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On the content of design problems

Claus Thorp Hansen & Mogens Myrup Andreasen
Section of Engineering Design and Product Development
Department of Management Engineering
Technical University of Denmark
Nils Koppels Alle, building 404
DK-2800 Kgs. Lyngby
DENMARK
cth@mek.dtu.dk* & *myrup@mek.dtu.dk

Abstract
To see designing as a rational problem solving activity has been the predominant understanding in design methodology literature. However, in a recent paper Dorst proposes seeing designing as a discursive activity, where a design problem is a paradoxical problem situation consisting of conflicting discourses, and where the designer has to create a solution that transcends or connects the discourses.

The authors see Dorst's proposal as a valuable framework to build upon. We see a challenge to combine Dorst's framework with existing concepts and methods in order to develop a new, operational and teachable description of design problems. The result should be a productive contribution to designers working in industrial practice and to the teaching in this area.

Keywords: Design paradox, need, task, design strategy.

1 Introduction

In design methodology the concept of 'design problems' is central. In his influential paper [1] Simon describes designing as a rational problem solving activity. Simon describes a 'design problem' as an ill-structured problem, and designing is understood as a special kind of problem solving, where the ill-structured 'design problem' is transformed into a 'design solution'. This understanding of designing has been predominant in design methodology and as Dorst [2] writes, "*has become the normal 'language' of thinking and talking about design.*" The way we as design researchers think and talk about design is reflected in the way we teach design and product development. In a recent paper Dorst [2] carries through a critical analysis of the assumptions behind Simon's approach to design. Dorst's analysis shows that Simon's description of a 'design problem' is problematic, and Dorst proposes "*a fledging framework of alternative concepts that could be used to augment our understanding of the nature of 'design problems'.*" Dorst sees designing as a discursive activity, and in his description the key-concepts are 'paradox' and 'discourse'.

The authors have more than 15 years of experience in teaching engineering design and product development at the Technical University of Denmark. We teach students in the study programmes mechanical engineering and design & innovation, and we teach undergraduates as well as master students. Since the establishment of the design & innovation study programme at our university in 2002 the authors have had the pleasure to supervise many rather large teams of design students, viz. 6-10 students in a team, carrying through their

projects based on open problem descriptions. When working upon an open description of a problem it becomes an important task of the team members to clarify their understandings of the problem and reach consensus on a common and productive problem formulation, i.e. what aspects are important to take into account and does the team believe it is possible to synthesise an attractive solution. This task can be difficult for many teams: it is not easy to identify what is important, and it is not easy for 6-10 team members to reach consensus. Often we as supervisors are enrolled to comment upon a team's obtained clarification and consensus. It is our experience that in these situations it is not beneficial to view the team as a rational problem solver and to use such a viewpoint to instruct the students on what to do. What is at stake here is the members' subjective preferences and understandings of important aspects to be taken into account. Thus, following Dorst's [2] line of thinking we observe, that the student design team is in a paradoxical problem situation consisting of conflicting discourses.

We see a challenge to enhance and improve our understanding of the nature and content of design problems, and Dorst [2] proposes a relevant and valuable framework to elaborate upon. Our aim is to identify origins and types of paradoxes, and to outline approaches to illuminate and transcend conflicting discourses in order to reach a design solution. We focus on the following research questions: what types of design paradoxes can we identify? What is the origin of a paradox? What is the content of different discourses?

The research method applied is a literature study. In order to enhance Dorst's fledging framework of design problems we confront the concept of a 'design paradox' with 'need', 'task' and 'design strategy'. Then we combine the enhanced description of design problems with design methods found in the design methodology literature. We expect that an enhanced description of paradoxes and content of discourses will become a productive contribution to designers working in industrial practice and to the teaching in this area.

In section 2 we describe two views upon designing: designing seen as rational problem solving, and designing seen as a discursive activity. Based on the description we formulate three insights into the nature of design problems. In section 3 we combine Dorst's description of designing with existing concepts and design methods in order to develop an operational and teachable description of design problems. The paper finishes with a conclusion.

2 Two views upon designing

In this section we describe two views upon designing. The description is based on our reading of a recent paper of Dorst [2]. Dorst states that the rational problem solving paradigm is dominant in design methodology. This paradigm is based on Simon's description of designing, and Dorst writes, "*There have also been many critiques of Simon's problem solving approach and its applicability to the field of design, and many of the original statements in the problem solving theory that deal with design have since been qualified and refined. However, these critiques have not produced a fundamentally different alternative to the conceptual framework.*" Dorst is not satisfied with rational problem solving as an only description of design, and he proposes a new description of design problems.

