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REFLECTIONS ABOUT REFLECTIVE PRACTICE

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1. Objectives

Reflection, as described by Schön [1983, 1987], is an essential characteristic of designing, but only a part of that process. An extensive literature has arisen about reflection and designing, but has so far failed to connect with any systematic and/or methodical view of design processes. In a narrow view, reflection according to Schön mainly involves ‘looking back’, ‘learning from mistakes’, ‘learning from experience’, ‘learning by doing’, and subsequent corrective behavior with respect to the subject of the problem, and with respect to the procedures of solving that problem. Few attempts have been made to specify what questions should be useful during reflection, in general, or in specific design situations.

This paper attempts to bring the concept of reflection into a meaningful relationship to the processes of incubation, intuition, questioning, and others. Further connections to several models of problem-solving and to more complete models of systematic and methodical designing (design processes) are drawn, especially to the theories contained in Design Science [Hubka 1996] and the Theory of Technical Systems [Hubka 1988a]. In this way, we hope to show where and how reflection can be usefully employed during the possible design processes for conceptualizing and embodying a technical system, as an enterprise product with a substantial engineering content.

2. Methods

A review of the literature of education, problem solving, systematic and methodical designing, psychology, and other subjects was undertaken. Some of this work is reflected in publications by the authors of this paper. In particular, Design Science [Hubka 1996] and its associated books [Hubka 1976, 1988a, 1988b, 1992, Eder 1996] contains a comprehensive model of steps that may usefully be taken in systematic and methodical designing of novel technical systems, in re-designing, and in problem solving. Relationships among concepts are explored and evaluated.

3. Results

3.1 Theory, Subject, Method

As G. Klaus [1965] stated in cybernetics, close relationships should exist between any *subject* under consideration (its nature as a concept, phenomenon, product, artifact, or process), any suitable basic *theory* about the subject (formal or informal, formulated or conjectured, as expressed in the human mind in mental models, or recorded in graphical and physical models, verbal explanations, and where possible symbolic/mathematical expressions), and a recommended or envisaged *method* (sequencing of planned actions). The theory should describe and provide a foundation for the behavior of the (natural or artificial, real or process) subject, i.e. it should answer the questions of ‘why,’ ‘when,’ ‘where,’ ‘how’ (with what means), ‘who’ (for whom – customer – and by whom – actor, agent), with adequate and sufficient precision. The theory should also support and allow specification and development of an appropriate utilized methods (or a set of methods), i.e. answer the questions of ‘how’ (procedure), ‘to what’ (subject), both for using and/or operating the subject, and for designing the subject. Then the method should also be sufficiently well adapted to the subject, its ‘what’ (existence), and ‘for what’ (its anticipated and actual purpose). Such questions are well known, e.g. as the “six work study questions”, and the Topoi of Aristotle. These three phenomena are of equivalent status. Quoting Klaus [1965]: *‘Both method and theory emerge from the phenomenon of the subject.’*

If the theory of a subject-region (e.g. engineering practice, engineering science, education, teaching, learning, technical systems, designing, reflecting) is mature, then the method can be founded in the theory. The theory describes reality, the method prescribes how the scientific and practical activity and behavior of the humans should occur – not necessarily as an algorithm (otherwise the procedure could be automated), but more usually as a (heuristic) flexible guideline or prescription for the operator to follow and use in order to improve the chances of achieving the desired transformation in a better, more rational way, and in less time. According to Koen [2003], ‘A heuristic is anything that provides a plausible aid or direction in the solution of a problem but is in the final analysis unjustified, incapable of justification, and potentially fallible.’

Where no comprehensive theory is available, or the theory is only informally expressed in a human mind, methods can still be (pragmatically and heuristically) proposed, even where the structure or behavior of the subjects is not completely known (cybernetic interpretation). The method can be characterized as an input-output-relationship (‘black-box’ principle, first formulated by Ashby in 1956). We know that corresponding results will be generated when we act on a system in a certain fashion. The theory will then (often after a lengthy time delay, allowing for research) give an explanation of why.

3.2 Design Processes

A review of Design Science [Hubka 1996] shows that designing (as a subject) and its theory and methods depend on the degree of abstraction considered (ranging from a most general and comprehensive to a detailed operational view), and has many dimensions. These include:

- types of product, ranging from purely artistic, through industrial design, various hybrids to purely design engineering (e.g. see [Eder 2003]);
- types of information and knowledge, especially about natural and artificial phenomena and objects, and about natural and artificial processes;
- types of information and knowledge about mental (human-internal) structures, and processes and methods, ranging from intuitive to systematic and methodical;
- general design process – operand/operators, hierarchy of tasks performed by them, see figure 1.

