NordDesign 2006
August 16 – 18, 2006
Reykjavik, Iceland

Conceiving product ideas in an initial and uncertain design situation

C. Thorp Hansen

Department of Mechanical Engineering
Engineering Design and Product Development
Nils Koppels Alle, building 404
Technical University of Denmark
DK-2800 Kgs. Lyngby
Denmark
cth@mek.dtu.dk

M. Myrup Andreasen

Department of Mechanical Engineering
Engineering Design and Product Development
Nils Koppels Alle, building 404
Technical University of Denmark
DK-2800 Kgs. Lyngby
Denmark
myrup@mek.dtu.dk

Abstract

As a consequence of the global market's demand for innovation industrial companies need employees with well-articulated innovation competences. Conceptualisation may be seen as the core activity of innovation: the concept is the new idea, the new initiative, the new organising, or the new approach, which carry innovation.

Traditional approaches to conceptualisation are no longer sufficient. Too many engineering designers have practiced or cultivated a one-sided product quality focus and too many believe that creativity can compensate for a lack of knowledge and insight into the users' perception of quality and value. Too many engineering designers work stereotypically based on an understanding of the physical product as the core of ideation, and use the conception of a "problem" as the point of departure for the design process.

The aim of this research work is to create a multisided, dynamic, and explorative view of conceptualisation. We propose an ontology for ideation in an initial and uncertain design situation, and we point out a number of approaches to conceptualisation to break with the traditional way of working. In its present form the paper has to be seen as a speculation. The authors believe that our research work contains an new contribution to theory, and that we have established a strong justification for the ontology, but we have to emphasize that the ontology has not yet been applied by students or in industrial practice. A test and verification of the ontology still remains. Thus, critical questions will be welcome, and comments from readers and the outcome of verification activities will probably result in modifications and adjustments of the proposed ontology.

Keywords: Product idea, innovative ideation, literature study.

Introduction

In the fuzzy front end of new product development the design team is working in a situation of great uncertainty with respect to creation of a new business, where user needs or market opportunities, solution space, design strategy and required resources are vaguely comprehended. The design team conceives product ideas based on tentative formulations or weak visions requiring explorative search for solutions and a preliminary understanding of customers' need and values. Some product ideas or market opportunities may be worth pursuing, whereas others shall be discarded due to a lack of business potential. A central task of the design team is to clarify this initial and uncertain design situation, and based on this clarification to articulate the customers' need and perceived values with respect to product properties and features in a product design specification document. The clarification of the initial design situation is critical, because if the believed clarification is poor the result of a product development project could very well be a product failing on the market, and as a consequence no business for the company is established.

The aim of the research work documented in this paper is to identify a set of dimensions or views to be considered in an initial and uncertain design situation. Our result is formulated as an ontology of design situation dimensions and a preliminary and careful attempt to relate these dimensions to known design approaches. The objective is to establish a new, comprehensive, and productive understanding of innovative ideation leading to the formulation of a mindset, hopefully productive for a design team, i.e. helps the design team to understand the complexity of an initial and uncertain design situation and to articulate important elements and aspects in order to develop an attractive product or service.

The structure of the paper is as follows. In the next section we describe the method applied in this research work. In the following section we describe concepts and ideas found in related literature. Then we propose an ontology for ideation in an initial and uncertain design situation. Thereafter, we firstly formulate a number of innovation-oriented questions for the design team members to consider in order to determine a suitable start point and a new and innovative approach to ideation, and secondly we make a first attempt to verify the ontology. The verification is based on applying four simplified, innovation-oriented questions as a representation of the ontology, and to structure proposals and concepts for innovative thinking and behaviour found in the literature. The idea is that if the ontology can result in an interesting, relevant, and complete mapping of the proposals and concepts found in the literature, then the ontology might provide a true and productive description of the content of an initial and uncertain design situation. The paper finishes with conclusions.

Research method

The research method applied is a study of literature and an analysis of early plans of design projects. We have studied design methodology textbooks and the business and innovation oriented literature, e.g. Leifer et al. [9] and Cooper [2], in order to identify each author's contribution to a total picture. We have analysed a number of design project proposals written by companies to attract design students to carry through a student project of explorative, innovative design. The analysis focuses upon identifying, which aspects and elements are predicted as being important in each project. The result is a broad understanding of the dimensions and elements of an initial and uncertain design situation.

