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A PROPOSAL FOR AN ENHANCED DESIGN CONCEPT UNDERSTANDING

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Abstract

In this paper we will present an enhanced design concept understanding. We outline a new insight into the nature and content of conceptualisation and design concepts, and on the basis of this insight we identify the implications on the design team's conceptual design activities.

In order to make the enhanced design concept understanding operational we formulate a mindset for conceptualisation. The mindset represents three explanations or models related to concepts. Firstly, the fact that concepts are composed by two elements: a concept mirroring the *idea with* and a concept mirroring the *idea in* the product. Secondly, an understanding of the proper nature of concepts articulated in four operation principles, and thirdly an understanding of the initial and gradual concretisation of a concept.

We expect that the mindset for conceptualisation will provide the engineering designer with an appropriate behaviour and a professional approach when carrying out conceptual design work, and a step towards verification of the mindset's productivity is described.

Keywords: Competitive products, customer satisfaction, early phases of design, design concept

1. Introduction

During the early phases of new product development the design team is working in a situation of great uncertainty with respect to creation of new business, where the dimensions: design problem, solution space, necessary procedure and required resources are vaguely comprehended. The result of early design work is a chosen concept, which normally leads to three tasks of clarification: a profitable business, a good product, and a manageable development process. Thus, it is critical that the design team establishes a rich and sound basis for concept selection.

In current industrial practice we see that conceptualisation is made an engineering task and most focus is laid upon the product's principle and structure. The literature for educating engineering designers has a narrow interpretation of concepts. However, for a design team to create good concept solutions the team members have to have a coherent and subtle understanding of concepts and conceptualisation, i.e. conceptual design work.

In this paper we will present an enhanced design concept understanding. Thus, the aim is to identify the nature and content of conceptualisation and design concepts and based on this insight to identify the implications on the design team's conceptual design activities. We formulate the following research questions: What is the engineering designer's proper understanding of a design concept? What is a rich and sound design concept description?

What makes concepts conceptually different? And finally, what are the implications on the design team's conceptual design work?

The structure of the paper is the following: In section 2 we describe explanations of concepts found in the literature, and we describe our research method. In section 3 we propose an enhanced design concept understanding. We have introduced this understanding in the form of a mindset to a class of engineering design students in order to make a preliminary test of it. This test, which can be seen as a step towards verification of the understanding's productivity, is described in section 4. The paper finishes with conclusions.

2. Related works

We have identified three different explanations of concepts in the literature:

1. Authors within the field of design methodology focus upon the engineering designer's synthesis of solution principle and form features to realise a required functionality. This is a technical side of a concept.
2. Authors within marketing and consumer research focus upon market acceptance and the behaviour of potential buyers and users related to the introduction of a new product on the market. This is a market-oriented side of a concept.
3. A few authors including the authors of this paper acknowledge the value of both understandings, and argue that the two sides of a concept should be understood as an integrity (showing totality and integration) during the conceptual design phase.

2.1 The technical side of a concept

Pahl & Beitz [1] prescribe a design process consisting of four phases: clarification of the task, conceptual design, embodiment design, and detail design. Each design phase comprises a set of activities, and the phases are carried out in a fixed sequence. During the conceptual design phase the concept is determined for the product being developed. Pahl & Beitz state that the conceptual design phase is preceded by a decision based on considerations concerning:

- Has the task been clarified sufficiently to allow creation of a solution in the form of a design?
- Must further information about the task be acquired?
- Is it possible to reach the chosen objective within the given financial restrictions?

Thus, we see that Pahl & Beitz understand the conceptual design phase as a certain level of clarification. This understanding is emphasised by the last question about whether or not it is possible to reach the chosen objective in the current design process.

According to Pahl & Beitz the result of the conceptual design phase is a concept variant, where solution principle and form design features have been determined. Thus, a concept variant reflects the physical effect chosen to realise the required function, and expresses product properties. We observe that Pahl & Beitz see conceptual designing as an activity where the engineering designer focuses on solution principle and structure of the design.

French [2] defines a "scheme" as the result of the conceptual design stage: "*By a scheme is meant an outline solution to a design problem, carried to a point where the means of performing each major function has been fixed, as have the spatial and structural relationships for the principal components. A scheme should be sufficiently worked out in detail for it to be possible to supply approximate costs, weights, and overall dimensions, and*

the feasibility should have been assured as far as circumstances allow. A scheme should be relatively explicit about special features or components but need not to go in much detail over established practice."

