6. Information Processing in Design

A Theoretical and Empirical Perspective

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6.1 Introduction

The research mentioned in this paper has been conducted in the sub-Faculty of Industrial Design Engineering at Delft University of Technology during the last seven years. This research belongs now to a big research program called "Ambition". Ambition is a program focused on three main topics: Product Conceptualisation, Intelligent Products and Sustainability. Information Processing is part of the Product Conceptualisation topic.
Product Conceptualisation has a special focus on the designer's thinking and behaviour in the conceptualisation of a product. Design thinking in the conceptual phase of the design process is aiming at the development of concepts through analytical, visual and conceptual activities. Although these activities are part of one process, they are seen here (for methodological reasons) as three parallel processing elements, i.e. (1) information processing, (2) visual thinking, and (3) conceptual thinking. The three elements all show a common ground and are linked together in focusing on the initial phases of the design process, dealing with aspects of one and the same activity: optimising the process which develops from the definition of the design task to the conceptualisation of a design solution.
Optimising the conceptualisation phase, being the main focus of the Product Conceptualisation research topic, should contribute to:

- The enlargement of knowledge and insights into the designer's knowledge and behaviour in the conceptual phase.
- Offering models and methods that will support the designer, with special attention to the visualisation of ideas and the use of visual media. Media that will include both traditional and electronic tools.
- The application of the knowledge acquired through developing machine-based strategies for information search.

Regarding the scope of Information Processing, this optimisation can be achieved through research focused on: i) how designers process information during the conceptual phase of the design process, taking into account the designer's expertise, and the communication with the design environment: stake-holders, users, society, etc.; and ii) the type and extent of (contextual) information considered during the design process.
While the designer or the design team needs information in identifying the 'problem' and looking for 'solutions', both internal and external information are rather diffuse, incomplete and unstructured. Moreover, information processing will strongly be influenced by the designer's expertise and by his social and cultural background and, as the member of a design team by the group communication and interpersonal relations. Hence there is a need for knowledge and insights into information processing so as to create a design environment that is conducive to innovative conceptualisation. It is also necessary to create a good support, in

terms of knowledge and technological media for designers and researchers to handle and include in practice diffuse and unstructured information, namely, contextual information. The main research questions are:

- Which aspects of the design environment are conducive to information processing allowing the designer to break through his schemata (knowledge frames) and to generate creative and innovative concepts? Some of these aspects include the accessibility of information, the communication within the design team (social behaviour within the team) and with the environment and the 'format' in which information is provided.
- Given the differences in designer's knowledge frames and experiential backgrounds, which evolutionary and adaptive tool-based strategies can be defined? An assumption is that the interaction with these strategies will result in explorative processes leading to a redefinition of the design environment and, at the end, to creative and innovative design solutions.
- What are the effects of the type and extent of the information processed, the support in which it is stored/presented to designers, and the strategies used to process such information in a designed object, in the satisfaction of stake-holders expectations?

In the next paragraph, some theoretical notions about the topic will be offered, which will illustrate the methodological approach of our group at Delft University. The content of this paragraph is mainly based on a recent paper by the authors (Restrepo et al. 2000). Then a number of empirical studies from our group will be presented, which has been conducted since 1993, focused on information processing in design. Although all of these studies cover only a small part of the entire field, partly due to their limited operational definitions of the relevant variables, together they form an interesting body of knowledge. Finally, conclusions for future research will be drawn.

6.2 A theoretical approach

From the point of view of design methodology and design education, it is important in design research to focus on the role of knowledge in the design process, and on the role of the information processed. Questions like how problem solvers (designers) select relevant information and how they represent and retrieve expert knowledge should be solved.

Research through observations of design processes has provided some relevant data on the role of knowledge. Firstly, designing is not just regulated by preconceived goals, but it remains more or less vague, ambiguous and conflicting. Secondly, the interplay between individual designers, design teams, and the environment, influencing each other, affect the outcome of the design process. Designing requires interference of several 'knowledge cultures' and is multi-perspective. Thirdly, the designer's perspective as an individual seems a cognitive one: the designer will reason and act based on knowledge 'frames'. Frames are imposed through tacit background knowledge, habits of perception etc., acquired through experience or enculturation into a community of practice. Designers' knowledge and ideas are filtered by these frames, while they will process external information to the extent that it conforms to their knowledge structure or ways of knowing. As a consequence designers can be blocked by past experience or fixated by information offered in a particular situation. In contrast, the role of the (contextual) information processed or needed during the design process has been scarcely studied.

