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SUPPORTING DEVELOPMENT TEAMS IN THE EARLY STAGES OF PRODUCT DEVELOPMENT THROUGH DFX-BASED KNOWLEDGE MANAGEMENT SYSTEM AND COMMUNICATION PLATFORM

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Abstract

In the product development, many aspects such as usability, safety, ergonomics, and recycling have to be taken into account. Development companies are required to make more robust and accurate decisions than in the past, as well as simultaneously promoting rapid innovation. In this, knowledge transparency and effectively sharing knowledge within the company are essential factors in reducing uncertainty and redundancy, which in turn can have a significant impact on firm competitiveness. This paper presents a concept, which combines a DfX-based knowledge management system and planned communication platform to assist development teams in more effectively communicating and accessing knowledge throughout the development process. This work considers to organize and access information through the use of key words, and also to retrieve knowledge via queries based on deep learning such as IBM Watson technology. This planned system aims to gather the implicit knowledge of experts and specialists in various areas of expertise based on DfX-aspects, which can later be accessed and used in order to reduce the time demanded for knowledge search and implementation in future development processes.

Keywords: Knowledge management, Design for X (DfX), Communication, Implicit knowledge, Knowledge acquisition

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1 INTRODUCTION

For every product development task, many aspects such as usability, safety, ergonomics, manufacturing and recycling have to be taken into account (Meerkamm, 2008), which leads to an increasing amount of information for development teams to consider. Therefore, it is difficult to identify relevant information for making a decision especially in the early stages of product development. An early and consistent consideration of essential requirements, guidelines, or knowledge, from different areas is a key prerequisite for cost, quality and environmental properties of a product (Stöber, 2009). Due to higher product complexity, the knowledge demand increases dramatically in all phases of the industrial production process (Langenberg, 2001). However, currently IT-Systems on the market can only insufficiently collect and link necessary information in order to deliver suitable, situation-dependent knowledge.

In recent years, knowledge has been recognized as an essential production factor and knowledge management has successfully established itself as a discipline in order to capture, disseminate and multiply knowledge in the company (Langenberg, 2001). The achievement of a successful knowledge transparency and effective knowledge sharing in the company is very important to decrease duplication of work and repetitive errors. Moreover, the gained knowledge during a project is only recognized and used to a limited extent by subsequent project teams. The reason for that is the limited and not goal-oriented communication of gained knowledge, which in turn causes the loss of implicit knowledge of experts and specialists in various areas of expertise. Furthermore, the increasingly rapid development of new products, as well as shortening the time to market (Neubauer, 2012) make cross-functional communication inevitable within the company as well as with external stakeholders, e.g. suppliers and customers (Brode and Dietrich, 2010). Without effective communication, misunderstandings often occur, which are usually only identified much later and may lead to higher costs.

DfX is a knowledge system that aids in the decision-making process of product development, with X representing various production characteristics including manufacturability (DfM), variability (DfV), cost (DfC), assembly (DfA), or reliability (DfR). In the field of DfX, there are many tools available, i.e. design guidelines, methods and software tools. These diversities make it very difficult to select concretely the most suitable tools for a development task and phase (Bauer, 2007). The use of DfX may be a success factor for a goal-oriented gathering and networking of knowledge from various areas; the opportunity to implement DfX-based knowledge in the innovation process can be of great significance for decision making.

This paper describes a concept for the development of a communication platform which aims to support the development teams in the early stage of product development through a DfX-based knowledge management system. Acquiring of implicit or rather empirical knowledge and also managing the collection and linking of this acquired knowledge with a tagging and scanning mechanism according to DfX principles is one of the main goals of this concept. This approach provides a dynamic system through constant development of knowledge and enables the development team to collaborate and communicate efficiently. Thus, development team members would be able to make right decision in the early stages of product development process to achieve shorter lead times, and lower product costs, and higher product quality.

This paper opens with a literature review. The subsequent section introduces a headlight development use case. In section 4, the concept including the following aspects is described: first the system architecture and modelling of knowledge processes for communication platform is introduced, and then knowledge representation and use are explored according to an ontology with the use case. In the last section, the conclusions and future work are discussed.