We observe that French see the concept solution in relation to the design problem where a consideration of a need might be included. However, the central question for conceptual designing is to determine the technical means of performing each major function.

From our study of the literature we have seen that the engineering approach to synthesis of design concepts focuses on the technical side: the emphasis is on creating a principal solution that realises a required functionality. The conceptual design work takes its point of departure from a problem formulation and a product design specification, and the concept solution is a result of primarily technical considerations. In the following we will question this approach.

2.2 The market-oriented side of a concept

Hultink [3] has investigated how companies can measure the performance of a new product in the marketplace. The result is that new product performance is a multidimensional construct in three dimensions: market, financial and technical performance. Hultink observed that the use of a certain product launch strategy depended on the novelty of the product.

Tidd et al. [4] discuss buying behaviour of consumers. Utilitarian theories assume that a consumer is rational and make purchase decisions by comparing product utility with the requirements, but such a rational process is seldom seen in practice. Tidd et al. state that behavioural approaches that emphasise the changing attitude of the consumer from awareness, via interest and desire, to finally buying the product, have greater explanatory power.

Creusen [5] focuses upon the consumers' responses to product appearance. In many purchase situations product appearance determines the consumers' impression, and based on this impression consumers reason about other product attributes, e.g. performance and quality. Creusen distinguishes six roles of product appearance: attention drawing, categorisation, communication of practical, ergonomic, hedonic, and symbolic product information. The roles are not independent, and consumers evaluate product appearance in a holistic way taking into account a global product appearance rather than the way specific functions are designed.

We observe that the conceptual aspects of a new product introduced on a market might result in new play rules and a new understanding among consumers of what to expect. Since consumers infer about product attributes such as performance and quality based on the product appearance, the design team has to expect that in some situations these inferences might be wrong. Thus, it is very difficult for a design team during the product development project to predict consumers' product preference related to a specific set of product attributes.

Our study of the literature indicates that consumers tend to focus on aspects or features, which are relatively marginal seen from the engineer's viewpoint. And further, a new and different technical solution in a product might have almost no appeal to the consumers unless certain features, marginal to the engineers' efforts, appeal to consumers. Thus, if the reason for the consumer's purchase decision should be linked to the concept, then a concept model should show such even marginal features in relation to the more complete product concept.

2.3 The two sides of a concept

Eekels [6] distinguishes in his description of design geography between what is going on in the realm of reality or the material reality on the one hand, and what is going on during the creation of the design and the realisation of the product on the other hand. During the creation of the design there must exist a perception of the existing state on the market and the need

satisfaction, and an intention to create a new, better state by designing and introducing a product on the market.

Based on Eekels' line of thinking Hansen & Andreasen [7] identify two important ideas to consider in the conceptual design work: a need/market-based idea and a design/realisation-based idea. Hansen & Andreasen articulate this dualism as illustrated in figure 1:

- On the one hand, in the world of utilisation of the product, the conceptual aspect means the creation of an *idea with* the product, i.e. a new dimension in the product's marketing, need satisfaction, and use value.
- On the other hand, in the world of creating the design, the conceptual aspect means the creation of an *idea in* the product, i.e. the engineering designer may have found a form, structure or mode of action, which realise the required functionality.

An illustrative example is the Walkman. The *idea with* the Walkman is that the user can walk and listen to music of his/her own choice, and the *idea in* the Walkman is miniaturisation of known solutions and a robust playing mechanism.

