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Visualization – a Catalyst for Creativity in New Product Development (NPD)

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Abstract. There is a keen need for research within the area of product development. The use of visualizations in the development process, especially, is often unstructured and ad hoc. By focusing on the creative process and the use of sketches and external representation, it is possible to develop better tools and methods for realizing new products in a more efficient, effective way. By increasing knowledge regarding the positive creative effects of using different rendering types when developing new products and learning when to use those types, one could consider developing the entire New Product Development (NPD) process. A model for creative use of visualization within NPD projects will be presented and advocated.

Keywords: Creativity, visualization, sketches, design processes, and design process improvement.

1 Introduction

In the development of integrated and complex products, engineering and subject-specific development processes based on problem-solving are often not enough. It is not certain that problem-solving can be the sole tool for developing even simple products or services, as problem-solving makes us less open to the variety of opportunities that arise in the process. When approaching a problem, the cognitive mindset demanded for solving the problem differs from that required when searching for opportunities to create something completely new. But, of course, we need both thinking styles in collaboration (Drucker, 1998).

Design, design thinking, design methods and tools are resources that should be better utilized and could be better integrated into future management strategies (Utterback, 2006; Brown, 2009; Verganti, 2009). This emphasizes the importance of design thinking and methods in realizing new innovative products and services. For example, visual and spatial communication is central in design and development work. Sketches and models are important tools that facilitate and support the development work during product realization.

All kinds of visual representations are exceptional, since they show appearance of objects. Language does not. A sketch can serve as a common reference for the team. However, to be able to communicate via a sketch, the use of verbal communication is essential. Sketch-based design processes can eliminate communication problems as long as the team members involved during the communication is the same. On the contrary, in handover situations, new team members will interpret the sketches differently because of a variation in pre-understanding. This is because pictures are arbitrary and can be interpreted in different ways. Therefore, it is necessary to complement the sketches with verbal information (Kress and Van Leeuwen, 2001; Eriksson and Göthlund, 2004; Eriksson, 2009).

Research is needed within the field of visual communication concerning what is essential for an image to be instructive in general, and for sketches in the design processes in particular. However, images can be divided into two kinds: those that portray essentially visio-spatial things and those that represent things not inherently visual (Tversky et al., 2006). Design sketches can be defined as a combination of the two. This is because they portray objects or parts of objects that should be created and at the same time operate as an instrument for exploration.

By focusing on the creative process and the use of sketches or models, this research will explore the possibility of developing tools and methods for conducting NPD projects in a more efficient, effective way. If communication in the NPD process is unsatisfactory, this implicates a need for a deeper and more structured way of using available tools for communicating. For example, the sketch is such a tool, and the use of sketches is seen as the real heart of visual communication (Henderson, 1999). The need to develop supportive tools for using sketches is vital, and the support for management to fully implement sketches in their own product development process can help improve the perceived performance of NPD.

1.1 Theoretical framework

The references and background of this research need to be defined in order to develop support that could assist industry. The theoretical foundation in this research extends from three different areas: design processes, innovation and communication. These areas are merged into a conceptual framework that serves as the foundation for the research. This foundation was used in the development of idPeo methodology (Wikström, 2008).

Design can be described in two different ways: as a process of designing or as a designed product or service (Clarkson and Eckert, 2005; Blessing, 2009). However, it is difficult to distinguish the design process from the designed product or service, since the design of the process has influence on the final product. Today, a product or service must emphasize more than functionality, esthetic elegance, simplicity, economy of means and low impact. It must also tell us a story, that we as customers can identify ourselves with. Conformity between the product and the company message in this sense is desirable. Design is about understanding the users´ needs and, through that, creating the product´s story as the deeper wishes, values and emotions of the users (Utterback, 2006; Verganti, 2009; Brown, 2009).

The design process is a model for the application of design in product development. It is part of the company's entire development process, and is used to achieve successful, creative results through the medium of design skills and know-how. The design process can be applied to many different areas and projects that concern processes, messages, goods, services, or environments. The review of these models has been done thoroughly by, for example, Clarkson and Wynn (Clarkson and Eckert, 2005) and Cross (Cross, 2000).

One problem in communicating this model is the complexity of the iterative process that characterizes the design processes (Utterback, 2006).

