INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED O5 MELBOURNE, AUGUST 15 – 18, 2005

# KNOWLEDGE SHARING CHALLENGES WITHIN THE EXTENDED ENTERPRISE

Åsa Ericson, Henrik Nergård, Tobias Larsson

## Abstract

The notion of functional products changes the existing relationship between manufacturing companies. The integration of hardware, software and services in functional products calls for close collaboration with companies having complementary skills. When employees from different companies are involved, strategic resources such as knowledge are shared. From an engineering design perspective, knowledge sharing supported by software systems are useful, though it seems like functional product development insists on integrating multifunctional skills and this is likely to affect the design of software systems. The objective in this paper is to explore knowledge sharing challenges between manufacturing companies, striving to create close functional product collaboration, and hence understand aspects in the design of software systems. In this paper the focus is on Knowledge Based Engineering (KBE) systems, these are considered to be internal engineering specific tools, while collaboration and need for knowledge sharing calls for coupled KBE systems between partners. In this context, knowledge sharing challenges within the extended enterprise are recognised to issues about who to trust and what and how to share. This affects how tightly coupled KBE systems can be.

In general, this paper contributes to the ongoing discussion concerning collaboration issues in concurrent engineering design, but especially to the overall understanding of what new demands on KBE systems that are motivated by functional product collaboration.

*Keywords: Knowledge Sharing, Collaboration, Knowledge Based Engineering, Functional Products*

# 1 Introduction

> *"Companies today strive to unify things that we have learnt to be contradictions. They try to be both local and global, both small and big, both centralized and decentralized both stable and dynamic. They want to become bigger without growing. They want to offer standardized mass manufacturing, customized mass manufacturing, and individually designed goods and services simultaneously" [1], ( p. 265).*

This situation is familiar to contemporary industrial product development organisations. Different efforts to manage the contradictions in the situation exist. One aspect recognised as a prerequisite in handling this type of situation is business relationships in form of partnerships, alliances, or joint ventures, or a combination thereof, to develop new products or enter new markets [2]. In business-to-business relationships all parties involved are best off as partners [3], not as competitors. Interaction in business-to-business relationships is not only about being influenced, but influencing [4]. Business relationships that all partners consider successful involve collaboration, i.e. to create new value together, rather than mere exchange, which is to get something back for what you put in [5]. Value-chain partnerships are considered to be the strongest and closest collaboration where companies *"... in different industries with different but complementary skills link their capabilities to create value for ultimate users"* [5] (p. 98). A relationship is about what companies can do for customers with an enhanced offering, rather than providing customers with existing products [3]. Relationships and enhanced offerings increase the dependency on intangible assets, such as know-how and collaborative problem solving. Suppliers and customers become partners who develop physical artefacts and provide enhanced offerings for the ultimate customer who is also a partner.

To establish, develop and maintain successful collaborative relationships between parties, trust is a key ingredient. Without trust the parties will not be committed to the mutual cause [6]. Mistrust starts a vicious cycle and makes success harder to attain: when success fails, someone has to be blamed. Who is different? The outsider, of course! [5]. Tomkins [7] argues that trust, defined as - *"...areas of life which one can take as given..."* (p.185), enables people to act as if the uncertainty they face is reduced, though it does not reduce the actual uncertainty. An assumption of equality, i.e. all parties bringing something valuable to the relationship, is the beginning for respect that in turn builds trust [5]. The formation of alliances and partnerships *"... rest largely on hopes and dreams – what might be possible if certain opportunities are pursued"* [5] (p. 99). In interactions between firms, there is an implicit impression of sharing knowledge, decision-making and mutual rewards [7].

In the context of business-to-business relationships, the notion of functional products and specifically product development knowledge has gained interest among researchers and industry. Functional products have been defined as a combination or integration of hardware, software and services [8], [9], [10]. Alonso-Rasgado et. al [10] conclude that functional products, if the contracted functional performance is achieved, create close business-to-business relationships and give stability and a constant revenue stream. Furthermore, the *"... stable relationship should remove much uncertainty and provide an attractive competitive business scenario."* (p. 537).