Designing seen as rational problem solving

According to Dorst [2] Simon describes a 'design problem' as an ill-structured problem, and designing is understood as a special kind of problem solving. Dorst writes, "*In his paper 'The structure of ill-structured problems', Simon sets out to explore the relation between ill-structured and well-structured problems. He starts with the remark that much kind of*

problems that are often treated as well-structured are probably better regarded as ill-structured." However, Dorst writes, "*The stated goal of the paper* [Simon's paper [1] CTH] *is to show that there is no real boundary between well-structured and ill-structured problems, and therefore no reason to assume that the solution of ill-structured problems would require new and hitherto unknown type of problem-solving processes."* As readers we would like to ask Simon: what do you mean by a 'real boundary'? Where shall we look for the real boundary; is it to be found by analysing the problem formulation or by identifying the way the problem can be solved? Dorst analyses carefully Simon's list of properties of well-structured problems, and based on the analysis Dorst observes, "*… the ill-structuredness of a problem depends on the solution methods that are available to solve it. This opens up the way for suspecting that the ill-structuredness of a problem may not be an* a priory *property of the problem itself, but is linked to the capabilities of the problem solver. In this way, the subject that does problem solving actually influences the very nature of the problem."* In Dorst's observation we find a very valuable and astounding answer to our questions. We have to take into account the problem solver, i.e. the designer or design team, and the solution methods he/she or the team is familiar with and decides to apply in order to solve the problem.

With respect to solving ill-structured problems Dorst's analysis unearths, "*There is a basic assumption here that even though well-structured problems as such do not exist in the real world, the construction of well-structured problems from ill-structured problems is the way to solve an ill-structured problem.*" Thus, in Simon's understanding the first step to solve an ill-structured problem is to construct a well-structured problem. Since Simon sees the problem solver as being rational, this construction consists of one or more rational structuring actions. Dorst questions this understanding, and he writes that the problem solvers' interpretation of the problem is important. The interpretation made by a problem solver is based on his/her capabilities. Thus, subjectivity creeps into the structuring actions. Dorst writes, "*This means that in a multi-step problem solving process, each problem solver will get the change to pile interpretation upon interpretation and thus end up taking their problem solving processes in completely different directions. The use of memory and subjective interpretation thus becomes a major influence on the problem solving behaviour of designers*."

Simon [1] concludes by stating that the boundary between ill-structured and well-structured problem solving is a vague and fluid boundary. Simon writes, "*It suggests that there may be nothing other than the size of the knowledge base to distinguish ill-structured problems from well-structured problems, and that general problem solving mechanisms that have shown themselves to be efficacious for handling large, albeit apparently well-structured domains should be extendable to ill-structured domains without any need for introducing qualitatively new components."* Dorst disagrees with this conclusion and writes, "*This conclusion is not supported by data at all, and contains a logical weakness: the fact that it is hard to draw a line that distinguishes between well-structured problems and ill-structured problems doesn't mean that there IS no difference. There may be elements within the process of solving ill-structured problems that can actually be more or less straightforward steps (that can be considered well-structured problems), but that doesn't mean that the solving of ill-structured problems can be reduced to these straightforward steps. There is no evidence to support the claim that both kind of problem solving are the same*."

Within the rational problem solving paradigm and based on an empirical study Cross and Dorst [3], [4] develop a model of creative design as the co-evolution of problem and solution spaces towards a matching pair. Dorst [2] explains the model, "*Creative design seems more to be a matter of developing and refining together both the formulation of a problem and ideas*

for a solution, with constant iteration of analysis, synthesis and evaluation processes between the two notional design 'spaces' – problem space and solution space. In creative design, the designer is seeking to generate a matching problem-solution pair, through a 'co-evolution' of the problem and the solution." Thus, according to this model there is not first a problem and thereafter a solution. This is in contrast with Simon's understanding of designing, and Dorst writes, "*We can probably stick to the problem solving theory only if we abandon the idea that there is a definable problem at the start of the design process, and postulate that it will be constructed later on. This then begs the question how this problem is constructed, and whether this process of 'problem construction' can be modelled at all*."

