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MODULARISATION OF KNOWLEDGE – A NEW APPROACH IN THE FIELD OF PRODUCT INNOVATION

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1. Introduction

In the field of product development a broad range of knowledge from "market to market" is covered and a variety of methods, processes, objects and structures are included. Managing this huge amount of knowledge in product development was the initial motive for the research project "*thekey to innovation*" (*thekey*). In collaboration with various universities a highly flexible and state-of-the-art definition of product development knowledge should be acquired and built up in a teaching, learning and training system [Birkhofer et al., 2001].
Thus, knowledge of product development must be prepared in specific ways for various applications and different types of users. Depending on the application, needs will differ between product developers with practical application in industry, students at the universities and teachers with regard to type, structure, extent and processing of product development knowledge.

2. State-of-the-art

Within the scope of increasing possibilities and usage of computer-aided information systems, many projects concerning e-learning, multimedia and knowledge management have been initiated. Flexibility, individuality, adaptability, communication, and up-to-date available information are some of the main goals for such projects. Besides several e-learning environment software tools (e.g., WebCT) and document management software systems (e.g., BSCW), there are several research projects which aim to build up learning and teaching systems. These systems are based on different approaches for modularisation of certain areas of knowledge. Examples are "Multibook", an adaptive e-learning system [Seeberg, 2001], "ViKar" [ViKar], a virtual university platform, and "ARIADNE" [ARIADNE], a proposal for standardisation and reutilisation, especially of multimedia-modules.
In the range of product development one of the main approaches of the actual research of the authors of this paper is the collaboration of various but limited number of authors with different backgrounds and competences, who contribute articles from their own area of competence to a common pool of knowledge. Due to the mutual supplements of the contents and intensive exchange during scientific discussions, one can expect a broader variety, and especially, an improvement in the quality of content.
In a first step, so-called sections have been created by every author of *thekey* in agreement with each other. A section deals thoroughly with a defined topic of product development (e.g., intuitive methods, function modelling), and consists mainly of a program adapted to lesson times and a structure (learning aims, motivation, chapters) conducive to teaching product development at universities.

Because these sections were not satisfactory enough, a new and more differentiated approach of content processing is required. The benefit to every author and user must be significant enough to ensure the acceptance and usage of the created contents. The contents of product development knowledge have to be available in a broad range and rank high in quality. On the same note, individuality in presenting and nearly complete flexibility in use and arrangement of contents have the highest priority.

3. Modularisation of product development knowledge

Based on the experiences with the *thekey*-sections, a more detailed approach to the modularisation, filing and accessing of various contents of product development knowledge has been developed. This approach considers the requirements of the different users, modularises the contents of product development knowledge in different granularity, and links and integrates them into a knowledge network. The aim is to configure distinct, application-specific content-units for different user groups from the available modularised contents.

3.1 Different types of users in product development

To define the resulting requirements from the „customer´s“ point of view, target groups, who will be working with, creating and using the modularised contents, can be classified according to authors, configurators and customers (Figure 1).

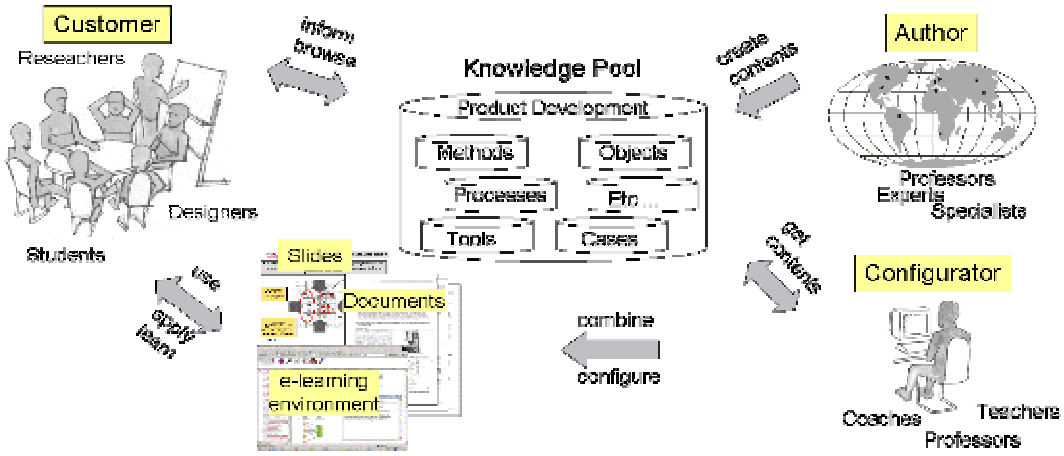

Figure 1. Knowledge Pool and different types of users

Authors create contents of defined fields of topics. In this connection they use existing guidelines, link their own contents and other, already existing contents to each other, and are responsible for the maintenance and updating of their contents. The contents, created by one author, will be reviewed by a Quality Board and will afterwards be placed at the disposal of all users.