The top diagram in figure 1 shows the essential constituents (actors, agents) of a design system for *design engineering*, including the process itself, its technologies, five necessary operators, inputs and outputs, and feedback. At level (1), the design stages for systematic and methodical design engineering are conventionally divided into product planning, clarifying, conceptualizing, embodying, and detailing (as the main means for transmitting information from design engineering to manufacturing), and represent the progressive development and concretization of a technical system (product) during designing – stages of specific object knowledge about solution proposals. The other levels represent (mental and other developmental) processes that can occur during designing, the *modus operandi* of finding solution proposals, and reflect design process knowledge that is available to develop solution proposals. Level (2) shows several examples of design operations, as outlined in [Hubka 1976, 1988b, 1992 and 1996], but these are beyond the scope of this paper. Level (3) illustrates problem solving which is a necessary and repeated set of operations for each of the operations in levels (1) and (2), and will be the subject in the following sections of this paper. Levels (4) and (5) list elementary tasks and operations that are no longer specific to designing.

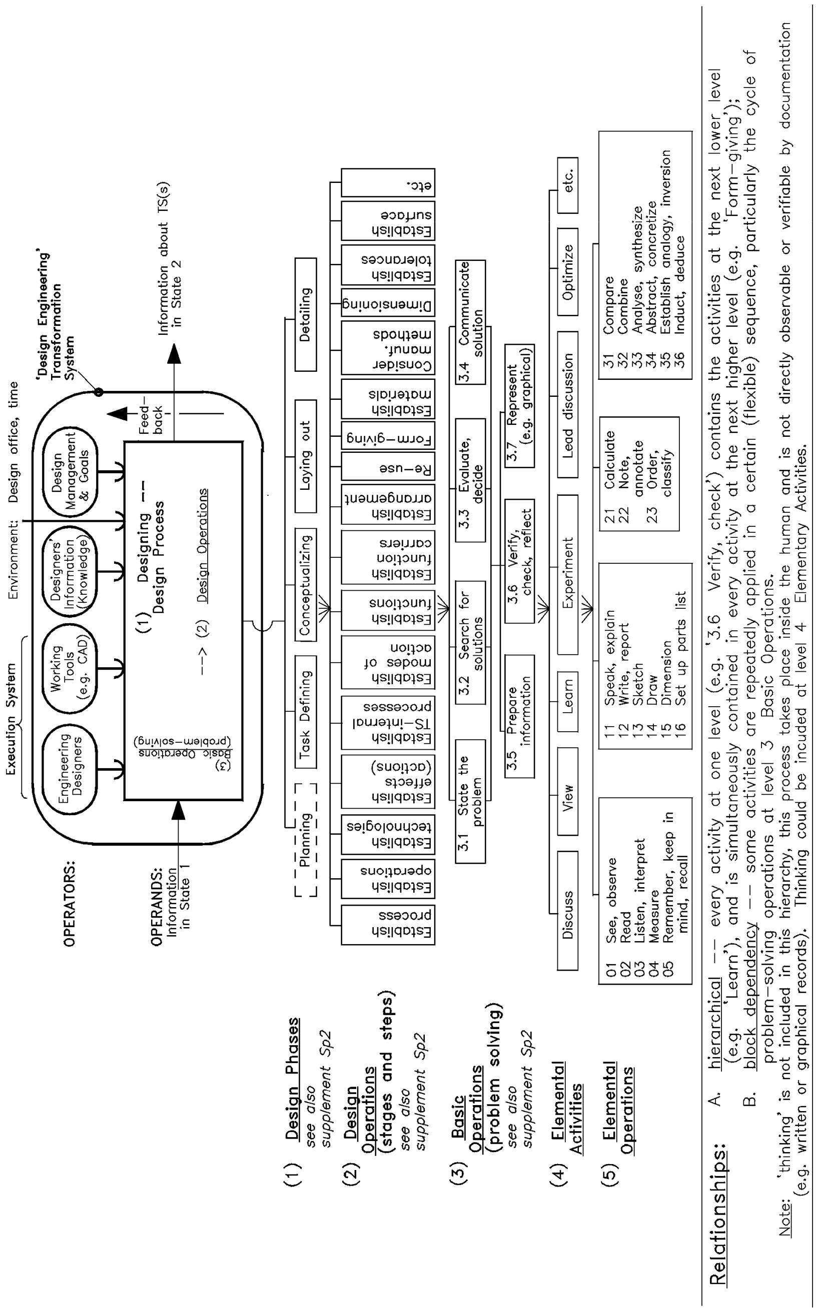

Figure 1. Survey of Hierarchy of Activities in the Design Process

Designers must use design processes and appropriate methods for conceptualizing and embodying the technical system [Hubka 1992] to make the system ready, suitable and preferably optimal for manufacture and its other life-cycle processes. The description of the future technical system must be developed, and a continual check should ensure that the resulting technical system is optimal (not an absolute optimum) for the envisaged usage at the time of designing.