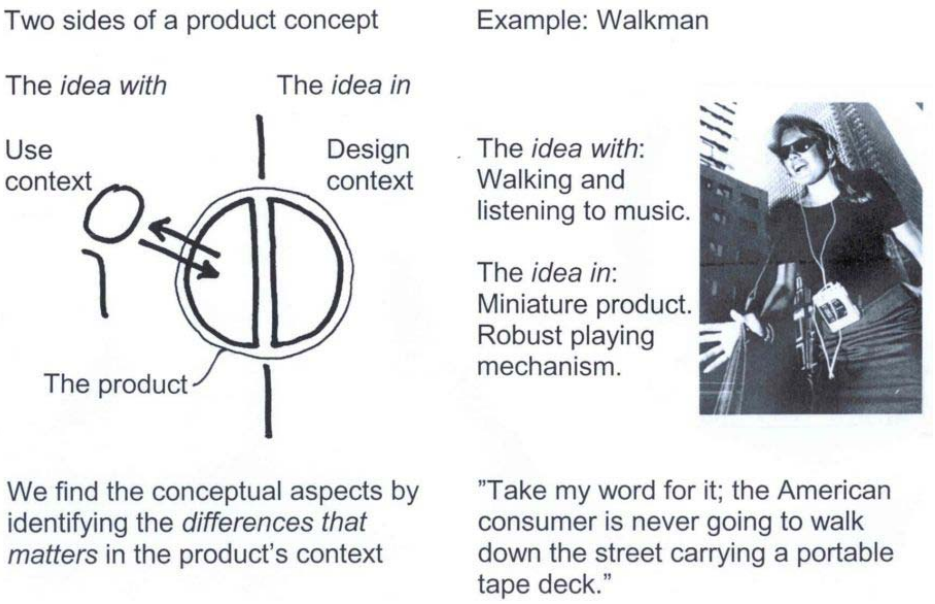

Figure 1. Two sides of a product concept, [7]. The picture and the quote are found in [8].

Hansen & Andreasen [7] recommend that a concept has to express the set of characteristics of the product being designed, which are conceptual with respect to the *idea with* and the *idea in* the product. We observe that this thinking pattern indicates, that it is a too limited approach to see conceptual design only as a search for new principal solutions or "engineered features". The two sides of a concept should be understood and explicitly considered by the design team as an integrity during the conceptual design work.

2.4 Need for research on conceptualisation

Our investigation into the area has shown that in order to enrich the engineering designer's understanding of concepts and conceptualisation, he/she has to understand that a concept has two sides, and he/she has to be able to externalise and communicate considerations not only regarding technical solutions, but also regarding the consumers' perception and the raison d'être of the product. Thus, for design researchers this area is full of interesting questions like: how can we create a conceptual idea and capture it by the means of a concept description?

What is a rich and sound concept design description? And what are the implications of the two-dimensional concept understanding on the design team's conceptual design work?

In the following we will go one step deeper into what we call an enhanced design concept understanding, based upon a phenomenological study. We have studied the literature and we have analysed a number of products on the market in order to understand their conceptual strength, i.e. which dimension or aspect made these products different and successful. For the sake of illustration we have analysed a final year engineering design project to identify descriptions that carry information on the *idea with*-aspect and have conceptual nature.

3. An enhanced design concept understanding

The purpose of this section is to explore the implications of the two-dimensional design concept on the engineering designer's or design team's way of carrying our conceptual design work. We will discuss the following questions: what makes concepts conceptually different? How to identify and articulate the conceptual aspects of a product? How to evaluate a concept? How to model a concept? And how to describe the *idea with*-aspect of the product?

The first four questions are discussed in section 3.1 and the results are formulated as operation principles. The last question is discussed in section 3.2, in which we present three models used in the mentioned final year design project to express the *idea with* the product.

3.1 The nature of conceptualisation and design concepts

What makes concepts conceptually different?

From authors within the field of design methodology, e.g. Pahl & Beitz [1], French [2], and Roozenburg & Eekels [9], we observe that the word "concept" has two meanings:

- In design process models "conceptual design" is a phase, in which activities focusing on determining a principal solution are to be carried out, i.e. the concept is a "complete" solution adding up all necessary means for realising the functionality of a product.
- A "concept" encompasses the few characteristics to explain essential functionality, but also showing part of the embodiment, i.e. a concept can be a partial solution, taking chunks of the product for granted, but showing the characteristics, which carry the conceptual aspect.

Thus, according to literature conceptual thinking allows the design team to synthesise unique new solutions and to focus on the few essential characteristics concerning the product's functionality. If we combine this line of thinking with the enhanced concept understanding proposed, we have to expect that the design team shall clarify also the need/market aspect during the conceptual design phase. This argument leads to the first operation principle:

1. For an idea to be conceptual, the design team has to relate it to its context and identify the characteristics, which show *the difference that matters* in the product-context relations.

How to identify and articulate the conceptual aspects of a product?

From Hansen & Andreasen [7] we have that a concept is an answer in two dimensions: On the one side, the conceptual aspect means the creation of an *idea with* the product, i.e. a new dimension in the product's marketing, need satisfaction, and use value. On the other side, the conceptual aspect means the creation of an *idea in* the product, i.e. the design team may have found a form, structure or mode of action, which realise the required functionality.

