin has to be grabbed and opened in one motion - likes the idea - plans - next: in the floor - thinks about this for a while, but sees no advantages - next: under the table - sees the two products combined

61 - 70 likes the idea of integrating functions - thinks of different ways of emptying, but finds his ideas too intricate to be attractive - then considers the central bin - supposes that people
will be active enough to stand up and dispose of their garbage at the end of the carriage - sees a lot of good points in this, but worries if it would be interesting for Lemmens to make - gets info on the total series - lists advantages of the idea: cheap, easy to clean/empty, safe (fire), vandal-proof finds the solution too 'invisible' for Lemmens, too - tries to think of ways to make it more interesting, then drops it - spreads out his drawings, and leaps back to his original criteria (form and gesture) - looks at the concepts, and decides to work on the best of each group a little longer - starts with 'bin under window', evaluates and selects one, sketches some different form solutions - draws it as concept one - looks at another group (combine with table) evaluates and sketches it as concept two -

then goes on to consider the bin above the head, takes the metaphor of a pouch, then takes it literally - thinks this through very enthusiastically: a pouch that you squeeze to open, and that closes of its own accord - generates different locations for such a product - could be emptied by taking it away - makes a small PS, just concentrating on 5 main issues - clearly chooses for the pouches, and starts detailing ways of emptying them in the train chooses the pouch, as the most interesting concept (the other ones have to be made interesting by their styling) - likes the idea of a soft, human material - plans, considers what he will present - generates info about the materials he could use - starts detailing the product - thinks of a wedge on the trolley to empty the pouch - in the end chooses for injection moulding and then sealing as the production technique -

determines the location, strengthening and size of the bin - says he would like to make a model, but limits himself to a 1:1 drawing -

chooses wall thickness, makes cost estimation (£20/item), begins to prepare a simple presentation - main points: the product has to have appeal, a nice gesture to the user, and it has to be functional -

makes a final drawing, to explain the working of the thing - starts reflecting on the process - evaluates the design for himself - is content about the integration.

Figure III.8 - The concept of designer 8
DESIGNER 9

0 - 10  reads the brief, and starts asking questions to Lemmens and NS, concentrating on the opinion of the NS - asks info about and compares to the current bin - has a very critical attitude about the format of the info, the brief and the test situation

11 - 20  gathers info, taking the NS-interview as a starting point - is critical about the assignment, doesn't get the detailed answers he wants - says he would normally have refused the assignment (Lemmens has a strange, middle position) - says the normal train interior designers should also make the garbage system, to make it fit in well

21 - 30  gathers info, tries to determine the philosophy behind the new train interior - becomes somewhat frustrated because of the vagueness of the info - reflects on the process, asks if he should design, or tell what he would normally do

31 - 40  asks further info about the train interior, the current bin and the proposal of the current manufacturer - still concentrates on the philosophy behind the new interior - builds up an image of the current interior

41 - 50  sees the required fire-resistance of the bins as a problem, wonders why Lemmens was invited by the NS in the first place - says he likes not to worry about production methods when designing - in the end, goes back to the brief

51 - 60  plans, then reflects: says you have to look critically on the information - gathers info about new design, wants to know the NS's comments, then asks the passengers' and cleaners' comments, and comparable products

61 - 70  gathers info in a systematic way, building up his image of the problem concentrating now on the passengers and cleaners, and looking at the cost -

71 - 80  makes a rough estimation of the costs, finds the margin very big - looks over his information, would have wanted to know more about the interior of the train begins to build the concept, looks at the possible locations, opts for the current one - considers the problem on the platforms - says he normally would have built up more affinity with the problem, but has to go on - considers and decides to ignore the wishes of the cleaners

81 - 90  considers the possibility of the total integration of the bin in the wall of the train - critically considers the current bin - then concentrates on the fire-resistance problem, and asks about the materials the new chairs are made of - these are thermoplasts, which leaves him surprised and in some doubt what to do

