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EARLY PROTOTYPES: A STRATEGY FOR EXPLICATING TACIT KNOWLEDGE IN DESIGN ACTIVITIES

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1. Introduction

The globalization of design activities has been an ongoing trend in industry for many years and at the same time sparked several research initiatives. One of the major reasons for globalizing design activities lies in accessing the global knowledge pool. People with different educational backgrounds work together to develop superior products or services. The main process is the sharing of knowledge and realizing products. Especially the former is difficult as experience and research has shown us. As knowledge is usually something tacit, it has to be made explicit to be shared by a team. This paper wants to identify some of the barriers in explicating knowledge and shows a strategy to overcome these barriers for successful sharing of knowledge and hence development of products or services in global design networks.

2. Theoretical framework

The following section focuses on two different theoretical backgrounds. First we will discuss some aspects of knowledge management, especially knowledge sharing. The second part of the framework will focus on prototyping and its importance for the development process. This prepares the ground for developing an initial framework for knowledge representation in prototypes.

2.1 Knowledge management in product development

One major obstacle in product development activities is rooted in the fact that people in companies share and manage their knowledge insufficiently (Bergman et al., 2004; Choi and Lee, 2003; von Krogh et al., 2000). Internally existing knowledge does not necessarily get to the right place at the right time, sometimes requiring a reinvention of the wheel, and hence resulting in innovative redundancy or simply in promising ideas remaining unimplemented. In order to facilitate the creation and development of new products, knowledge from different sources, internally and externally, is required. The resulting challenge consists in managing the collaborative knowledge creation and transfer process in such global design networks.

As a basis for analyzing knowledge sharing along the innovation process, one key issue is to determine the type of knowledge involved. Knowledge is context-specific and can be seen as a dynamic human process of justifying personal beliefs towards the truth (Nonaka et al., 2000).

Generally we distinguish between the commonly used definitions of tacit and explicit knowledge. Tacit knowledge is personal and is hard to formalize and communicate. It is rooted in ideas and values as well as actions and routines. Hence, tacit knowledge can be regarded as experience-based intuition (Nonaka et al., 1996). Tacit knowledge is related to know-how, meaning knowing how to do something. Know-how can also be seen as the accumulated practical skill that allows one to do something efficiently.

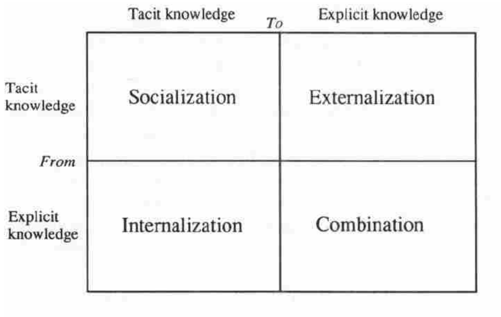

Figure 1. Explicit and tacit knowledge (Nonaka 2000)

Explicit knowledge on the other hand can be expressed in a formal and systematic language. It can be stored in documents, databases or – in the case of product design – in prototypes. Furthermore, it is related to the term know-what, meaning what something means (Scarbrough, 2003). Explicit knowledge can be seen as information and it can be transferred at relatively low cost.

However, explicit and tacit knowledge are not completely separable but rather complementary; 'explicit knowledge without tacit insight quickly looses its meaning' (Nonaka et al., 2000, p.8).
As can be seen from the figure below, one main problem that can be found in several quadrants is the externalization of knowledge. Inganäs et al. analyzed the use of tacit and explicit knowledge along the product innovation process within four large companies (Inganäs et al. 2006). The figure shows the results for two of these for companies. Both companies see the explication process as problem, not only within their respective company but also when operating in design networks.

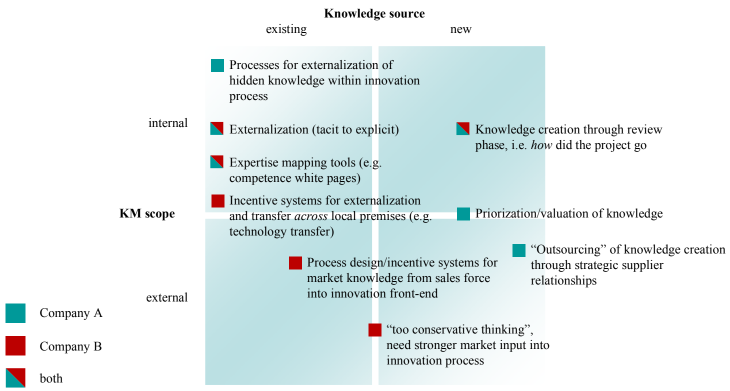

Figure 2. Knowledge barriers in product development (Inganäs et al. 2006)

