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GENERATING INNOVATIONS THROUGH ANALOGIES

AN EMPIRICAL INVESTIGATION OF KNOWLEDGE BROKERS

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GENERATING INNOVATIONS THROUGH ANALOGIES

- AN EMPIRICAL INVESTIGATION OF KNOWLEDGE BROKERS -

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ABSTRACT

In this paper we explore how knowledge brokers – specialised design and engineering companies offering services to clients in diverse industries – use analogies for product development. Our research is based on interviews with project leaders of 13 knowledge brokering companies. The interviews focused on product development projects in which analogies were used. First, we categorize these cases according to the motivation to use analogies (efficiency vs. innovativeness). Second, we describe and analyse the process of using analogies. Our results show that analogies are frequently and very pragmatically applied throughout the whole development process. We also found that individual characteristics of the persons participating in such projects are the crucial factor that influences the outcome of the project.

INTRODUCTION

The phase of crucial importance in most product development projects is the front end, often called “Fuzzy Front End” (Koen, Ajamian et al., 2001; Kim and Wilemon, 2002). Here the decision is made which projects will get resources and which ones won’t. Additionally, several studies indicate that a major part of the product-development costs heavily depend on the decisions taken in the front end (Herstatt and Verworn, 2003).

A key activity of the front end work is to develop ideas for new products and generate product concepts. Hence the front end of product development requires creative work. A new and creative solution usually results from the combination of pieces of knowledge that have not been connected before (Geschka, 1992; Geschka, Moger et al., 1994; Hargadon, 2002). One promising avenue to create new combinations of knowledge is the use of analogies. As a basis for developing something new one has to access one’s own knowledge pool and other sources

of knowledge. Accessing this knowledge and transferring it to the new solution usually requires the use of analogies – although this is not always obvious for the creative person. An analogy between two objects exists if these are similar to each other in some aspects – i.e. similar appearance, similar function or similar structures – and are at the same time different in some other aspects.

A key problem in using analogies for product development is to find relevant analogies early in the process. Firstly, analogies can only be accessed if relevant knowledge of the different knowledge domains is available to the innovating person or group. Secondly, even if relevant knowledge is available, several factors can impede realizing the relevance of that knowledge in the current context. For example, learning is contextual, meaning that acquired knowledge is linked to the situation and meaning in which it is learned (Gick and Holyoak, 1980; Holyoak and Thagard, 1995; Schild, Herstatt et al., 2004).

The question arises as to which factors foster the use of analogies in product development. Firstly, it seems to be important to have access to diverse knowledge domains. Additionally, some practice in combining knowledge from diverse sources can have a positive effect. Furthermore, open-mindedness can foster looking in different domains even though obvious similarities between the domains are rare. According to Hargadon (Hargadon, 2002; Hargadon, 2003) certain companies, so called “knowledge brokers”, are in a special position to use analogies better than others. These companies are familiar with a wide range of knowledge domains and are therefore able to transfer a solution from one domain to another. Their unique position in a network enables them to take advantage of so-called structural holes. Structural holes describe the separation between nonredundant contacts (Burt, 1992). For example, there usually exist no contacts between manufacturers of sport shoes and manufacturers of medical devices. This structural hole was used by Design Continuum, a full-service product design firm, while developing the Reebok Pump sport shoe. They put an inflatable splint in the shoe and used a medical IV bag as the air bladder (Hargadon, 2003). This shows how bridging such a structural hole and transferring knowledge between formerly separated domains can lead to innovative solutions. Knowledge brokering can be conducted by consulting companies, design agencies and product development companies working for clients in diverse industries.

So far, the role of knowledge brokers in the context of product development has been explored based on a limited number of case studies (Hargadon and Sutton, 1997; Hargadon, 2002). With this research we want to enlarge this empirical basis and develop a richer

understanding of the processes and the actors behind the use of analogies in product development. Specifically the present study aims to answer the following questions:

- Which purpose does the use of analogies serve in product development projects?
- How do knowledge brokers ensure the access to diverse knowledge domains in order to find analogous solution approaches?

Our results indicate that analogies fulfil a greater variety of functions than usually considered in the relevant literature. For instance, analogies are not exclusively used to develop truly new products or solution strategies, but are also an important means to increase the efficiency of the innovation process. Besides, our results show that the combination of knowledge from diverse sources is primarily based on existing experience and knowledge of the persons participating in such projects. Therefore, the team configuration is a key (limiting) factor for companies tackling the development of new products, services or processes based on the usage of analogies. Hence, human resource management plays a crucial role for the formation of such product development teams.