91 - 100  begins to draw the current bin, considers the dimensions, tries out with newspaper - gathers info about the construction of the wall - says he tries to involve the experimenter in the discussion, but doesn't succeed

101 - 110  tackles a number of problems in quick succession: the material, the platforms (asks info about the thickness of the wall there), determines the global dimensions of the bin, thinks of using bags in the bins, comments on the form of the current emptying help

111 - 120  deals with the form of the current emptying help, improves it - first considers the possibility of making a bin in the back of the chair, but then takes the decision to go for split garbage collection, and starts drawing two bins, side by side, together making one form, sunk into the wall of the train - works out the dimensions

121 - 130  poses priorities, concentrating on the split garbage collection, unobtrusiveness of the bin and the problems of the passengers - looks into the platform situation - compares his concept with that of the current producer - plans, and goes on to sketch his proposal in side views, adds measures
works on details while making a 1:1 side view sketch - determines what properties the lid should have, and opts for a small lid, connected to the wall - allows the possibility of using a garbage bag - checks the information about litter bins for other possibilities

sketches front and side views of the design, solving details about the movement of the bin and the lid - combines the back of the bin with the frame of the table.

Figure III.9 - The concept of designer 9
SUMMARY

Design methodology has successfully developed rigorous descriptions of design processes, as well as methods and techniques to control them. But some issues that are close to the designer's experience, such as 'design as a situated activity', the need for coherence and integration in design, and experiential learning in design, have not been addressed by design methodology. In this thesis the limitations of current design methodology in describing such activities are investigated in an empirical study. The aim is to contribute to the development of a design methodology that can address these issues.

THE TWO PARADIGMS OF DESIGN METHODOLOGY

To determine the descriptive abilities of current design methodology we have to investigate the two fundamentally different paradigms* that the field is based on. The main paradigm of design methodology, in which design is seen as a rational problem solving process, was introduced by Simon in the early 1970s. In this paradigm, design is viewed as a rational search process: the design problem defines the 'problem space' that has to be surveyed in search of a 'satisficing' design solution. Seeing design as a rational problem solving process entails adopting a positivistic view of science, taking natural sciences like physics as the model for a science of design. There is a strong emphasis on the rigour of design research: 'objective' observation and logical analysis should lead to general, formal models of the design process. Simon quotes 'hard' models and methods, as are used in optimisation, as prime examples of what a real science of design could and should be.

A radically different paradigm was proposed fifteen years later, by Donald Schön [1983], who describes design as an activity involving reflective practice. This constructionist theory is a reaction to the problem solving approach, specifically made to address some of the shortcomings Schön perceived in mainstream design methodology. Schön particularly objects to training programmes for design that are defined in terms of generalities about design processes. He stresses the uniqueness of every design problem, and identifies the core skill of designers as their ability to determine how every single problem should be approached. Schön calls this the essence, 'the artistry' of design practice, and finds it unacceptable that this cannot be described in the prevalent analytical framework. To describe the tackling of fundamentally unique problems, Schön proposes an alternative epistemology of design practice, which describes design as

* A paradigm is defined as 'a fundamental image that... defines and interrelates the exemplars, theories, methods and instruments... within a science' [Ritzer,1975].
a ‘reflective conversation with the situation’. His view of design research is modelled on the social sciences.

THE EMPIRICAL STUDY

To explore the descriptive properties of these two paradigms they are translated into description methods, which are then turned into concrete encoding systems for use in the empirical study. The performance of these encoding systems is used to evaluate the description methods, which informs our assessment of the paradigms. To provide more focus the paradigms are evaluated on their ability to describe integration in design (one of the key issues of design-as-experienced). A protocol analysis study was made of nine experienced designers who worked on a design task for 2.5 hours. The resulting design concepts were graded by design specialists. The comparison of the performance of the description methods led to three main conclusions:

- Activities like integration, in which process and content of design activities are intricately combined, can be described from within the rational problem solving paradigm, and they may be further understood on the basis of reflective practice.
- Rational problem solving descriptions work best in the information phase, while the conceptual phase can be better described from the perspective of reflective practice.
- The changing and subjective connotations of words in the conceptual phase pose problems for the rational problem solving paradigm. These problems do not occur when describing design as reflective practice.

