Design methodology and the nature of technical artefacts

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Design methodology aims at the improvement of design processes. In contrast to the methodology of science, it is strongly process oriented and takes a normative point of view. The paper argues that, despite its process orientation, design methodology cannot avoid addressing questions concerning the nature of the products being designed for two reasons. The first is that the design process and the design product are so intimately related to each other that an understanding of the nature of the design process requires insight into the nature of the kind of product designed, and vice versa. Second, in order to justify its normative stance towards design processes, design methodology will have to consider the issue of the quality of the product being designed. To support these claims, the nature of technical artefacts, considered to be the outcome of a design process, will be examined. It will be argued that they have a dual nature: they are physical objects on the one hand, and intentional objects on the other. Some of the consequences of this dual nature of technical artefacts for the research agenda of design methodology will be explored.

Keywords: design methodology, philosophy of design, design process, design studies, human factors

The aim of design methodology is to improve design processes; this means that it takes a normative stance towards its object of study. Given this aim it is no surprise that research in design methodology has always had a strong focus on the nature of design processes. The study of the nature of technical artefacts, considered to be the outcome of a design process, has received little attention. For several reasons, however, including its normative standpoint, design methodology cannot avoid a closer analysis of the nature of technical artefacts. Here, an interpretation of technical artefacts in terms of a dual nature—which refers to the fact

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that they are physical and intentional objects at the same time—is offered and it is argued that this interpretation has far-reaching consequences for the research agenda of design methodology. The paper starts with a comparison of design methodology with the methodology of science. This is followed by an exposition of the dual nature of technical artefacts. Finally, some consequences of this interpretation of technical artefacts for the research agenda of design methodology are discussed.

1 Design methodology versus methodology of science

There are two striking differences in orientation between methodological studies of technical design and of scientific research. Design methodology takes a normative stance towards design and is very much process oriented, whereas research methodology is descriptive and strongly product oriented. We will first have a closer look at these differences.

Methodological studies of science, as part of the broader discipline of the philosophy of science, typically concentrate on the outcomes of scientific research processes, such as empirical claims, laws, theories and explanations, and focus on questions about the interpretation of these products and their reliability (or truth). This product orientation in the methodology of science is related to the classic logical positivist's distinction between the context of discovery (how are phenomena, laws, theories, etc., discovered?) and the context of justification (how are phenomena, laws, theories, etc., justified?) and their highly influential idea that there is no 'logic' of scientific discovery. In so far as logical positivists were process oriented, they were interested in a very special kind of process, namely a 'rational reconstruction of science', that is according to Carnap[1] 'a schematised description of an imaginary procedure, consisting of rationally prescribed steps, which would lead to essentially the same results as the actual […] process' (p. 16). The real research process, as it was actually performed, was only of minor interest to them or of no interest at all. Admittedly, there has been an empirical turn in the philosophy of science since the work of Kuhn, but although this turn has led to more interest in actual research processes, particularly in experiments, the underlying issues remain, as before, issues about the interpretation and justification of scientific knowledge claims. Moreover, mainstream methodology of science is not driven by the aim to improve the practice of scientific research. It is mainly a descriptive activity.

Design methodology, characterised by one of its leading figures, Nigel Cross, as 'the study of principles, practices and procedures of design' (see note 1), aims at improving design practice and is strongly process oriented.

1 **Carnap, R** 'Intellectual autobiography' in **P A Schilpp** (ed.) *The philosophy of Rudolf Carnap*, Open Court, La Salle, IL (1963)
2 **Dorst, K** 'Describing design; a comparison of paradigms' PhD thesis, Delft University of Technology, The Netherlands, 1997
3 **Love, T** 'Philosophy of design: a meta-theoretical structure for design theory' *Design Studies* Vol 21 (2000) 293–313

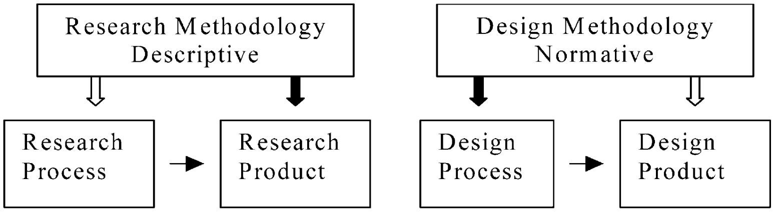

Figure 1 Differences in focus between research methodology and design methodology

According to Cross's history of design methodology, the founding fathers of this discipline had a strong normative attitude: design methodology should contribute to the improvement of design practice, particularly by exploiting scientific methods[4]. Cross's history also illustrates the strong process orientation of design methodology. He mentions five categories of recent work in this field, four of which are explicitly process (activity) oriented (namely, the development of design methods, the management of design process, the nature of design activity and the philosophy of design method which deals with the philosophical analysis and reflection on design activity); only the work which he classifies under the heading 'the nature of design problems' is not process oriented.