Designing seen as a discursive process

In his efforts to develop a new model of design problems Dorst finds inspiration in the work of researchers, who see design problems as situated problems, e.g. Dreyfus and Suchman, and in Hatchuel's ideas on 'extended rationality'. We will not describe these contributions in details, but just mention two important points in seeing design as a situated activity:

1. When designing is seen as a situated activity the key interest of the researchers is to understand what design problems are to the designer during the design project. Dorst writes, "*Seen from this perspective, the 'design problem' as such does not really exist as an objective entity in the world. There is an amalgamate of different problems that centres around the basic challenge that is described in a design brief. This amalgamate of problems is partly there to be discovered by the designer in the design process, and part of it has to be MADE by the designer. The process of 'approaching a design problem' or 'dealing with a problematic situation' becomes the vital clue to understanding what design problems are*."
2. When designing is seen as a situated activity there will be two types of problem solving steps. There will be many situations, where the designer's problem solving steps are routine and implicit, and there will be situations, where the designer's normal problem solving behaviour is inadequate. Dorst writes, "*Dreyfus holds that problematic situations are the results of a 'breakdown' in this normal, fluent problem solving behaviours (…) These 'breakdowns' then are the moments of real choice*."

Thus, the key point is the problematic situation. Dorst proposes to see designing as a discursive activity, and in his description the key-concepts are 'paradox' and 'discourse'. With respect to the word 'paradox' Dorst writes, "*The word 'paradox' is used here in the sense of a complex statement that consists of two or more conflicting statements. In the initial state of the paradoxical problem situation, all the statements that make up the paradox are true or valid, but they cannot be combined. A paradox, a real opposition of views, standpoints or requirements, thus requires a redefinition of the problematic situation in order to create a solution*." To explain the word 'discourse' Dorst writes, "*In most design disciplines, there are many discourses that have to be somehow linked in the creation of a design solution. In product design practice, for instance, relevant discourses include the bodies of thought about technology, form and aesthetics, ergonomics, etc etc … these are called the 'aspects' of a design (Dorst 1997). Discourses can also be embodied in a design situation by the roles and the value systems of the different stakeholders involved in the project. The creation of a solution to the paradoxical design situation then also becomes a social process.*

The designer, in his/her paradoxical problematic situation, needs to construct a design that transcends or connects the different discourses, in a general sense (by the construction of a meta-discourse), or just in the concrete instance of the design-to-be-developed. To do this, the designer has to step out of the ways of thinking embodied in the discourses. This step is likely to include a strong intuitive element."

On the outcome of a design activity Dorst writes, "*The paradoxical problem situation works as both a trigger to creative imagination and as a context for the evaluation of the design. For the solution to BE a solution at all it needs to be recognized as such in the contexts of all the relevant discourses (in practice this often means, first and foremost, that it should be acceptable to all the relevant stakeholders).*"

We find Dorst's description relevant and valuable. If we compare his description with Simon's understanding of designing, we find three important insights into the nature of design problems:

1. The design problem is not an objective and static entity of the world. It is an articulation of the designer's understanding based on the clarifications obtained so far in the project. Thus, the design problem is an entity, which is developed during the project.
2. The design problem does not come first as a result of an analysis. The core of designing is to develop an understanding of a problem and an understanding of potential solutions, and to identify a suitable match of a problem-solution pair.
3. The designer has influence on the design problem. The designer decides the discourses to be taken into account and determines their relative importance in the current situation.

These insights fit nicely to our experiences when supervising rather large teams. Often when a design team asks for supervision the reason is that the team finds itself in a paradoxical problem situation, and cannot see or agree upon a way to proceed. In order to develop an operational and teachable description of design problems based on Dorst's view of designing as a discursive activity we have to clarify the following issues:

1. As a trigger to initiate a design project the design team requires a motivation or argumentation. Thus, we will focus on the question: what is the origin of a design paradox?
2. During the design project the design team has to synthesise a solution that transcends or connects the different discourses, and to do so the design team has to obtain a proper insight into the relevant discourses. Thus, we focus on the question: what is the content of different discourses?
3. Dorst focuses on a designer, whereas the authors are concerned with supervising design teams. For a design team a shared understanding of the problem is important to motivate team work, but according to Dorst's model the design problem is not an objective and static entity of the world. Thus, we focus on the question: what is the role of the problem formulation for the design team?

3 The content of design problems

In this section we combine Dorst's model with concepts and methods found in design methodology and product development literature in order to develop a new, operational and teachable description of design problems. We will use examples from design projects we have supervised to illustrate types of design problems and ways to go about a task.

What is the origin of a design problem?