The product's principle may be of no importance with respect to competitive power, because all products of that type follow the same principle (like bicycles), whereas details may be essential, e.g. choice of material. Thus, what is seen as conceptual depends upon what is already created in the actual area concerning solving the task or concerning the principle or design of the artefact. So the conceptual new aspect could very well be e.g. man/machine interaction, form features, or ease of manufacture. Thus, the second operation principle is:

2. A new product concept should be understood in both the use context and the design context, and *show conceptual new features* in at least one of these dimensions.

How to evaluate a concept?

When the design team makes decisions during the product development process the goals of the company and the values of external stakeholders have to be taken into account, but also the design team's effort to synthesise an attractive design solution within the resources and time allocated must be taken into account, Hansen & Andreasen [11]. Thus, the decisions made during the product development process have a critical impact both on the design solution obtained, but also on the process in itself. So the following operation principle may be proposed:

3. The concept has to provide an answer with a respect to a set of criteria, which expresses a good solution. This set of criteria has at least three dimensions: *a profitable business* for the company; *a good product* for the user; and *a tractable process* for the design team.

How to model a concept?

In the literature we do not find comprehensive guidelines of how to describe design concepts. According to Pugh [10] alternative concepts have to be represented in *sketch form* visible to all design team members during concept selection. By French [2] and Tjalve [12] we find examples where principal solutions have been given an exemplar embodiment, which allows the design team to reason about properties. During later design process phases the engineering designer has to replace the exemplar embodiment with an embodiment carefully worked out.

The description of a concept has to allow the design team to reason and communicate about the relevant conceptual aspects, and it has to inspire and motivate the design team to synthesise competitive solutions. For these uses a sketch of a principal solution is not suitable, and as a fourth operation principle we propose:

4. The design team has to expect *inhomogeneous descriptions in form and content* of a concept depending on the conceptual aspect currently in focus.

3.2 Descriptions of the *idea with* aspect

In this section we will focus upon how to describe the *idea with* aspect, i.e. the need/market-oriented side of a concept. We will present three different descriptions in form and content to express the *idea with* the product. The descriptions were used in an engineering design project, Eiland & Smith [13], which were supervised by the second author of this paper.

Eiland & Smith carried out their final year project in cooperation with the Danish company Novo Nordisk, which is a world-leading supplier of insulin to diabetics. The aim of the project was to develop product ideas and devices directed at easing the diabetics' use of insulin. Novo Nordisk and the students agreed on an initial assumption that incorporating the consumers' opinion at an early stage of product development is an important tool in the identification of new business opportunities.

The students had their daily workplace at the university, and therefore it was critical for the students at meetings with Novo Nordisk to communicate observations and intermediate results. The students made a number of models/descriptions to carry their considerations and intermediate results. These descriptions were used in the communication with Novo Nordisk.

After the students handed in their project report we analysed the models/descriptions made by the students during the project. Three of these descriptions carry information regarding the *idea with* aspect and have concept nature in the sense that they express the characteristics, which show the difference that matters. We will present the three descriptions:

- A product concept to identify need situations and consumer segments, which are not covered by existing devices on the market.
- A mission statement pointing in the direction towards attractive devices seen from the users viewpoint.
- A physical form model to evaluate the man/device interaction and the users' reaction.

In the early phase of the project the students analysed the current need and market situation. The students made a number of interviews with external stakeholders, e.g. diabetic nurses and diabetics, and internal stakeholders at Novo Nordisk. The students analysed existing insulin devices available at the market, both Novo Nordisk devices and the competitors' devices. The synthesis activities in this phase focus on a creation of new product ideas. Each product idea corresponds to a need situation and a user segment, which is not covered by existing devices. Each product idea was expressed in a product concept description, see figure 2.

Figure 2. A product concept description, [13]. The headlines are enlarged for showing the principal dimensions.

Such a product concept description was made on one sheet of A4-paper and it encompasses five characteristics: Product idea, variants, user segment, positioning properties, and closest competitor. The description also contains comments from the Novo Nordisk marketing department and the students' prediction of pros and cons. Thus, the result is a rich concept description, which encompasses the market, the users, and the competitors.