A look at the broader field of design research indeed confirms the strong bent towards processes and activities in this field. According to Dorst, two paradigms within design research can be distinguished, design as rational problem solving and design as reflective practice, and both are process oriented[2]. Schön's theory about the reflective practitioner, which has attracted much attention in recent years within design research, approaches design as a reflective process[5]. Bucciarelli's work, also well known within this field, analyses design as an essentially social process[6]. Finally, a quick scan of the contents of volumes 16 (1995) through 22 (2001) of one of the leading journals in this field, *Design Studies*, confirms the strong process orientation. The topics addressed typically concern: (creativity in) design thinking, design education, design effort, conceptual design as a process, design progress, communication of design knowledge, managing design information, the role of computers in design, design as a cognitive activity, decision making in design, etc. This journal explicitly presents itself as a forum for the discussion and development of the theoretical aspects of design, including its methodology and values, but almost without exception the methodological contributions concern the actual methods and techniques used in solving design tasks, not the methods and techniques used in justifying the outcome of a design process (see note 2).

So, there are two differences between design methodology and research methodology: the former takes a normative stance and is process oriented, the latter is descriptive and product oriented (see Figure 1). Compared to

4 **Cross, N A** 'History of design methodology' in **M J De Vries, N Cross and D P Grant** (eds) *Design methodology and relationships with science*, Kluwer Academic Publishers, Dordrecht (1993) pp 15–27
5 **Schön, D** *The reflective practitioner; how professionals think in action* Ashgate, Aldershot (1991)
6 **Bucciarelli, L L** *Designing engineers* The MIT Press, Cambridge, MA (1994)
7 **Galle, P** 'Design rationalization and the logic of design: a case study' *Design Studies* Vol 17 No 3 (1996) 253–275

research methodology, design methodology is interested in a rather different kind of 'rational reconstruction', namely in a schematised description of real (not imaginary) design procedures, consisting of rationally prescribed steps, which should lead to essentially better (not the same) results compared with existing design procedures. Not surprisingly, therefore, design methodology has resulted in a variety of schemes for dividing the design process into various phases, varying from the very simple analysis–synthesis–evaluation scheme to, for instance, the rather detailed and elaborate scheme proposed by the Verein Deutscher Ingenieure (VDI)[8].

Because of these differences, design methodology and methodology of science bear little resemblance to each other. It is even confusing to call both 'methodology' because that suggests that they address similar kinds of questions for design and research. That is not in fact the case. Suppose we were to construe a field called 'design methodology' analogous to the field called 'methodology of science'. Then it would have to deal with the following kinds of questions, some of which will surface again later on (see note 3).

- What is a design?
- What makes a design a good or a successful design?
- What are the proper criteria for evaluating proposed solutions for a given design problem?
- Is it possible to characterise in a general (logical?) way notions such as the effectiveness and efficiency of design solutions?
- How can a proposed solution for a design problem be rationally justified?
- How can design decisions with regard to trade-offs between conflicting design specifications be rationally justified?

Shifting attention from design solutions to design methods, the following questions crop up.

- Does the correct application of design methods guarantee a successful outcome or make a successful outcome probable to a certain degree?
- If so, is there a 'logic of design methods', that is, can we understand this property of design methods from a logical (analytical) point of view?

Furthermore, a technological design (ideally) contains an explanation of how a given physical (chemical, biological) device realises a certain function.

- How is such a technological explanation, i.e. an explanation of a function in terms of a physical (chemical, etc.) structure, possible?

8 **Verein Deutscher Ingenieure (VDI)** *Systematic approach to the design of technical systems and products: Guideline VDI 2221* Beuth Verlag, Berlin (1987)

9 **Kroes P** 'Engineering design and the empirical turn in the philosophy of technology' in **P Kroes and A Meijers** (eds) *The empirical turn in the philosophy of technology* (C Mitcham (series ed)) *Research in philosophy and technology* Vol 20, JAI/Elsevier, Amsterdam (2000) 19–43

10 **Simon, H A** *The sciences of the artificial*, 3rd edn The MIT Press, Cambridge, MA (1996)

11 **Kroes, P A** 'Technical functions as dispositions: a critical assessment' *Technè* Vol 5 No 3 (2001) 16

12 **Losonsky, M** 'The nature of artifacts' *Philosophy* Vol 65 (1990) 81–88

- What kind of adequacy conditions apply to technological explanations?

