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Tools and techniques for product design

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ABSTRACT

For product designers, tools and techniques are essential in driving the design cycle. Nevertheless, their employment usually is implicit, while passing over e.g. the design and project environments empowering their adequate use. This publication presents an overview of approaches in structuring and using tools/techniques, based on the effectuation of creativity and decision-making in the design environment. In elaborating on characteristics of tools/techniques and ensuing ways of selecting them, the designer's portfolio of tools/techniques is characterised. Representative problems of tool/technique usage are depicted and contextualised by illustrating their industrial application. Prospects for future developments are also reviewed.

1. Introduction

In the hands of competent craftsmen, the right tools become powerful resources, which intrinsically seems to reinforce their capabilities and capacities. It more or less becomes an inherent component of their efforts to reach a specific goal. For product designers, a wide variety of working methods, best practices and software packages can fulfil that same role. Given the fact that product designers habitually balance on the verge of arts, crafts and science, while customarily co-operating in teams consisting of designers and representatives from other fields of expertise, they might be rather discerning in identifying the set of implements to draw from. Such instruments, or more specifically tools and techniques, can significantly further design projects and the way in which those projects are executed. In most cases, tools/techniques are deployed best if designers experience them as inherent to their work; i.e. if the tool/technique in itself does not compel attention in its application. The tools/techniques work best if they are 'ready-to-hand' [109] and do not intrude with the craftsmanship of the designer. At the same time, the design environment changes rapidly, as, for example, new tools/techniques emerge, information alters its role [222], virtual or augmented reality comes within reach (e.g. [21]), and also the characteristics of products that enter the market are subject to change (e.g. [141]). In such circumstances, tools/techniques can no longer only be seen as inherent and implicit. They alter into 'present-at-hand' [109]: their implementation and employment calls for attention and interplay of the designer as well as of the company.

Because designers and companies encounter tools/techniques that explicitly manifest themselves, it is purposeful to survey the conditions in which such tools/techniques find employment. Research on this topic is limited [157], although tools/techniques for product design are key with respect to design efficiency [17]. Even more, a lack of employable tools/techniques is, traditionally, already seen as an internal obstacle to the successful introduction of new products [24].

The rationale of this publication is certainly not based on compiling exhaustive lists of tools/techniques, as that would not do justice to the complexities of the design environment, nor would it benefit designers in their work. At the same time, no enumeration can possibly be complete. Moreover, the half-life of any observation on a specific tool is surprisingly short. Consequently, in this publication the focus is on the embedding of tools/techniques in the context of the environment in which they are used.

The structure of this publication is based on the driving impetuses of the design process and on the different functional objectives of product design. Creativity and decision-making are introduced as major components of design projects. They have a major impact on design efficiency, bearing a strong relation to the employment of tools/techniques in the design environment. Given the wide use of the notions tool and technique, definitions are derived that do justice to the design environment, but will not act as straitjackets or fault-finding in describing the role of tools/techniques. With these definitions, the designer's work is dissected to allow for depicting the relation between design activities, product/project typification and the characterisation of tools/techniques. In this, the ever-changing and reactive design environment emphasises the relevance of the many life cycle aspects that play vital roles. As this environment entails much uncertainty and

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ambiguity, their influence on tool/technique employment is illustrated. To contextualise characterisations of tools/techniques, exemplary industrial embedding is described. Based on the overviews given in this publication, future developments will be proposed and commented upon from the application, research and development viewpoints for tools/techniques.

1.1. Scope

Although much of the reasoning in this publication is applicable to a wide variety of product types, the background of the work presented here stems from an environment that aims at engendering discrete, physical products. For example, the reasoning might well be applicable to the (integrated) design of services [166,185,211] or even the processing industry; however, the wording and terminology is geared to and based on design cycles for discrete products. In this, focus is explicitly on the design of these discrete products, rather than on the ensuing engineering tasks covered by product development.

Nevertheless, even for these discrete products, the staggering amount of existing products immediately illustrates that it would be an endless task to group products according to 'classical' product classification methods (e.g. [132,192]). Even more elaborate classification methods (e.g. [251]) are only appropriate for a specific domain of the entire range of products. Consequently, another way to classify products is required. Rather than function, geometry, material, required processes, etc. this typification is based on more abstract properties of products. However, in this case, a relevant set of appropriate properties has to be selected, in order to avoid the hazard of arriving at an infinitely large set. In literature, ample attention has been paid to this problem, with varying results. An important contribution [117] values the mutually independence constraint of the properties of so-called technical systems. A categorisation of properties and a 'model of models' (based on [198]) is used to arrive at the co-ordinate system in the model shown in Fig. 1.