Innovations are an important factor in both the development of high technology companies and their success internationally. If SMEs are to become successful, they need to manage continuous innovation and perform the development process in a good way. Their innovation capability needs to be on a high level. According to Jevnaker (Jevnaker, 1998), innovation capability is necessary for companies to be competitive in the market and to withhold competitive advantage. Creativity, ideas, needs, problems and new opportunities are some of the sources needed for innovation to occur.

> *"The most important source toward innovation is people with their free opportunities to use their skills, express their ideas, develop inventions and create intra- and entrepreneurship for innovations and companies" (Ekman and Jackson, 2006).*

However, it is often too complex to handle innovations today unless one is using larger groups of people.

By combining different knowledge areas and supporting the work with innovative tools and methods, it is possible to increase creativity (Johansson, 2004).

Visual communication is important in the innovation and product realization process. Barbara Tversky (Tversky, 1981; Tversky, 2001; Tversky, 2003; Tversky et al., 2006) shows that visual representations relieve the pressure on memory since they externalize memory and reduce processing load by allowing the understanding to be based on external representations rather than internal. When working memory is released, new information can be processed and creativity stimulated.

Ferguson (Ferguson, 1992) describes the evolution of visualization in engineering design and focuses on visual thinking as the language of engineers in the modern world. The creating of "the mind´s eye" is something we do all the time by collecting images of remembered reality and imagined contrivance. And if thinking is the realm of images (Arnheim, 1969/2004), the representation of these must be abstract sketches of the content if the finished thoughts are represented by drawings, paintings and models.

The designers see more in their sketches than they put in when they drew them, and these insights drive further exploration (Schön, 1983). Cross (Cross, 2000) describes this "dialogue" as the perception that the designer has with the representation of the idea and the internal mental process that involves perception, reflection and implications for the resolution of the problem.

Also, creativity is enhanced by allowing designers to interpret sketches and create new knowledge through them. The designer views this interacting with the sketches as a conversation: the designers see more in their sketches than they put in when they drew them, and these insights drive further exploration (Schön, 1983). In creative processes, one often refers to a five-step model consisting of preparation, incubation, insight, evaluation and elaboration.

1.2 Research objective

In order to implement new methods and tools in the process of making new products, it is important to add

value at different levels in an organization. The need for detailed information about project enhancement for management and the teams' need to communicate within the group and with other interest groups are important issues to be handled.

Based on the background and the described problem area, the overall objective of this research is:

> *"to analyze how and why visualization can be used and managed to improve product development execution"*

The intention of this research is to develop a model supporting the use of visualization within the innovation and product realization process. The model needs to be both communicative and supportive in order to achieve acceptance in practice. When developing any model, good knowledge regarding the current situation and the best practice in organizations is needed.

1.2.1 Research question
The main research question is:

How should visualization be managed in order to increase the perceived performance of execution in product development projects?

The focus is on both team members involved in the process and the management level in the organization. To facilitate the process of developing new products and services, management needs to have access to the process and understand each meaning of the phases in the process.

2 Research Methodology

The main focus in this research has been to develop useful methods and tools for the industry in an applied research project. Thus, the research questions are a starting point for the real problems in industry, as well as in theory. The approach supports the research, where the objective is to contribute to theory and the solution of industrial problems. Within this research, it is the industrial world of the SMEs with their own product development skills and the theories pursued ports in the research design. When trying to describe a phenomenon like this, case studies are most likely to come up with an explanation. Therefore, a qualitative approach has been used in this research. A quantitative approach could also come up with an explanation, but that approach does not fit as well in this research.

The overall aim of design research is to improve design by support, focusing on their practical use. Blessing et al. argue that descriptive studies not are enough when the aim of the research is to improve the design process (Blessing, Chakrabarti et al. 1995). The descriptive studies only provide the characteristics of existing processes. You need to continue the research process with phases of development of support, testing and refining this support,

2.1 The phases in the research

This research is based on the Design Research Methodology (DRM) developed by Blessing and Chakrabarti (Blessing and Chakrabarti, 2002; Blessing, 2009), Figure 1 shows the basis of the methodology. Based on the objective of this research, the applicability to the DRM methodology is high.