2 LITERATURE REVIEW

Before detailing the concept in the next chapters, this section will briefly review knowledge management, DfX, and communication in the product development processes since this concept aims to bring these areas together in a knowledge management system to provide an effective communication platform. Afterwards, deep learning and cognitive technology are shortly described, which can be applied in order to use knowledge via queries.

2.1 Knowledge and knowledge management

Many definitions and perspectives of knowledge are described in the literature. Firstly, a suitable definition of knowledge has to be provided to identify some important questions that must be addressed in order to formulate a useful concept. This research follows the definition of knowledge put forth by Probst, Raub and Romhart (Turki, 2014):

"*Knowledge refers to the whole of proficiencies and skills, which persons apply to solve problems. This includes both theoretical findings as well as the practical rules of daily life and handling instructions. Knowledge is based upon data and information, but in contrast to these, it is linked always to persons. Knowledge occurs as an individual process in a specific context and manifests itself in activities.* "

According to this definition, knowledge is based on data and information and linked to an individual. This raises the question of who creates knowledge and who uses it. Knowledge is generated in a specific context but where and how this knowledge is generated, for example at which point in the company, must also be addressed. These questions have to be taken into consideration within the concept. Furthermore, we also have to discuss knowledge generation and knowledge transfer according to the concept. The knowledge spiral of Nonaka in Figure 1 is a way to understand the generation and transformation of implicit and explicit knowledge, because one of the main goals in this work is to gather the implicit knowledge of experts in the communication platform.

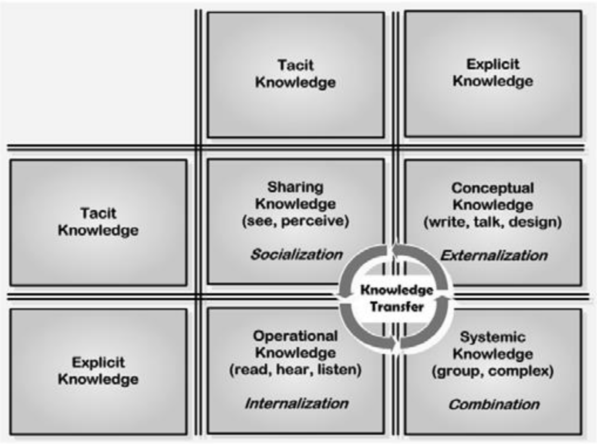

Figure 1: The four basic standards for the knowledge creation or ways of converting knowledge (Nonaka and Takeuchi, 1995) (Rosu, 2009)

According to this dynamic spiral model, knowledge is created through the four interaction modes (socialization, externalization, combination, and internalization) between implicit and explicit knowledge in organizations (Rosu, 2009). Socialization is the sharing of tacit knowledge between individuals through social interactions. In externalization, tacit knowledge is converted into explicit knowledge. In the third interaction mode, combination, two or more pieces of knowledge are combined to generate new explicit knowledge. In the last mode, explicit knowledge is converted into tacit knowledge through learning (Gürder and Yilmaz, 2013).

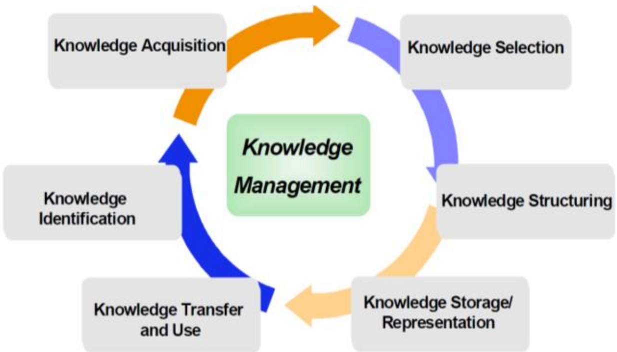

Figure 2: Product knowledge lifecycle (Sainter, 2000)

In order to effectively communicate and share experiences, values, beliefs and ways of working as well as a better treatment of the source of knowledge, it is necessary to manage the knowledge process. Figure 2, which describes knowledge management within a company to achieve a goal-oriented development of knowledge, consists mainly of the elements of knowledge identification, knowledge acquisition, knowledge preservation (selection-structuring-storage), and knowledge sharing and use (Kaiser, 2008).