THEORETICAL ANALYSIS

These conclusions were the starting point for a further theoretical analysis of the epistemologies and the way the paradigms abstractababstract from reality. The two paradigms are the representations within design methodology of two fundamentally different ways of looking at the world, positivism and constructionism. They are at the opposite sides of a deep schism that runs through science and philosophy. In this study we do not mean to stress these differences, but try to develop a modus vivendi for design methodology.

Intersubjectivist philosophers like Habermas and Gadamer have tried to do just that by distinguishing different kinds of human activities. Gadamer [1986] produced a dual definition of interpretation, seeing it both as a ‘revealing of what the thing itself already points to’ (objective interpretation) and as ‘an attribution
of value to something' (*subjective interpretation*).

Our empirical study shows that these two kinds of interpretation, objective and subjective, both have a role in design activities. The dominant kind of interpretation changes over the stages of design activity, and across design situations. This difference in dominant interpretation-mode allows us to make a distinction between two *kinds of design activities:*

- Those activities in which the interpretation of the design task or solution is based upon an impression made by something outside on the designer. The designer then behaves according to the assumptions of the rational problem solving paradigm.
- There are design activities that involve 'subjective interpretation', when the designer impresses meaning and value upon something in the design task or design solution (in Schön’s terms, this is the ‘framing’ action). This kind of design activity can best be described by the paradigm of reflective practice.

**CONCLUSIONS FOR DESIGN METHODOLOGY**

The empirical study demonstrates that the properties of the two paradigms of current design methodology are quite different in their ability to describe design, and that both of them describe distinct parts of the total design activity. The design researcher has a choice of which paradigm to use, and when making this choice the researcher must adapt to the kind of design activity that is being studied. The choice is summarised in the dual-mode model of design and design methodology (Figures 6.6 and 6.7). With this model, no grand unified theory of design has emerged, but the model illuminates the dilemma design methodologists face in trying to capture the design activity. It is an attempt to let design methodology, in the way it studies design, more closely follow the object that is being studied; design activities are partly subjective and partly objective, and design methodology should recognise this.

In order to extend the rational problem solving models of design into a more precise description and understanding of conceptual design activity, design methodology will have to adopt some of the fundamentals and approaches of the more 'subjective' reflective practice paradigm. The subjective mode of designing is undoubtedly more difficult to describe, to model and to make methods for than the objective mode. Still, it is a very important part of design practice. The theory of reflective practice as it stands is admittedly weak and fuzzy, and the research methodology of this paradigm is such that it will always lead to less rigorous insights into design. But the methods that result from these 'weak' insights could
be implemented, and then tested in rigorous experiments. Design methodology could thus become a rigorous, experimental science.

I hope that the dual-mode model of design and design methodology will be a basis for a discussion within design methodology on the use and combination of the two paradigms. A model, linking and signposting of the two roads of design methodology could become a subtle and valuable tool for the study of design. I also hope that this study provides an impetus to the use and further development of the much undervalued reflective practice paradigm.

CONCLUSIONS FOR DESIGN EDUCATION

Educating designers requires the approaches of both paradigms: students should learn to address design tasks in an 'objective' way, by learning how to use the tools of project planning, concept analysis and evaluation. And they have to learn how to approach the more 'subjective' phases of design.

The paradigm of reflective practice can help us define clear targets for the open-ended method of experiential learning. It provides us with a language to discuss how designers address concrete design situations. The role of a design tutor can be defined within this paradigm as helping students to reflect on design, so that they learn how to frame their design tasks, and to stimulate them to explore and experiment while they design. Design is an activity that involves intense, continuous learning.