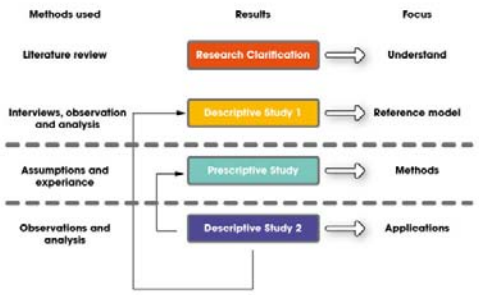

Fig. 1. The DRM methodology in this context.

The "Research Clarification" and "Descriptive Study" phases have been conducted using methods such as literature review, multiple case study research, workshop, open and semi structured interviews, and internal company document reviews. The "Prescriptive Study" phase has been conducted using single case study, open and semi-structured interviews, and internal company document reviews. One could debate however a prescriptive model is suitable as a method for increased creativity in NPD, this kind of top-down abstractions and generalities could be seen as wishful reflections, rather than derived from grounded research. Questions to be answered in future research.

Research clarification. The outcomes of the Research Clarification stage are current understanding and expectations of the research area and an initial reference model that provides an understanding of the use of visualization. An initial impact model was developed using "best practice" studies that gave initial success factors for improving the process of NPD with visualization.

The focus of the research was identified, and the objectives and goal of the research were described. This led to the development of a research plan where the problems within industry were identified, along

with the area to be consulted. The main research questions, the hypotheses that addressed the problem and the research approach were all developed. This led to the decision about what kind of research strategies to adopt and what the main stages and methods should be.

The expected area of contribution and deliverables to industry and science was investigated and a plan to fulfill these expectations was integrated with the research plan and time schedule.

Descriptive Study I. The outcome of Descriptive Study I stage is a reference model that highlights the problems in the investigated area, shows the relevance of the research topic, clarifies and illustrates the main line of argumentation, and points to the factors most suitable to address in order to improve the situation. The result of this step is the findings and implications of the developed support.

Prescriptive Study I. The outcome of Prescriptive Study stage is an impact model with a description of the intended implementation of the support to address the key factors and an implementation of the actual support. The result is an initial evaluation of the suggested support, along with a plan for evaluation in the Descriptive Study II.

Descriptive Study II. The outcome of Descriptive Study II stage is an application evaluation with criteria for success and implications of the findings for the developed support. The results are an assumption of the developed support and the concept behind it, a description of the impact model and the reference model and the criteria used. This step is in research right now and therefore will not be presented in this paper.

2.2 Data collection

The selection of the companies was done according to the criteria of SMEs with 20-200 employees and with in-house design engineers. The final selection was made based on the availability and applicability of the company. Three reference groups were selected according to the scope of the research. The number of interviews conducted was 26, and the interviews were performed during a six-month time period.

The interviews help to provide an understanding of how and why visualization is used in the execution of NPD. They give an opportunity to get a subjective experience of the situation. Through the use of “the grand tour," they offer a chance to reconstruct a significant part of the experience. The directed open interview creates an open climate where insight into how and why questions is gained in a natural way.

Direct observations have been conducted primarily by observing the work of a number of workshops within the Descriptive Study 1, where the aim has been to develop new concepts in a specific field. Notes and pictures have been taken during and after each workshop, and the work material has been copied as well.

By using Direct Observation, the data could be used to provide additional information about the topic being studied (Yin, 1994). The environmental conditions and behaviors could be used as evidence and provide useful validation of other sources of data collection.

To be able to collect data from ongoing NPD projects, the Participatory Observation have been used. This provides access to otherwise closed events (Yin, 1994). The need for direct reconfiguration is important during the development of methods and tools for support in NPD, and Participatory Observation provides this opportunity.

The main focus in this research has been to develop useful methods and tools for the industry in an applied research project.

Finally, the scientific motivation for this research can be found in areas such as the importance and the need of visualization and communication in product development execution while the industrial motivation are within the development of processes, methods and tools to create successful products.

