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WHERE DO INNOVATIONS COME FROM?

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1. Introduction

Innovation is closely connected to the concept of design, especially if design is used as a verb, i.e., designing [Hubka 1996]. Designing is a transformation process which aims to create something new or to change a less desirable situation to a preferred one [Friedman 2002]. From an engineering design point of view innovation is a constantly present ingredient, in varying degrees, for an engineer to handle. Therefore, among other things, innovation as a concept is in industrial focus.
In turn this industrial interest in innovation stimulates academic research in the field. Looking at the contributions from 4 ICED conferences ranging from 2003 to 2009, and 2 Design conferences, Design 2006 and Design 2008, a search for the word innovation gives the following result:

Table 1. Use of the word 'Innovation'

ICED	Mentioned in papers	Total hits	Design	Mentioned in papers	Total hits
ICED 2003	29%	459			
ICED 2005	31%	915	Design 06	45%	203
ICED 2007	30%	717	Design 08	42%	641
ICED 2009	26%	622			

Hence, the topic of innovation has a fairly established role within the engineering design community. Innovations within an industrial setting should be results-focused and opportunity-focused. [Drucker 1998] One way for top management of stimulating these foci is by rewarding employees with an award for innovations showing high technical standards while also seizing or creating a market opportunity. Awards are often also used for marketing the company as being innovative and creative, e.g., "creating the future". However, in general, in these announcements the roots of the innovations do not show. So, we started to wonder – where do innovations come from? This paper is based on a descriptive study of two types of innovation awards within a manufacturing company and aims at identifying sources and understanding the background of these awarded innovations.

2. Delimitation

The study is delimited to the point of view of the actors that has received awards for innovations. The study presented here includes an implicit top management point of view, i.e. top management is involved in the award decisions but they have not been interviewed in this study. We do not distinguish between the two awards when presenting the empirical data.
The company's view of innovation is shown in the description of the two prices.

Thus, in this paper, we have chosen to take an industrial view and use the innovation awards at the company to investigate the background of innovation activities.

3. Method for data generation

Five semi-structured interviews have been performed to generate qualitative data for this study. In total seven respondents have participated in the interviews, which lasted from about 45 minutes up to 1.5 hour. The interviews have been performed by three of the authors, face to face or by phone. The respondents are found within a large manufacturing company and have academic backgrounds ranging from high school to PhD, in different technical areas.

The company has established two awards for innovation. When rewarded, the respondents had an employment with the company where they worked as product developer, project manager or researcher. The interviewees were selected from the five most recent award winners for each award. All interviewees are still employed at the company.

Semi-structured interviews means that the questions are focused on certain topics, but the respondents can formulate their answers freely in relation to the topic. The topics for the interviews in this study were broadly settled to: the *circumstances surrounding the idea* and the *process from idea to product*. Often, semi-structured interviews start with an open-ended question. The first question in these interviews was: *Tell us about the prize?* From this, the interviews have emerged deeper into the topic of what initialized the innovation process. Firstly, the follow up questions are built upon words coming from the respondents answers, thereby the words are based upon the terminology "natural" for the respondents. Secondly, in general follow up questions have been, for example: *"why?", "tell me more about…", and "can you explain…"*. This has encouraged the respondents to go deeper into the area and to some extent biases by the researchers have been avoided. The interviews were carried out in Swedish, recorded and transcribed; the citations in the papers are translated by the authors. The written texts have been interpreted and analysed in relation to the context of the question, meaning that the analysis has identified categories, which have emerged from the empirical data.

The innovation awards that frames the study presented here can be awarded to any employee of the company that has performed an innovative activity. For both prizes, the winner/winners are selected by a review committee.

The Haglund medal:

This award has a tradition going back to the midst 80's, and is annually distributed within the company. The purpose is to recognize contributions from employees which lead to a commercial success for the company and results in future work or employment. The winners can be individuals or groups of employees. The committee consists of CEO, a union representative and three people with excellent experiences and knowledge of the company. All employees can be nominated and can nominate others to the award.

The Innovation prize:

This award is a complement to the Haglund medal and was established in 2003 to give faster feed-back by having a less stringent demand on commercial success. Any individual or group who has developed the most innovative product or process over the past two years can be nominated. The company's R&D Council determines the winners.

Two of the interviewees have been awarded both awards. First they received the Innovation Prize in 2005 and later when the innovation became a commercial success, they also received the Haglund medal. This shows the complementary character of the awards.

4. Theoretical Framework

This section is three folded. First innovation is put into context, secondly the relation of knowledge and innovation is described briefly and finally the innovation setting where innovations occur is described.