2.2 Prototypes

A prototype is "the first example of something such as a machine or other industrial product from which all later forms are developed" (Cambridge 1995). Wikipedia defines a prototype as an "original type, form, or instance of some thing serving as a typical example, basis, epitome, or standard for other things of the same category." (Wiki 2007). In general we distinguish prototypes by the way the are used, e.g. function or form. A functional prototype for example is able to demonstrate one or several specific functions of a product. A form prototype is produced to show the form features of a product. So far prototypes have mainly been seen as a tool to facilitate design and manufacturing of products. Especially in connection with global design teams the use of virtual prototypes has been discussed. In this case the computer generates three dimensional representations of a product and distributed teams can access and work with these representations (Barone et al.2002).

2.3 A framework for representation of knowledge in prototypes

As mentioned above, this paper is interested in developing a framework to show that the *prototyping process* early in the product design process can be seen as a catalyst to help explicating tacit knowledge of a group and at the same time that early *prototypes* can be seen as a representation of the shared knowledge of this group. The problem usually is that making tacit knowledge explicit leads to different language representations. That means that even if the process of making something explicit works, it is very difficult for an outsider to understand this explicated knowledge due to differences in wording, meaning or understanding. Here the prototype helps to translate the meaning into the language of form.

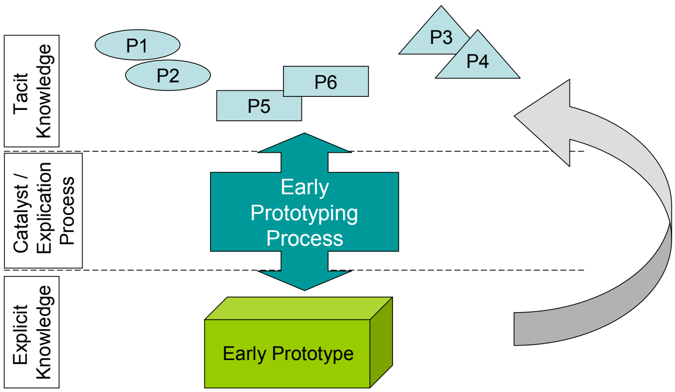

Figure 3. Framework of knowledge representation in prototypes

The framework shows three levels: the area of tacit knowledge, the catalyst / the explication as well as the explicit knowledge represented in the prototype. The first level shows the personal, individual knowledge of the team members in a design network. The knowledge dots are grouped, as based on the definitions of tacit knowledge they are also influenced by values and norms, which will differ between organizations in a global design network. The catalyst level of the model consists of the early prototyping process. This process allows different individuals to make their tacit knowledge explicit and at the same time focus the results of this process on developing a joint real world early physical prototype. This only works if the early prototyping process is a joint effort and leads to the question, whether this can be done in a distributed setting or should be done collocated. The last level of the framework is a physical prototype. It allows to experiment and triggers – by handling it – new explication processes. This means it is not only the end point of the process, but can also be seen as the starting point of a new cycle in an iterative activity.

3. Application in industry and education

The following section describes two applications of the above ideas. The first part shows an example from a partner firm and the importance of the prototyping process whereas the second part focuses on our own experience in teaching product development in small and medium sized firms.

3.1 Industrial application and use

Prototyping is frequently used within our partner firm (Siemens) to improve the efficiency and effectiveness of design outcomes, hence the design performance. The experiences shows that the overall design quality can be increased since problems or opportunities to improve the design can be seen in early phases, where the changes are almost cost neutral.

Depending on the development phase different types of prototypes are used. The choice of the right prototyping process is within the decision of the development team and depends on a case by case decision. General guidelines are difficult to establish and often not valid. Obviously time, cost and objectives of the prototyping and the required numbers of prototypes and boundary conditions like availability and knowledge determines the process choice.

The firm uses different prototyping processes. In the presented project the Stereo lithography process plus, in a second step, a combination with a silicon mould and casting has been used. Besides this also basic instruments like paper and cartons have been used for modeling and making variants. The advantage of the Stereo lithography is the speed and the relatively low cost. With the Stereo lithography prototype fruitful discussions with Sales, Marketing and Product Management are possible and the design can be modified to improve look and feel, human machine interaction, ease of installation and serviceability. Especially in these interdisciplinary design teams, even with partners the early prototyping shows its high potential.

In a later step of the project, when the design is almost finalized a silicon mould has been made based on a Stereo lithography with a very thin layer thickness has been used to create a high quality model. With the silicon mould a limited numbers of models can be casted. These functional models are characterized by a better accuracy to the final design. Functional models can be used for system tests, or sometimes field tests can be made. Even in these later stages the prototypes show its relevance for explicating tacit knowledge in collaboration with customers.