Negotiation to determine the terms of collaboration is necessary when moving towards collaboration across organisations [7]. Information needed for partnerships is not given on a take it or leave it basis. Relevant information is part of the interactive process [7]. Tomkins [7] distinguishes two types of information, one that is needed to create trust, the other relates to expectations about a collaborative future. On a daily basis, engineers need yet another type of information, which relates to product development processes. Since close collaboration and product development are vital for functional products, it is necessary to mutually consider what relevant information is needed and what information could be shared for an interactive development process of such a product.

Today, engineer designers are used to computer support in the form of for example Computer-Aided Design tools and simulation tools. These tools focus on the technical development process, while functional products, being a total commitment involve service aspects beside hardware aspects.

Thus, the objective in this paper is to explore knowledge sharing challenges between manufacturing companies, striving to create close collaborative functional product partnerships, and hence understand aspects to the design of software systems.

The study presented in this paper is conducted from an engineering design perspective and is limited to KBE software systems deployed in Engineering Design activities. Information about, for example, materials and machining process can be relevant to other parts of the manufacturing firm. To be able to lower costs for development work, the purchasing department is interested in information about new materials as early as possible, though, based on the same information, the user interfaces diverge between computer support aimed for technical development use and business development use. An underpinning thought for the study is that computerised systems will have a positive impact on the possibilities for the knowledge sharing process.

Studying knowledge or information sharing challenges are in itself a challenge. What is knowledge? What is information? Some equalise information and knowledge. Langefors [11] does so in his infological equation, while others do not, for example, Nonaka, Toyama and Konno [12] in the Ba concept. Erickson and Kellogg [13] argue that knowledge management is not just an information problem, but also a social problem. Accordingly, knowledge is contextually dependent. In this paper the focus is on sharing and collaboration supported by computer software, not on defining *what* is shared. We agree to each other that the sharing process can be computer supported, though each one of us holds a different position as to *what* is represented in the computer software.

# 2 Disposition of the paper

The following section starts with a brief presentation of MOKA, a methodology developed for design of knowledge based engineering systems. Although not used in this study MOKA has inspired and given valuable input to the structure of this study. An overall view of the steps in MOKA will be presented. After this, product development is outlined in general terms followed by a presentation of concept design activities based on engineering design literature. Business strategy literature is the basis for the described extended enterprise section. A presentation of KBE systems, and a description of the studied case follow this. The discussion section begins from the theoretical framework applied on issues found in the studied case. Finally, the paper ends with conclusions and suggestions for further research.

# 3 Methodology

Methodology and software tools Oriented to Knowledge based engineering Applications, or MOKA [14], have evolved from a project to a two level framework to represent and store knowledge with the aim to reduce cost and time of building KBE applications [14]. The study presented in this paper does not consider the designing or evaluating of any KBE application, though one of us will do this as further work. Reading about MOKA has given us an overall understanding about the iterative nature of knowledge and, accordingly, the iterative nature of understanding knowledge processes. In Figure 1, below, the lifecycle steps in MOKA are shown, i.e. Identify, Justify, Capture, Formalize, Package and Activate. According to MOKA [14], the activities of Identify and Justify *"...are not in focus of MOKA and are not supported by the MOKA tool"* (p. 47), though identified as *"...crucial for the success of a KBE project"* (p. 44). Hence, the identify step has some similarities to our approach in this study, and involves six sub-steps, i.e. (1) identification of stakeholders, (2) define role and scope, (3) identify possible knowledge sources, (4) identify means of knowledge capture, (5) identify target KBE platforms and (6) assess technical feasibility. The sub-steps 1 and 2 in the identify step have been partly performed in this study.

To generate and gather data, people holding expertise in industrial product development were identified, the data to be focused upon were defined and how to get access to these people and their experiences was detailed. This has been done in an iterative way.