Configurators arrange documents (e.g., scripts, slides, method collection) suitable to their own needs on the basis of existing and published contents. These documents can be a course for students of a certain semester at a defined location or even a guideline for the practical application of methods for product developers.

Customers are the final users of the available modularised contents. Typical customers are students of a university course or product developers in the industry. On the one hand, they are navigating in course documents such as scripts, slides or e-learning-systems, which are especially arranged for them by the configurator, e.g., to learn a certain assignment. On the other hand, customers are free to navigate through all publications, independent of certain courses, to deepen or refresh their knowledge in a defined topic or even to receive detailed application guidelines for methods.

For defined individual persons it should be possible to use the whole performance that is offered by changing their roles. For example, a professor can inform himself about certain topics as a customer, can then create contents of associated topics as an author and publish these contents for others. Afterwards, he can arrange a course for the students at his location as a configurator.

3.2 Structure of the contents within the modularisation approach

To guarantee a broad and high-quality coverage regarding contents, an appropriate structure is essential and it has to be carefully worked out. The structuring of contents takes place by assigning modularised content units to topics or to keywords of a glossary, at least one content unit has to be assigned to one or several topics or glossary entries. A prerequisite for both assignments is the pre-definition of an appropriate content structure, i.e., the compilation of a topic ontology and of a glossary for keywords of product development.

Therefore, in a first step a hierarchical classification for the presented modularisation approach was chosen, because of the advantages of defined assignment, and its extensive use, existing classifications will be able to be adopted. For the future, an approach with a semantic network (also called topic maps, [Gerick, 2000]), or a combination of both classification systems is planned to be applied and adapted to the needs of product development. This seems to offer new and promising possibilities in the structuring of contents. In contrast to a strong tree-like structure, it is simpler to present or process all necessary links in a “user-focused” way, i.e., based on one topic the user can navigate either to linked neighbours on the same level or to sub-topics on a different level.

3.3 Content units of the modularisation approach

The modularisation approach is based on the assumption that contents of product development knowledge can be divided into smaller units, and that these units can be combined again respectively, and configured to larger, coherent, new or even newly structured contents.

On the one hand, a high granularity of content units is essential to reach the best possible flexibility. On the other hand, in order to define coherent contents with less granularity, it is necessary to reduce the expenditure of arranging individual learning and teaching content units. Therefore, a modularisation approach was chosen, which defines content units on three different levels: elements, modules and containers (Figure 2):

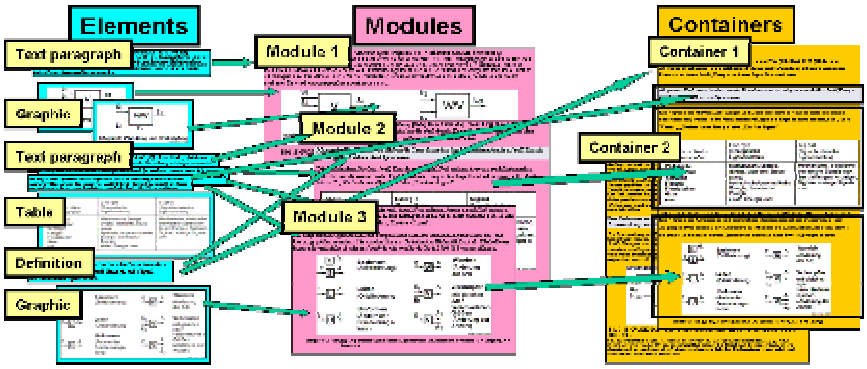

Figure 2. Script-Container configured by modules and elements

Elements are the smallest content units. They are stored physically in a database. Certain types of elements can be distinguished, for example, in pictures, text paragraphs, enumerations, and diagrams. Elements are more or less formally defined and most have no convenient statement, so they are seen as a syntactical, rather than semantical, unit.

Modules are the smallest distinguished units with regard to content. Typical examples of modules are arranged diagrams with inscriptions, individual chapters, coherent paragraphs, as well as individual definitions. Modules are semantically independent units with an unequivocal statement regarding content. Modules are composed of individual elements by linking the contained elements in the database.