4.1 On innovation

At the heart of innovation activities is the effort to create meaningful and focused change within a company's economical and social potential [Drucker 1998]. A driving force for innovation activities is the intention to change a situation, a thing, a condition or the like into something better. This broad application of the concept makes it possible to view innovation from multiple perspectives, for example from a product development, a process, a marketing or a business model point of view [Moore 2004]. In general, the definition of innovation is something new that has reached a market, but such a simplification does not support understanding. For instance, what is new? And, what is a market? From a management point of view one can recognise at least 15 different constructs that embarks from the word innovation, and at least 51 different variants which relates to these [Garcia 2002].

Three basic archetypes of innovation outcomes can be discerned, namely incremental innovation, evolutionary and revolutionary innovation [Jacoby 2007]. The innovation outcomes can be seen in Figure 1. The incremental innovation, is based upon existing users and existing offerings. Evolutionary innovation is based upon existing users and new offering, or new users and existing offerings. Revolutionary innovations are based upon new users and new offerings. According to [White 2000] innovations can originate from customers, creative individuals or by including ideas from other fields. This study takes a closer look at some of these factors.

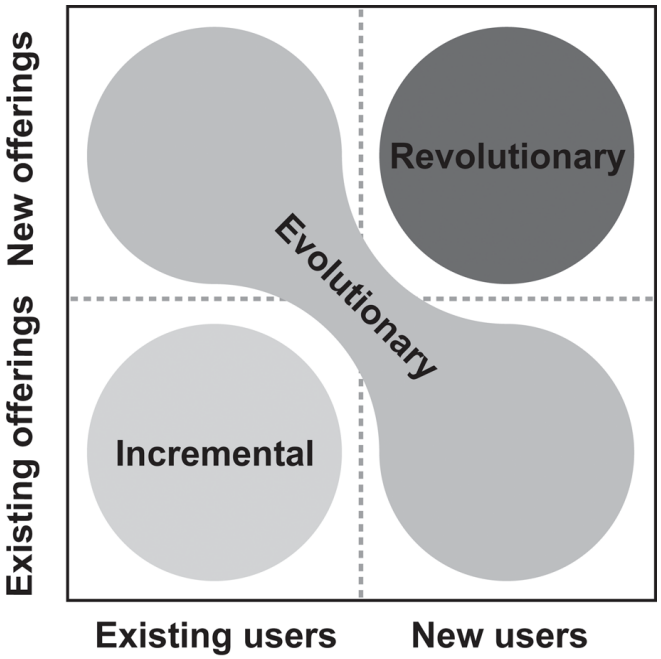

Figure 1. Innovation outcomes, from Jacoby & Rodriguez 2007

Since a main effort of innovation is economical and social growth, newness in terms of markets (users) and/or technology (product) is vital. The firm's growth can come from every quadrant in Figure 1, thus the tool can be used to identify the intentions of the innovation activities, to deploy an appropriate innovation process and to assess the portfolio of innovation effort [Jacoby 2007].

4.2 Innovation and knowledge

Innovation is based on previous knowledge, Nonaka [p. 237 1995] states:
"'Something new' is created by having tacit and explicit knowledge interact with each other" and they concludes that this conversion process is the essence of knowledge creation. Explicit knowledge can be readily codified by symbols, objects or models. Tacit knowledge is context dependent, based on experiences, thoughts, and feelings. The concept also comprises both cognitive and technical components and is hard to codify.

4.3 Innovation setting

The *innovation setting* describes the environment and team in which the innovation occurs. In large organizations the ease of internal communication has a great effect on the innovation climate [Jensen 2007], both knowing what and knowing who is important. Further more as elaborated on by Lopez-Mesa (2004) in Isaksen's 4P model and Rhodes 4P+N model respectively, the innovation setting is dependent on the following five factors; person, product, (development) process, press and (customer) needs. The aggressiveness of the goals and how achievable they are perceived to be is part of the concept press.

New ideas can come from a range of different sources from inside or outside the organization, such as customers, competitors, R&D, and production staff [White 2000]. The actors within a product development team have to possess innovation capabilities such as curiosity, empathy, and so forth. These individual and "personal" capabilities are drivers in an innovation process [Gutiérrez 2009].

The team setting is also important for innovation, the team needs both knowledge of process, product and people. The composition of innovative teams is difficult. Sosa and Danilovic (2009) present an approach to identify the individuals who contributes to innovations by 'creative interactions'.

Gish et al. (2009) followed the idea work of a specific product and concluded that *"Early idea work is a complex process and interlinked with many other activities both inside and outside the organization"* They also concluded that the idea work includes a wide range of actors and needs continuous support from these actors.