3 Results

3.1 The research clarification study

As described in Section 2.1 the outcomes of the Research Clarification are current understanding and expectations of the research area and an initial reference model that provides an understanding of the use of visualization. The categories in Figure 2 are a result of the analysis of the interviews. Yin points out the need to use an analytical approach for the analysis of research data (Yin, 1994). Merriam describes analysis as a complex process that moves back and forth not only between concrete data and abstract concepts, but also between inductive and deductive reasoning and between description and interpretation (Merriam, 1994). How some researchers are doing to create meaningful results is not some logical process. Rather, it depends more on intuition and the researcher’s sensitivity for the information. In this analysis, three different analysis approaches have been used: pattern matching, clustering and probability.

The categories are divided into two groups, where four are behavior types and four are rendering types for visualization. The different categories are shown in Figure 2 below.

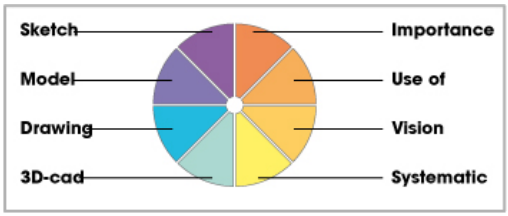

Fig.2. The eight categories of interest.

The four focus groups and their differences within the categories are shown in Figure 3. The intention of the figure is not to present numerical values but to create a visual understanding of the findings.

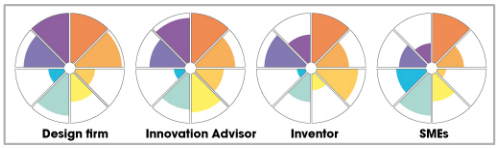

Fig.3. The differences between the eight categories of interest.

According to the model of eight categories, a clustering of data was performed that led to a conclusion to classify the categories into four groups; namely, awareness, strategies, solution- and idea-based rendering types, and two different kinds of approaches, Figure 4.

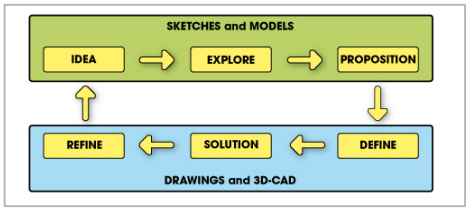

Fig.4. Types of rendering according to reason of use.

This leads to the conclusion that SME design engineers are aware of their use of visualization; however, they think they use visualization better than they do. They tend to prefer solution-based rendering types and are through that weak in their idea phase. This could easily be taken care of, and is partly being solved through the use of design firms in those cases in which they prioritize that kind of competence. This puts the management in a difficult situation: they have to take these kinds of situations without sufficient information. This leads to a need for visualization knowledge and its implementation in the product realization process.

Design firms are good in the idea phase. However, they could be more structured during the whole process. This leads to problems when communicating ideas and solutions to the customer. However, this is not purely a communications problem. It is also a knowledge problem. Customers tend to believe that they know what the process consists of and what to expect from it.

3.2 Descriptive Study 1

By clarifying and exemplifying the problems that exist in the current situation and identifying those factors most likely to improve the situation, a better understanding of what can be done is achieved. Furthermore, by focusing on concrete activities, the execution of NPD can be more efficient. Clarifying the relationship between different parts of the design process and the implementation of development projects demonstrates the importance of the research area, both practically (in industry) and theoretically.

In addition, a clear description of the factors important in the visualization of the product and the gaps identified in the SMEs leads to the development of a new method for the visualization of the product under development.

The factors to focus on when attending the problem constitute common sense. Nonetheless, in most companies, they are forgotten, ignored or even not seen as work. The fact that these factors are mainly in the beginning of NPD projects calls for extra attention. The cost of failure in later stages is so much higher compared to failure in the beginning of NPD projects. The following factors are the ones most suitable to address when improving the perceived performance of NPD projects with regards to visualization:

- The use of sketches and low-fidelity models for exploring the problem area.
- Identifying the problem.
- Understanding the problem.
- Communicating with words instead of visualizations.
- Creating visible and visionary goals for teams.
- The management of NPD is focused on solutions.

This implies the need for methods and tools to apply visualization in SME innovation processes as well as for design firms. Use of a roadmap like the one IDEO uses could lead to better understanding and more effective projects .

As shown in this research, there is a need to develop new approaches to using visualization as a tool and method in NPD projects. Problems arise when using visualization in a structured way in these projects, and these problems are generated by management and project teams. By addressing these problems, the process should be made explicit for both management and the team. This also leads to more

opportunities for new products and improved processes.