I hope that this study, by distinguishing two kinds of design activities, and by providing insight into the strengths and weaknesses of the paradigms for studying design, serves to bring design methodology nearer to design as it is experienced in practice.
HET BESCHRIJVEN VANONTWERPEN -
EEN VERGELIJKING VAN PARADIGMA'S

SAMENVATTING

INLEIDING

De ontwerpmethodologie beschrijft ontwerpprocessen, en construeert methoden en technieken voor het beheersen daarvan. Maar enkele onderwerpen die in de praktijk belangrijk zijn, zoals 'het omgaan met een concrete ontwerptaak', 'het ontwerpen van een coherent en geïntegreerd produkt', en 'het ervaringsleren tijdens ontwerpprojecten' zijn aan de methodologische aandacht ontsnapt. In dit proefschrift wordt aan de hand van een empirische studie gekeken wat nu precies de eigenschappen en beperkingen van de huidige ontwerpmethodologie zijn. Het doel van dit onderzoek is bij te dragen aan het ontwikkelen van een methodologie die deze kanten van de ontwerppraktijk wél belicht.

DE TWEE PARADIGMA'S VAN DE
ONTWERPMETHODOLOGIE

Om de mogelijkheden en beperkingen van de ontwerpmethodologie te bepalen moeten we teruggaan naar de basis van het vakgebied, de paradigma's* waarop het gebaseerd is.

Het invloedrijkste paradigma in de ontwerpmethodologie, RATIONAL PROBLEM SOLVING (rationeel probleemoplossen), werd in de vroege jaren '70 geïntroduceerd door Herbert Simon. In dit paradigma definieert het ontwerpprobleem een 'probleemruimte', die door de ontwerpers onderzocht wordt tot hij/zij een oplossing vindt die tot tevredenheid stemt. Binnen dit paradigma is de ontwerpmethodologie een 'klassieke' positivistische wetenschap, naar het model van de natuurwetenschappen. Er ligt een sterke nadruk op de strakheid en eenduidigheid van het onderzoek: 'objectieve' observaties en logische analyse moeten leiden tot algemene, formele modellen van het ontwerpproces.

Een radicaal ander paradigma werd zo'n vijftien jaar later geïntroduceerd door Donald Schön [1983]. Hij beschrijft het ontwerpen als een REFLECTIVE PRACTICE ('reflecterend werken'). Deze constructionistische theorie tracht een aantal tekortkomingen in de 'harde' benadering van ontwerpen als rationeel

* Een paradigma is een 'fundamenteel beeld dat ... de voorbeelden, theorieën, methoden en instrumenten in een wetenschapsgebied definieert en met elkaar in verband brengt'.
probleemoplossen op te vangen. Zo maakt Schön er bezwaar tegen dat ontwerpen alleen beschreven zou kunnen worden in termen van algemene eigenschappen van ontwerpprocessen. Hij benadrukt de unieke eigenschappen van elk ontwerpprobleem, en vindt dat een belangrijke vaardigheid van ontwerpers juist ligt in het bepalen hoe er met elk uniek probleem moet worden omgegaan. Schön noemt dit de essentie, de 'kunst' van het ontwerpen. Hij vindt het onacceptabel dat deze zaken niet binnen het methodologische begrippenkader beschreven kunnen worden. Hij stelt een nieuwe epistemologie van het ontwerpen voor, gebaseerd op het beeld van ontwerpen als een 'reflective conversation'. Zijn beeld van de ontwerpmethodologie is sterk geënt op de sociale wetenschappen.