Related literature

Empirical research indicates that early planning and specification is a key success factor in new product development, see e.g. Baxter [1] and Cooper [2], but unfortunately the research

also shows that establishing a good product design specification does not get much attention in industrial practice, see e.g. Hollins & Pugh [3] and Foxley et al. [4]. Why should a professional design team forget to pay attention to such an important activity of new product development? The reason cannot be found in a lack of understanding of the importance of this activity. We have to look for other reasons. In this research work the authors assume that the reason shall be found in the lack of a productive mindset explaining the characteristic elements of an initial and uncertain design situation.

In design methodology textbooks, e.g. Cross [5] and Baxter [1], the focus is upon an analysis of user need, systematic methods to explore the solution space and staging human creativity, i.e. the focus is to create something different. Unfortunately, creating something different is not necessarily something better, and the situation is more complex than outlined in the textbooks. Cross & Dorst [6] describe that two spaces co-evolve during the design process, namely the problem space and the solution space, and that the insight created in one space influences the design team's understanding of the other. The description of Cross & Dorst is a very important first step to shed light upon an initial design situation. However, Cross & Dorst do not describe the characteristic elements or dimensions of the problem space and the solution space, i.e. they do not answer the question: what is the content of problem and solution space? Furthermore, the authors of this paper recognise a third space in design practice: the designer space or development space, where at least the project manning, choice of design strategy and allocation of resources are characteristic elements. Thus, to explore the need space is not the only start point of ideation. The design team might instead find a suitable start point by focusing on promising solutions or by selecting an ambitious and different design strategy.

The design team's willingness to break traditional patterns of doing and thinking is another aspect in the creation of innovative ideas. To break traditional patterns could be seen as a productive means to create new and innovative ideas, and here is the relation between a concept and the knowledge related hereto important, Hatchuel & Weil [7]. Merging different types of knowledge and new insight may be seen as a condition for ideation, and vice versa synthesis of solutions may be an initiator for gaining new insight and knowledge. Different types of knowledge and insights shall be understood in the widest sense, i.e. the knowledge creation activities shall not necessarily take their point of departure in an imagination of a concrete, physical product, but could have a much broader scope, e.g. in the identification of the composite development arena with competitors, competing products and technologies, potential alliance partners, customers and users, and in an identification of the trends and dynamics on this arena, Jørgensen & Sørensen [8]. Breaking traditional patterns of thinking and doing, a broad perspective of the development arena, and an imagination of possible concepts and solutions might be important elements in creating new and innovative products.

A proposal for an ontology

The goal of this section is to create an ontology for ideation in an initial and uncertain design situation. A central task of the design team is to clarify this situation, and the clarification requires considerations in at least three spaces, which we prefer to call the need space, the solution space and the designer space. Considerations on characteristics in the need space encompass at least the need, e.g. who are the subject of the need and the characteristics of the need, the attitudes and value of customers and users, and the opportunities on the market, e.g. size of the market, number of potential customers, and competing products. Considerations on characteristics in the solution space encompass at least requirements and criteria for the good solution and considerations on the scope of the design object, i.e. is the design object a

physical product or a service? Is the design object a product and its user? Are the product, its user, and the circumstances around the use the design object? Are the product and its production the design object? Considerations on characteristics in the designer space encompass at least project manning, choice of design strategy and allocation of resources to carry through the project.
In order to propose an ontology for ideation we have to discuss the nature of ideation. The authors of the paper believe that ideation has at least two aspects:

- *Something*, which the idea is about, i.e. the content of the idea.
- *Somebody* who has intention, insight as result of awareness, argumentation, or who has a "solution".

Thus, in relation to product development we see that one or more subjects, viz. the engineering designer or the design team, carry an idea. The subject has:

- an intuition, an idea, a mission, a goal, a concept, or a solution,

which is related to:

- a market opportunity, a user or need, a product, a realisation, or a required resource.