5. The respondent's point of view

The innovation activities that the respondents have described have been categorized into four categories: *Initial knowledge* (and lack of knowledge) in the team, *Knowledge creation*, *Innovation setting* and *Idea initialization*.

Extracts from the interviews are presented here.

5.1 Initial knowledge in the team

In this study initial knowledge means the knowledge the interviewees had when entering the project. This includes but is not limited to knowledge concerning; competitors offerings, the company's existing offerings and users.

The starting position for the innovation process is recognised by the respondents as a situation where knowledge is lacking in various degrees i.e. experience in the specific area, customer needs or existing technology. One respondent perceived that none of the project members had the appropriate knowledge:

> *"No, there was no one who had it [the knowledge]. That's what the problem was; there were no knowledgeable persons available. Those who had developed the previous solution had left or changed jobs."*
>
> *"We had all worked within the company for several years, but we where new [within this specific application area]."*

Another respondent explained that their innovation process was really starting from scratch, were previous knowledge and experiences was lacking.

> *"This started really with a blank paper.* […] *Many things had not been done before."*

Yet another respondent described the innovation activities as a stepwise exploration of possible solutions:

> *"We had lots of different solutions. We had seven different concepts of solutions that we decided to try out. If we had understood more beforehand, then maybe we would not have done so. So it was more like an exercise. Five concepts was not realistic, but was useful for us for the sake of understanding."*

These excerpts show that innovation activities are closely linked with a learning process, where knowledge is built successively. A clear example of incremental product development where existing knowledge were built upon is:

> *"We have a similar product, something to replace. Because of this we have a deep experience of how the product should be constituted. That experience has also helped this project to succeed."*

It is seen from the statements above, that when working in projects the persons available might not be those actually needed for the task, since the most suited persons can be fully occupied in other projects. Also, people leaving the company means that valuable knowledge disappears. For these innovation activities, the respondents expressed that there existed previous knowledge within the company. One interpretation of this situation is that the team was able to recognize what knowledge that would be needed for the innovation activities, but for different reasons, they could not get access to it.

5.2 Knowledge creation

The activities of knowledge creation are part and parcel of the innovation activities. The respondents have expressed that knowledge creation and progressing understanding are perceived to take a significant amount of time.

> *"The problem was that throughout 2000, we dedicated maybe 7-8 months to build competence within the group. None of us had the experiences of this particular application, so we were forced to go down to the workshop to watch what happened when* [the product] *was in use. We were sitting there watching this… So it was a slow start."*

The necessity of spending time observing like in the above project seems to be common. Also, knowledge is explained by the respondents to evolve in dialogues with colleagues possessing expertise skills. From such collaborative efforts new practices can evolve:

> *"We will launch the project in the autumn, what skills do we need before we start the project? …I came up with the idea that we needed more knowledge about the forces involved. So, for three months, I sat down with a colleague and created a force calculation program"*

Over time, this respondent perceived that they might have started something that they might not be able to finish:

> *"We thought that we couldn't do anything [about the forces] - it's physics"*

Though, the development of the calculation program changed that situation:

> *"With the help of the program, we were able to experiment with different types of forces to investigate what happen. It was only after playing with different values we really started to come up with an understanding that it may be possible to find a solution."*

Another respondent explained that knowledge domains that have once become obsolete for the company might come into play in innovation activities. Though, the revival of such old knowledge can take long time, and the business environment is moving fast:

> *"It was for an area, in which the company actually has not been active for a relatively long time. The first attempts to find a solution was made in something we could call a knowledge development project. We started working guided by the old specifications, but we felt that this was not true any longer. The market had changed and the customers' requirements had also changed, so it was no longer the right product. We understood that if we continued on that track the right product would not come out of the process."*

A respondent from another innovation project described how his perceptions changed when learning in the innovation activities:

"When I came up with the idea, we had some knowledge, but there was much we had to learn along the way. Things that we, from the start, had not realized were really important. There were surprises on the journey, one can say."

The importance of knowledge creation when working in innovation activities is recognised at the company. When knowledge is identified as lacking a parallel project to build knowledge is in some cases started. The respondent expressed the links between such projects and innovation activities:

"To build knowledge was a systematic work. We did that in a parallel knowledge project while we in the main project tested the idea of the new product."

Yet another respondent described the innovation activities as a stepwise exploration of possible solutions:

"We had lots of different solution ideas. We had seven different concepts of solutions that we decided to try out. If we had understood more beforehand, then maybe we would not have done so. So it was more like an exercise. Five concepts were not realistic, but they were useful for us for the sake of understanding."