These questions concern either the justification of the outcome of the design process or a rational reconstruction of the design process in the Carnapian sense (i.e. in terms of imaginary steps and procedures).

Design methodology, as it has been practised up till now, has largely neglected these questions. Because it aims at the improvement of design practice, it has focused mainly on the design process. By analysing in detail the nature of this process, it tries to rationally reconstruct it in the sense described earlier. In my opinion, however, design methodology will have to address some of the issues described above for at least two reasons. The first is that the design process and the design product are so intimately related to each other that an understanding of the nature of the design process requires insight into the nature of the product designed and vice versa. Consider the design of various kinds of artefacts, e.g. the steering wheel of a car, an air bag, a car, a car transport system, a police system, a law on traffic regulations. Roughly speaking, these artefacts may be ordered on an axis ranging from technical objects through socio-technical objects to social objects. It is a matter of fact that the design processes which lie at the basis of these various kinds of artefacts differ strongly. It seems implausible that it will be possible to construct a domain-independent theory about design processes, which will cover all these cases (see note 4). An analysis of the design process of technical artefacts should therefore take into account the specific nature of those objects (see note 5). Second, the normative stance taken by design methodology towards the design process implies that it cannot escape questions concerning the quality of the outcome of that process. Since that outcome is the design of a technical artefact, it has to address some of the questions listed above about criteria for success of a design. So, let us now turn to a closer analysis of the nature of technical artefacts.

2 *The dual nature of technical artefacts*

According to the view defended below, technical artefacts have a dual nature: on the one hand they are physical objects (man-made constructions) that may be used to perform a certain function, on the other hand they are intentional objects since it is the function of a technical artefact that distinguishes it from physical (natural) objects and this function has meaning only within a context of intentional human action. Before presenting this dual nature view of technical artefacts, I will briefly discuss Herbert Simon's theory on artificial things as exposed in his classic *The sciences of the artificial*[10] (in the following text, page numbers refer to this book). This theory proves to be a useful stepping stone to the dual nature view.

For Simon, the science of the artificial will closely resemble the science of engineering because engineering deals with the synthesis of things. In contrast to the scientist, the engineer and more in particular the designer are ‘concerned with how things *ought* to be—how they ought to be in order to *attain goals*, and to *function*’ (pp. 4–5). One of the striking features of (technical) artefacts is precisely that they can be characterised in terms of functions and goals. Functions and goals are analysed by Simon in the following way (p. 5):

> Let us look a little more closely at the functional or purposeful aspect of artificial things. Fulfilment of purpose or adaptation to a goal involves a relation among three terms: the purpose or goal, the character of the artifact, and the environment in which the artifact performs.

For instance, the purpose of a clock is to tell time and the character of the clock refers to its physical make-up (gears, springs, etc., for a mechanical clock). Finally, the environment is important because not every kind of clock is useful in every environment; sundials can only perform their function in sunny climates. Simon’s analysis of artefacts is represented in a schematic way in Figure 2 (see note 6).

According to Simon, the environment of an artefact is very important because it moulds the artefact. He considers the artefact to be a kind of ‘interface’ between ‘an “inner” environment, the substance and organisation of the artifact itself, and an “outer” environment, the surroundings in which it operates’ (p. 6). The inner environment of the artefact, its character, is shaped in such a way that it realises the goals set in the outer environment (p. 10). Therefore, the science of the artificial has to focus on this interface, since the ‘artificial world is centered precisely on this interface between the inner and outer environments; it is concerned with attaining goals by adapting the former to the latter’ (p. 113).

Simon’s distinction between inner and outer environment points to two different ways of looking at technical artefacts. Looked at from the outer environment, the technical artefact presents itself primarily as something, whatever its inner environment, that fulfils a certain goal, purpose or function. From this perspective the artefact is characterised primarily in a functional way; the inner environment remains a black box. Looked at from the inner environment, the artefact is described as some kind of physical system; from this perspective, the goal that it fulfils in the environment remains a black box (see note 7). As Simon remarks (p. 7) ‘*Given* an airplane, or *given* a bird, we can analyze them by the methods of natural science without any particular attention to purpose or adaptation, without