The paper is organized as follows: In the next section we describe our empirical approach. Afterwards we present the results of our qualitative research based on 13 cases. First, all cases are categorized according to the primary purpose to use analogies. Second, the process of using analogies is thoroughly described and analysed. The paper ends with a summary and an outline of aspects for future research.

EMPIRICAL APPROACH

We concentrated our research on companies that are in the position to act as knowledge brokers in product development bridging “otherwise disconnected worlds” (Hargadon, 2002; Hargadon, 2003).

The companies participating in our study all offer services in product development – particularly industrial design and engineering – to clients from diverse industries. Therefore, these companies have the opportunity to transfer solutions between knowledge domains to generate innovations. In addition, they are all experts in product innovation, simply because it is their main activity.

As a research method we chose semi-structured interviews that were conducted mainly via telephone. The interview guideline was addressed to managers in charge of product development projects in the companies participating in our research. The interviews started with a general part including questions concerning the company (e.g. services offered, client industries) and the interviewee (e.g. experience with the application of analogies in former projects). The major part of each interview focused on a project in which analogies played a role for developing a new product. The interviewee was asked to first describe this project. After this and the explanation of the analogies that were used, the rest of the questions dealt with the formation of the team and the way the team worked with the analogies. Our interview ended with an evaluation of the effects on the project resulting from the use of analogies.

13 companies participated in our research, including 3 companies offering engineering services, 4 companies offering engineering and design services and 6 companies that specialised solely in industrial design. The companies range from large international companies like IDEO to small companies with 6-8 employees. Of the 13 persons interviewed, 8 persons have a degree in industrial design (one of them additionally has a degree in engineering), 4 persons have a degree in engineering and one person has a degree in information technology. The projects described in the interviews can be arranged between solely technical problems and problems where design aspects dominated. An overview of the cases is given in table 1.

No	Knowledge broker (employees)	Industry of client	Target of project	Team configuration
1	Small industrial design studio (<10)	Music industry	Design of a mixer for audio engineering	Industrial designers
2	Small industrial design studio (<10)	Tools	Design of a steering lawn mower	Industrial designers
3	Small industrial design studio (<10)	Tools	Design study of a mini cordless electric screwdriver	Industrial designers
4	Medium industrial design studio (>30)	Vehicles	Design study of a fork-lift truck	Industrial designers
5	Large engineering company (180)	Medical technology	Electronics for a medical device to create high voltage in very small dimensions	Electronic and mechanical engineers, a physicist and a technician for precision mechanics
6	Small industrial design studio (<10)	Aircraft	Design of a cockpit of a big passenger aircraft	Industrial designers and an engineer
7	Large industrial design company also offering engineering services (~ 400)	Sports	"Baton" for the Common Wealth Games	Industrial designers, human factor specialists and engineers
8	Medium engineering company (30)	Mobile phone services	Mobile phone appliance for tunnels	A Hardware engineer, a software engineer, a design engineer and a model maker
9	Medium engineering company also offering design services (40-50)	"Baby equipment"	High-quality baby stroller	Engineers and designers
10	Medium Design and engineering company (45)	Medical technology	Purifier for dental tools (e.g. bur, polisher)	An industrial designer, mechanical engineers and technicians, a model maker and a tool and die maker, electronics and software engineers
11	Small to medium design studio (12)	Promotion	Original promotion item with long lasting value	Industrial designer
12	Medium to large industrial design studio also offering engineering services (>60)	Office furniture	High-quality backrest of an office chair	Industrial designers and design engineers
13	Large engineering company (>200)	Transport sector	Facility to rearrange allocation of train wagons	Soft and hardware engineers, technical experts

Table 1: Overview of interviews

FUNCTIONS OF ANALOGIES IN NEW PRODUCT DEVELOPMENT

The function of analogies in product development processes we observed can be characterized along an efficiency / innovativeness dimension. That is, in some projects analogies are primarily used to increase project efficiency and in other projects analogies rather serve to generate highly innovative new product ideas and concepts. In some projects both strategies were followed.