2.2 Design for X

DfX is known as a knowledge system for the consideration of various aspects and it stands for all endeavors towards making the right decisions in the product development process on the basis of sufficient and universally applicable knowledge (Bauer and Meerkamm, 2007). In the sense of DfX the product developer is to be supported by DfX guidelines, methods, and tools to find the suitable characteristic value according to the required property and thereby he is able to consider numerous dependencies and impacts of different influential factors on a product as well as implement these into product development (Stöber, 2007).
In Figure 3, the hierarchical structure recognizes the relationships between different DfX aspects with various levels of detail. There are also some other structural forms that are based on the product life cycle and properties, characteristics, and objectives, but they will not be discussed in this paper.

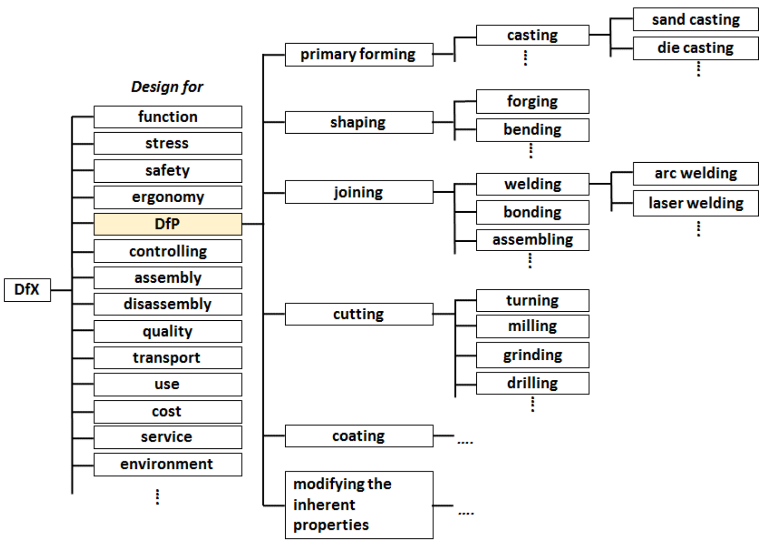

Figure 3: hierarchical structure of DfX aspects [Bauer, 2007]

In the presented concept, the hierarchical structural form will be mainly utilized to make it possible to develop and spread knowledge with a clearly defined goal. Moreover, the findings can be collected and organized in this structural form.

2.3 Communication in Product Development

Communication is an essential process of the product development for exchanging information, knowledge, and ideas among team members. Many studies have shown that if the product development team members have a better connection to each other and also to key external parties, it has a positive impact on the performance of innovation (Paasivaara and Lassenius, 2001). Achievement of efficient and effective communication provides valuable new knowledge and reduces uncertainty and equivocality (Brode and Dietrich, 2010). Moreover, the quality of communication can remarkably affect innovation goals and creativity, which is the focus of product development especially for manufacturers and new product development groups (Nguyen, 2013).
Many different types of communication tools are available in development projects, for example, messaging systems, group editors, electronic meeting rooms and conference systems. Messaging systems are based on an asynchronous information exchange such as an email system, which provides mainly text messages and also enables the sharing of graphics, photos, sounds and videos. Messaging systems have been established in the form of chats for synchronous information exchange. Group editors are designed as a synchronous processing tool and enable group members to work with the same spreadsheets, CAD-data, etc. Electronic meeting rooms include computers and projectors to visualize

information. Conference systems differentiate between real-time and not real-time conference systems. Real-time systems provide synchronous communication with different levels e.g. chats, phone or video and not real-time systems enable asynchronous information exchange over one`s personal computer (Brode and Dietrich, 2010), (Schlichter, 2001).