The result of the empirical studies has been analyzed with the intuitive approach probability. This method focuses on the conclusion that seems reasonable and logical. The method works as a kind of guide that draws attention to what appears to be proper and reasonable.

4 Discussion

The purpose of this research was to develop a practical model using visualization, thereby increasing the perceived performance of project execution. Based on the factors listed in Desriptive study 1, a method is designed for improving the success criteria in NPD execution, a prescriptive study.

When developing a new model for support in the design process for SMEs, the focus should be on making impact at low cost. In other words, implementing the suggested model should be easy and smooth. This model was developed through the results of the Descriptive Study 1, a thoroughly literature study and by combining practice with the actual problem factors.

4.1 The prescriptive study

The eight categories, four groups and two different kinds of approaches developed in the research are the main focus in this model. Using different rendering types according to these approaches is how it is suggested in this reference model. If we look at Figure 4 regarding dependencies of rendering type according to reason of use and adopt the knowledge from literature regarding visualization, we could look at a generic model like Figure 5.

This suggested model provides direction of when to use what type of rendering and map this to one generic design process. This gives us directions on supporting systems for using visualization in NPD projects. By improving the knowledge about the positive effects of using different rendering types according to the process and learning when to use these different types of rendering, one could consider a development of the entire process, as shown below. However, this model focuses on the exploration of ideas towards defining a solution, and there are steps to be taken both before and after these exploration and define phases. These steps need more research in the future.

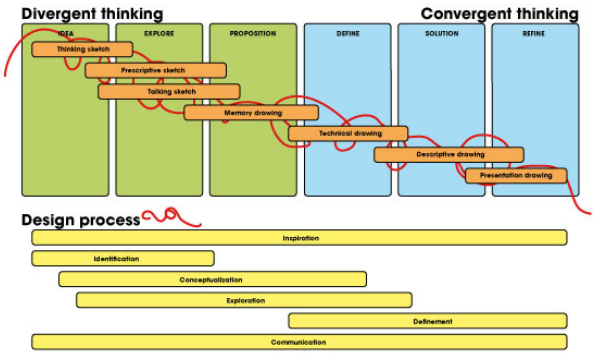

Fig.5. A generic model of visualization according to rendering type, with generic design process as a reference.

The different phases in the model are described as guidelines for management and methods for teams. By exemplifying the content of the different phases according to what value it creates, one opens the door to design thinking and learning projects.

The different phases in the conceptual phase are: Thinking sketch, Prescriptive sketch, Talking sketch, Memory drawing, Technical drawing, Descriptive drawing, Presentation drawing. The phases are described in more detail below.

Thinking sketch. It all starts with an idea inside the mind. To capture this idea before it flows away is difficult. It could be gone within seconds. Reloading the working memory by simply putting thoughts down on paper or into a model is the easiest way to capture the idea. These sketches of thoughts are "for your eyes only," and are there to help you recapture the thought you had at that specific time. Because the only purpose of this specific sketch is to help you remember the idea and the thought you had, the resolution/exactness of the sketch is irrelevant.

Knowledge about the capacity of our working memory is insufficient. One does not have knowledge about how quickly the idea or thought is released to make room for other things that load working memory. By creating hundreds of sketches, no bigger than a postmark, you are able, just by looking at them, to recapture most of the information connected to those sketches.

Prescriptive sketch. Making sense out of the thinking sketches and adding knowledge and creating new knowledge for them is the main goal in this step. In this phase, the sketch work becomes more intense as the conversation between the designer and the sketch grows. In this conversation, new knowledge is created, providing value throughout the whole phase.

The use of this prescriptive sketch is mainly for your own benefit. However, it could also work as a group thinking tool, allowing others to add their knowledge to the exploration and creation of new

knowledge to the idea. These sketches should be made at quite a high level of abstraction in order to facilitate creativity and to support long term memory. The creation of ”the mind’s eye” is of great importance at this point, and designers see more in their sketches than they put in. These sketches are often too detailed and too much time is spent on the finish.