The motivation to use an analogy in a product development project has an impact on the search space explored and the type of transfer. Aiming at efficiency means a solution that fulfils the given demands in the shortest possible time – restricting the search space to well known and proximate solutions. Due to intense competition, innovating companies can be forced to use analogies to reach the given time and cost limits. How pressure from outside concerning cost and time limits can provoke the efficient use of analogies for highly innovative products is described by Majchrzak et al. in their study concerning knowledge reuse in NASA projects (Majchrzak, Cooper et al., 2004).

Contrastingly, aiming at a high degree of innovation leads the team to a wide search space and a focus on far analogies. In the literature a distinction is made between near and far analogies (or intradomain and interdomain analogies respectively) (Dahl and Moreau, 2002; Bonnardel and Marmèche, 2004). If source and target of an analogy are closely related or stem from the same domain respectively, we talk about near analogies. Far analogies, on the other hand, have fewer surface similarities – here source and target belong to different domains. Dahl and Moreau have shown that the number of far analogies that are discussed during a creative product design task is an indicator for the originality of the resulting design and the appreciation of the design by the customer (Dahl and Moreau, 2002). An example of a breakthrough product innovation based on a far analogy is the Speedo Fastskin swimsuit. Here an analogy to the structure of shark skin was used bridging domains that are very far apart – biology and sports equipment. Applying bionics in product development offers very innovative and original solutions, but also difficulties in the transfer-process.

The cases can be located along the efficiency / innovativeness continuum, coming up with three main clusters (see figure 1). On the one end, we found 3 projects mainly focussing on reaching tight timeframes and cost-limits and/ or a reduction of risks. On the other extreme of this continuum we identified 2 breakthrough projects that were mainly driven by finding a really new product solution. Finally, we found 8 “Balanced” projects which are located

between pure efficiency and breakthrough. These are characterized by a compromise concerning efficiency and the goal of finding a highly innovative solution.

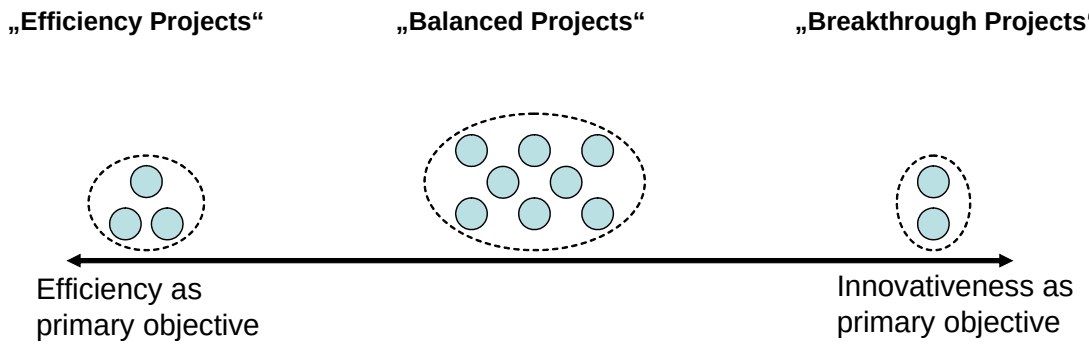

Figure 1: Project clusters according to primary function of using analogies

In the following sections we describe and analyse the various projects within the three clusters.

Efficiency Projects

No.	Target of project	Analogy	Characteristic of analogy based transfer
8	Mobile phone appliance for tunnels	Transfer of a processor used in a control board of an amplifier for a mobile phone mast	Transfer of an existing technological solution that was already used in a former project
13	Facility to rearrange allocation of train wagons	Transfer of a solution of consistent time measurement in shared systems	
5	Electronics for a medical device to create high voltage in very small dimensions	Transfer of a technological solution from light electronics	

Table 2: Efficiency projects

The three cases portrayed in table 2 all belong to engineering companies that reported to use analogies mainly to meet time and cost constraints set by their clients. Hence, in these cases the search for analogies was mainly driven by the aim to increase efficiency. In order to succeed the engineers built upon their experiences from former projects and transferred existing technological solutions. For example, in case No. 8 a mobile phone appliance for

tunnels had to be developed. One of the participating engineers who was responsible for the hardware development made use of an already existing control board that he had developed in a former project as part of an amplifier for a mobile phone mast. He realised that he could use the complete processor for this new application. Due to this transfer of an existing technological solution the development time and costs could be reduced. In addition, existing contacts to the manufacturer of the processor could be used which had a positive effect on the procurement of the component. Altogether, the use of the analogy helped to reach the cost and time targets that had been defined by the client.