The authors see designing in the context of product development. When an industrial company launches a new product at the market the goal is to obtain a viable business. Asimow [5] writes, "*Engineering design is a purposeful activity directed toward the goal of fulfilling human needs, particularly those which can be met by the technological factors of our culture*." Thus, the idea of a need is a first origin of a design problem. Asimow [5] concludes the first chapter with a list of 14 principles, and some of these principles express

Asimow's understanding of a need: "*(1)* Need. *Design must be a response to individual or social needs which can be satisfied by the technological factors of our culture*.", "*(2)* Physical Realizability. *The object of a design is material good or service which must be physically realizable*.", "*(3)* Economic Worthwhileness. *The good or service, described by a design, must have a utility to the consumer that equals or exceeds the sum of proper costs of making it available to him*.", "*(4)* Financial Feasibility. *The operations of designing, producing, and distributing the good must be financial supportable*.", and "*(6)* Design Criterion. *Optimality must be established relative to a design criterion which represents the designer's compromise among possibly conflicting value judgements that include those of the consumer, the producer, the distributor, and his own*."

We observe that a need is linked to individuals or the society, i.e. needs are subjective, and they do not have an objective and isolated existence. A design team cannot interpret a need isolated form consumers, users, or the society. From principles (2), (3), and (4) we observe three types stakeholders involved in the relation need-design-business. Physical realizability is the concern of the team, because the team has to synthesise a solution. Economic worthwhileness is the concern of potential consumers. Financial feasibility is the concern of the company: will the development and production of the product result in a viable business?

Dym & Little [6] identify "*three 'roles' being played as the design of a product unfolds. Obviously there is the* designer, *and it seems equally clear that there will be a* client, *the person or group or company that wants a design conceived*." The third role of design belongs to the user, as Dym & Little write, "*The users hold a stake in the design process because a product 'wont sell' if its design doesn't meet their needs.*"

Based on the three types of stakeholders Hansen & Andreasen [7] define a design task, "*The task (-specification) is a construct created by the company/client and the team, identifying and articulating the activities, i.e. the project, and the results to be synthesised by the team, mainly the product or service and the new business opportunity. The task becomes an activity when executed*."

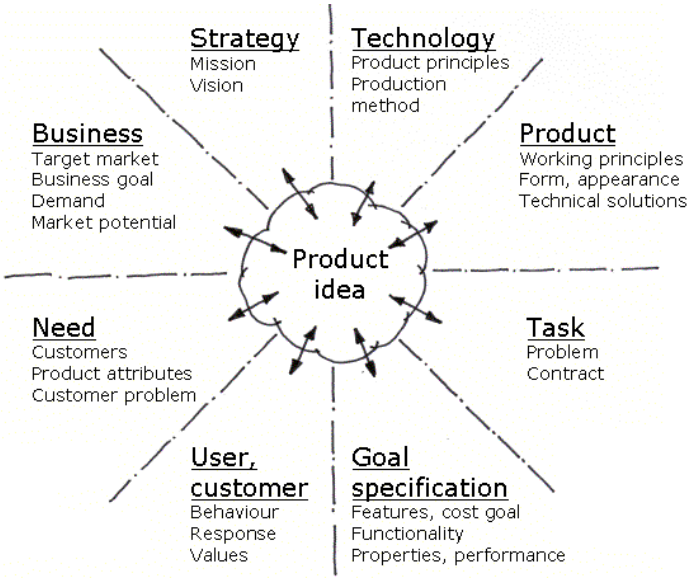

Figure 1. In an initial paradoxical design situation the design team may find relevant discourses in the eight dimensions of a product idea, Hansen & Andreasen [7]

Cooper [8] sees a new product idea as the trigger for a product development project. Cooper writes, "*An idea occurs when technological possibilities are matched with market needs and*

expected market demand." Cooper's understanding fits nicely with Dorst's, viz. the core of designing is to identify a suitable match of problem-solution pair. However, Dorst states that many discourses may have to be taken into account in the creation of a solution. Hansen & Andreasen [7] propose the product idea model, see figure 1. According to this model the team may in an initial paradoxical situation find relevant discourses in the eight dimensions of a product idea. Thus, for a team in the action of clarifying a design paradox the product idea model can be seen as a guideline or checklist.