The product ideas were evaluated with respect to business for Novo Nordisk, value for the user, and the students' competence in order to obtain a tractable development project. We observe, that the third operation principle reflects the dimensions applied in this evaluation.

A product idea based on the idea of "minimalism" aiming at making life easier for so-called type 1 diabetics was selected. The students conducted a number of focused interviews with

potential users in order to understand the users' needs and perception of minimalism. The result was formulated as a mission statement capturing the need and the values of the users:

"*The need for discretion in connection with injection, handling and the device's appearance as well as the need for easy storage outside the home are the fundamental elements, which have to create the positioning of the product on the market. The means to satisfy these needs are minimal weight and size. Also the time needed for an injection and the complexity of the use are important in order to obtain a discrete injection.*

The above needs should be covered on condition that user friendliness and security for correct dose can be satisfied."

The mission statement functions as a guiding star during the synthesis of device concepts by pointing towards a direction in the solution space, which is attractive for the users.

A number of alternative concepts for the insulin device were synthesised. Novo Nordisk and the students evaluated the device concept solutions and a solution was selected for detailing. In order to check whether the selected device fulfilled the users' perception of a discrete injection a physical form model in scale 1:1 (a mock-up) was made. The mock-up was presented to a number of potential users, and the students observed the new use pattern and the users' reactions, see figure 3.

Figure 3. A mock-up was made to observe use pattern and establish users' reactions. The photos show the concreteness of this demonstration even if the device has to be hidden due to confidentiality.

4. Towards verification of the enhanced understanding's productivity

The purpose of the enhanced design concept understanding is to provide the engineering designer with an appropriate behaviour and a professional approach when carrying out conceptual design work. When we see the enhanced design concept understanding as a result of research work, we have to ask for some kind of verification. It is not possible to make a test to check whether the presented understanding is true or false, just like the authors of this paper would never claim that Pahl & Beitz's or French's proposals were wrong. However, what we can do is to formulate a mindset, introduce it to a number of engineering designers, and then set up experiments to show its productivity. Thus, the core question becomes: is the mindset accepted by engineering designers and do engineering designers, which use this way of thinking, fell that they are better equipped to do conceptual design work.

We have introduced the mindset for conceptualisation to a class of fourth year engineering design students, and we observed the students' way of working and presenting results for a number of assignments given in the course module. In total 14 students participates in the course module, and they were divided into four project groups. In the module the students had to make an analysis assignment and three synthesis assignments. In the analysis assignment the student groups analysed several products available on the market in order to explain their

conceptual strength. In the synthesis assignments the groups: firstly, outlined a product idea for a device or system to help active people remembering to take their medicine, secondly they developed a product concept for a personal digital assistant to a specific user segment of the group's own choice, and thirdly they developed a man/machine interface for a modern adjustable hospital bed.

Due to space limitations we cannot report in detail on the students' working behaviour and the design results obtained. However, our main observations can be reported:

- The students were able to identify and present the two sides of a concept for several existing products.
- In their synthesis projects the groups were able to argue and reason about both sides of the product concept during their design work.
- The students developed a broad understanding of design concepts, where both sides were developed simultaneously.

Thus, we conclude that the students developed an attitude towards conceptualisation, where not only the technical considerations have to be taken into account, but also marketing and concerned users must be included as important sources for information in order to obtain design results, which have the potential to become a sales success for the company.

5. Conclusions

In the paper we have presented an enhanced design concept understanding. The understanding is based upon the argument that a design concept has two sides: the *idea with* and the *idea in* the product. We have furthermore identified the nature and content of conceptualisation and design concepts, and we have outlined the implications of this understanding of the design team's conceptual design activities. A main finding is that a new product development project should not start with analyses of need and market followed by a search for principal solutions. Instead, the design team should simultaneously draw their attention to the need/market side and the design/realisation side. We have formulated our findings in four operation principles.

In order to verify the productivity of the enhanced design concept understanding we introduced the mindset for conceptualisation to a class of engineering design students, and we observed their way of carrying out conceptual design work. Our observations showed that the students developed an appropriate attitude and a professional approach towards conceptualisation. These observations are by no means conclusive with respect to the general productivity of engineering designers applying the enhanced design concept understanding, but we feel encouraged to continue our research activities in this area.

The authors believe that the enhanced design concept understanding presented in this paper will become an important contribution to design methodology research and to the professional engineering designer's mindset for conceptualisation.

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