Literature in context or contextual information related to design is rare. This suggests a disregarding in research and practice of the roots of motivational aspects that make the creation process of designed objects possible. A process that is always contextualised and

socialised. To expose this aspect it is necessary to discuss the concepts of context and contextual information.

Context can be understood as the reference frame in relation to which a linguistic expression (semantic context), an event of the phenomenological reality (cultural context), an intersubjective situation in the time-space relations (situational context) or an object of the reality (physical context) acquires, or is able to acquire, one, and only one particular sense. The reference frame consists of a set of conditions that pertain to different elements in relation to which an event, or an object, is acquiring sense: the creator, the interpreter and the milieu. Recognising that this frame depends not only on environmental conditions (economic, social, technical, natural, etc.) but also on actors, as the creators and the interpreters (designer, manufacturer, client, final user, etc.) empowers the notion of context, because it gives the opportunity to study and act on subjects as well as on objects. Finally, it is important to annotate that the notion of context, as the entity that gives ground to shared understanding of representations among individuals, cannot be individualised. A generally accepted cognitive approach tends to regards the social context as an external stimulus field (Restrepo et al. 2000). However, a shift in attention from an individualistic to a more social approach should lead to the opposite conclusion, by considering that the interpreter is implicated and is part of the context, and that perception and interpretation are structured by virtue of the involvement and interests of the perceiver or interpreter (Spears et al. 1997).

All the information required and processed by a subject in relation to his intentional objects, in order to interpret initial states of the world and to create representations of the aimed states of the world, is what constitutes what here is called contextual information (see Figure 6.1). In an even broader sense, the subject could be just a person (user, designer, etc.) or a group of persons (a society, a design team, etc.).

Observing the research methods and design methodics, it can be said that designers (and design researchers) have put the object (object understood as the product of a design process) –as economy did– in the centre of the discussion. The goal of most methodics is too focused on the embodiment of a concept into an object and the meeting of all the economic facts around it. The object's finality (its effects in the world or in the users), as well as the motives of the subject that made the requirement are not explicitly considered, seriously restricting the amount of contextual information a designer is able to handle and embed in the object and in the design process itself.

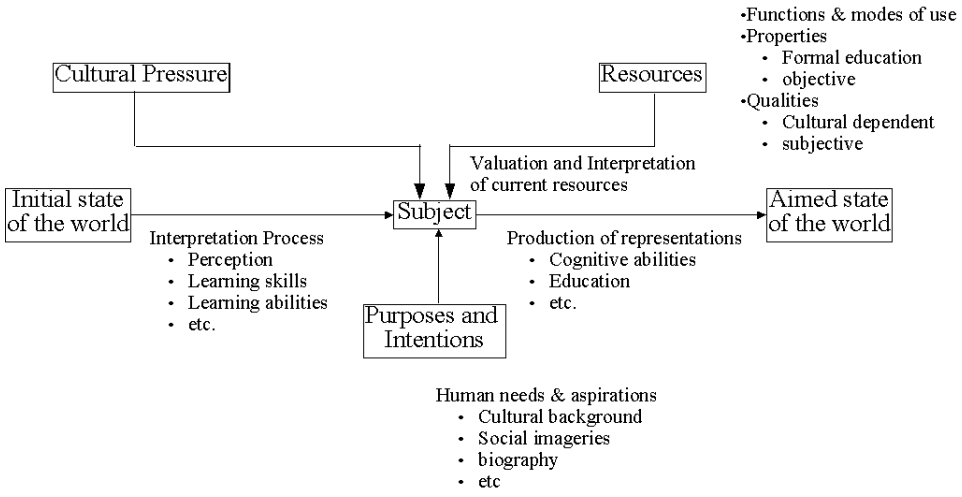

Figure 6.1: Social and cognitive factors and processes involved in the interpretation and production of representations of initial and desired stated of the world.