One research question is concerned with identifying types of design problems, and through our supervision of projects and literature study we have identified two keys to classify design problems. The first key is related to the *intention*, and the second to the *formulation* of the design problem. We have in [9] outlined a list of *intentions* of taking up a design project:

1. Egocentric curiosity or idea about …
2. To fulfil a mission, a purpose related to e.g. company strategy.
3. To realise a goal or specification related to e.g. competitive performance.
4. To wish exploiting an identified market opportunity.
5. To wish exploiting an identification of potential users or need.
6. To be driven by any opportunity for making an improvement that matters, e.g. cost reduction or quality improvement.

"Bicycle helmets for teenage girls" is a design project taken up due to two design students' egocentric curiosity. In Denmark many people use a bicycle for their daily transportation from home to school or work. When a parent transports a child to and from kindergarten on bike the parent ensures that the child is wearing a helmet. Thus, Danish children are used to the helmet. Unfortunately, many adults *including parents* are reluctant to use a helmet, so as a consequence many teenagers decide not to use a helmet. This is obviously a bad decision, and the team searched for ways to increase teenage girls' use of bicycle helmets.

An intention of a team could be related to creating a radical innovation. Leifer et al. [10] define, *"a radical innovation project is one with the potential to produce one or more of the following: an entirely new set of performance features; improvements in known performance features of five times or greater; or a significant (30 percent or greater) reduction in cost*." We observe that a radical innovation project could be related to intention 3 or intention 6.

A design problem can be *formulated* as:

1. A wonder, e.g. "I wonder if we can synthesise an attractive bicycle helmet for teenagers."
2. A challenge, e.g. "The goal is to reduce costs significantly; more that 35% reduction."
3. A 'what if' question.
4. An idea about the elegant solution.
5. An intention to satisfy an identified need.

A colleague of the authors formulates design tasks as 'what if' questions: "*What if cars were not allowed to enter the centre of Copenhagen? What means of transportation could be an attractive alternative?*" Thus, the design task has an open formulation, and it is the team's task to identify and refine their problem.

Design strategies – ways to go about the design task

A design strategy does not necessarily begin with an analysis of need and problem, followed by a search for solutions. Cross and Dorst [3], [4] emphasise the co-evolution of problem and solution spaces towards a matching pair. Kruger & Cross [11] report a protocol study of nine

experienced designers performing a task individually in a laboratory setting. The experiments were conducted as 'think–aloud' studies, and the sessions were videotaped. Kruger & Cross use the protocols to identify four cognitive strategies, which they characterise as follows:

1. Problem driven design. The designer pays attention to careful reading the design assignment. The designer's focus is on understanding and defining the given problem.
2. Solution driven design. The designer quickly scans the assignment for basic requirements. The design problem remains ill defined, and on this basis the designer generates solutions.
3. Information driven design. The designer spends a lot of time reading the assignment and gathering information. The strategy while reading the design assignment is to look for pointers to other information sources.
4. Knowledge driven design. The designer carefully reads the design assignment, and compares it to his knowledge about similar problems. New aspects are explored through gathering information.

The cognitive strategies identified reflect an individual designer's way of working. Now, let us change focus from an individual to a design team, and let us assume that a team can be either information or knowledge driven. If the design team is information driven we can ask: what can the team gather information about? The team can gather information about the design paradox, or about technological possibilities and existing solutions. With respect to being knowledge driven a team can work based on its knowledge about similar paradoxes or the team can begin generating solutions. By this argument we unfold two dimensions in determining a design strategy: an information-knowledge axis, and a paradox-solution axis, see figure 2. The two dimensions articulate, as shown in figure 2, four different overall design strategies. Within an overall design strategy a team can choose between several design methods and approaches depending which methods the team is familiar with and find suitable in the current situation.

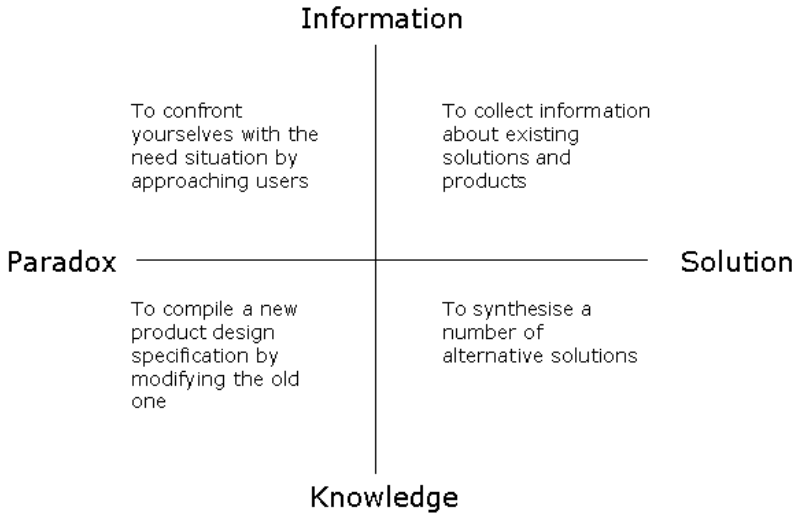

Figure 2. Two dimensions for the design team to consider when deciding upon an appropriate design strategy, i.e. how shall we go about the design task?