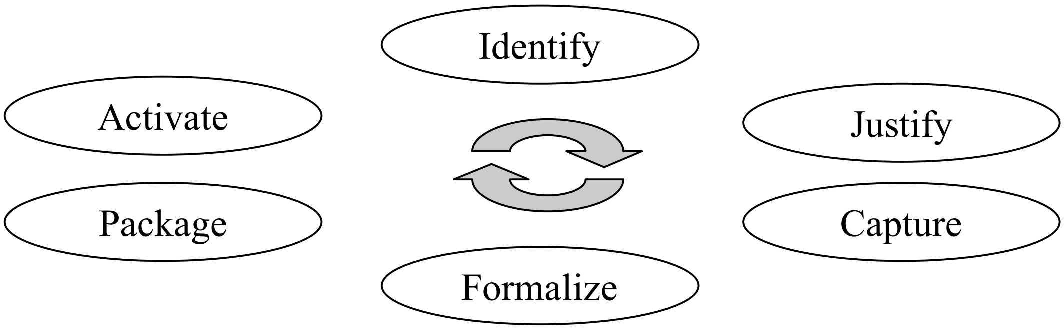


Figure 1. The MOKA lifecycle steps

## 3.1 Generated data

The generated and gathered data composed of both primary and secondary sources. Primary sources were interviews conducted with employees of Swedish manufacturing companies and meetings with a project group consisting of both academia and industry. Secondary sources were literature, such as books, articles and dissertations.

The choice of theoretical framework for this study not only emerged from previous studies identifying functional products insisting on close collaboration, but also from empirical results highlighting computer technology and thoughts about a virtual space for knowledge sharing. The empirical base consisted of two Swedish manufacturing companies engaged in industrial product development. Both have a long-term relationship based on traditional customer-provider roles, but a contractual preferred supplier relationship has recently been established. The studied case is the evolving collaboration for functional products between these companies. Both companies are involved in a research project with the aim to realise functional product development in a distributed environment.

Due to the study's explorative nature, qualitative data were in focus. Qualitative data is well suited for locating the meanings people place on events, processes and structures and for connecting these meanings to the social world around them [15]. Qualitative data is based on interpretations, understandings or experiences [16], and usually appears in the form of words rather than numbers [15]. Accordingly, talking with people makes sense.

## 3.2 Interviews

The interviews conducted in this research study were a mix of group and individual interviews. Three group interviews and two individual interviews were performed. A total of 12 persons were interviewed and the interviews lasted from one to two and a half hours; the longer time for two of the group interviews. The interviews were semi-structured [16], where the informants could freely formulate their answers, but not freely choose the issues to talk about. Instead of following a predefined interview guide, a set of themes were focused on. These themes were ideas about functional products, product development, conceptual development, collaboration, information and knowledge issues. The approach in the interviews was to start a dialogue accordingly; the interviewees were encouraged to expound their views. The interviews were tape-recorded. The description of the empirical base was returned to industry for comments.

In addition to the interviews, meetings with a project group consisting of both academia and industry have contributed to the study. Participants in the project group are involved in the research project aiming for realisation of functional products and the interview themes are of utmost concern. During these meetings notes were taken and follow-up questions were asked.

## 3.3 Data processing

When focusing on qualitative data in fairly open-ended interviews, interpretation occurs along the way. Data are summarised and reflected upon during the conversations with respondents, and the choice of relevant data and interpretation are integrated. The gathered and generated data has been read in a non-cross-sectional way, a practice guided by a search for both the particular and the holistic [16]. The non-cross-sectional indexing starts by simply reading the material and looking for particular ideas, similarities and differences. This method is also regarded as a cyclic process, where the material is read several times. The first step of analysis yields an overall description of the empirical base, as is presented in this paper.

# 4 Theoretical framework

Product development and engineering design are presented in the following section. The extended enterprise based on literature studies will be outlined. The theoretical section ends with a description of KBE systems.

## 4.1 Product development – concurrent engineering design

Time is perceived as a main challenge in product development [17]. Shifting markets and increased competition force companies to develop products fast enough to keep pace. Two issues have to be addressed when getting new products to the market quickly, i.e. the amount of work to develop a product has to be minimized and a way to do this effectively has to be found [17].