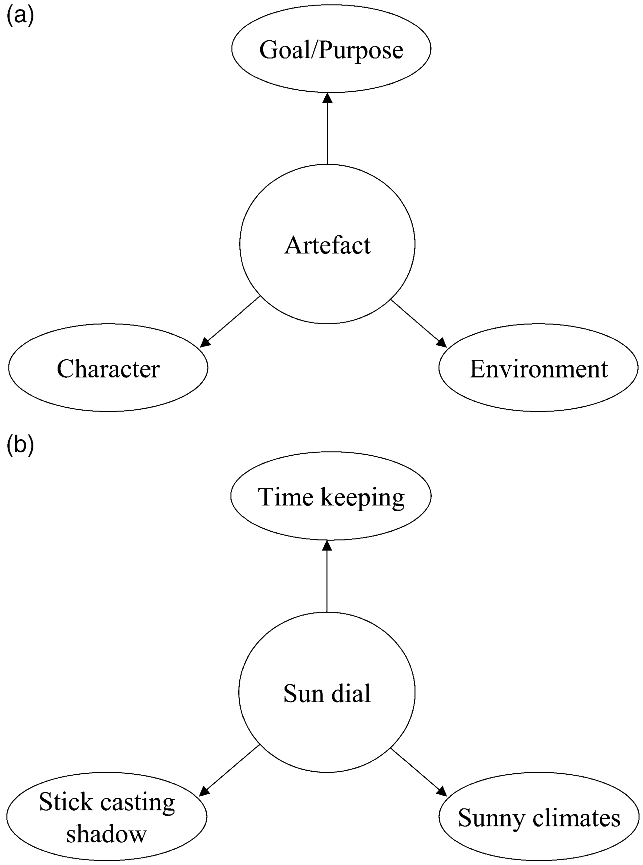

Figure 2 Schematic representation of Simon's analysis of artefacts with an example

reference to the interface between what I have called the inner and outer environments.' These two different ways of characterising an artefact, in terms of its inner and outer environment, correspond closely to what we call the dual nature of technical artefacts.

The view that technical artefacts have a dual nature finds its origin in the observation that we employ in our thinking, speaking and doing two basic conceptualisations of the world, and that we do not know how to integrate these two together into one coherent conceptualisation (see note 8). On the one hand, we see the world as consisting of physical objects interacting through causal connections. This will be called the 'physical' or 'structural' conceptualisation which is employed and developed by the physical sciences. On the other hand, we see the world as consisting partly of agents (primarily human beings), who intentionally represent the world and act intentionally in it, and whose behaviour is explained partly in terms of reasons (and not causes). This is the 'intentional' conceptualisation of the world which underlies most of the social sciences. One aspect of this latter conceptualisation is that certain activities are interpreted in terms of realisations of goals and that functions are attributed to certain objects or activities. The existence of these two different conceptualisations poses a problem in cases where both offer competing explanations for the same kind of phenomenon, e.g. for raising a hand to vote in a meeting: one in terms of physiological causes, the other in terms of reasons. This is the well-known mind–body problem.

The question that concerns us is how technical artefacts fit into these two conceptualisations of the world. Our starting point for exploring this issue will be the following characterisation of technical artefacts: *technical artefacts are objects with a technical function and with a physical structure consciously designed, produced and used by humans to realise its function* (see note 9). In short, a technical artefact is a physical object with a technical function. This characterisation of a technical artefact makes it a hybrid kind of object which does not fit in either the physical or the intentional conceptualisation. Looked upon as merely physical objects, technical artefacts fit into the physical conceptualisation of the world; the way the artefact works can be explained in terms of causal processes. But as a mere physical object, it is not a technical artefact. Without its function, the object loses its status as a technical artefact. This means that technical artefacts cannot be described exhaustively within the physical conceptualisation, since it has no place for its functional features. But neither can it be described exhaustively within the intentional conceptualisation since its functionality must be realised through an appropriate physical structure and the intentional conceptualisation has no place for the physical features of a technical artefact (see note 10). Hence the conclusion that technical artefacts have a dual nature: on the one hand they are physical, on the other intentional objects.

According to the above line of thought, the notion of technical artefact is related to three key notions, namely the notion of a physical structure, of a (technical) function and of a context of intentional human action (see Figure 3 and note 11).

The inclusion of the context of human action into our analysis of artefacts needs some clarification, since we have characterised technical artefacts earlier as physical objects with technical functions. I have included the context of human action because it makes no sense to speak about technical functions without reference to a context of human action. As remarked earlier, functional discourse is part of the intentional conceptualisation of the world; it is meaningless to speak about technical functions without a