2.4 Deep learning and cognitive computing technologies

Deep learning is a set of algorithms in machine learning and allows computational models that are composed of multiple processing layers to learn representations of data such as images, sound, and text with multiple levels of abstraction (Deng and Dong, 2013). Deep learning algorithms have emerged the field of artificial intelligence, which aims to emulate the human brain's ability to observe, analyze, learn, and make decisions. These algorithms use a huge amount of unsupervised data to automatically extract complex representation (Najafabadi, 2015). One example technology stack, that includes deep learning, is IBM Watson cognitive computing. This technology is an artificial intelligence computer system that is able to answer questions based on a DeepQA (Deep Question Answering). DeepQA is a software architecture for analyzing natural language content in both questions and knowledge sources. It discovers and evaluates potential answers and gathers, and scores evidence for those answers in both unstructured sources, such as natural language documents, and structured sources such as relational databases and knowledge bases (Gliozzo, 2013). This cognitive system has three fundamental technologies which are first natural language processing for understanding of natural language and human speech, second machine learning to adapt and learn from user selections and responses, and third hypothesis generation in order to generate and evaluate hypotheses for better outcomes. Some potential business applications of this technology are for example, diagnostic assistance and collaborative medicine for healthcare as well as enterprise knowledge management (IBM Watson, 2016). In this concept, we aim to adapt these kinds of technologies in order to help developers access or obtain information for decision making in the early stages of product development.

3 USE CASE – DEVELOPMENT OF HEADLIGHTS

Headlights have been produced for more than 100 years and technologies used in the headlight industry have been developed rapidly, for example, Xenon technology, LED technology and Camera-based driver assistance systems (Hella, 2016). On the one hand, these changes increase the amount of information to consider in the headlight development process, and on the other hand, involve new DfX-aspects. Therefore, the consideration of the headlight development according to our concept is a suitable use case.

Headlight components such as the housing, reflector, headlight lens, and projector lens have to be constantly adapted to the previous mentioned new technologies and requirements. For the production of these components, manufacturing technologies like injection moulding, hydraulic press and coating are available. Moreover, different materials are used for the production of headlight components. Early versions of headlight lenses were mostly made of glass; modern headlight producers utilize polycarbonate due to its impact-resistance, light weight, and smaller manufacturing tolerances compared to glass.

4 CONCEPT

This chapter gives first an overview about stakeholders as knowledge sources or users of the knowledge management system. Secondly, the main concept is defined with regards to a scenario, and then the proposed communication platform is explained in detail with a knowledge process model. Finally, knowledge representation and use based on an ontology with the use case of headlight development is discussed.

4.1 Stakeholders

A key aspect in this approach as described within the following sections is the consideration of users as main stakeholders in the planned communication platform. Users acquire and capture knowledge. Knowledge can be obtained internally, for example, through in-house research and development or through a company's internal education and training programs. Knowledge can be acquired on the other hand externally from interactions with clients and/or suppliers, interaction between the manufacturer and users of products (Svetina and Prodan, 2008). In order to improve collaborative knowledge management, firstly the actors who may access the system must be identified. Within our concept, internal actors can be in the development team, colleagues of other departments, management, and innovators (everyone who has an idea) inside the company or organisation. External actors include outside partners, suppliers and customers.

4.2 A scenario of a development engineer and team in the planned communication platform

In the proposed work, the main goal is the support of development teams for decision-making processes in the early stage of product development with a DfX-based knowledge management and communication platform. In Figure 4, a scenario is presented with the principle idea of the current work. Henrich and Morgenroth (2006) discuss how the important DfX criteria can be used to accomplish the goal-oriented searching for potentially relevant documents in a project.