Relying on ones own experiences can be highly efficient: In that case not only explicit knowledge, but also implicit knowledge can be transferred. Besides, it helps in judging the relevance of the analogy if one has profound knowledge based on own experiences in the source domain.

Balanced projects

In all "Balanced projects" the reduction of development time and costs played an important role with regard to the use of analogies. At the same time all projects aimed to develop a really new solution to differentiate the innovation from existing products in the market. Thus, the common basis of the balanced projects is that a time and cost frame to develop a marketable solution is given by the client and within these constraints analogies are used to maximize the innovativeness of the solution. However, slight differences can be identified in-between the cases concerning their approach of making a transfer based on an analogy. The related eight cases are portrayed in table 3.

First, in the projects 7, 1 and 6 design elements or principles that had already been used in former projects were transferred. The transfers were not as direct as they were in the case of the "Efficiency projects", because only basic shapes and solution principles and not existing technological solutions were transferred. For example, in order to develop a new "baton" for the common wealth games an analogy was detected to a digital antenna that had been developed in a former project. The antenna had the form of a stick with a swelling in the middle on which a display was mounted showing lights to visualise strength and activity of the received radio signals. In analogy to this antenna the baton was designed as a thin stick with a swelling in the middle containing a display that showed the pulse rate of the person holding the baton.

No.	Target of project	Analogy	Characteristic of analogy based transfer
7	"Baton" for the Common Wealth Games	Transfer of form and technical ideas from an antenna for digital radio	Transfer of design elements or principles from former projects.
1	Design a mixer for audio engineering	Transfer of solution principles from an ergonomic study of the interior of cars	
6	Design of a cockpit of a big passenger aircraft	Transfer of ergonomic principles from vehicle construction and chairs in general	
10	Purifier for dental tools (e.g. bur, polisher)	Transfer of technical solutions from high-pressure-cleaners and premium car-doors	Transfer of technical solutions from other industries. Ideas are based on former projects, but not directly transferable without building up new competences.
9	High-quality baby stroller	Transfer of disc brakes from mountain biking and single wheel suspension from vehicle construction	
2	Design of a steering lawn mower	Transfer of solution principles from vehicle construction	
12	High-quality backrest of an office chair	Transfer of technical solutions from sports and medical technology	
11	Original promotion item with long lasting value	Transfer of material and movement of a piece of ship yard waste	Transfer of design elements based on direct contact to the environment of the designer

Table 3: Balanced projects

Next, in the cases 10, 9, 2 and 12 technical solutions were transferred, but these transfers were not solely based on experiences from former projects. Although the ideas that were followed originated from personal experiences of the team members, the teams were also willing to look into different areas to build up new competences if required. These projects targeted at developing a really new or premium solution that could be manufactured with reasonable effort and be introduced to the market in the foreseeable future. For example, in the development of a purifier for dental tools two analogies were used. First, to develop a cleaning mechanism, an analogy was detected to high pressure cleaners that were already known in the market for cleaning tools. This approach originated from a participating designer who had experience in the area of high pressure cleaners. A second analogy concerned the door of the purifier. In analogy to high-class cars an automatic closing mechanism was developed that draws the door shut if it is not properly closed or left ajar. The

developed product was unique in design and handling. Most project goals were reached. Only the development costs were higher than targeted, because core competences for this apparatus had to be developed. Neither the knowledge broker nor the client possessed extensive knowledge in this area before the project.

Finally, a slightly different approach can be observed in case No. 10. The client requested the designer to develop a promotional item with substantial benefit for the user. The client did not restrict the solution space. Just after receiving this job, the designer participated as a tourist in a harbour tour. There he encountered a hump of waste which stemmed from rivets punched by a shipyard. One of those small curved metal plates inspired him to develop a bottle opener as a skipjack transferring movement and material from the piece of metal waste. In this case inspiration was sought in the direct environment. On the one hand, this approach was driven by high efficiency: The product should be given away as a promotional item – therefore having limits concerning production costs. On the other hand high originality of the product was demanded. This case however stands apart from the other displayed cases, because the developed product was from a technical point of view very simple and the client provided only few restricting parameters for the project.

Breakthrough projects

There is a last cluster encompassing two cases (see table 4) where innovativeness was the predominant objective– almost totally neglecting project efficiency. In these two projects the intention was to develop a design study for imaginary product lines of the future not having the restriction to be directly marketable. However, these studies inspired the development of products being successfully brought onto the market.