Our ontology for ideation is an attempt to create a language, i.e. a set of concepts and their relations, for describing ideation. On the basis of our description of clarifications in the three spaces and the description of the nature of ideation in product development we will create an ontology for ideation. The core elements of an ontology are a set of concepts and a set of relations between the concepts, Gilchrist [10], and we create the ontology of ideation in three steps. In the first step we will define the ideation dimensions, in the second step we will propose the content in each dimension, and in the third step we will define the relations between the dimensions.

Firstly, in a simplified and idealized form, ideation is characterised by:

	Ideation is
Who?	when ***somebody*** imagine, arrange, transfer to, or do ideation
Why?	with ***the purpose*** to realise a mission, a goal, an opportunity, or a dream,
What?	based upon an initial ***image about what*** to realise. This initial image could encompass a set of ***core characteristics and properties*** of a sustainable product or service, an improved performance, a better work space, or a viable business,
How?	and already has ***preliminary ideas*** or at least imaginations about design ***approach*** and project ***feasibility***, and therefore set up a task, a plan or realisation process ***to be executed***.

Thus, we see four dimensions in ideation, and in the second step we propose the content in each dimension. Characteristics of each ideation dimension are:

The *who* This dimension contains the subject of ideation, e.g. the engineering designer, the client, or the design team.

- The initiator or creator:
  - Independent inventor, company entrepreneur, consultant, …
- The team asked to find ideas by:
  - Company internal client, e.g. product manager, product committee, or management.

    - Company external client, e.g. client, organisation, or authorities.
- The actors networking for strong ideation:
    - Network of companies, cooperation with specialists, knowledge resources, service-oriented cooperation, …

The *why* This dimension contains the intention of ideation, e.g. mission or goal.
- Egocentric curiosity or idea about …
- To fulfil a mission, a purpose related to e.g. company strategy.
- To realise a goal or specification related to e.g. competitive performance.
- To wish exploiting an identified market opportunity.
- To wish exploiting an identification of potential users or need.
- To be driven by any opportunity for making an improvement that matters, e.g. cost reduction or quality improvement.

The *what* This dimension contains an image of what to realise seen as a design object.
- "Something" searched for, i.e. the search is the "what".
- Product, service, or solution identification.
- Realisation opportunity.
- A concept to be utilized.
- An image of solution to be utilized.

The *how* This dimension contains an imagination how to realise the design object, i.e. the approach to develop the design object within limited resources and time.
- Information and/or knowledge oriented.
- Need and/or solution oriented.
- Creative idea search and/or systematic exploration of solution space.
- The way to test and validate potential ideas, e.g. laboratory test, design reviews, user critique, field test …

The third step in creating the ontology of ideation consists of defining the relations between the four dimensions. If we see the four dimensions as axes describing a four-dimensional space of ideation, we can name the axes and then define a number of relations. Firstly, a proposal for names of the four axes in the space of ideation:

The who The *actor* axis. Along this axis we find the subject or subjects taking up the task to ideate and design innovative systems, products, or services.

The why The *intention* axis. Along this axis we find the intention or motivation carried by the actors.

The what The *image* axis. Along this axis we find the actors' image of what to realise. The image might encompass e.g. a few design characteristics, a sub solution to be exploited in a product or service, or core system elements.

The how The *activity* axis. Along this axis we find the actors' imagination of design strategy to be applied in order to solve the task.

Secondly, on the basis of the concepts we have introduced in the ontology of ideation we have to define relations between these concepts. The definition of the relations between the ontology concepts is an important step in creating a model-based theory. We define the following relations between pairs of concepts:

- A *human actor* carries the *intention*.
- The *intention* is not necessarily followed by an *image*.
- The *actor* does not necessarily know the *activity* to solve the task.
- In the *ideation activity* there is always an *actor*.
- The *ideation activity* is not always supported by an *image*. A search for ideas may be explorative and open.

With respect to carrying out innovative ideation based on the created ontology at least two relations can be defined:

- The start point of ideation can be any point on any of the four axes (without any imagination or considerations of the three other axes), or the start point can be a combination of two or more axes.
- There is not a general sequence in clarifying the aspects of the four axes in order to determine a suitable start point of ideation.