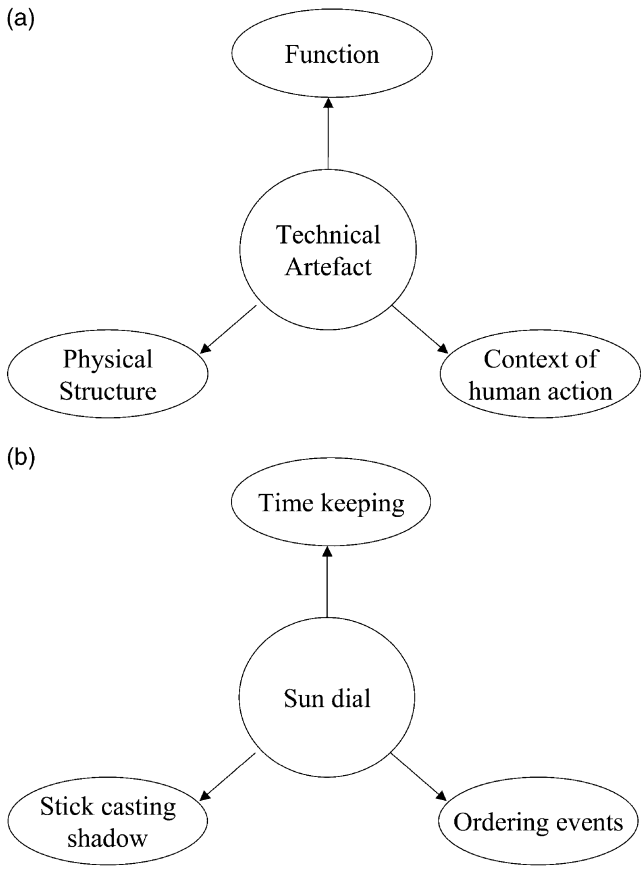

Figure 3 The dual nature of technical artefacts with an example

context of intentional (human) action. This can be expressed in an ontological way by saying that some context of human action is constitutive for a technical function. This is in line with Searle's claim that technical functions are attributed, in or with regard to some context of human action, to objects; they are not intrinsic properties of those objects[13]. In his analysis of the relational ontology of technical artefacts, Meijers[14] also claims that human action is constitutive for functions: 'A central part of my argument focuses on functions and functional properties. These are realised by the physical structure of the artifact together with the practice of its design and use' (p. 81). Thus, in Figure 3 function and context of human action are intimately connected; they both belong to the domain of the intentional. Technical artefacts have a dual nature since they are at the same time part of the domain of the physical and of the intentional.

There are some notable differences between our analysis of technical artefacts and Simon's. Simon's notion of goal or purpose has been replaced

13 **Searle, J R** *The construction of social reality* Penguin Books, London (1995)
14 **Meijers, A W M** 'The relational ontology of technical artefact' in **P Kroes and A Meijers** (eds) *The empirical turn in the philosophy of technology* (C Mitcham (series ed)), *Research in philosophy and technology* Vol 20 (2000) 81–96

by the notion of function. This may seem an insignificant move but it is not, because we may attribute functions to technical artefacts but not goals (in the sense of an aim or an end (telos)). That notion has its place in a context of intentional human action; within such a context a means used to achieve a goal (end, aim) is attributed a function. Thus, Simon's analysis implicitly refers to a context of human action by referring to goals and purposes. Furthermore, the notion of environment has been replaced by the notion of context of human action. It could be argued that this is also a minor change, because one form of environment is a context of human action. Simon's claim that the artefact has to adapt to its environment then reduces to the, rather obvious, claim that the artefact has to adapt to the context of human action in which it is used. Nevertheless, this is a noticeable change because it brings out the fact that not any kind of environment is relevant for the analysis of technical artefacts; only references to environments comprising a context of human action are appropriate. In his example of the sundial, for instance, Simon interprets the environment in a physical way (sunny climates are the required environment for sundials). But this is problematic. It is not this physical environment that turns the object involved, a stick that casts a shadow on a surface, into an artefact of the type sundial. Only within the context of human action (e.g. of ordering events or comparing time intervals) does this physical object acquire a function and become a technical artefact (a time-keeping device or clock).

The main difference between Simon's analysis and ours is that the latter gives a much more prominent and explicit place to a context of human action in analysing the nature of technical artefacts. The advantage of this is that it brings much more into the open the dual nature of technical artefacts: we cannot make sense of technical artefacts without taking into consideration their physical structure, but also not without their context of intentional human action. Within Simon's analysis this dual nature stays more implicit and is related to the two different perspectives on technical artefacts, namely the perspective of the inner environment (physical structure) and the perspective of the outer environment (context of human action).

Note that the above characterisation of a technical artefact involves processes in an essential way: without some context of human action (activity, processes) the notion of function loses its meaning, and what is left of a technical artefact without its function is just some physical object. In order to arrive at a better understanding of how the design process is involved in characterising a technical artefact, we have to take a closer look at what we have called 'context of human action'. This is a very general and rather vague term. With regard to technical artefacts, at least two significant kinds of context of human action can be distinguished, namely the design context and the user context (see Figure 4 and note 12).