A product development process *"... is the set of activities beginning with the perception of a market opportunity and ending in the production, sale and delivery of a product"* [18], (p. 2). Ulrich and Eppinger [18] describe a generic development process that is divided into a sequence of five steps or activities, i.e. (1) concept development, (2) system-level design, (3) detail design, (4) testing and refinement and (5) production ramp-up. Some organisations might define and follow an exact and detailed development process, while others might not even be able to describe their process [18]. No distinct divisions between the sequences can be drawn, since they are carried out iteratively and thus achieve a step-by-step optimisation [19]. In each phase alternative solutions can be thought up; the design team is therefore urged to diverge and converge in each phase [19]. Understanding that a phase model does not show the problem-solving process is useful [19].

From an information point of view, the product development process can also be described as *"... a process of gradually building up a body of information until it eventually provides a complete formula for manufacturing a new product"* [17] (p. 158). Traditionally, the design of physical artefacts was known as the 'over-the-wall' process [20], where information about the artefact was 'thrown over the wall', meaning that activities where disconnected. The perceived market need was initially passed on from marketing to design engineers. Design engineers interpreted the information and transformed it into a manufacturing specification that was then passed on to production units, who interpreted the information and built what they thought the design engineers wanted [20]. Information flows describe a phase-based process where information is transferred from one activity to the next [17]. The issue is to provide complete information; hence, the following activity cannot start until the first has been completed [17]. To go from phases to a continuous flow of information requires working in overlapping activities, i.e. the information is incomplete and requires good communication to find out how well the product meets current needs [17]. An integrated product development process integrates the working tasks within the organisational functions marketing, design and production into a concurrent parallel interactive process [19], [21], [22], [23]. An integrated approach to product development is *"...essentially a pro-active one in which the design is redefined and developed on the basis of 'real-time' interaction so that it is constantly evolving and improving"* [24] (p.252). A design team or development team is required in integrated product development and therefore introduces problems of organisation and communication [21]. In an integrated product development process, these design teams are recommended to be multifunctional [22] and have a sufficient diversity of knowledge [18].

Even though the whole integrated development process insists on continuous communication due to incomplete information, an engineering design perspective focuses on concept development activities in particular. The concept development activities within the organisational function design involve the investigation of feasibility of product concepts, the development of industrial design concepts and the building and testing of experimental prototypes [18]. Concept development is described as early design stages; a dilemma here is that knowledge of the product and the processes involved is low or vague, while decisions made at this stage can determine almost 80% of the product costs [25].

## 4.2 Extended enterprise

Product development organisations can be considered as having two main development areas, for example interpreted as a technical development process and a commercial development process [19]. In a globally connected world, characteristics like collaboration, knowledge sharing, change and learning become important [26]. Thus, development skills in addition to the technical and commercial development must to be considered and might be regarded as intangible information-centred skills. Computer technologies are useful for information issues and allow information to be known simultaneously anywhere in the world. Furthermore, they are inherently border-crossing and enable companies to create alliances and networks with numerous companies around the world [26]. The ability to play with virtually limitless possibilities, interchangeability of product parts and the capacity to continually try out new combinations of resources are enabled by a shapeless organisation that allows for the recombining of resources [27]. Within this interconnectivity an extended enterprise can evolve. The company will create relationships inside and outside its boundaries, and accordingly *"...the extended enterprise blurs the boundary between external and internal collaboration..."* [26] (p. 16) *"... and encourage people to reach further, faster to gain or spread knowledge"* [26] (p.17). This promising and unclear situation calls for an understanding of what are the favours and what might be the pitfalls in an extended enterprise. Kanter [26] has pointed out some aspirations and some challenges of the entire extended enterprise.

Aspirations are to:

- create value for end users
- collaborate, neither commanding from the centre nor letting each partner act on their own
- learn from local customisation and innovation
- use of collaborative methods, for example cross-boundary teams
- derive strength from diversity and shape a share culture of unity

And, challenges are the:

- "out of sight, out of mind"-problem, immediate work is driving out collaboration with distant people
- few incentives for working across boundaries
- communication overload on small matters and too little communication on big matters

- lack of collaborations skills
- too few tools that truly work everywhere

How the extended enterprise is seen and interpreted varies depending on the viewer's perspective. From a knowledge perspective, the extended enterprise can be interpreted as a shared context for knowledge creation [12] and knowledge sharing. These are considered as interdependent activities. The shared context does not necessarily mean a physical place, it can, for example, be a virtual space such as e-mails, a mental space such as shared ideals or it can unify physical, virtual and mental spaces [12].