Even though designers in practice could be aware of the necessity of introducing such contextual information into the design process and into the object itself (and say they already do), they often fail to do so, due to its vast extension and the lack of both epistemological and technological support.
The claim is then, that a clear understanding of the generation process of aimed states of the world (see Figure 6.1), and its associated information, as well as the mechanisms that make possible its flow throughout the whole (design) process (see Figure 6.2), could lead to the creation of (technology and knowledge-based) means to support designers in the inclusion and handling of contextual information.
The framework (see Figure 6.2) proposed shows, in a very rough and yet-primitive way, some aspects of the information involved in the construction of representations of possible (better) worlds and its translation into objects that (could) make those worlds possible.
The potential applications of this framework are: i) The creation of means (technology and knowledge-based) that can provide the support designers need in the inclusion of contextual information, not only on the design process, but also on the designed objects themselves; ii) The generation of new research methods on society-product (instead of human-product) interaction, given the non-individual character of the information involved; and iii) The generation of new (design) methods that start, not from the idea that there is an object to be configured, but from the idea that there is a mental state, a need or an aspiration to be achieved or satisfied, so the pressure on designers (natural) ability to do that is eased.

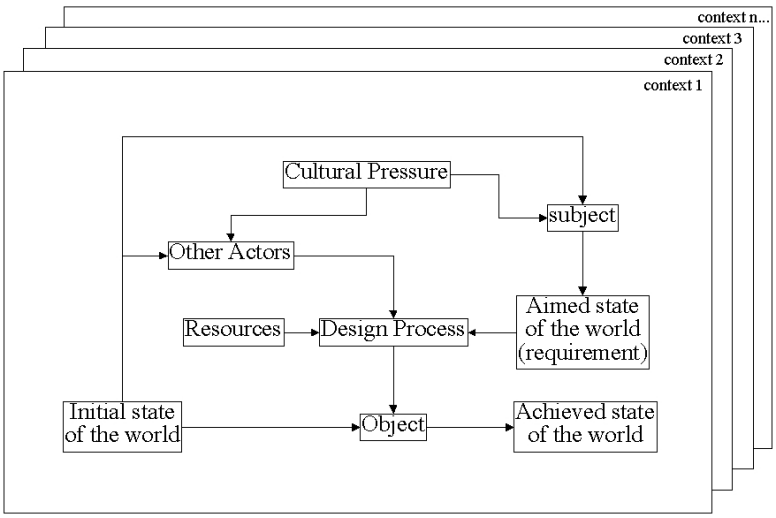

Figure 6.2: Information flow framework. Note that (design) representations are the communication conduit among the levels (contexts)

6.3 Empirical research

The theoretical approach goes hand in hand with gathering empirical data about parts of the hypotheses. Within the project on "Information processing in design" several studies have been conducted and published over the last seven years. All of the four studies mentioned here have contextual information as their main focus. Although the definitions used slightly differ between the studies, quite a clear picture is presented of the area of research they are focusing on.

6.3.1 Study 1: Impact of information mode on the design outcome (Christiaans & Van Andel 1993)

The first study was concerned with the question under what conditions relevant contextual information from external sources would be more accessible for designers as measured by the design output. The contextual information concerned the psychological aspects of the child's playing behaviour in using different kind of toys. Designing a go-cart (in The Netherlands called a 'Flying Dutchman', see Figure 6.3) was the assignment for a group of 21 second-year students of the sub-faculty of Industrial Design Engineering at Delft University of Technology.