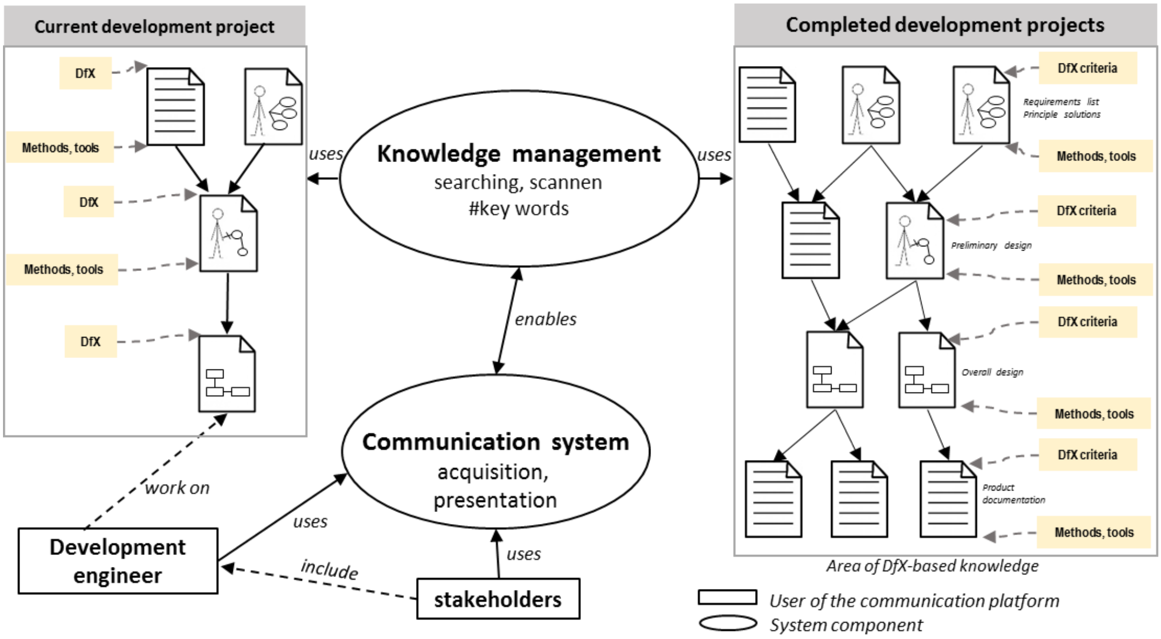

Figure 4: The basic concept of the knowledge management and communication system (adapted from Henrich and Morgenroth, 2006)

In our case, the concept consists of communication, knowledge management and storage component. Communication system provides acquiring and presentation of knowledge by using of keywords or tagging mechanism. The knowledge management system manages to systematically identify and acquire context specific knowledge by scanning of key words in present communication and provides user to share their relevant explicit or implicit knowledge. This knowledge can be determined and stored in a structural form in DfX-based knowledge storage for further use in the next projects. In a current project, the development team and other stakeholders communicate development tasks during the development processes. Knowledge management system supports development engineer to work on present DfX-based knowledge within the communication, moreover he or she can also share and add new information or experiences in the form of text, graphic, images, etc. In a further project if the scan mechanism identifies potential keywords in the communication platform, which are linked with the DfX-based storage, it provides this knowledge to development engineer. (See details in section 4.4)

At the beginning of the scenario, list of requirements, basic solutions, applied methods and tools are known. If a development engineer begins to work on an overall design and requires relevant information to secure a decision, he or she can use a query in the communication system to search for relevant DfX-based knowledge. Queries give opportunities to reach, present and use knowledge in communication platform through tagging mechanism. The presentation of the information can be applied in the form of text or story, and documents such as analysis, graphic, images, etc. which were identified, captured and stored in the previous projects in DfX-based storage. At this point, the use case of the headlight development can be considered, for example, a development team work on improvement of a headlight for a new technology and car model. In the previous project, there were already many key words communicated and defined such as "roughness, tolerance, surface quality, section thickness, moulding accuracy". The knowledge management system stored acquired relevant information regarding DfX-aspects by means of these key words. The same key words may be communicated in the current development project for the design of the headlight reflector and its production process injection moulding. Developers may be able to find and present the relevant DfX-based knowledge by use of the same key words "roughness, tolerance, surface quality, section thickness, moulding accuracy" in the communication platform.