In these two contexts the technical artefact manifests itself in different ways. In the design context, the main emphasis lies on how to construct a physical system (object) that realises a certain function. This function is often described in terms of a list of specifications which the object to be designed must meet. Here we encounter what Simon calls the 'inner environment' of a technical artefact. In the context of use, the 'outer environment' presents itself. There, the function of the artefact in relation to the realisation of goals (ends) is of prime importance and the physical constitution of the technical artefact becomes of secondary importance. Note, however, that in the context of design as well as in the context of use, the technical artefact has a dual nature: within the design context it is not only a physical structure, just as it is not only a function in the context of use.

In many cases, there is no continuity between a context of design and a context of use in the sense that the same people who design a technical artefact also use it. This situation creates problems with regard to the communication of functions between designers and users. To what extent is it possible to design a technical artefact so that it will communicate its 'proper' function, i.e. the function it was designed for, to its potential users? Or is it the case that the technical artefact itself plays no intermediary role at all in the communication of its function, which means that this communication has to be established by other means? It is interesting to note that Dipert has worked out a theory of technical artefacts in which it

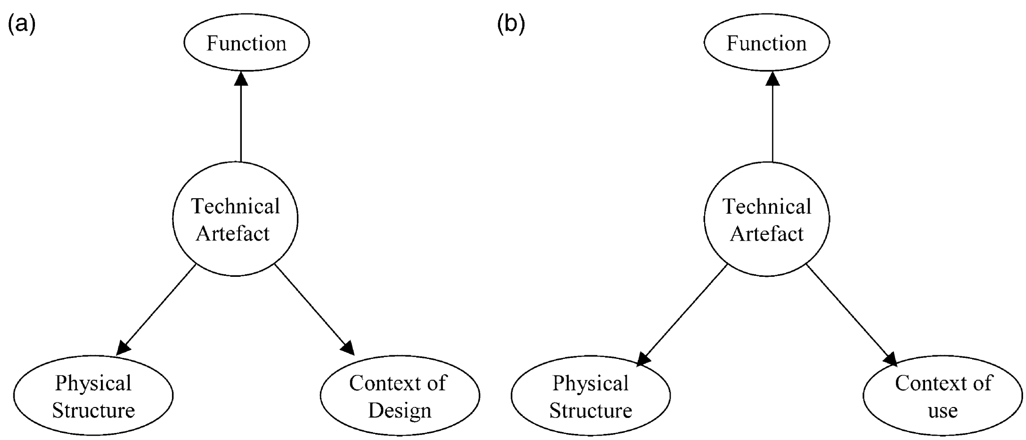

Figure 4 Technical artefacts and their contexts of design and of use

is a defining feature of artefacts that they are explicitly designed to communicate their artefactuality and functionality to their users[15]. This view presupposes that in principle it is possible that an 'artefact itself' communicates its function. However, since the function is not an intrinsic property of the artefact, it is not clear what it is in the 'artefact itself' that is the source for the communication of its function. Part of this problem may be solved by taking into consideration the user manual of a technical artefact. A user manual has at least two functions: it is a means to communicate the intended function to the user and to makes this function accessible to the user by prescribing which actions have to be performed to realise the intended function. If we assume that a user manual is an integral part of the technical artefact, then part of the communication problem can be solved easily by way of the user manual (see note 13). But even in that case the question as to how much of the function of a technical artefact can be communicated without recourse to a user manual is of great importance for design practice. To study this matter, design methodology will have to focus on the nature of a technical artefact, more in particular on the notion of the intended or proper function of an artefact, on the various ways technical artefacts may communicate their function, and what kind of theory of communication this presupposes.

At this point I conclude the exposition of the dual nature of technical artefacts. In the next section, I will explore some of the consequences of this interpretation of the nature of technical artefacts for the agenda setting of design methodology, particularly from the point of view of the relationship between the design process and the design product.