No.	Target of project	Analogy	Characteristic of analogy based transfer
4	Design study of a fork-lift truck	An egg as an archetype form to provide protection	Transfer of basic ideas and shapes from very distant areas. Use of very far analogies.
3	Design study of a mini cordless electric screwdriver	A hand-axe (/ hand-wedge) from the Stone Age	

Table 4: Breakthrough projects

In these cases the project teams chose a different approach for finding relevant analogies. The scope of analogies was broader than in the other two clusters – basic ideas are transferred from really different areas like for example nature or Stone Age habits. Analogical thinking

does not lead to the direct transfer of a technical solution or material, but it is used to get a profound understanding of the solution strategy and transfer very basic design elements.

For example, in the case of the fork-lift truck study the designers started with the question of what is really important for the driver. Imagining themselves to be in the position of a fork-lift truck driver, the designers identified the importance of shelter. An analogy was detected to an egg as an archetype form to provide protection. Therefore, the cabin of the driver showed the basic shape of an egg. The study resulted in the production of a prototype that was not suitable for the market, because of high production costs and a too futuristic approach. However, this prototype served as inspiration for other fork-lift trucks that were successfully introduced into the market. Besides, the analogy helped to focus the project and to communicate the goals to be reached.

Looking back at the three different clusters, it can be summarized that most of the cases were attributed to the "balanced project" cluster. That is, the project teams followed mostly a mixed strategy to maximize the innovativeness of the solution concepts within a given time and cost frame. In addition, some projects clearly favoured one function of analogical thinking: Either efficiency or innovativeness. It could be shown that the motivation of using analogies influenced the approach where to look for analogies and which kind of transfers to consider. In the projects dominated by efficiency considerations, the teams conducted the search for analogical problem solutions in a rather narrow space and primarily relied on personal experiences from former projects. These teams focused on finding an already existing solution that could be transferred without substantial development effort. In contrast, the more considerations of innovativeness dominated the use of analogies the further the teams went to look out for analogies. In those cases the teams did not only search for easy transferable solutions, but were also willing to build up new competences or merely to transfer some basic ideas or shapes.

DETECTING RELEVANT ANALOGIES

After the exploration of the different functions analogies can be used for in product development and the resulting search space we will now describe and analyse the process of detecting relevant analogies based on the results of the interviews. Thereby we focus on the importance of the human factor.

An ideal process model of using analogies derived from literature analysis is displayed in figure 2 (Schild, Herstatt et al., 2004; Herstatt and Kalogerakis, 2005).

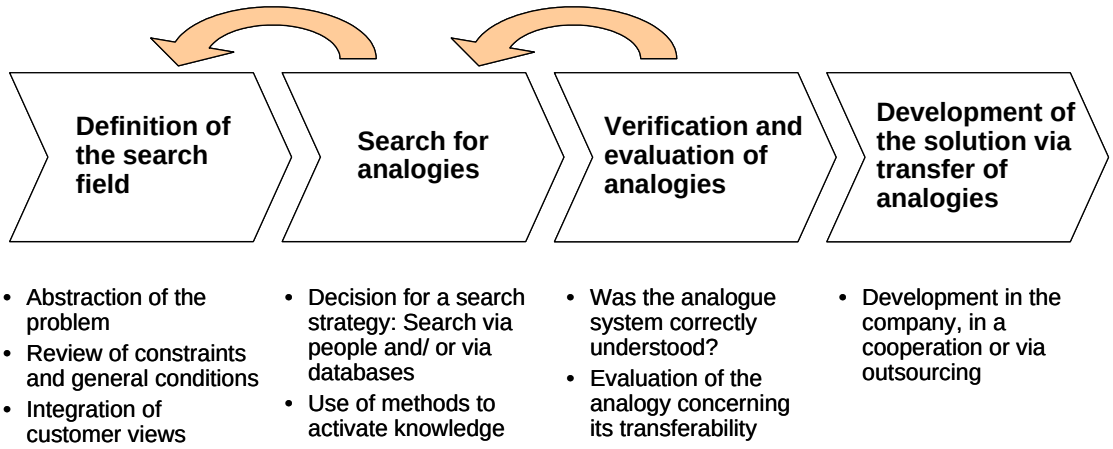

Figure 2: Process model of using analogies in product development

Premises to search for analogies

As the examined companies are service providers, basic goals and constraints of their product development projects are set by their clients. Based on this information a project team has to be configured. Taking into account that the search for analogies in the examined cases is mainly based on own experiences and personal contacts, characteristics of the team members seem to be decisive for the outcome of the processes. Therefore, it can be valuable if former projects of the developers are considered while staffing the teams. In one of the engineering companies it is for example the job of the leader of the development department to choose the team members. He reported choosing the team members with the intention to increase the probability that experiences from former projects can be used for solving the current problem. If he realizes that there is no relevant knowledge in the company, he acquires external experts. The search of external experts and their contacting is again based on his personal network. However, from the interviews there is little indication that the consideration of increasing the success of analogical thinking strongly influences the team composition. Altogether, the