This shows that knowledge creation can be enhanced by developing alternative tentative solutions. Of course, in retrospective it is simple to see the dead-end solutions and think that they were unnecessary. These excerpts indicate that innovation activities are closely linked with a learning process, where knowledge is built successively. Two respondents explained their way of working as follows:

"We sketched a lot in the CAD-system. And it felt like an absolute must to see how an idea worked out"

"We did sub-structures, tested and simulated forces by applying load in the laboratory. Some calculations were made in early FEM-systems that were available"

5.3 The innovation setting

One respondent highlights the importance of informality and fun when working with innovations. This, he explained, was as a way to cope with the big dips of hopelessness and doubt when the team feels that the task might not be doable:

"We managed to create an open and informal climate. We laughed and had lots of fun. We called our humor a sort of resignation jokes. We used it when it went so goddamned bad that it is almost ridiculous".

He continued to describe how the team worked closely together, as he saw this as important for coming up with new ideas:

"The team was very tight. We where sitting very close together. And, we were throwing ideas between each other; we were really on each other."

One of the respondents explained the innovation setting as follows:

"One needs to have a network of people, it does not need to be hundreds, but if you have a network you will know who to turn to in order to solve the problem. And in my opinion the closer you sit, the easier it is to get this network. "

Another respondent had a different view for how an innovation setting best support the creation of new products:

"...we have so specific boundary conditions to work with, so I personally do not think that brainstorming is something that is directly useful. A more structured discussion on a problem, or to seriously discuss what we can do differently… instead of having this kind of… but, yes, the difference is subtle, structured brainstorming."

Yet another respondent had the opinion that the demands posed on the end result matters a great deal:

"One should take in consideration that clear objectives make it easier. Then there are the unclear objectives, that also were present, but in that case it is necessary to get them quantified from the customers."

5.4 Idea initialization

How the ideas were generated and what initialised the subsequent innovation activities, are explained by one respondent as a "Eureka" moment:

"We had gathered a number of people in a meeting. We talked about our perceptions about the problem. This is how it is, it works likes this and this is the rational and so forth. We do not have a solution for this… So, what do we do? From this conversation, suddenly… It was actually, bang! Why can't we do like this? Then it was obvious, this how the solution should look like!"

The respondent continued to describe what has been different from previous meetings.

"It was a new person [previously not involved in the project] *from the production that we had invited. We wanted someone to look at it from a slightly different direction."*

Another respondent answered the question from where did their ideas come by describing how their innovation activities started by a request from another industrial sector:

"They asked if we could develop a free-cutting steel without lead. They thought that regulations would make lead in this material not allowed in the future. So, the trigger for the idea was the possibility that the authorities would put higher demands on the industry. They thought that something like this would happen, since such regulations already were established in Europe."

Emotions can also be a trigger for innovation activities. One respondent explained:

"I became frustrated. I had tried to find a solution for so long. We had tried several different approaches; we had tried to think this through. Nothing worked."

She continued to describe what encouraged her to keep on trying:

"I was part of another project at a university, and had learnt that it might be possible to do this in another way than what was commonly understood. So, I tried. And, it worked!"

Another respondent explained how his project got started:

"We had some sort of objective and some alternative solutions."

From this tentative objective, he described how the innovation activities started of from previous patents at the company and from benchmarking competitor's products:

"It is interesting to look at old patents, on things that have been. Very interesting solutions that a lot of people have spent time and effort on, to find a solution to these small gadgets. There are an abundance of solutions if you scrutinize patents."

He continues:

"If you stretch it, an idea virtually always comes from one individual from the beginning"

As seen above stimulus for ideas can come from many sources, often the initial idea is formulated by one individual but then developed and refined in the contact with others. This contact can also give motivation and momentum to develop the idea into a solution.

6. Discussions of respondents point of views

The individuals interviewed work in the incremental, possibly evolutionary, innovation paradigm, see figure 1. This because existing users and existing offerings where the basis for their projects.

6.1 Initial knowledge in the team

Despite the incremental situation knowledge can be lacking in the beginning of a project on either individual, group or company level. Knowledge can exists within the company; however persons that possess it might not be available for the innovation project at hand. Since people go in and out of projects this situation is common for all sorts of projects. Further, in relation to this aspect, a relevant question is how to achieve the best possible result with the available competences? This study shows that there are challenges when setting up a team of designers that are supposed to work with fuzzy and vague problems. This is also true when working with problems with very tough requirements (that could be seen as unachievable). In several of the projects the requirements on the new product were so demanding that a solution could not be developed from the existing knowledge within the company.
In reality there is no "dream team" because the team is set up based on available resources and the basis of what type of knowledge is assumed important at the beginning of the project.