4.3 System architecture

In the proposed concept, the system architecture consists of three main components which are access, knowledge management system, and storage (Figure 5). Access component is an interface between the knowledge management system and users. It provides a web interface where members of a development team, customers, suppliers etc. may participate in the system. The communication component serves chat functionalities. However, it is not specified in detail how this component should look like. Moreover, communication component can be applied to retrieve knowledge with the knowledge management component and store it in accordance with DfX. The Query Component enables users to collect information from the knowledge management system based on user queries. As a result of such a query the user is, for example, able to get context-based information about a significant problem in the past in the form of pictures, documents or chat history etc.

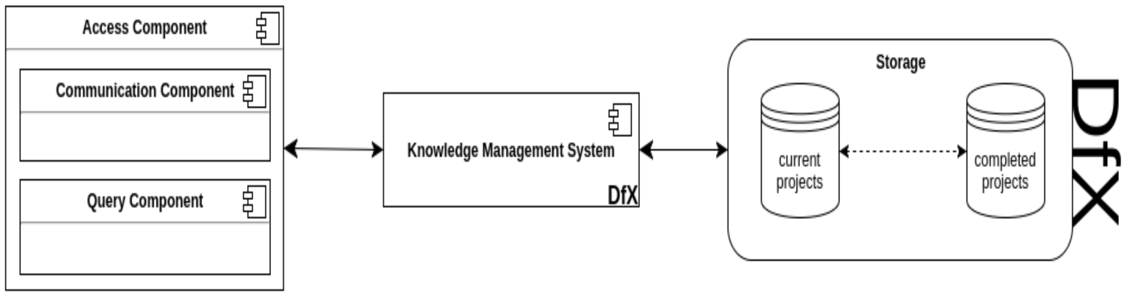

Figure 5: System components

The knowledge management system is the core component of this platform. It is basically responsible for scanning the communication platform by using key words and storing the gathered information based on DfX guidelines in the database. The last component, storage, is demonstrated with two databases in the diagram: already existing knowledge from completed projects and newly gathered knowledge within the context of a current task.

4.4 Modelling of knowledge processes for communication platform

The schematic representations in Figure 6 shows the concept of the intended process in detail. Knowledge processes of communication platform begins with the access of the user. As already described in a previous section, the system may support role-based access for internal and external participants to enable the knowledge base to include as much relevant information as possible. Users can access the knowledge system directly through the query engine or can use the collaborative communication interface. If the former is chosen, the knowledge management component processes the query and provides either a simple direct access or a trend analysis for controlling purposes which gives the managing entity a way to control and maintain the demanded knowledge. If the communication engine is accessed, the knowledge management component is responsible for the scan of the information provided within the individual, labelled channels and uses the provided keywords to perform a classification according to the DfX principles to retain the knowledge. At this point, the use of hashtags (#) or other keywords, which have already found successful application in social networking tools, may be considered as a useful tagging mechanism for identifying and linking important information.

Knowledge processing part in the Figure 6 provides the capturing and structuring of knowledge. Capturing of DfX-based knowledge includes firstly identifying of potential keywords through scanning the current communication among development team. then the user can share or add his/her knowledge in the form of text or story, and documents such as analysis, graphic, images, etc. subsequently knowledge processing system classifies this information by using keywords, and structures it according to the DfX-aspects. The collaboration and query parts enable the presentation and application of DfX-based knowledge. In the collaboration or communication process, the scan mechanism this time finds out pre-defined keywords, which are linked to classified and structured DfX-based knowledge in the storage. Therefore, development engineer or user can be provided DfX-based relevant knowledge in the collaboration platform. Finally, the query part as mentioned before allows the user to present and use knowledge by means of certain keywords.