DE EMPIRISCHE STUDIE

Om te onderzoeken wat de beschrijvende eigenschappen van deze paradigma's zijn worden ze vertaald in beschrijvingsmethoden, waarvan weer concrete coderingssystemen voor een empirisch onderzoek kunnen worden afgeleid. Dit coderingssysteem wordt dan getest, en op basis daarvan worden conclusies getrokken over de beschrijvingsmethoden, en over de paradigma's. Het empirische onderzoek zal zich toespitsen op het vermogen van de ontwerpmethodologie om integratie binnen ontwerpen te beschrijven (integratie is een van de belangrijkste 'ontbrekende onderwerpen' in de ontwerpmethodologie (zie inleiding)). Er is een protocol analyse uitgevoerd van negen ervaren ontwerpers die een typische industriële ontwerpstaak onder handen hadden: de opdracht was om - hardopdenkend- een afvalbak voor een nieuwe trein te ontwerpen. Van de ontwerpactiviteiten werden video-opnames gemaakt. De gemaakte ontwerpen werden beoordeeld door specialisten. Vervolgens zijn beide beschrijvingsmethoden, die voortkwamen uit de twee paradigma's, getest. Dit leidde tot de volgende conclusies:

- Activiteiten als integreren, waarin de proces- en inhoudelijke kant van het ontwerpen nauw verbonden zijn, kunnen tot op zekere hoogte worden beschreven binnen het RATIONAL PROBLEM SOLVING paradigma, en verder begrepen worden aan de hand van het REFLECTIVE PRACTICE paradigm.

- De beschrijving van ontwerpen als RATIONAL PROBLEM SOLVING werkt het beste in de informatiefase, terwijl de conceptfase het beste als een REFLECTIVE PRACTICE kan worden beschreven.

- De veranderende betekenis van de termen die ontwerpers gebruiken om hun
produkt te omschrijven zorgt voor grote problemen in de RATIONAL PROBLEM SOLVING beschrijving. Deze problem traden niet op bij het andere paradigma.

THEORETISCHE ANALYSE

Deze drie conclusies waren aanleiding voor een nieuwe theoretische analyse van de paradigma's. De twee paradigma's zijn vertegenwoordigers binnen de ontwerpmethodologie van twee fundamenteel verschillende (en tegengestelde) manieren om de wereld te beschouwen, het positivisme en het constructionisme. De uitdaging in deze studie is te proberen een brug te slaan tussen deze stromingen. Intersubjectivistische filosofen als Habermas en Gadamer hebben dit al eerder getracht door verschillende soorten activiteiten te onder scheiden. Zo heeft Gadamer het begrip 'interpretenen' tweezijdig gedefinieerd: als een 'openbaring van wat er in het object besloten ligt' (objectieve interpretatie) en als een 'toekenning van waarde en betekenis aan iets' (subjectieve interpretatie). In de empirische studie hebben we gezien dat beide soorten interpretatie een rol spelen bij het ontwerpen. Welke soort interpretatie dominant is verschilt per fase van een ontwerpproject, en per ontwerpsituatie. We kunnen nu twee soorten ontweractiviteiten onderscheiden:

- Activiteiten waarin de interpretatie van de ontwerptaak en het zich ontwikkelende ontwerp gebaseerd is op de indruk die iets buiten de ontwerper (bijvoorbeeld een stuk informatie) maakt op de ontwerper (objectieve interpretatie). Het gedrag van de ontwerper laat zich dan goed beschrijven met behulp van het RATIONAL PROBLEM SOLVING paradigma.

- Activiteiten waarin de subjectieve interpretatie belangrijker is, dat wil zeggen dat de ontwerper betekenis en waarde toekent aan iets in de ontwerpsituatie. Dit kan uitstekend beschreven worden binnen het paradigma van de REFLECTIVE PRACTICE.