formation of teams was predominated by general project management considerations. What kinds of skills are required? Who is the right person for contact with the customer? Who has the right determination for this project? Who is available?

For a knowledge broker it seems to be important that all employees participating in product development projects possess individual characteristics fostering the use of analogies. Firstly, according to the interviews, a person needs a certain amount of experience to rely upon. Therefore the building of diverse experiences through project work in a broad area of domains should be fostered. Only if people have knowledge from different areas are they able to make transfers based on analogies. Less experienced engineers or designers can continually broaden their horizon while working, if the teams are generally composed of people with different levels of experience. Secondly, communicative habits of the individuals are important. One has to be able to share his experience and knowledge with his colleagues. Finally, a certain curiosity, diverse hobbies and an open view of the world can have positive effects.

Considering the interdisciplinarity of teams, there were teams of engineers, teams of designers and engineers and teams of designers. In the mixed teams, the designers usually lead through the phases of idea generation and development of a basic concept. At the beginning engineers are mostly involved to guarantee the manufacturability of the solutions that the industrial designers create. Then, in later phases of the development of technically based products, engineers take over more responsibility. In the mixed teams, especially the designers are expected to look in diverse areas and get inspiration through analogies. However, the examples show that in the engineering-teams the use of analogies is also an essential part of product development. But engineers, probably due to their education, tend to look for simply transferable solutions close to the original area of the task.

If the project team is set it has to work on the project definition. The respondents revealed that a good problem definition at the beginning of the project is very important with respect to a successful outcome of the project. As indicated by the process model of using analogies, a project definition that includes an abstraction of the problem and considers given restrictions as well as customer views is needed to open a search space for analogies.

The need for an abstraction of the concrete problem could be confirmed by the results of the interviews. Abstracting the problem enables the developer to use knowledge from other domains. With a higher degree of abstraction a wider search space for analogies is opened.

However, a too abstract definition of the problem can also hinder solution finding – a compromise has to be aspired.

As the examined companies work as service providers they are not only confronted with the requirements of the future user of the product, but also with the wishes of their clients. The demands of the future user are especially important in design projects. In order to consider ergonomic factors designers often perform human factor analysis at the beginning of a project. These ergonomic factors can be the basis for drawing analogies to former projects from different areas.

Altogether, a good communication – within the team as well as with the client – is an important premise in developing the project definition. Here, analogies can also help on another level. For example, designers sometimes use mood-boards to find a common understanding of the project with the help of analogies. Mood-boards are a form of visual stimulus: On large boards a collage is made with images that are usually cut out from magazines. It is used to help capturing the 'values' of the product which will appeal to the target customer. According to its name a mood-board should transport the mood of the product – "the sentiment, feeling or emotion which the product engenders when first seen". (www.betterproductdesign.net; www.aqr.org.uk/glossary/)

Search for analogies

The search for analogies is based on the problem definition and the identified general framework of the project. According to the interviews the search for analogies is not the outcome of an explicit and conscious decision, but emerges in the context of general creativity sessions held in the early phase of the development projects.

In general, as depicted in the process model, a search for analogies can be either based on knowledge stored in databases or on personal knowledge of the participating experts. None of the examined companies used databases to find analogies. The interviewees stated that the effort to initialise such a database and to fill it with new knowledge is too big. Furthermore, solutions in pattern matching to efficiently search in such databases were still not been sufficiently developed. One of the designers also explicitly mentioned a lack of time to search in databases or to execute thorough internet searches. Besides, he considered that a database-search for analogies was not a task that could be delegated to assistants, but would need to be performed by the participating designers and engineers themselves.