We have in this section in three steps created an ontology of ideation. The ontology describes four dimensions of ideation, which the authors see as the fundamental dimensions in clarifying an initial and uncertain design situation and in determining a suitable start point for ideation. Thus, the ontology can be interpreted as a map, which gives an overview of the landscape of the fuzzy front end of new product development. In this way the ontology imposes a certain structure in a fuzzy situation, and hopefully the structure will support the design team's deliberations and clarifications in a productive way. The ontology will be an important element of the engineering designer's mindset of conceptualisation, if it can support innovative ideation, and this issue is taken up in the next section.

Towards innovative ideation

It is the authors' intention that the application of the ontology will help a design team to structure the activities to clarify an initial and uncertain design situation, and thereby reach a common understanding of a suitable start point and approach for ideation. However, we cannot expect that the ontology in itself ensures innovative ideation. The design team members have to articulate design intentions, to join with persons with complementary and new knowledge, to try new ways to solve the task, and to question existing truths and aspects taken for granted in their company or organisation. The ontology gives four dimensions to question, and in the next subsection we will formulate innovation-oriented questions under the label *rethinking*, and we will discuss design approaches found in the literature in relation to our ontology of ideation.

Rethinking – to question the existing

The purpose of rethinking is to create new, improved conditions in the company and in the design team in order to be able to initiate and carry through innovative product development projects. It might be necessary to question the existing situation and conditions, the company's goals and strategy, and current strengths on the market, in product performance, or internal in the company. Rethinking has to be understood both literary as to reinterpret or express a critical attitude towards the current situation and conditions in the company, in a business area, or in a product development project, and as establishing new conditions detached from an existing situation. Following the ontology we can question the existing by applying an abstract and simple questioning technique: Who? Why? What? And how?

The *who-question* shall be asked in relation to the persons taking up the design task, their composition of the design team, their insight in many aspects, e.g. market, customers and technology, their strengths, reputation and awareness. The who-question may be answered by

the company management, who allocates resources, by the product development manager, who creates teams, by the project leader, who may be concerned with the appropriate manning, or the individual entrepreneur or engineering designer, who may want to empower his/her work. The innovation improving answers could encompass the creation of a new innovation task force, or a reorganisation of the product development function.

An approach with growing importance is the *creation of network alliances* with other companies, Norell et al. [11], for instance with the goal to join a product/service-system. The joining is of course closely related to considerations of new business possibilities (why) and obtaining new competences or market relations (what).

The *why-question* relates to the intention, and shall be asked to the source of the task. What are we designing for whom? Do we as a design team solve this task at an appropriate level, and with the right perception of need and value? Are the intentions clear and shared within the design team, and with the alliance partners? Do we have a narrow or innovative perception of the development arena? Do we know the actors on the arena, and do we understand trends and dynamics on the development arena? What is our mental picture of possibilities and challenges? There can be formulated many innovation improving answers to these questions, at least in the form of hypotheses, which can be tested and reconsidered before the design team initiates a product development project.

An approach, which may expand the role and action of the company, is the *product life thinking* approach, McAloone & Tan [12]. The idea is to see the company as responsible in the larger perspective of the product's life cycle. Insight may be created by an explicit modelling of what happened and happens with existing or imaginary, future products in all life phases, and based upon this to offer the customers a longer product service period, leasing, or recycling.

The *what-question* is meant as a question to the task and the solutions, which the design team expects. The design team shall consider: is it the right type of means to synthesise seen in relation to the need, to society, to their company and its goals and strategy? The design team can formulate several innovation-oriented questions: Are we solving the task with the right perception of need? Is our perception of the problem coloured by tradition, our background, or our believes of the wishes of the client, market, customers, or users? Do we have a proper perception of the solution's system relations, product life aspects, and use? Are we focusing on the right technologies? What are our ambitions with respect to quality, performance, etc? What is the market expecting? What is the competitive situation? Many innovation improving answers can be formulated by the design team to answer these questions, e.g. to develop a product with superior product performances, to apply a new and powerful technology, or to agree on the right level of ambition.

A popular innovation approach at present is the *Blue ocean strategy*, Kim & Mauborgne [13], where the idea is that a company shall identify the clusters of businesses, concepts, and technologies, which dominate a need satisfaction or business area, and then position itself in the open areas, the "blue oceans".