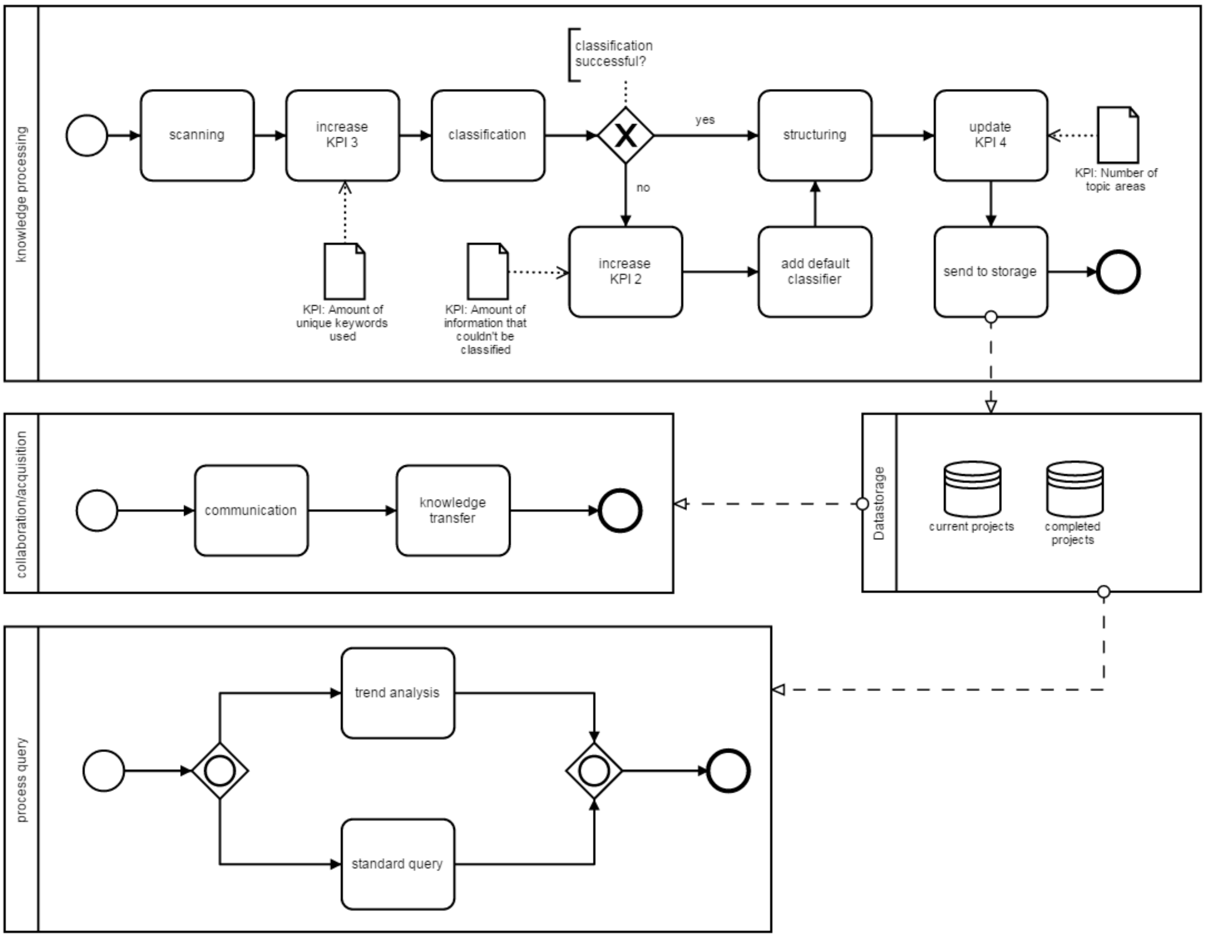

Figure 6: Processes of the communication platform

In the model, some key performance indicators (KPI) are already defined in order to understand and evaluate relevant dimensions in the communication platform, for example, fraction of successful queries and number of used different keywords.

4.5 Knowledge representation and use based on an ontology with the use case of headlight development

In this section, knowledge representation and use are taken into consideration. Figure 7 presents a general ontology for a product, which includes mainly functional components, manufacturing technologies, resources and also related DfX-aspects. This ontology can provide to order knowledge structures in the context of product development. Moreover, mapping and classification of the potential knowledge sources can be identified for understanding the relationship in a networked context, and also the environment, in which knowledge is created or used, as well as relations with other classes can be described. If the ontology is adapted to the engineering design and production of headlights, functional components can be replaced by housing, reflector, headlight lens, projector lens with their manufacturing technologies such as injection moulding, hydraulic press, coating etc. The used materials as resources for the production of headlight components are, for example, polycarbonate, silicon and aluminium. For the DfX classes in the ontology, firstly design for manufacturing, assembly, maintainability, safety and environment are defined.