Knowledge management area focuses on how organisations effectively can manage, store, retrieve and augment their intellectual properties [28]. Ackerman et. al. [28] recognised two views of supporting knowledge management through software. One view focuses on gathering, providing and filtering available knowledge into shared repositories or information databases to easily reuse the information. Expertise sharing involving human components is considered as the other view, and the second wave of knowledge management. The aim is to bolster communication, learning and organisational knowledge.

## 4.3 KBE systems

Knowledge based engineering or knowledge based engineering *systems* both occur under the acronym KBE; its understanding is not straightforward. Chapman and Pinfold [25] suggest that KBE vendors should not concentrate on their particular KBE software, but also treat KBE as a methodology to provide an understanding of the philosophy of object oriented techniques. In the same article, KBE is described as an engineering method representing a merging of object-oriented programming, artificial intelligence techniques and computer-aided design technologies. KBE is thus a software tool, a method and a methodology. A difference between method and methodology is partly seen in the above description, hence it is possible to interpret method simply as *how* to do something and methodology as not only encompassing several methods, but also the underlying philosophy to understand to *what* and *why* these methods are used. The emphasis in KBE is on providing informational complete product representations captured in a product model [29]. *"The product model represents the engineering intent behind the product design, storing the <u>how</u>, <u>why</u> and <u>what</u> of a design"* [29] (p. 906, underline added). KBE can be defined as *"...The <u>use</u> of advanced software techniques to capture and re-use product and process knowledge in an integrated way"* [14] (p. 11, underline added).

Based on these definitions KBE can be regarded in two ways. KBE can be considered as the use of a methodology to capture and re-use product and process knowledge. As well, KBE can be considered as a software system consisting of several advanced software techniques used in product design. Contributing to the difficulties in capturing the core of KBE can be that the KBE approach is described as taking a holistic view on design [25]. Nevertheless, the KBE approach aim to capture both *"...product and process information in such a way as to allow businesses to model engineering design processes, and then use the model to automate all or part of the process"* [25] (p.259).

Computer systems that apply reasoning methodologies to knowledge in a specific domain to provide advice or recommendations belong under the umbrella term *expert systems* [30]. A variety of systems are related to expert systems, knowledge based systems (KBS) being one of them. KBS is described as a typical rule-based system providing expertise or specified intellectual tasks [30]. Hence, a variant of KBS is KBE systems. These systems are often like narrowly focused expert systems [31]. *"But knowledge-based systems need not be so narrow as expert systems, and certainly need not be limited to diagnostic and selection tasks.*

*Knowledge-based systems can also deal with at least some of the more complex kinds of intellectual tasks involved in engineering design (e.g., evaluation and decision making). The knowledge required to perform such higher level design tasks is not readily coded into small unitized rules, but still may be represented in various other ways"* [31] (p. 11). The shape of something, i.e. geometry, is a vital aspect from a manufacturing viewpoint. Thus, the appearance of geometrical features is characteristic for KBE systems, as well as what distinguishes it from KBS [14].

Computerised engineering design tools can be roughly described in three clusters. A first group is used to visualise and provide possibilities for making design changes quickly, e.g. Computer-Aided Design (CAD). Compared to CAD, KBE systems can integrate a variety of geometric and non-geometric knowledge [14]. As routine tasks are captured in the KBE systems, time is released, thereby allowing engineers to concentrate on the creative aspects of design [14] and instead work with the synthesis and analysis of result generated from captured tasks. KBE systems are especially useful when dealing with routine design processes for which the knowledge is well understood [14]. A second group of computerised engineering design tools are used to reduce technical risk and uncertainty along with the number of prototyping cycles needed, e.g. modelling and simulation tools. A third group of tools enhances communication and facilitates the flow of partial information, e.g. tools based on shared databases [17]. *"The ultimate goal of the KBE system should be to capture the best design practices and engineering expertise into a corporate knowledge base"* [25] (p. 260). The corporate knowledge base is built on available computer software, regulations, design guides, handbooks, existing design, analysis results and human expertise [25]. KBE systems can thus be seen as a fourth group of computerised engineering design tools bringing all the other groups together [32].