Containers are the largest units. Examples of containers are the main chapters of scripts, methods with explanations and guidelines, or the complete slides for a lecture. They can be composed of several modules, individual elements, but also of complete sub-containers. Containers deliver information on broader areas of knowledge and assist in the didactic processes of the mediation of knowledge. Containers are arranged for specific teaching and learning situations, and different types of presentations.

3.4 Description of the content units and navigation

For effective and efficient work (retrieval) with the content units it is necessary to have a sufficiently detailed description of the individual content units. Although the users have different motivations and are variously grounded in this system, they should have a highly flexible and quick access to the content units.

A well-known approach is the description with defined sets of metadata. Such approaches can be found for example in the field of e-learning software. For this application a metadata standard (LOM - Learning Objects Metadata) has been adopted especially for teaching and learning objects [IEEE LTSC 2000] with the purpose of exchanging learning objects between different e-learning systems. Based on these actual LOM standards a set of metadata has been defined for the description of the individual modularised content units of product development.

Examples of descriptive metadata attributes regarding to content are name, topic and keywords either out of a pre-defined topic-structure and a glossary or, if necessary, in addition self-created. Regarding formality, metadata are also stored, e.g., data of the author, dates of creation and access. While the attributes regarding formality can be established by the system at the time of content creation, others, such as attributes regarding content, must be set up by the user, i.e. the author.

To decrease the authors expenditure, some strategies of transmission are considered. Using a bottom-up strategy the attributes of the elements are transmitted up to the linked modules and further on up to the linked containers. A top-down strategy transmits the attributes from containers down to the linked modules and elements. Combinations of these two strategies, such as transmitting the attributes of the modules to the above linked containers as well as to the lower linked elements, seem to be suited, but they still must be thoroughly analised.

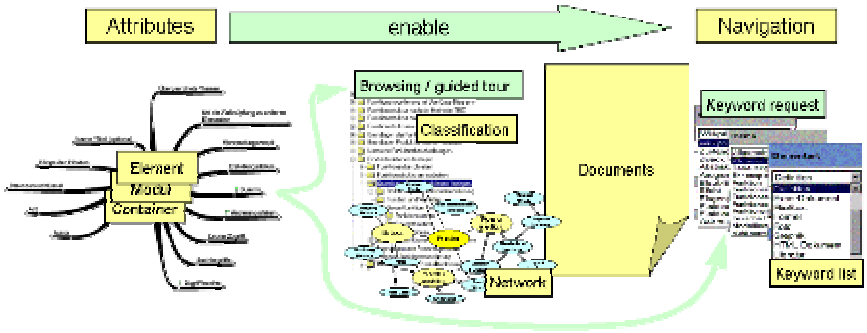

Figure 3. Attribute-based navigation

To support individual and flexible access to the content units, two different ways of searching are considered (Figure 3): One way is browsing through the topic and keyword structure, e.g., a network or hierarchical classification, and also through documents themselves. Second, direct search for content units using metadata attributes should be provided by using public disposable IT-components, such as search engines, index servers and ranking methods, adapted to the special needs of the users.

4. Operating with modularised contents

Operating with modularised contents should and could be very flexible in the fulfillment of individual requirements, given peripheral requirements, and areas of application.

The different types of users (author, configurator and customer) are supposed to work with the modularised content units on different levels (Figure 4). Thus, they can support their specific needs and optimize their own methods of working.

In creating new content units it is very important for the author to have unlimited access to all existing elements, modules and containers. This is necessary to adapt the newly created contents to already existing contents and to avoid duplicates. Authors are supposed to create elements and modules and furthermore, they have to configure at least one or several so-called sample containers.

A sample container is defined as a pre-defined collection of contents. With the creation of a sample container the author makes a suggestion as to how the created contents (elements, modules) should be arranged for the other users (especially the configurators). In this way, the author documents his

knowledge and competence. Furthermore he can make sure, that he will not create and store elements without the linkage to a context, so that they cannot get lost. Sample containers can also be created by other persons (configurators). They can arrange containers specifically for different purposes and applications (“user specific container”). For example, for the same topic the container for a script will differ from the container for a slide presentation or a method application. Furthermore, sample containers can be arranged in a variety of sizes (short or long version) or depths.