Novelty manifests itself in unconventional ideas, features and conceptual combinations that 'are not obvious from the state of the art', whereas maturity relates to the firmness of a system design. Complexity is interpreted in direct relation to risk of failure. Evolution of systems, in terms of the model, tends towards lower novelty, higher complexity and higher maturity.

Fig. 1b shows an alternative [225] where the evolution of product development is related to the competitive insistence on higher quality, increasing complexity and lower lead times. As the determination of the quality of products in general is rather subjective, this property might be a fragile basis to compare and classify different (types of) products. Moreover, the lead-time probably is more an indication of the production process and its organisation than of a product.

These two deficiencies have been overcome by selecting a different perspective. Reasoning not from the manufacturer, but from the customer, the product can be valued against its direct requirements. This allows for the same approach of independent properties, however, the selection of properties is partially different (see Fig. 1c). The first property is complexity, basically indicating the same property as in Figs. 1a and b, but with emphasis on the complexity pending the entire product life cycle (i.e. during manufacturing, maintenance, repair, recycling, etc.). Based on the different ways in which customer-supplier relationships

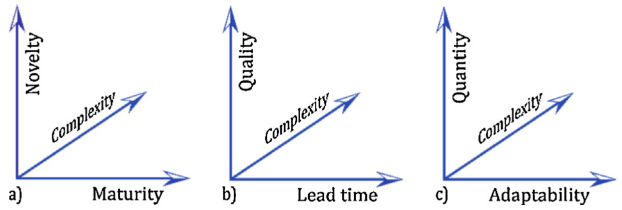

Fig. 1. Different ways to characterise products.

[59] and the customer-order decoupling point (see e.g. [139,190,209]) can be modelled, the adaptability of products can directly be used. The third property is the quantity of products.

2. Problem solving, creativity and decision-making

The design of products is, and will always be, an act of craftsmanship. It is characterised by the ability to repeatedly employ problem solving, creativity and decision-making in a controlled and efficient manner to reach an adequate product definition. In this, the balance between creativity and systematic approaches strongly depends on the type of product (see Fig. 1), where the difference between routine and non-routine design as well as between incremental and breakthrough innovations plays an important role [83,87].

2.1. Creativity

Irrespective of the context, the team involved and the tools, techniques, methods and frameworks that support the design team, it will always be the ingenuity and inventivity of the designers that provide for and ignite the creative sparks that decisively discern individual product development cycles. With this, designers are really at the heart of product development. This is all the more true, because the product design cycle consists of a set of activities that has no equivocal starting point; it has a result that is not known on beforehand and that is reached by a trajectory that is capricious. Therefore, a design cycle thrives on creativity as the main propulsion mechanism, producing the vital incentive for the evolution of the product definition that goes with the headway of the product development project. Consequently, creativity is the cause of progress in development cycles, but may simultaneously hamper the predictability thereof.

Infused by the unique role it has in development cycles, literature addresses the phenomenon 'creativity' from a variety of viewpoints, ranging from cognitive aspects [33,140], via experience [7,116], team work [250] to educational aspects [61,144] and investments [229]. Resulting from a detailed study of definitions of creativity [35] is the definition: "creativity occurs through a process by which an agent uses its ability to generate ideas, solutions or products that are novel and valuable".

What seems to be a common factor in most literature on creativity is a focus on its realisation: preconditions, means, environment and challenge. Also, the differences between 'personal' and 'social' views on creativity – depending on who perceives the newness and usefulness – are recognised [163]. A discernment that is contributive from the perspective of the overall design cycle is the dichotomy between the 'content' of creativity and its 'structure'. It is evident that a designer will always observe the coherence between the mechanisms of creativity and the subjects these mechanisms are applied to. Junior designers might explicitly struggle with this split, whereas experienced designers might have grown to implicitly value the amalgamation of the two.

For design teams, it is impossible to adequately tackle a design cycle and have a meaningful overview over the design tasks if the content and structure of the work are too intertwined.

Creativity is a means to an end: it explores beyond the frontiers of the current product definition. The results of such explorations are contributive, much more than the initiatives that caused those results to be achieved. Consequently, creativity is not the only precondition for progress in development cycles: the possibilities opened up by creativity must be assessed, elaborated and incorporated in the overall design cycle to make actual headway. Moreover, it is the progress in the design cycle that determines if there is room and demand for a next creative step [248].

The progress in design cycles is characterised by the myriad decisions taken by members of the design team (and selected other stakeholders) that subsequently, concurrently, conjointly but also contradictorily raise the extent and level of the product definition (see Fig. 2 [182]). All these decisions, in a sense, are the building