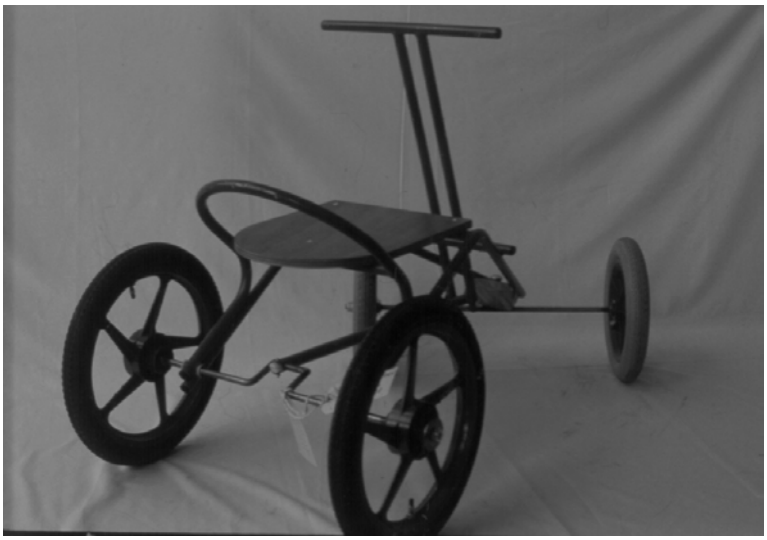

Figure 6.3: A Flying Dutchman

Two different ways of presenting this information were compared. In the control situation, students received only general information on six psychological topics related to the design assignment, while in the experimental condition, students received more detailed information using verbal and visual examples. In this way, and by stimulating the students to actively 'work' with the information, compilation of the transferred declarative knowledge was supposed to take place. Knowledge compilation, or proceduralisation is defined by Anderson (Anderson 1993) as the creation of task-specific knowledge through practice. Pictorial information together with an active way of using this information on designing was expected to have a greater impact, although this impact might result in mimicking behaviour.

The study showed that the experimental condition, using visual information together with verbal information, had a strong effect compared to the control condition. Not only in the designed prototypes but also in the technical reports the differences were obvious. A second finding of this study was a fixation effect in the experimental group; some students in the group mimicked one of the examples offered during the experimental instruction.

The introduction of behavioural or psychological aspects in the design assignment was a rather new phenomenon in the design course of the sub-faculty of Industrial Design Engineering. In spite of that, the results of this study showed that, if (student) designers are taking into account that part of the knowledge from the domain of psychology, which is relevant in the design activity, they are able to design objects which are closer to the users' expectations.

6.3.2 Study 2: A cognitive view on information processing (Christiaans & Van Andel 1998)

The aim of the second study was to explore what typical strategies designers use in their information gathering behaviour; if designers would mainly look for technical information in using external sources, while user-related information is given low priority; and to prove if a database, offered to a designer, could be more accessible when it is adaptable to the designer's idiosyncratic way of processing information.

In order to tune the information system to a design problem a design assignment was defined, that would force the use of external information and come close to the core activity of industrial design (engineering): bringing together the intentions of the designer, the user's needs and experiences and the system image of the product to be designed. A bicycle for people of 55 years and older (55+), a topical subject in The Netherlands, was chosen as the design assignment. Both technical and functional information and specific knowledge on the users were essential in the development of this design assignment. Subjects were student designers working in teams of three people. They worked on the task for two days, full-time.

An 'Internet' hypertext information system was developed with information on several aspects regarding the assignment. According to expectations about how designers should look for information the main menu started with three general categories: (1) Information on the manufacturer and the market; (2) Information on bicycles; and (3) Information on the user. Both text and pictures were used.

As an example, in Figures 6.4 and 6.5, the type of information asked for is presented for team I and team VII. Each team showed one's own specific graph, representing the way they go through the information system and also indicating what information is most important for the team. The two teams differed not only in the amount of information consulted on both days, but also in the choice of the topics. On the other hand, teams also showed some similar behaviour.

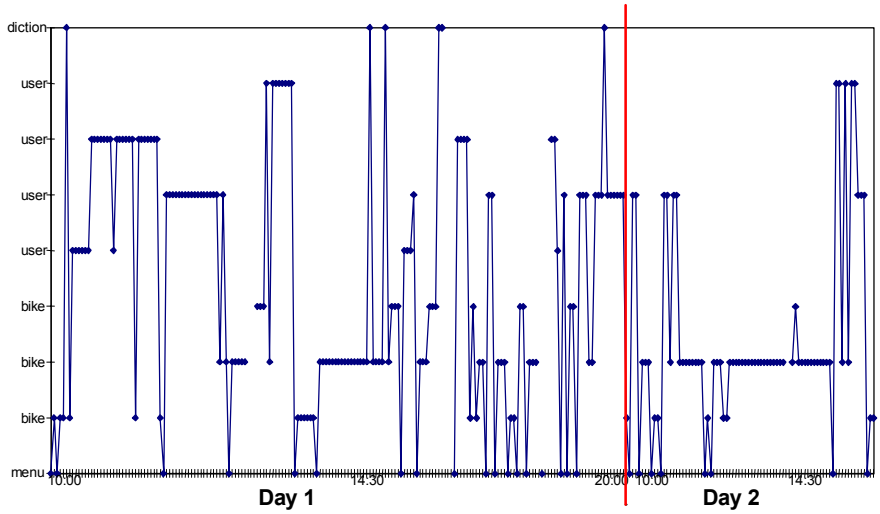

Figure 6.4: Information asked for by team I. y-axis: menu = navigation pages, bike = bicycle category, user = user category, diction = dictionary, edit = pages edited by the team.