The *how-question* shall be asked to the design team members and is related to their design approach and selection of methods. This question has some overlap to the who-question with respect to the proper composition of design team and organisation in order to solve the task. The innovation-oriented questions of the design team can be the following: Will we organise

a completely different search for solutions in this project? Have we chosen the newest technology? Will we involve potential users in the conceptual design activities? Do we choose *not* to involve potential users? Are we applying sufficiently advanced means to obtain an optimal dimensioning? Do we know the product life cycle in details?

In our design and innovation education at the Technical University of Denmark we are experimenting with a project type for training the students for ideation, called *Campus technology search*. The idea is that student teams on their own initiative seek up campus researchers and their research results, and try to create innovative business and product ideas, imagining existing or future companies as customers. The search for ideas is exploratory, based upon building scenarios and synthesising concepts, Jørgensen & Sørensen [8], Hansen & Andreasen [14,15] and McAloone et al. [16].

The authors see the ontology and the innovation-oriented questions as a proposal for a mindset to be introduced to engineering students and engineering designers in practice. The mindset is to be applied in order to clarify an initial and uncertain design situation. It is the authors' hope that the mindset will be productive in clarifying both a suitable start point for ideation and a different approach to carry through the ideation, and thereby point towards new and innovative concepts and solutions.

Towards verification of the ontology of ideation

In this section we will make a first attempt to verify the ontology, i.e. we will consider the question: Is the ontology's proposal to map and structure an initial and uncertain design situation complete and productive? From a theory building perspective the ontology has to provide a complete mapping of the proposals and concepts found in the literature. From a design practice perspective the ontology has to be productive, i.e. has to make design team members better equipped to identify suitable start points and design approaches for innovative ideation.

The ontology's content encompasses an understanding of both the design object's nature and the human beings' ways to think and invent. Design objects are of different types, e.g. product, service, or system, and have certain characteristics and properties, which have to be synthesised and determined in order to obtain an innovative result, e.g. a product with "*an entirely new set of performance features*", Leifer et al. [9]. Human beings have intentions, where explicit formulations support deliberation and arriving at consensus. On one side design team members need to know many types of solution elements, different ways to realise goals and solutions, and have insight into uncovered needs and potential market opportunities. On the other side open minds might help, i.e. to question the existing and identify new start points and approaches for innovation.

In this paper we have applied the four simplified, innovation-oriented questions to structure some proposals and concepts for innovative thinking found in the literature, e.g. Blue ocean strategy and product life thinking. This preliminary structuring indicates that the ontology can provide a complete mapping of the content of an initial and uncertain design situation. However, a more careful analysis of more proposals and concepts found in the literature is still required.

With respect to the design practice perspective the ontology shows the complexity of ideation. The design teams' deliberations and considerations to clarify an initial and uncertain design situation can be structured in four dimensions. An awareness of this complexity might in itself

help the design team members and other relevant actors. However, the real productive power could very well be found in the fact that the ontology asks for open-mindedness and rethinking when initiating and carrying out ideation.

It is our belief that the ontology presented in this paper combined with the authors' recent research work on a mindset for conceptualisation, Hansen & Andreasen [14, 15], and on the content of a product idea, Hansen & Andreasen [17], will constitute a comprehensive understanding of innovative ideation and conceptualisation, which will empower design team members and other actors in these important design activities for companies operating on the global market. As we wrote in the papers' introduction the ontology has not yet been applied by students or in industrial practice, so also in the design practice perspective tests to verify the ontology remain.

Conclusions

The research work documented in this paper is a reaction to a current situation, where industrial companies need employees with well-articulated innovation competences. Traditional approaches to conceptualisation are no longer sufficient. The authors' contribution is an ontology of ideation, and set of innovation-oriented questions to be considered in an initial and uncertain design situation, and the formulation of a multisided, explorative rethinking as an important innovative approach.

The contribution of this paper moves the knowledge within our research community from a level, where innovation can be understood and treated as creativity and "think different", to a level giving insight into the content of the fuzzy front end of product development. The ontology imposes a certain structure on early product development activities, and emphasises four important aspects: The need for appropriate product design specifications, the identification of a suitable start point for ideation, the willingness to break with traditional patterns, and not least the understanding that the design object is not only to be seen as a physical product.