The authors know of no similar division for the more artistic design occupations such as industrial design and architecture. According to the literature, part of *reflection* involves *framing the problem* – which in terms of Design Science [Hubka 1996] implies clarifying the problem, setting up and elaborating a design specification, developing a list of requirements for external properties of a future (technical) system as interpretation of a given (by a sponsor) design brief from designers' viewpoint, taking into account the current design situation. In subsequent design situations (re-designing), reflection involves *reframing* – changing a design specification (with agreement from the sponsor), and/or changing a transformation process, a technology, a function structure, and organ structure,

and/or a constructional structure in response to the insights gained from the analytical processes applied to a proposed candidate solution. The main tasks of artistic designing seem to be studio conceptualizing of a product, and rendering for presentation to decision-making executives of an enterprise.
All such models (including these models of design engineering and artistic designing) can be used as heuristics for actually designing. Even the information and knowledge of the pure sciences (as processed into engineering sciences, and further adapted to design engineering), social sciences and others acts merely as heuristic for designing.

3.3 Problem Solving

The basic operations of problem solving (according to Design Science [Hubka 1996]) are shown in figure 1 at level (3). The first four form an iterative cycle of operations that is repeated many times during designing, usually to increase concretization of solution proposals – 'solving by successive approximations from an appropriate (abstract) starting point' [Koen 2003]. This cycle is not necessarily performed in any strict sequence. The cycle can represent the essential tasks at a very detailed level, but can also be considered as a paradigm for sub-processes, minor design steps (level 2 of figure 1), major design stages (level 1 of figure 1), and overall design processes – and each of these may be identified by a more specific title. This cycle is augmented by a set of three auxiliary operations, which can be called upon at any time.
This model is one of about 80 published in recent years. Three of these ([Wallas 1926], [Wales 1986], and [Woods 1994]) were compared with the Design Science model. Important hints and questions from these models are combined in figure 2, augmented by some heuristics from [Koen 2003], to show a more complete problem solving procedure – level (3) of figure 1.
It is noteworthy that several of these questions and hints refer to operations of checking, verifying, looking back, etc. *Reflection* is a major part of this checking process, it should include appropriate questions with respect to analysis, synthesis, decision-making, and communication, and should include appropriate time delays to allow incubation [Wallas 1926]. As the attention span of humans, and their short-term memory capacity, is limited [Miller 1956a, 1956b, 1956c, 1970], there is a continual need for sketching (graphical, verbal, symbolic) and modeling (graphical, mathematical, physical/appearance, physical/functioning) to externalize a part of the developing design proposals and to interact with them. There is equally a need for team discussions, comments by one participant often trigger mental associations for another.
During designing, especially for non-routine tasks, critical situations can arise [Badke-Schaub 1999, 2001, 2003], where the way is unclear. The need for reflection in these situations may typically arise from: (a) new requirements from customer/sponsor, (b) new recognition of an unanticipated (evoked) function, (c) radical choice among alternatives, (d) recognition that previous work needs to be changed, e.g. because it did not fulfill the promise, (e) change of team leadership and/or membership, etc.
Other competencies (skills and abilities) and attitudes are necessary for design engineering [Pahl 1994, 1996]. In addition to and/or as part of *reflection*, they include abilities of *analysis* – verbal and visual analysis of a problem situation, and engineering-scientific (mathematical) analysis of proposed solutions to explore and/or verify the expected properties of a designed (technical) system. The competencies also include abilities of *synthesis* – to synthesize candidate (alternative) solutions to a problem situation, and to synthesize and apply methods of approach to solving the problems. These two are an aid to the ability for *decision making* – defining the scope of the problem, and deciding on a suitable solution. An ability of *communication* is also needed – communication with ones self (and within the designing group) is essential to generate a 'design intent' and agreed understanding of the problem, but communicating to others (by verbal, graphical, symbolic and mathematical means) is also necessary in order to capture and transmit the 'design intent' and necessary information to implement a proposed solution.
Other pragmatically developed methodologies may need to be augmented by the concept of reflection. Intuitive designers, especially among the more artistic practitioners (e.g. industrial designers), need to be made aware of the benefits of careful reflection, preferably with the help of a theoretical basis of

problem solving strategies and tactics. The usual typical statements from experienced practitioners that "systematic methods destroy creativity" need to be countered by an explanation that the methods (e.g. reflection) must be properly learned and become routine, and performance will usually be improved (another heuristic).