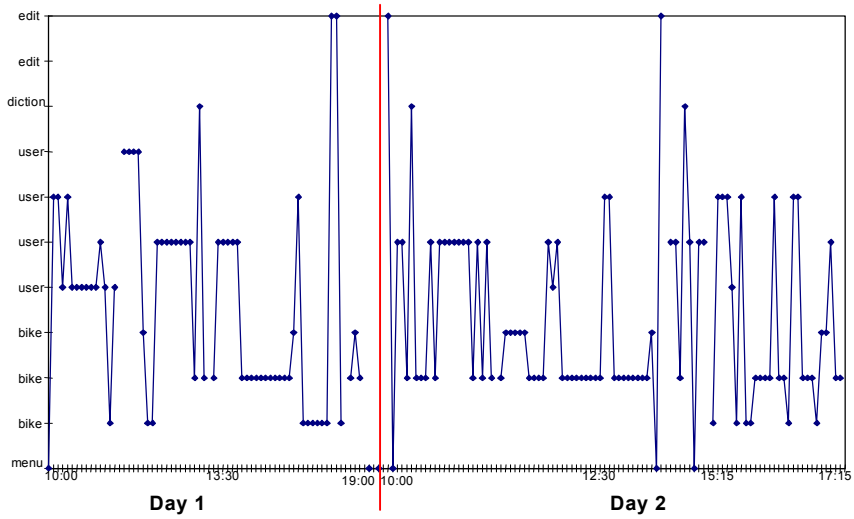

Figure 6.5: All information asked for by team VII. Values on the y-axis: see Figure 6.4.

The first conclusion of the study was that the information system played a very relevant role during the design process. All teams, except for one, made extensively use of the system and were very positive about the usability and efficiency. Another way to test the relevance of the information was to consider the design specifications, as reported by the teams, and to look for data that was derived directly from the information system. The application of data from the system was evident.

Data from the system was used mostly in the analysis phase and in defining the design specifications. Although there were differences in the way the teams went through the information, most teams started with user-related topics. Later in the process, the type of information asked for seemed very typical to the phases of the process the teams were involved in. These phases can be defined as conceptualisation, decision-making and evaluation. During these phases the two sources mainly looked for, were technical data (such as geometry of the bicycle, materials, and production methods) and legal norms and standards. While on the first day teams looked for user information, this was hardly the case on the second day.

One hypothesis was that the possibility to adjust the database to one's own wishes and preferences should have a positive influence on the processing of knowledge from the information system and thus on the influence of this knowledge in designing. However, as the results showed this possibility was hardly used by the experimental teams. The most important reason was that the editing facilities offered were not user-friendly. Hence, this hypothesis could not be tested in this study.

6.3.3 Study 3: Implicit knowledge of the designer (Trousse & Christiaans 1996; Christiaans 1999)

In the study discussed here the aim was to understand the nature of the design process as a communication process modelling the argumentative knowledge of the individual designer or the designers in a team. Design was viewed here as a meaning-construction activity.

A theoretical framework was introduced based on argumentation theory, proposing that the problem-solving actions of the designers are performed in one of three specific spaces: (1) A structural space in which the action-based and linguistic skill of the designer(s) manifests itself; (2) A socio-linguistic and socio-action based (ritual) space related to the context in

which the designer(s) and the design assignment are situated; and (3) A discursive space in which the designer implicitly pre-constructs his cognitive devices that will be used for design purposes in the two other 'meaning-construction spaces'. The more the discursive space is based on relations between the two others spaces, the higher is the discursive skill of the actor (designer).

The actor knowledge in the 'socio-linguistic and ritual space,' validates and guides his argumentation. If actors do not share the same space, then a valid statement of one actor can be of no meaning for another actor who has to interpret it. For an actor performing an activity and using the three spaces (in a variable way) the argumentation will be the way to orient and modify the real world.

In this study two teams of designers were analysed through the written transcript of the protocol. The design brief for two design teams and two individual designers (all professionals) was to develop an artefact that connects a backpack to a bicycle (see Figure 6.6).