Figure 4-A: Stereo lithography

Figure 4-B: Plastic Cast from a Silicon Moulds based on a thin layer Stereo lithography

Figure 4-C: Foto used in the marketing brochure (with one prototype on the picture)

Figure 4. Prototypes of sample product (Courtesy Siemens Building Technologies Ltd.)

Such later stage functional prototypes can also be used for marketing photos (with a little desktop publishing), presentations at sales events and fairs, etc. The difference to the real products is almost invisible as can be seen in figure 4. One of the three parts in figure 4-C is such a model, whereas the other two are original parts.

The presented example is the new operating device of the Siemens Intrusion system Sintony Plus consisting of a keypad, key switch and universal annunciation module which can be assembled modularly. The differences and design improvements can be seen in figure 4-A to 4-C.
The most obvious difference is the shape of the key switch to assure an attractive and flat design as well as to improve mechanical resistance for specific security approvals. In the keypad and the universal annunciation module, the LEDs have been moved to assure a better visibility, mechanical support, resistance against condensing water and other little changes to improve installation and operation have been implemented. This was the joint effort of the design team to improve design performance.

3.2 Educational application and use

The above mentioned use of the prototyping process to explicate knowledge in design teams of large firms can also be used in other settings, e.g. in education. One of the authors has developed a workshop for small and medium sized enterprises and is either a half day or day course and focuses on several stages. The course teaches owner-managers from small companies in product innovation. In several of these courses it was shown that the option to develop a prototype of a product parallel to the teaching process has not only increased participation, but also stimulated people to express their tacit knowledge about developing products in their respective professional area. As time is very limited and usually there are only limited resources for developing prototypes, the course setting uses either games or other simple products to illustrate the prototyping process. The figure below shows the process of such a game prototyping session. The participants in this specific course all come from handcraft or small trade. After a first period of astonishment the five teams participated very well in the process and two of the groups even kept the results to further use the methodology.

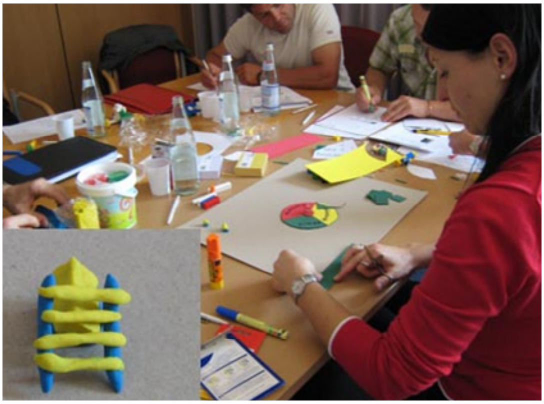

Figure 5. Use of prototypes in education

Another observation of this group is also shown in the above figure. Especially participants with a background in handcraft like working with prototypes as they have a natural affection to this way of working.

4. Implications and conclusions

This paper tried to outline a framework which could help to better understand in which way early prototypes can be seen as a mean to facilitate the explication of tacit knowledge in design teams. Using to examples we have shown the practical application and use of this idea in an industrial and an educational setting. Two things should be discussed here in more detail. The first covers the question, whether we are really seeing an explication of tacit knowledge in a prototype and the second focuses more on the question, how this concept could be applied in distributed settings.

To see the prototyping process itself as a catalyst in this process of explicating knowledge is supported by some other observations. A former colleague interested in creativity once described a situation he had encountered in a design department. He went there twice, once with the manager of the department and once without. The first time he saw all those designers sitting in front of their CAD screens drawing and developing their products. He had the impression it was a very sterile environment and doubted that it was really creative. The second time he went, he got into discussions with designers and one after the other opened the lower drawers of their desks and they were filled with all types of prototypes. Their argument was that they would need these tools to help them think. It seems obvious that the haptic feeling of a prototype helped to make their thoughts explicit, to share an idea quickly and have an object to focus on. The good thing is that ideas can also be very quickly discarded. This short story also seems to support the claim of our suggested framework.
The second question is easier to answer. How can this be done in distributed global design teams? A logic answer would be to use a virtual prototype. The main problem with virtual prototypes is that a group of designers cannot touch them simultaneously. The question is whether the catalyst function of a prototype is still there if you only have a virtual representation. Within a survey of nearly forty science to market transfer projects the importance of real prototypes could be observed. The existence of a prototype must be seen as one of the main success factors of these collaborations.
We are aware that this paper only gives a first, fuzzy idea of that importance of this topic, but we think it is worth further exploring.

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