The authors believe that this paper contains an innovative contribution to theory, and that we have established a strong justification for the ontology. However, we have to emphasize that the ontology has not yet been sufficiently verified, neither from a theory perspective nor from a design practice perspective. Thus, critical questions will be welcome, and comments from readers and the outcome of verification activities will probably result in modifications and adjustments of the proposed ontology.

References

[1] Baxter, M., "Product design – A practical guide to systematic methods of new product development", Chapman & Hall, 1995.

[2] Cooper, R.G., "Winning at new products", Addison Wesley Publishing Co., Boston, 1993.

[3] Hollins, B. & Pugh, S., "Successful Product Design", Butterworth & Co. Ltd, 1990.

[4] Foxley, D.M., Blessing, L.S. et al., "Closing Report. Partnership for profitable product improvement: P3I", Sector challenge project number 328, The Royal Academy of Engineering, 2000.

[5] Cross, N. "Engineering design methods – Strategies for product design", third edition, John Wiley & Sons, 2000.

[6] Cross, N. & Dorst, K. “Co-evolution of problem and solution spaces in creative design”, Proceedings of International Workshop on Computational Models on Creative Design, Heron Island, Queensland, Australia, 1998.

[7] Hatchuel, A. & Weil, B., “A new approach of innovative design: an introduction to C-K theory”, Proceedings of 14th International Conference on Engineering Design, pp. 1-15, the Design Society, 2003.

[8] Jørgensen, U. & Sørensen, O., “Arenas of Development – A Space Populated by Actor-Worlds, Artefacts and Surprises”, in K. Sørensen & R. Williams (eds) “Shaping Technology, Guiding Policy: Concepts, Spaces and Tools”, Cheltenham: Edward Elgar, pp. 197-222, 2002.

[9] Leifer, R., McDermott, C.M., O´Connor, G.C., Peters, L.S., Rice, M.P. & Veryzer, R.W., “Radical Innovation: How mature companies can outsmart upstarts”, Harvard Business School Press, Boston, Massachusetts, 2000.

[10] Gilchrist A., “Thesauri, taxonomies and ontologies - an etymological note”, Journal of Documentation, Vol. 59, No 1, pp 7-18, 2003.

[11] Norell, M., Ritzén, S., Adamsson, N., Kaulio, M., Sundström, P. & Uppvall, L., “Interne und externe Kooperation in der Produktentwicklung – Praxiserfahrungen”, in B. Schäppi, M.M. Andreasen, M. Kirchgeorg & F.-J. Radermacher (eds) “Handbuch Produktentwicklung”, Carl Hanser Verlag München Wien, 2005, pp. 341 – 353.

[12] McAloone, T. C. & Tan, A., “Sustainable Product Development through a Life-Cycle Approach to Product and Service Creation: An exploration of the extended responsibilities and possibilities for product developers”, in Proceedings of Eco-X Conference: Ecology and Economy in Electronix, 8-10 June 2005, Vienna, Austria, 2005.

[13] Kim, W.C. & Mauborgne, R., “Blue Ocean Strategy”, Harvard Business School Publishing Corporation, 2005.

[14] Hansen, C.T. & Andreasen, M.M., “The content and nature of a design concept”, in “Visions and Values in Engineering Design”, Proceedings of NordDesign 2002, P. Boelskifte & J. Sigurjonsson (eds), Trondheim, 2002, pp. 101-110.

[15] Hansen, C.T. & Andreasen, M.M., “A proposal for an enhanced design concept understanding”, in “Research for Practice”, Proceedings of 14th International Conference on Engineering Design (ICED 03), A. Folkeson, K. Gralén, M. Norell & U. Sellgren (eds), Stockholm, 2003, pp. 1-10.

[16] McAloone, T. C., Hansen, P. H. K. & Larsen, J. H., “Images of Innovation: An Ontological Approach”, in: Proceedings of the DESIGN 2004 - 8th International Conference on Design, D. Marjanovic (editor), Dubrovnik 18-21 May 2004, Faculty of Mechanical Engineering and Naval Architecture, Zagreb, 2004, pp. 53-60.