3 Discussion: consequences for the research agenda of design methodology

Our analysis of technical artefacts as having a dual nature of itself leads to a question that is of crucial importance for understanding the nature of design processes and therefore deserves a prominent place on the research agenda of design methodology. This question is: How can we account for the fact that designers are able to bridge the gap between a functional and a structural description of a technical artefact? That they are able to bridge this gap stands without question. But from a philosophical point of view, we are dealing here with two different conceptualisations of an artefact. It is not clear how these two are related to each other and how it is possible to go from one conceptualisation to the other. Schematically (see Figure 5), a design process may be characterised as starting with a functional description of the desired artefact; this may be considered to be the input of a design process. This functional description is a black box description with regard to the physical structure of the technical artefact. It is precisely

15 **Dipert, R R** *Artifacts, art works and agency* Temple, Philadelphia (1993)

16 **Kroes, P A** 'Technological explanations: the relation between structure and function of technological objects' *Technè* Vol 3 No 3 (1998) http://scholar.lib.edu/ejournals/SPT/v3n3/html/KROES.html

17 **Rosenman, M A and Gero, J S** 'Purpose and function in design: from the socio-cultural to the techno-physical' *Design Studies* Vol 19 (1998)

18 **Kroes, P A** 'Reflections on technological design as art' *Integrated Design and Process Technology* Vol IDPT-3 (1998) 104–109

Figure 5 The design process and the gap between functional and structural descriptions

the task of the designer to fill this black box with a physical structure such that this structure will realise the intended function. The output of a design process, therefore, is a description of a physical structure which adequately performs the function, that is, with a design of the technical artefact (which may be taken to include the user manual).

Given this interpretation of the design process, two observations may be made. First, designers manage to bridge the gap between functional and structural descriptions of artefacts in a systematic way; they use all kinds of design methods to help them solve their design problems. Second, they are in most cases able to explain why a proposed design will adequately fulfil its function. From the point of view of the dual nature of technical artefacts, these observations raise the following questions:

- What kind of design methods are used by designers to bridge the gap between the two modes of describing technical artefacts?
- How are we to interpret the role of these design methods in bridging the gap between the two conceptualisations of the artefact. In other words, can we provide a rational account of the use of these design methods, showing why their use is successful, given the conceptual gap?
- How do designers explain the function of an artefact in terms of its structure?
- How can a function be explained in terms of a physical structure, given the conceptual gap between the two kinds of descriptions involved (see note 14)?

In order to answer these questions much empirical and conceptual work still remains to be done. But given the aim of design methodology to improve design practice, it cannot avoid addressing these questions: without clarification of these issues an adequate understanding of the nature of the design of technical artefacts is, to say the least, problematic (see note 15).

The final topic that I would like to draw attention to concerns the quality of a design, in particular the notion of a successful design. It is self-evident that design methodology has to establish some criteria for the quality, the success and the failure of design processes if we are to take its normative stance towards design processes seriously. Otherwise, the notion of an improvement of a design process loses its meaning. These criteria are also necessary to uphold the idea that designing technical artefacts is partly a rational activity (see note 16). Without some criteria for improvement or progress, the notion of rationality becomes problematic.

So, what are the criteria for quality on the basis of which design processes may be evaluated? In line with their process orientation, design methodologists seem to have approached this problem primarily from the point of view of the organisation and management of design processes. There are many prescriptive phase diagrams of how to split up the overall design process into various parts. The suggestion is implied, explicitly or implicitly, that following these diagrams will lead to or at least contribute to the quality (success) of the design process. Thus, implementing adequately the prescriptive phase diagram becomes a criterion for success. Without an assumption of this kind, the rationale behind these diagrams becomes problematic. This may be part of the answer, but it is highly questionable whether it addresses the real issues involved. It is not difficult to imagine, and probably has often actually been the case, that a design process follows painstakingly all the required procedures and nevertheless its outcome is deemed a failure by the people involved. In such cases, the design process has to be considered a success, whereas its outcome is a failure (the proverbial successful operation with a dead patient). Conversely, a badly organised and poorly managed design process may lead to an excellent design.

The relationship between the quality of a design process and the quality of its outcome does not seem to be straightforward. Abiding by the rules of procedural rationality is not a sufficient criterion for success (neither does it seem to be a necessary criterion). More is involved, namely the criteria in terms of which the outcome of a design process is evaluated. So, we arrive at the question: What is a good or successful design? That itself is a complicated issue and it is doubtful that there is one set of criteria that is universally valid in every context. In our analysis of technical artefacts we have distinguished so far two different contexts of human action, namely the design context and the use context. It is not at all self-evident that the same criteria for quality apply in both contexts. Within a design context, a general criterion for success may be that a proposed design meets all the specifications and constraints. A particular design that satisfies this criterion may nevertheless be considered a failure in the context of use because it does not meet the expectations or satisfy the needs of the users; the latter will be their criterion of success. This situation may be due to, for instance, poor communication between designers and users about the desired functionality. But even if we assume that the communication about needs and functions is flawless, then it is nevertheless doubtful whether the community of designers applies the same criteria of quality as the community of users. For instance, the introduction of an ‘engineering change’, i.e. a change in the physical make-up of an artefact that does not affect in any way its technical function, may considerably improve the quality of a design judged in the context of design, whereas in the context of use its quality remains the same.