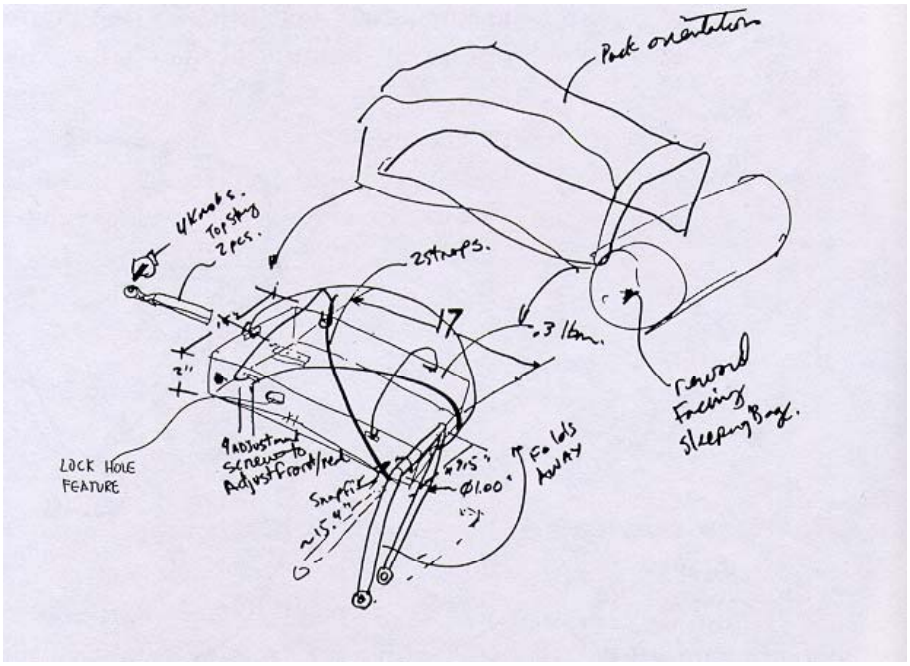

Figure 6.6: Strapping the backpack on the bike.

The conclusion was that argumentative knowledge seems to be an important component of design rationale by contributing to a better understanding of the design activities and to the specification and development of real co-operative knowledge-based design support environments.

All designers gave their information mainly in the structural space, technical aspects regarding bicycle, backpack and joining device. It means that the socio-linguistic and socio-action based (ritual) space hardly place a role. This is quite a dramatic conclusion, because it holds for professional designers.

The content of the 'topical' models was based on not only explicitly expressed meanings but also implicit ones. The expectation was that every model shows the underlying knowledge base and structure of the designer. Examples of these models gave indeed differences between the designers in their problem approach and their knowledge input. One of the conclusions of

this study was that the better the discursive skills, both structural and 'contextual', of designers are, and thus the larger the topical fields, the better the design results will be in terms of creativity, potency and distance.
Studying the role of argumentation in team design makes clear that the design process is not a mere knowledge-based activity but also a confrontation of belief systems and attitudes, and of social roles. Finally, fixation effects were disclosed, especially fixation on arguments or ideas as a consequence of the background knowledge (Mey 1993) and the knowledge structure of the designer(s) or by social factors.