# 5 Empirical findings – the studied case

To differentiate the roles, the words provider and customer are used, while in a future collaboration all parties will be partners. Functional products are recognised as encouraging new ways of collaboration for the traditional provider-customer business-to-business relation between the companies. The structure for functional product collaboration is regarded as an extended enterprise enabled by computerised technology. Collaboration, close partnership, win-win situation and shared information and knowledge are key words when discussing functional products and product development, while responsibilities, roles, confidentiality, payment and profit have been predicted as risks to deal with. Seeing computerised technology as a driver for change gives a plethora of possibilities to share information and knowledge, though the issue of what *can be shared* is not evident. Companies regard information and knowledge as strategic resources and some information is considered as not shareable, e.g. the revenue for a product developed in cooperation with another company. Knowledge is seen as a part of products that are sold or bought. Intellectual property rights, how to communicate and what to communicate are all of interest for the functional product scenario. Furthermore, juridical issues like contracts are vital. Today, business partners usually have a contractual relationship, with the contract being set before the cooperation, though one dilemma mentioned is that contracts may prevent cooperation. Cooperation actually occurs daily without contracts, when an agreement is sometimes signed after a finished business deal. Functional product collaboration is recognised as a long-term business relationship involving the whole company, all parties and all stakeholders. Establishing contracts that consider all aspects during that time span has been recognised as problematic.

Functional products have been recognised as selling added value of some kind to an ultimate customer. To do this, collaboration is seen as a prerequisite for functional product development. The interest in being involved in product development processes of all parties at an early stage become important. The ideal stage to be engaged in is *before* concept development, but being involved in concept development seems realistic. To be involved as early as possible means having the possibility to influence the final solution, and to interact with the party when decisions are made. A dilemma mentioned is that knowledge of how to communicate and how to collaborate to realise this is lacking. Today, providers are operating in later phases, but what type of information is needed if the collaboration moves to the conceptual stage or even before that stage? How will this new scenario affect the product development process?

For information and knowledge sharing, an identification of personal contacts and social bonds has been recognised. It is important to have a competent contact person at the other organisation, with a social network within his or her own organisation. This is said to ensure that the right person with the proper competence will handle the matter, who can also gather competence or knowledge from within the entire company, e.g. the customer has to trust the provider to get in contact with persons who have the relevant competences. Today, the flow of information about technical issues is described as depending on people, while a perceived future supported by computerised technology is thought of as occurring between companies. The possibilities for information and knowledge sharing in close collaboration have been recognised, as well as the risk for loosing competences in certain areas, but the advantages to gain complementary competences is perceived as valuable. But, how can this value be understood and evaluated?

Still, telephones, faxes and e-mail are used for information sharing between companies. Each company uses computerised support systems for information storage, retrieval and reuse, e.g. software support for project information and product knowledge. Expert systems are used for the actual product development process to generate concepts for design and construction. The challenge of understanding the different types of knowledge has been talked about. For example, knowledge based on rules is possible to express, but knowledge based on experiences requires a different approach. Judging whether the information found in computerised technology is relevant or not is said to be a human process of interpretation. To interpret and judge the relevance of information, humans have to be trained and have some kind of experience. Formal meetings, courses and on the job training are parts in the companies' human resource management strategies. To know where the expertise is situated within the company informal sharing of information has been mentioned as important, along with an understanding of the organisation's formal structure. The formal and informal way to find expertise are said to be interacting.