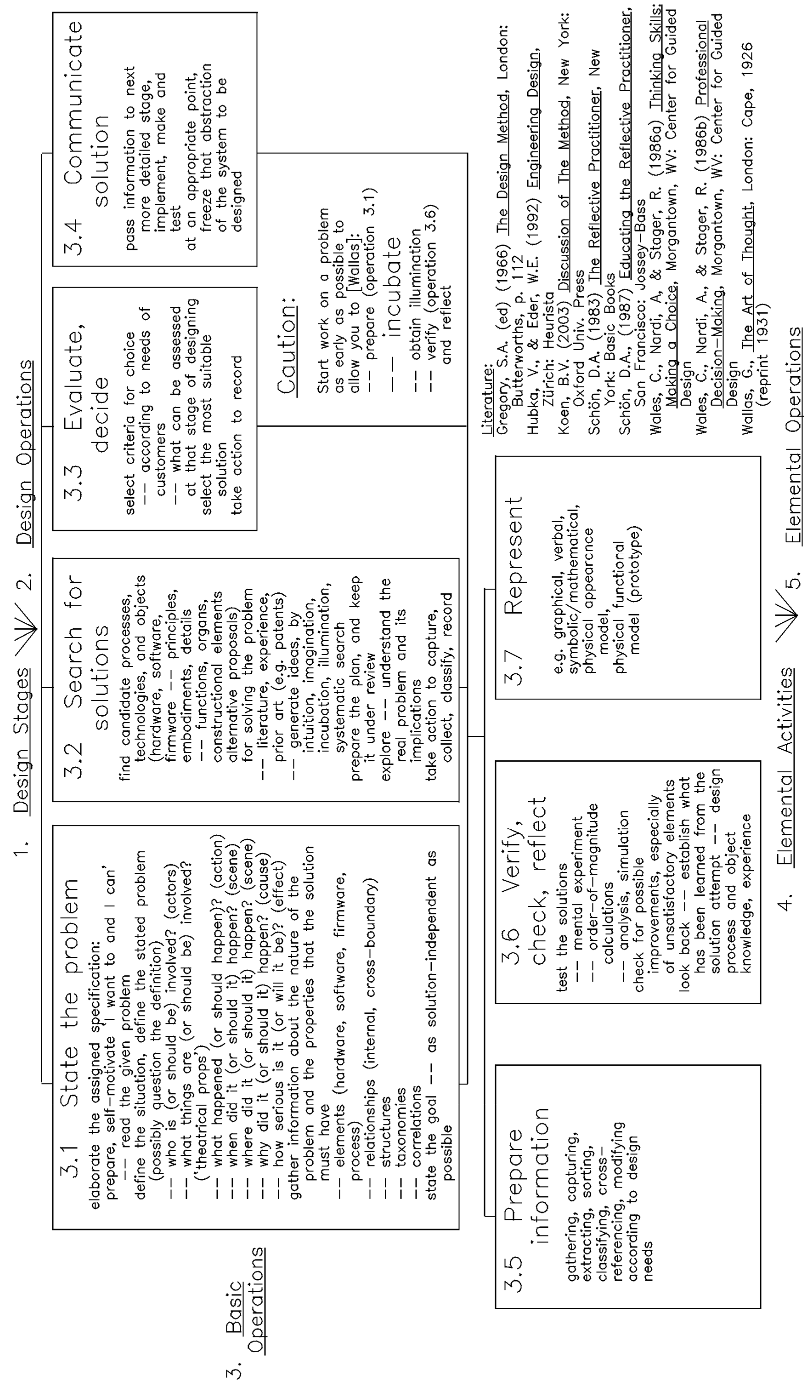

Figure 2. Basic Operations – Problem Solving in the Design Process

4. Closure

An overview is proposed that shows connections among many design operations to reflection. This demonstrates that reflection is an integral part of systematic and methodical designing, especially for methodologies based on Design Science. Other practices need addition and consideration of reflection.

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