Altogether, database-search seems to be inefficient and is thus reducing the willingness to use analogies. Furthermore, only explicit knowledge can be transferred via databases. Implicit knowledge on the other hand has a subjective and intuitive character and is tied to persons. For example, experiences with implementing a certain technical solution can be relevant implicit knowledge in product development. According to Swan et al. attempts to codify implicit knowledge of persons usually create knowledge that is useless, hard to verify, trivial as well as redundant (Swan, Newell et al., 1999). Therefore, access to knowledge while searching for analogies has to concentrate on the participating persons. Information technologies are only of secondary interest.

Experience and knowledge of the team members that is used to search for analogies can stem from diverse sources. First, former development projects are an important source. This type of direct solution transfer from former projects is especially relevant in the “efficiency projects”. A transfer from former projects also plays a crucial role in most “balanced projects”. Other knowledge sources can be hobbies of the team members, their general education or an inspiration of the direct environment of the developers. In addition to applying personal knowledge, the team members can also make use of their personal networks. If none of the team members has personal experience in an apparently relevant area it might be that one of them has heard of a solution that could be relevant and knows where to find further information. The personal contacts of the team can lead to experts within or outside the company.

The question arises how the knowledge of the team is activated. According to the interviews some teams perform brainstorming or other creativity techniques (i.e. 6-3-5 method) under a given time frame. Although the formality of these creativity sessions differs, a discussion of diverse ideas within the team seems to always be an essential part of the search process. In addition, especially for designers, visual stimuli are important: for example looking into magazines, building mood-boards or trend-boards, studying other projects on the market or watching for inspiration in the direct environment.

The search for analogies is completed by an evaluation of the found analogies. It has to be checked if the analogue system was correctly understood and what kind of transfer can be made. In the examined cases the verification and evaluation of analogies is facilitated, because team members could refer to their own experiences in the analogue domain. This phase was mostly done in team discussions based on the project definition developed at the beginning of the project. At this point, it should also be considered if problems will arise

through the transfer due to intellectual property rights or covenants with other clients. If this is the case a more abstract transfer might be a solution. However, in the given examples such conflicts did not appear.

Overall, the approach of the knowledge brokers to search for analogies follows no strict or formalized process. Several of the interviewees stated that their procedure of finding solutions needs to be very flexible, because each project possesses very individual characteristics. Furthermore, there is often insufficient time to follow a formal method or long and thorough search for analogies. This indicates that efficiency reasons often predominate. And the search for analogies usually is not identifiable as a distinct phase, but integrated into other approaches of finding a solution for the given task.

The most important factor seems to be experiences and characteristics of the participating persons. Therefore, human resource management has to be considered as an important factor. A diverse and broad knowledge of employees should be fostered if the company aims to use analogies in product development. Measures have to be taken to prevent the forming of specialists – employees of a knowledge broker have to be able to work to a certain degree as generalists.

RESUMEE AND FURTHER ASPECTS

All interviewees had positive experiences with the use of analogies in product development – designers as well as engineers. However, using analogies in their daily business is a more or less automatic process, because it is permanently part of the routine work of these people.

Analogies are used very pragmatically throughout the whole development process. First of all, they play an important part in the development of solutions. Here, we can differentiate between efficiency projects, balanced projects and breakthrough projects. The function of analogies to increase project efficiency is an important result, because analogies are often just considered as a means to increase creativity. As shown before, the motivation to use analogies to create a new product directly leads to a narrower or broader search.

Secondly, analogies are also used for improving communication throughout the whole development process. They can already be used in the phase of project definition to develop a common understanding of the goals of the project. The project goals have to be

communicated within the development team as well as to the client. Further, analogies can help not to lose the focus of the project and are valuable in discussions about possible solutions ("Shared picture or vision"). Additionally, analogies can be used to transport a message with the product to its future users.

Finally, an important result of our research is that the search for analogies is mostly based on the knowledge of the participating persons. Therefore, human resource management has a crucial impact on the success of development projects. Design and engineering companies offering product development services to diverse clients seem to automatically provide such a stimulating environment: Letting people build up experiences in diverse areas, supporting the personal communication throughout the company, but also to external experts, and using analogies as part of their daily work seem to have positive effects. The question arises how these mechanisms can be seized by industrial companies in their product development projects. To begin with, it might be positive to compose rather heterogeneous development teams in order to increase the diversity of knowledge within the team. And, as far as this is possible within one company, people should be encouraged to participate in projects that differ in their required knowledge base. Additionally, it might be needed to integrate external experts from other domains in the development team right from the beginning of the project. The detailed conception and testing of these mechanisms will be subject of succeeding research projects.

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