6.3.4 Study 4: The influence of contextual information on the design outcome (Snoek, Christiaans & Hekkert 1999)

The goal of the most recent study regarding the overall research theme in information processing was to test the hypothesis that application of certain information, i.e. not directly related to the (design) problem at hand, contributes to an enlargement of the (metaphorical) solution space. In turn, such an enlargement of the solution space should offer more interesting starting points for an original design solution. In performing a design task individually, subjects were offered information by means of an information system containing traditional, i.e. domain information, and contextual information. It is important to clarify that the sense given here to the definition of contextual information is different from the definition given in this paper. These empirical studies, together with reflection on to which extent contextual information should be considered, have lead us to the conclusion that the scope and sense given to contextual information in the past, in our own studies in particular, and in literature and other studies in general, is limited, inexact, shows a disregard of the contextual information as an indispensable piece in the design process and therefore, must be broadened.
Analogous to the aforementioned study 2 (Christiaans and van Andel 1998), an 'Internet' hypertext information system was developed, which was available to the subjects during the design process.
A 'search engine' was available enabling subjects to search on any word in the system. In using the information system, standard facilities of the browser could also be used by the subjects, such as the buttons 'back', 'forward' and 'bookmark'. However, the access to other sites of the WEB was blocked. In the information system, both text and pictures were used.
The system contained two types of information, traditional 'industrial design' information, and 'contextual' information. Traditional information is defined as information that is directly and obviously related to the problem domain. Subjects were 23 senior students from the sub-faculty of Industrial Design Engineering at Delft University of Technology.
The design assignment given to the subjects was designing a new concept for a modern office environment. This assignment was further explained by a text of about 500 words. The text stressed information on the changing environment, due to a variety of factors such as developments within the area of information technology, globalisation, and a knowledge-base increase in general; the rise of a dynamic environment that forces companies to change both on an organisational level and in respect of their accommodation; the change in work culture that can be characterised as 'flexible'. The core of the design assignment was formulated as: "The problem is that an employee must have at his disposal the things he needs for his specific task at any time and in any place. Also, he wants to be able to adapt the desktop to make it his own personal work station at any time and in any place."

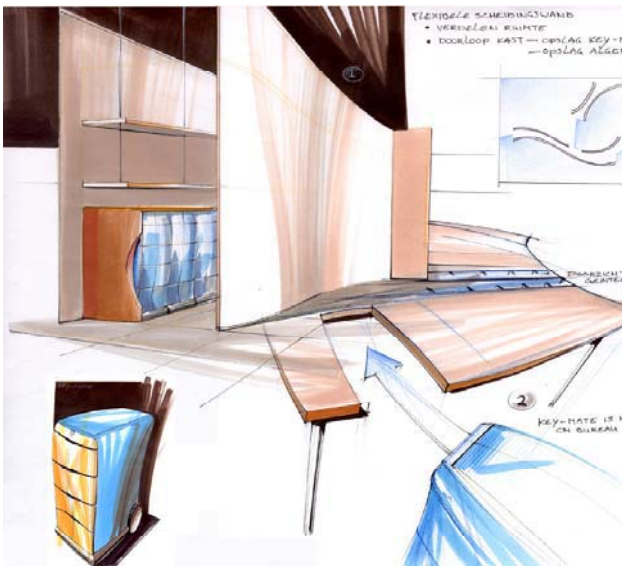

Figure 6.7: A new office environment.

At two points in the design process, the subjects were asked to report their conception of the problem, which is considered to be a reflection of the solution space. It is demonstrated that the originality of the (second) problem conceptions and consequently the final design solution were affected positively by the relative amount of contextual information processed. Since this latter measure had a negative effect on the appropriateness of the concepts, it is concluded that students should be trained in translating contextual information into creative design concepts. Appropriateness can be understood as the feasibility and constructibility of the designed objects.

6.4 Overall conclusions and discussion

From observing literature in design and in design research, it can be concluded that there is not a consequent definition of context or contextual information related to design. This is upheld by methods and methodics that appear to be more helpful in pruning the information than in introducing it into the design process, and by the amazing human ability to manipulate large amounts of fuzzy information based on cognitive economics strategies. As a result, potentially valuable contextual information is missing in the design process.

There is no strong evidence on how the inclusion of contextual information can help in making an object (a product) more easily accepted into a community or by an individual, or how to make it fit better the stake-holders aspirations. This is probably because there is not (yet) a strong understanding of the relevance and real extent of this information, and because of the lack of a suitable support to handle it.

On the other hand, there is strong evidence, from the studies mentioned in this paper, that the inclusion of contextual information in an appropriate way has a positive effect on the design process, leading designers to break their own fixations. There is a direct relationship between the amount of contextual information processed and the creativity, potency and distance of the resulting concepts. However, the relation between contextual information processed and the appropriateness of the concepts is still in doubt. It seems that the more contextual information is processed by an individual, the less appropriate his concepts will be. A possible reason for this is the lack of a good training of designers in translating contextual information into

feasible products. Hekkert and others have already proposed a way to overcome this weakness (Hekkert 1997).
The studies also confirm the claim that too much effort is being put in methodology and in design in the consecution of means to allow designers to generate a concept and to embody it into a product. The scope does not go beyond this point, missing the information related to motivators, needs and aspirations, motivators that appear in every creation process, consequently missing the contextual information that comes with them.

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