6.2 Knowledge creation

The core team started the project with its existing knowledge, and during the project this knowledge was expanded and the team had the opportunity to acquire knowledge from knowledgeable people outside the project. This shows that it is more important to have team members with competences that make them good at finding, and wants to find knowledge, instead of trying to find the right front-end competence in the beginning.
From the presented material it seems that communication within the groups is open i.e. knowledge exchanged between individuals and group and vice versa is abundant. This means that if knowledge is lacking at group level it is not present with the individual either. This leaves the group with the following four possibilities to acquire lacking knowledge:

1. *find who knows, ask an individual or group* within the company having the knowledge (tacit and explicit knowledge),
2. *revise corporate knowledge* such as databases, models, current offer, existing prototypes (explicit),
3. *search externally* e.g. university collaboration, patent search, and projects with customers (explicit),
4. *develop knowledge internally*, e.g. by sketches, observations, tests, simulations, and prototyping (tacit and explicit). The material indicates preference in this case for possibility 1 and 4.

The level of the requirements for the product to be developed is clearly interlinked with the perceived lack of knowledge. Co-location of group members enhances the well-functioning knowledge exchange. This can also indicate why possibilities 1 and 4 are preferred for creating knowledge since they are performed within the company and with people located near the project group. The lack of preference for possibility 2 can either be that face-to-face knowledge acquisition is preferred or that company knowledge is internalized in experienced individuals hence linked to possibility 1.

6.3 Idea initialization and innovation setting

Commonly, innovations can be seen as sprung out of previous knowledge that is gradually built up over time. On an abstract level this holds true, but we have found that the mix of previous knowledge and the creation of new has been a parallel, and necessary, effort that has led to successful innovations. This can be exemplified from the empirical data that in two projects they acquired new knowledge that changed the view on some phenomenon. In the beginning of the projects these phenomena were considered as rigid 'Nature laws'. When the project acquired more knowledge about the nature of the phenomenon they realized that they could change its behaviour.
The teams had the opportunity to acquire knowledgeable people from outside the project. Having a structured discussion where the constraints and ideas where discussed was a major part of the idea initialization. In the same way solutions were refined. Innovations can also burst out of a eureka-moment; however this has a random component to it, which is hard to reproduce. One of our respondents perceived that the solution was a breakthrough in a dialogue where they had been focusing more on settling the problem situation that they were going to solve. As opposite to focusing

on the problem solving issues, the open and informal dialogue suddenly provided for the "Bang!" where they immediately understood what to do. This "moment" was said to come from an individual invited from outside the project.

7. Concluding remarks

So the purpose of the paper was to identify sources and understand the background of some awarded innovations. So where do innovations come from? Based on the interviews of several team members in awarded innovation projects, some aspects can be emphasized: *the importance of the exploration and knowledge acquisition phase*, *importance of external triggers and innovation is not a linear process.*

- *Importance of the exploration and knowledge acquisition phase*: In fact the awarded solutions that were found and developed by the respondents came from varying sources and ways of working. There seems to be preponderance for acquiring knowledge either by asking someone who knows or developing the knowledge within the group. This however does not mean that retrieval of corporate knowledge existing at the outset of the project (e.g. simulation models, reports, etcetera) or university collaboration is contra productive.
- *Importance of external triggers:* basically, inspiration from outside the project has been identified as vital as triggers for several of the innovation activities. The possibility to acquire knowledge from others outside the project relates to how new ideas are born. The importance to allow outside knowledge into the project to influence the solution is in this study obvious. However to be of use, such sources need to be aligned to the preferences of the workforce. It is likely that so called lightweight solutions to knowledge sharing, i.e. wikis and like, is a way of supporting these preferences.
- *Innovation is not linear:* we can conclude that the innovation activities were complex and certainly not linear or sequentially performed. Backtracking of the innovative products show that the products were not based on just one innovation. Often part of the solution was found early in the process but certain requirements were very difficult to fulfil. The final solution consists of a complex mix of innovations and classical engineering (i.e. structured problem solving based on existing knowledge). The vague phases when knowledge was lacking, not available or could not be identified insisted on an iterative, stepwise, experimenting and reflective learning process.

In this study we have not problematized the term innovation, though in future studies an analysis of the material based on the interpretation of the concept as "a thing" or as "a process" is interesting. Moreover, mapping an innovation process on the basis of the empirical data in this study seems doable and would provide deeper understanding. In the development of products, three processes seem interesting to compare and contrast, namely the product development process, the innovation process and the knowledge creation process. In several projects the respondents describe that the product development process was not that explicitly described, during the last year a new product development process has been introduced, so it shall be interesting to see if and how the new process will impact future innovations.

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