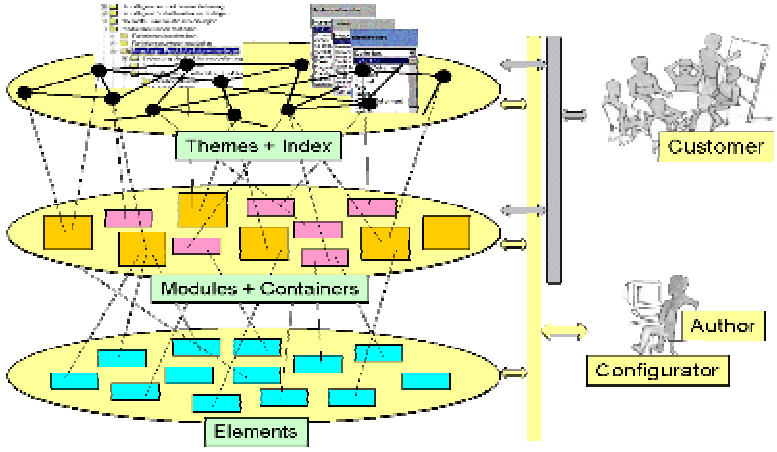

Figure 4. **Different levels of modularised contents and user-specific access**

For configurators particularly, the levels of elements and modules are very important. Configuring their own content units (e.g., a course for students), they should have the greatest possible scope to concentrate on individual points of emphasis, or to consider specific conditions. Therefore, configurators must have access to a broad and varied selection of content units. If required, access to single elements should be supported, e.g., to change a photo within the same context. Because it is not practical to configure a large, coherent container from many single content units (elements or modules), the following procedure is suggested. Based on one or several relevant sample containers, pre-defined by an author, the configurator copies and changes them regarding his own aspects. The advantage of this procedure is that the configurator works with a given context and so he/she has the chance to profit from the suggestions and competences of the author or of another configurator.

Customers, such as students or designers in industry, are interested especially in coherent contents, e.g., for learning or applying them. For this purpose, the level of containers is most appropriate, as well as access and navigation tools, e.g., search engines for keywords, indexes and hyperlinks. For some specific customer-groups, especially configurated containers are very important, e.g., courses for students at a certain university or seminar lessons for industrial designers in industry. Access to the level of modules is less important for customers, with certain exceptions, e.g., searching for single definitions. The level of elements is not appropriate for customers and it will not be offered to them.

5. Conclusion

The described modularisation approach seems to be suited to provide answers to different questions of product development, such as improvement and assurance of quality, storage of contents and access to product development knowledge. Based on a common knowledge pool, different users will have the possibility to use pre-defined content units, as well as to create individual units. They will be able to cover a broad field of application, e.g., for specific teaching documents at university and for training or application in industry.

First experiences and results in working with the modularisation approach are available, based on previously worked out modularised content units in the range of conceptual and embodiment design. The content units have been described with attributes and have been stored in a prototype of a database. Positive experiences have been made to identify and define the elements using primarily formal rules. In defining modules, some problems have cropped up, such as fixing the size of modules. From the point of view of the authors, some more experiences have to be gathered in the future in order to derive explicit rules for modules. At least positive experiences have been made by configuring

new and specific containers for different applications. Using the modularised content units in the database exemplary, containers have been configured, e.g., slide presentations, scripts for lectures, and practical lessons for students. Different kinds of contents, such as design methods, tips and example cases, could have been integrated in these exemplary containers.
Concerning the management and the maintenance of the knowledge pool, advantages will result, because all relevant content units will be updated automatically. Included elements will be edited and duplicates of elements almost will be avoided.
The modularisation approach is supposed to significantly improve the quality of product development contents, which takes place on different levels. Using elements, modules and containers enables a review process for a detailed and well-defined content range, e.g., review of a glossary and definitions or single modules. Furthermore, working on the detailed level of elements and modules, additional or existing content units can be created or edited easily - they can be adapted to existing content units or at least integrated into the existing knowledge pool without reviewing the previous contents again.
Quality improvement is expected out of the cooperation of different authors at several university locations, so that their competence can be complemented by one another. The modularisation approach can be used as a platform for cooperation in the scope of product development between universities. Standards of the modularisation approach concerning creating, preparing and structuring the contents of product development will enable the integration of existing contents and the systematical supplementation and enhancement of product development knowledge.
The modularisation approach enforces the demand to manage the complexity and variety of product development knowledge in a holistic way. To answer open questions and to achieve the initial aims, such as providing a knowledge pool for learning and teaching product development knowledge on a high quality level, theoretical research will be continued, public disposable solutions will be adapted, and modularised contents will be extended and applied practically at university and in industry.

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