CONCLUSIES VOOR DE ONTWERPMETHODOLOGIE

Uit deze studie blijkt dat de beschrijvingen die de twee paradigma's van ontwerpen geven sterk verschillen, en dat beide een deel van de ontweractiviteit dekken. Het is aan de ontwerponderzoeker te kiezen welk paradigma te gebruiken, en bij het maken van die keuze zal hij/zij rekening moeten houden met de aard van de ontweractiviteit die bestudeerd wordt. De ontwerpmethodologie zal, in haar beschrijving van het ontwerpen, de aard van het ontwerpen zelf moeten volgen. En die aard is voor een deel objectief, voor een deel subjectief.
Deze keuze is samengevat in het dubbelmodel van ontwerpen en ontwerpmethodologie (zie de figuren 6.6 en 6.7). Met dit model hebben we meer inzicht gekregen in de dilemma's waarmee ontwerpmethodologen geconfronteerd worden als ze ontwerpen proberen te beschrijven. Om de rational problem solving modellen van het ontwerpen verder te brengen zullen elementen van de meer subjectieve reflective practice moeten worden overgenomen.

Deze subjectieve zaken zijn ongetwijfeld lastiger te beschrijven, modelleren en met methodes te ondersteunen dan de 'objectieve' ontwerppraktijk. Maar ze vormen een belangrijk deel van het ontwerpen. Het paradigma van de reflective practice is nu nog zwak en op sommige punten vaag, en door de aard van de achterliggende onderzoeksmethodologie zal zij nooit tot 'harde', eenduidige uitspraken over ontwerpen kunnen leiden. Maar de methoden die op deze 'zwakke' inzichten gebaseerd zijn kunnen wel weer 'hard' getoetst worden. Ontwerpmethodologie wordt dan een experimenterende wetenschap.

Ik hoop dat het dubbelmodel van ontwerpen en ontwerpmethodologie een basis zal zijn voor een discussie over het mogelijk gecombineerde gebruik van de twee paradigma's. Een model dat de beide wegen binnen de ontwerpmethodologie verbindt en van wegwijzers voorziet kan een waardevolle bijdrage zijn aan de studie van het ontwerpen. Ik hoop tevens dat deze studie een stimulans is voor het gebruik en de verdere ontwikkeling van het zo onderschatte reflective practice paradigma.

CONCLUSIES VOOR HET ONDERWIJZEN VAN ONTWERPEN

Bij het onderwijzen van ontwerpen zullen de inzichten uit beide paradigma's moeten worden gecombineerd: studenten moeten leren hoe ze met ontwerptaken 'objectief' om moeten gaan, door zich de methoden van procesbeheersing en projectplanning eigen te maken. Maar ze zullen ook moeten leren met de 'subjectieve' interpretatie van de ontwerptaak om te gaan.

Het paradigma van de reflective practice kan ons helpen duidelijke doelen te formuleren voor de ontwerppractica, en het levert ons een taal om te praten over de manier waarop ontwerpers met concrete situaties omgaan. De taak van de ontwerpbegeleider kan binnen dit paradigma omschreven worden als het studenten leren reflecteren op hun ontwerpactiviteiten, zodat ze ontdekken hoe ze een ontwerptaak kunnen 'framen' (kaderen) en het ontwerpprobleem al experimenterend op te lossen.

Ik hoop dat deze studie, door het onderscheiden van twee soorten
ontwerpaktiviteit, en door het verkennen van de sterke en zwakke punten van de
paradigma's bijdraagt aan een ontwerpmethodologie die dichter ligt bij het
ontwerpen zoals dat in de praktijk wordt beleefd.
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Kees Dorst (1965) was trained as an Industrial Design Engineer at the Delft University of Technology, and studied some philosophy at the Erasmus University Rotterdam. Since obtaining his Master’s degree in 1989 he has worked as a designer for various design firms, participating in about fifty projects. He is now a part-time assistant professor in the Department of New Product Development of the Faculty of Industrial Design Engineering. Major research projects there were the development and co-organisation of a joint design research project and international workshop on protocol analysis, called Analysing Design Activity, and this thesis. He is involved in tutoring Master’s students, the teaching of courses in design methodology for design staff and students, and the supervising some of the growing number of empirical design researchers in Delft. He also teaches design methods at the Academy of Industrial Design in Eindhoven and at various management institutes in The Netherlands, and works as a consultant in the fields of product design and (the organisation of) product development.