The aim of the defined ontology is the representation of stored knowledge according to DfX classes. As explained in section 4.2, the potential key words, for example, moulding accuracy and section thickness, are related to headlight lens, which is made of polycarbonate and produced with injection moulding. This relation provides storage and representation of the acquired knowledge regarding design for manufacturing (DfM). Furthermore, use of knowledge by means of a query mechanism, for example, based on deep learning or cognitive computing technology for discovering potential answers can help developers to find and use the relevant assembly properties. Therefore, developers are able to make decisions for designing housing and reflector according to information which is available in the storage at design for assembly (DfA).

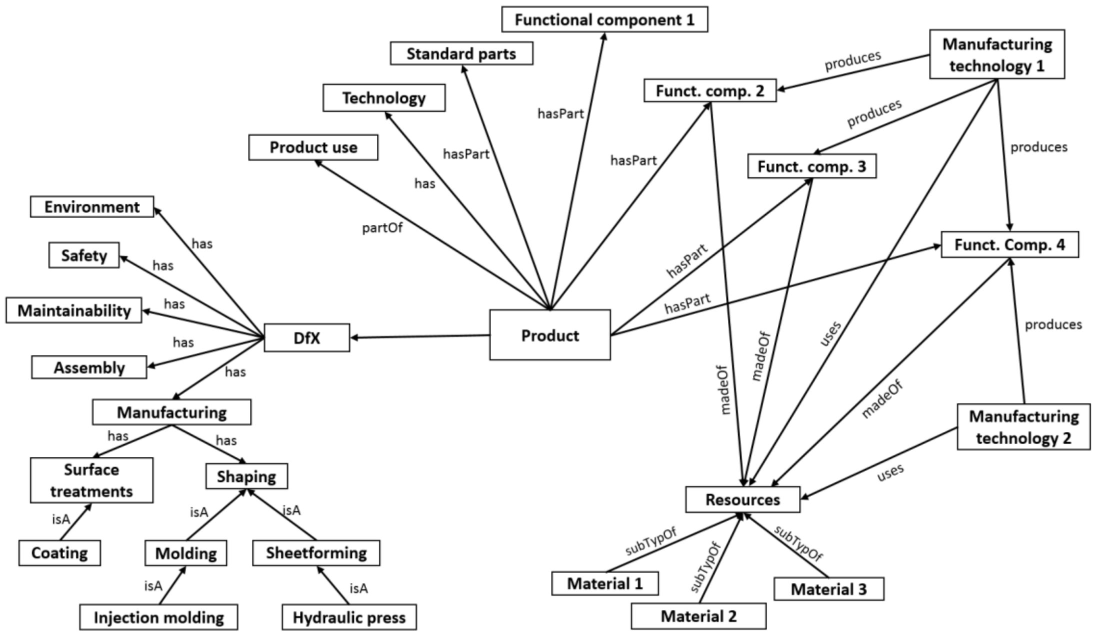

Figure 7: An ontology for the development of a product with DfX aspects

5 CONCLUSION AND FURTHER WORK

Knowledge is a key factor in gaining a sustainable competitive advantage, especially for development and manufacturing companies. Acquisition, use, and management of knowledge allow for more robust and accurate decision-making, as well as rapid and successful innovation in the early stages of product development. Moreover, achievement of a successful knowledge transparency and effective sharing of knowledge in the company is very important to gain valuable new knowledge and reduce uncertainty and equivocality. This paper presents a concept, which consists of a DfX-based knowledge management and communication platform. Therefore, implicit knowledge of experts and specialists in various areas of expertise can be collected and stored according to DfX aspects. In addition, development processes may be accelerated through reducing the time required for knowledge search and implementation in the development process.

In this paper, a scenario is presented to summarize the concept and main objectives. The communication platform is explored through a model of knowledge processes. Furthermore, knowledge representation and use are discussed based on an ontology with a use case of headlight development. In future work, first of all the concept has to be detailed according to the developed model and prototypic implementation is going to be conducted.

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