If we as an example look upon a case where a design team has decided to work information-paradox oriented, i.e. to gather information in order to claify and refine the paradox, we can propose at least three different approaches within the chosen overall strategy:

1. Anlysis of a need. Thomas [12] states that there exist seven aspects of a need: four aspects relate to the *shape* of the need, and three relate to the *temporal* aspects. Thus, an analysis of a need can be based on exploring the seven aspects: subject of need, newness of need, complexity, clarity, frequency, duration, and urgency of need, Thomas [12].

2. Collecting information based on a socio-technical approach, Bijker [13] and Latour [14]. The team identifies a relevant actor-network and collects information from the actors. For human actors, e.g. the authorities, interest groups, and users, information collection can be based on observations of actors in action and interviews. For non-humans actors, e.g. legislative requirements or public opinion on relavant issues, information collection can be carried out by a discourse analysis of documents and newspaper articles.
3. Playing design games, Brandt & Messeter [15]. Brandt & Messeter write, "*The overall aim with our design games is to provide multiple stakeholders with means for developing, negotiating and expressing a shared understanding of users, use contexts and technology as part of concept design activities.*", and they propose four design games: the user, the landscape, the technology, and the scenario game. Playing the design games in a dialogue with relevant stakeholders will illuminate and prioritise conflicting discourses based on the stakeholders' perspectives.

The role of the problem formulation

For a design team a shared understanding of the problem is important. However, according to Dorst's model a design problem is not an objective and static entity, and the question is: what is the role of the problem formulation? The problems formulation must be seen as an initial articulation of a design problem, and we observe two functions of the problem formulation:

1. The problem formulation has to ensure that the design team and the client agree upon what kind of solution has to be conceived, Dym & Little [6].
2. The problem formulation has to establish a shared understanding within the design team in order to motivate teamwork and to join forces in exploring the problem and in synthesising an attractive solution within the given time and resource limits.

However, since we understand the design problem as an entity, which is developed during the project, the design *team's process of writing* the problem formulation can be seen as a third function of the problem formulation:

3. The problem formulation has to work as *a sensitising device*, i.e. it has to raise the awareness and sensitivity of the design team members with respect to the design paradox, the properties of an attractive solution, and the approach to carry through the project.

Thus, the process of *writing and rewriting* the problem formulation is a tool for the team members to agree upon the core of the problem, the goal, and the approach as these elements gradually develops as a result of the team's considerations and clarifications. For a problem formulation to fulfil the three functions outlined we propose that it shall contain:

1. An articulation of the perceived design paradox. What is the background and the design team's motivation?
2. The chosen design perspective. What will the design team create, e.g. a better product performance, a better workspace for the users or an environmental friendly solution?
3. The goal to obtain. What characterises the attractive solution? What type of solution is anticipated? What will the solution do for the stakeholders?
4. The chosen design strategy. How to go about the task? Is the team aware of any critical issues, which have to be clarified? Which subtasks have to be carried out first?

We believe that such a multifaceted problem formulation will be an invaluable tool for the team in order to agree upon the task, the solution's raison d´être, and key goal statements.

4 Conclusion

In this paper we have described two understandings of designing. Comparing these two understandings has given us new and valuable insights into the nature of design problems; a design problems is an entity, which is developed during the project, and the design team taking up a design problem influences and makes the problem based on the members' experiences and understandings of which discourses are relevant to take into account.

We combine Dorst's new model of design problems with existing concepts and design methods, and the result is an unfolding of design problems in different types and an unfolding of design strategies in two dimensions. We have by examples shown that within an overall information-paradox oriented strategy there exist at least three ways to go about a problem.

The authors believe that our contribution contains an interesting supplement to Dorst's new model of design problems, and that our contribution will be productive to designers working in industrial practice and to the teaching in this area.

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