KBE systems are recognised as a possibility to speed up the responses between companies. Access to information from joint projects makes it possible to respond to queries faster. The possibility to use this information in collaboration with other firms was mentioned as an uncertainty. Trust is seen as a key to how knowledge could be used in a joint project with other organisations. The conversation shifts towards functional products when discussing KBE, since some sort of connection between ideas about KBE and ideas about functional products seems to be recognised. Further, when talking about functional products, the difficulties in understanding each other within the company were mentioned: *They are on a strategic level and we are on a tactic. We have another language and another time horizon. We are implementing the ideas of today and they are somewhere in 2010 or so.*

In a business-to-business situation experienced personnel having a widespread social network, willingness to collaborate, genuine knowledge about existing solutions and a future perspective focusing on innovations are perceived as value-adding characteristics. In our interviews one respondent recognised the future of close collaboration as particularly challenging: *The technical part, that's no problem, we can solve that, but all the people who should work together – how shall we do that?*

# 6 Discussion

It is concluded that close business-to-business relationships are created by functional product collaboration [10], though an existing relationship has to be developed before functional product relationships. Close functional product collaboration is about investments in adapting to other companies in the form of, for example, organisation, methods and technology. From our point of view, it is critical to understand knowledge sharing activities in the existing relationship to adapt. Those chosen to be functional product partners are supposed to be long time partners, with some kind of value to add to each other as well as to an ultimate customer. The companies in our study have today a contractual relationship. Thus, an important aspect identified during meetings and interviews was the emphasis on the contractual agreement. The issues of a contractual agreement for a functional product are neither fully understood yet, nor are the notion of functional products.

The intangibility increases due to the involvement of services in a functional product development process, requiring a continuous communication process with all partners to understand the needs of the ultimate customers. As the functional product commitment is recognised as a long-term relationship involving ultimate customers, their needs are likely going to change over time. Ultimate customers' need can vary over time from needing transactions of standardised goods to needing total commitment as functional products are. The forms of collaboration between the providers are affected of the customers changed needs. A consequence of this is that the terms of collaboration between partners are also under continuous change and urge to be renegotiated and updated on a frequent basis. Hence, negotiations to determine the terms of collaboration are necessary [7] in such a flexible environment.

The vision for functional product collaboration involves the idea of an extended enterprise, perceived as a virtual common ground for collaboration. The interaction of the companies in the extended enterprise blurs the boundary between external and internal processes, and a new versatile organisation is perceived to exist. The extended enterprise appears when an interaction in a joint project takes place. From our point of view, an extended enterprise can be described as consisting of relationships serving as channels for information and knowledge sharing. Today, KBE systems are used as an internal tool, while close collaboration to develop functional product call for these systems to be connected or coupled between partners, i.e. actual sharing of resources. The coupled KBE systems can thus be seen as a one of many relationships serving as channels for knowledge sharing, and thus a part of the extended enterprise.

Introducing KBE systems where entire processes are captured thereby introduces new issues of how to design the systems to adapt to a shared development process with partners. Technically, the opportunity exists, but a vast challenge is to understand how the systems can be connected between the partners. We have identified trust between the partners as a key to, for example, the amount of integration between the coupled KBE systems. Trust is considered to be vital to the relationship. Without trust knowledge sharing is not possible. A paradox here is that a joint project where knowledge is shared thereby nurtures trust, and when trust emerges knowledge sharing is made possible. It seem like companies have to deal with the risk of loosing some knowledge to gain some. The knowledge sharing process between companies has to be managed and monitored. What documents, blueprints and so forth are distributed between the companies? Supporting this by computer technology enables the sharing process to be traceable and the level of knowledge sharing in the collaboration to be flexible.

The KBE approach is described as taking a holistic view on design [25], while having a background in domain specific knowledge. In an integrated development process the organisational functions marketing, design and production are involved concurrently [19], [21], [22], [23]. The design of functional products integrates hardware, software and services; hence, competences for designing functional products are not limited to engineering skills. However, a perceived integrated situation can also occur in a specific domain such as engineering, since the area involves a vast range of engineering competences that also need to be shared. In the context of functional product development the integrated process crosses organisational borders.

Seeing KBE systems as support systems for engineering design in product development processes implies the benefit of the systems being the ability to capture specific activities in a process and convey the captured information to where and when it is needed. An issue to consider is what activities in the entire collaboration process software systems could or should support. Two main development areas, the technical development process and the commercial development process, have been identified [19], and additional skills like collaboration, knowledge sharing and learning have been recognised as important [26]. What are the possibilities for KBE systems to support all these aspects in a development process? What capability do KBE systems have to support functional product development collaboration? For functional product development, divergent competencies from hardware, software and services are needed for cross-border collaboration in multifunctional integrated design teams. From an engineering design perspective an issue for functional products can be interpreted as integrating service aspects into the hardware design, thus how to solve the problem and also what hardware that is actually developed will be affected. Therefore, knowledge needs to be shared in the conceptual development phase.