Apart from the context of design and the context of use, technical artefacts figure in many other contexts of human action, such as the context of production, context of maintenance, context of consumer markets, etc. Each of these contexts has its own criteria for quality and success which may be relevant to the way the quality of the design of the artefact is evaluated. Aesthetic criteria pose a problem of their own in evaluating the quality of a design because it is a problem to find objective standards for these criteria (see note 17). Moreover, the importance of these criteria varies strongly over different engineering domains (for instance, in many areas of electrical and mechanical engineering they are almost irrelevant, whereas in architecture they are important). There is but one conclusion to be drawn from the foregoing, namely that a clear insight into the notion of the quality (success) of a design or a design process is lacking.

Given this conclusion, it is rather remarkable that, although design methodology professes to aim at improving design processes, it has, to my knowledge, not addressed these issues systematically. Either the success of a design process depends wholly or in part on the success of the outcome of this process, in which case it appears rather obvious that the above issues about the quality of a design should rank high on the research agenda of design methodology. Or the success of a design process does not depend at all on the success of its outcome, but in that case the rationale for improving the design process, that is, for the aim of design methodology, becomes problematic. Design methodology needs a foundation for its normative point of view on design processes, and it appears plausible that this foundation is partly to be found in criteria for a successful design.

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Notes

1 Quoted in Dorst[2] (p. 8). There seems to be some confusion about what design methodology is about and how it relates to the wider field of design studies[3]. I will not go into this matter; for my puposes, Cross's description is a good starting point.

2 A notable exception is Galle[7].

3 For more details about how design methodology in this sense fits into the broader field known as the philosophy of engineering design, see Kroes[9].

4 This claim does not go undisputed; see for instance, Simon[10], who remarks: 'The intellectual activity that produces material artifacts is no different fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare policy for a state' (p. 111).

5 In the following analysis, I will consider the outcome of a design process to be a technical artefact. Although a design is not yet itself something that justifiably may be called a (full-blooded) technical artefact, it is an integral part of a process that produces a technical artefact. Moreover, the ultimate validation of a design involves the actual making and use of the technical artefact described in the design. Thus, if the design validation phase is taken to be part of the design process, this process implicitly implies the making of the intended technical artefact.

6 The arrows stand for conceptual implication: the notion of an artefact conceptually implies the notion of a character, a goal or pupose, and an environment.

7 For more details about the black box character of functional and physical descriptions of objects, see Kroes[11].

8 Parts of the following are based on the NWO grant application *The dual nature of technical artifacts*, 1999, written jointly by Anthonie Meijers, Maarten Franssen, Pieter Vermaas, Wybo Houkes and the author. For the full text of this application, see http://www.dualnature.tudelft.nl.

9 Of course, all kinds of demarcation problems arise about software or natural objects used for practical purposes. I will leave those problems aside. This characterisation seems to be adequate for technical artefacts which are the result of engineering design and development.

10 This is related to the fact that a functional description is, from a physical point of view, a black box description of an object; in general, a functional description states that something, whatever it may be from a physical point of view, may be used as a means to realise a certain state of affairs.

11 In a more or less similar way, Losonsky analyses the nature of artifacts in terms of the following three features: internal structure, purpose and manner of use[12].

12 For an action–theoretical account of the design and use context, see W. Houkes, P. Vermaas, K. Dorst and M. de Vries, 'Design and use as plans: an action–theoretic account', in this issue of *Design Studies*.

13 'Part of the communication problem', because there is no guarantee that a user will reconstruct from the technical artefact (including its user manual) a function that is identical to the intended function. An argument for including the user manual in the technical artefact is that it strengthens the ties between a technical artefact and a context of action, since the user manual prescribes how the artefact in question has to be used in order to realise its intended function.

14 For a discussion of this issue, see Kroes[16].

15 The fact that designers have to deal with two conceptualisations of the world has not gone unnoticed in design methodology. Rosenman and Gero[17], for instance, explicitly characterise design as involving the 'transition of concepts from the socio-cultural environment to the description of technical objects' (p. 161).

16 The notion of rationality may be interpreted in this context in various ways. It may be taken in the sense that it is possible to provide arguments why certain design decisions will lead to better results than other ones. If we take designing to be a goal-oriented activity, then the notion of rationality as adaptation of means to an end may be applied (means–end–rationality).

17 For a discussion of the role of aesthetic criteria in design and how this role affects the question whether design is an art or a science, see Kroes[18].