Talking sketch. It is in this phase the real communication starts. These sketches are supposed to explain the idea and its context. The creation of this “information graphic”, with sketches and text in combination, facilitates both individual thinking and interaction between team members and management. The ”talking sketch” communicates effectively and gives understanding to the idea explored. The purpose of this phase is to create a common mental image of the idea and to have the necessary information in one place. These sketches serve as building blocks in the development of knowledge regarding the idea and the focus area.

The roughness of the sketch allows other team members and colleagues to add value to it by interpreting the sketch in their own way and leaving drawn or written comments on it. This phase focuses on the combination of internal and external information, giving new meaning to known areas and ideas.

Memory drawing. This is the first drawing of the idea. The main focus is to communicate with more accuracy in the image, and computer application could be used. However, one must not forget that the main goal is still to use divergent thinking and create ideas.

Even though this phase is used to create ideas, the focus slides towards finding solutions. One uses this phase in order to develop more understanding about the ideas created and to build upon other ideas. The verbal comments in the previous phase are drawn into the concept externalizing its meaning and communicating the solution of that verbal exploration.

The level of detail is in focus, changing the earlier abstract concept into something explicit and concrete. The combination of imagery and reality becomes clear and creates new meaning in the concept.

Technical drawing. A new focus with definition and convergent thinking dominates, even though new ideas may occur and be implemented. The communication is broader, with technical content and concept design to detailed design. More people have to be able to understand the drawing. The handover situation between different stages in a company's development process usually takes place now. As a result, the diversity of people with information needs increases. This phase should solve these needs.

This phase concludes the exploration stage and creates an understanding of the complexity of the idea. It also illustrates the solution in detail. The technical drawing is also a foundation for decision-making. It transforms ideas into technical solutions, forcing team members to make decisions.

Descriptive drawing. Further development drives the level to detailed designing, with a focus on delivering the solution to the problem. The ideas narrow down in order to explain and describe the solution to an even wider group of people. Both the detailed design and the complete solution of ideas solving the problem spotted on the market are in focus.

Explaining the solution in its context with storyboards or scenarios is an important step. This results in even more information about the solution and gives marketing and sales new knowledge about the use of the solution. This could lead to a new meaning of the product within its scope, which in turn can create even more value to the company behind the product.

The systematic approach of the design engineers is useful and creates value in this phase. This is the phase that most design engineers strive to get to as soon as possible because this is where the ”real” work is done (with computer applications describing the solution).

Presentation drawing. This drawing contains the entire information of the solution, presenting it in an esthetical way. Containing a combination of drawing and text, this could be more information graphic than drawing. This information should be able to present the entire solution to everybody involved, explaining both the solution and the scope of the problem solved.

A ”walkthrough” of the entire process and the visual work from divergent to convergent thinking could be helpful in order to fully understand the process of designing the solution. This creates a deeper understanding of the presented solution, as well as the process of creating the solution. It gives understanding to the iterative process of designing and explains the importance of the exploration phase in coordination with the solution phase.

5 Conclusion

This research provides a classification and characterization of SMEs need for resources in visualization for communication in there ambition in creating innovations. The big difference between best practice and the current practice within SMEs needs attention. The result of the research provides a model for creative use of visualization in NPD.

The main objective in this research was to analyze how and why visualization can be used and managed to improve product development execution.

The Research Clarification investigated how and why visualization is used in product realization projects today in industry. The learning from this research is that knowledge about the effectiveness of renderings as a tool is low. Visualizations in NPD processes are often unstructured and ad hoc. A categorization of the use of visualization was developed. Eight categories are divided in two groups, behavior and rendering types. By clarifying the current situation, the next step was to exemplify the problems of using visualizations.

Descriptive Study 1 clarifies the factors that affect the perceived performance of NPD projects. The factors could be seen as common sense. Nonetheless, they are for the most part forgotten, ignored, or even not seen as work. The focus is to deliver a solution as soon as possible, ignoring or neglecting the important phases of knowledge gathering and exploring ideas. This implies the needs for increased creativity where tools and methods for applying visualization in the early phases of NPD projects could be supportive.

Finally, Prescriptive Study 1 proposes a model of visualization according to a rendering type. This model is based upon the empirical findings in the different cases, literature studies and the researchers' own experiential knowledge about design processes and development projects. The model is mapped upon a generic design process in order to be adapted within organizations using different design processes. The different phases are justified according to the creative process, and support both creative and design thinking.

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