In a value-chain partnership, companies have different but complementary expertise [5]. This expertise is linked into a shared capability to create value for end users. One incitement for developing a functional product relationship is the interest in selling added value of some kind to ultimate customers. The identification of added value can be interpreted as the recognition of complementary skills which has to be to be linked together into a functional product development process. For a functional product development process, the parties have recognised the need to interact earlier in each other's development processes. Providers are not involved in the concept phase, but are contacted when important decisions are already made. At this point providers initiate their product development process on the basis of requirements achieved from the customer. Being involved early on means that instead of interacting at different stages in the process, all parties initiate their processes concurrently. Furthermore, information and knowledge about what is going to be performed requires being communicated to all parties. Interacting with partners makes ultimate customers and their needs visible to all parties, and make collaboration possible, i.e. to create new value together [5]. This value-chain partnership or the closest and strongest relationship [5] calls for ultimate customers to also be involved in the functional product collaboration. Interacting early on gives all partners the possibility to understand the requirements of the customer, and then the product lifecycle can be customised. Linking complementary skills gives the picture of an integrated development process, where some parts or activities in the process are "lifted" out and performed and owned by a partner. In such a concurrent and border crossing process the need for knowledge about each other's processes is a prerequisite to collaborate. For functional products, an increased openness and greater trust is recognised as contributing to the overall efficiency in the product development process. The question for software systems, is how tightly coupled the systems need to be to support a functional development process? And, how tightly coupled will the companies allow them to be?

# 7 Conclusions

In this paper the aim has been to explore knowledge sharing challenges between manufacturing companies to understand aspects vital to the design of software systems, in particular KBE systems. Previous studies have concluded functional products as generating close business-to-business relationships, giving stability and a constant revenue stream [10]. Interviews with engineers and meetings with people involved in a functional product research project have provided a view of functional product collaboration in an extended enterprise supported by computerised technology. Computerised technology has been recognised as an enabler for an extended enterprise and for knowledge sharing. Our study has focused on KBE systems, which differ from other knowledge-based systems by their geometrical characteristics, and are particularly useful for engineering design activities. Knowledge sharing challenges between companies can be concluded as to *what extent* knowledge could be shared and *who to trust* is identified as a key to this. This gives implications about *how tightly coupled* KBE systems between companies could be. Functional products integrate hardware, software and services, and as a result, the *view on the product changes* to encompass a total commitment towards customers. The prerequisite of collaboration in functional product development insists on software systems to be coupled between partners. Furthermore, the integration of hardware, software and services in functional products calls for knowledge sharing issues to encompass more aspects than technical. For coupled KBE systems, *more aspects than technical*, e.g. business aspects, service aspects, need to be considered to support an integrated development process crossing organisational borders.

# 8 Further research

Our study contributes to the understanding of what new demands on KBE systems are motivated by the notion of functional products. The vision of functional product development as collaboration in value-chain partnerships between companies with complementary skills also gives a view of a distributed situation. We have not considered what changes are motivated by functional product collaboration on computerised technology specially designed to support distributed work, but this is a part of the already initiated research project.

Coupled KBE systems are likely to be a driver for new thoughts about the core of the KBE concept. Research about this is ongoing and some ideas are presented, e.g. [32] [33].

Functional products are recognised as a total commitment towards ultimate customers. This means that functional products, as an evolving area, can be viewed from several different perspectives. Juridical issues have in our study been recognised as important and needs to be further investigated

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## Acknowledgements

We are greatly appreciative of the financial support provided by the ProViking research programme, SSF (Swedish Foundation for Strategic Research), VINNOVA’s “Effektiv produktframtagning”, and for the industrial partners for their time and contribution to our study.

Åsa Ericson, Division of Computer Aided Design, Luleå University of Technology, SE-971 87 Luleå, Sweden.
Phone: +46 920 49 20 61. E-mail: asaeri@ltu.se