

## MODULARISATION OF PRODUCT DEVELOPMENT CONTENTS AS A BASIS FOR A FLEXIBLE AND ADAPTIVE USE IN LEARNING, TEACHING AND PRACTICE

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### Abstract

Contents of product development knowledge have to be available in a broad range and rank high in quality for teaching, learning and application. This paper describes an approach for the modularisation of product development contents based on three levels: elements, modules and containers. Using a database software, the content units are defined, stored and described with attributes. Different users are able to access the content units and configure them to larger coherent content units. Thus, individual and situation specific teaching, learning and application documents within a wide range can be composed for appropriate transfer of product development knowledge at university and in industry. Besides technical aspects, important influencing factors, such as acquisition of information resources, presentation of contents and configuration for individual kinds of users in different situations are discussed.

*Keywords: Design education, design information, knowledge representation, adaptability, modularisation of contents*

## 1 Introduction

The situation in learning and teaching product development knowledge and methods is considered to be similar at several universities: Often there is a reliable but unstructured, incomplete and fragmentary basis of documents, scripts, methods, examples and even more available. Out of these documents lectures and lessons have to be prepared within a short time and with a lot of individual expenditure. Because of the great complexity and dynamic of the research area it is hard and time consuming to develop well-founded documents [3]. Thus, one time created, they are never or even seldom changed or adapted to changing situations over years. This scenario results out of the specific kind and properties of product development knowledge, which covers a broad range of knowledge from “market to market” and includes knowledge of a variety of methods, processes, objects, structures and best practices. This knowledge in product development exists in various domains [7] (e.g., design theory, methodology, human assets) and in a variety of ways. The knowledge of product development can be found in literature and in practice at different depth levels and types of description depending on the user and the application.

## 2 State-of-the-art

To give a brief overview of knowledge management research in engineering design, Troxler [12] described a model of the six challenges of knowledge management (acquire, retrieve,

model, Re-Use, publish, maintain). He compared these challenges to the needs in engineering design by investigating the published articles at the ICED Conferences 1999 and 2001. Out of the investigation he suggests issues for future research especially in the areas of acquiring, modelling, publishing, re-using, and maintaining knowledge in engineering design. Concerning the area publishing of knowledge it is pointed out, that personal and customised content publishing for the actual needs of an engineer is of interest, but still a new field of research and application in general.

According to these findings, 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 a lot of research projects in Europe which aim to build up learning and teaching systems. Some of these systems are based on different approaches for modularisation of certain areas of knowledge. Examples are “Multibook” and “Medibook”, two projects for adaptive e-learning systems [11] or “ViKar”, a virtual university platform. Regarding the knowledge base of already implemented systems, they often deal with knowledge out of the range of computer science, because usually developers are computer scientists. Also projects out of medicine are another big field of e-learning applications. One of the reasons for these priorities is, that both research areas have the general characteristic of being clearly structured, standardised and strictly defined, so the knowledge base can be defined relatively easy e.g., conditions, structures and results of programming languages [11].

In the range of product development the research project “thekey to innovation“ (*thekey*) was founded in collaboration with different universities [3]. The motivation of the project was the vision of a highly flexible and state-of-the-art definition of product development knowledge to manage this huge amount and variety of knowledge. The primary aim of the *thekey* project was to develop a teaching, learning, and training system for product development. One of the main approaches of *thekey* was the collaboration of different authors with different backgrounds and competences in product development, who contribute articles from their own part of competence to a common pool of knowledge. These articles have been created by every author as so-called *thekey*-sections, which deals with a defined topic of product development (e.g., intuitive methods, function modelling). Guidelines have been developed for the description of methods and processes to guarantee as far as possible common materials within the *thekey*-sections [3]. While a very extensive documentation could be prepared within a very short time and every author could profit from the complete collection, some significant problems especially in adjusting the section to ones personal and site-specific needs became obvious. Thus, a different and more differentiated approach of content processing is required. The contents of product development knowledge have to be available clearly structured and with the right granularity, to ensure a high acceptance by individuality and flexibility in use and arrangement of contents.

### 3 Aims, objectives and requirements

Appropriate transfer of product development knowledge is essential for its learning, understanding and applying at university and in practice. With the aim to cover a wide range of learning, teaching and application situations a flexible and adaptive teaching, learning and training system for product development contents is being built up [3]. To reach high flexibility and adaptability, an approach for the modularisation of product development contents has been developed [1][11]. Therefore contents of product development knowledge are modularised and they are linked and stored within a product development database. Using

this database of modularised contents, the paper will present advantages and possibilities of configuring individual and situation specific teaching, learning and application documents within a wide range.

Being aware, that successful transfer depends on many influencing factors, this paper will discuss three main factors: kind and quality of information resources, presentation of contents and configuration for individual kinds of users in different situations. With regard to the modularisation approach, these influencing factors are analysed concerning their characteristics and requirements. Thus, possibilities, guidelines and hints for the configuration of appropriate contents are derived out of first experiences. In this way, individual adapted documents, according to certain user profiles or specified situations, can be configured out of the modularised contents on demand, considering, e.g., the appropriate kind of presentation, structure or extent of documents.

## 4 Modularisation of product development contents

In the field of product development, the nature of knowledge and the relations between its different units are highly complex and varied. To handle these problems, an appropriate modularisation approach has been developed in advance [1] to structuring, filing and accessing various contents of product development knowledge.

The modularisation approach is based on the definition of different modular content units, the elements, modules and containers, which can be configured to distinct, application-specific documents and presentations. The modular content units are uniformly structured, stored and linked to each other within a database, which will be reviewed continuously by a quality board, to ensure a high quality and up-to-date available contents.

To consider different requirements and intentions, the users of the modularised database are classified into different user groups. These groups have different legitimating and possibilities to create and work with the modular contents, to fulfil their individual and situation specific needs in accordance with the actual standard of knowledge in product development.

### 4.1 Different content units

The basic assumption of the modularisation approach is, that contents of product development knowledge can be divided into smaller units, and that these units can be configured to larger, coherent, new or even newly structured contents. A high granularity of content units is essential to reach the best possible flexibility. On the contrary, for defining coherent contents with less granularity, it is necessary to reduce the expenditure of content units. To reach the best compromise, a modularisation approach was chosen, which defines content units on three different levels: elements, modules and containers (Figure 1).

The smallest content units are the elements, which are the basic parts and which cannot be broken down further. Elements are stored physically within the database using metadata for description. Certain types of elements can be distinguished, for example, individual 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.

The smallest distinguished units with regard to content are called modules. Modules are defined as self-contained semantic units which have a definite statement regarding content. Typical examples of modules are arranged diagrams with inscription, individual chapters, coherent paragraphs or sections, as well as individual definitions. Modules are composed of

individual elements. This is done by simply linking the contained elements in the database. Modules are considered to be the most important content units, because of their unequivocal statement and independence they represent knowledge units, which can be accessed and transferred without the necessity of a situation specific context.

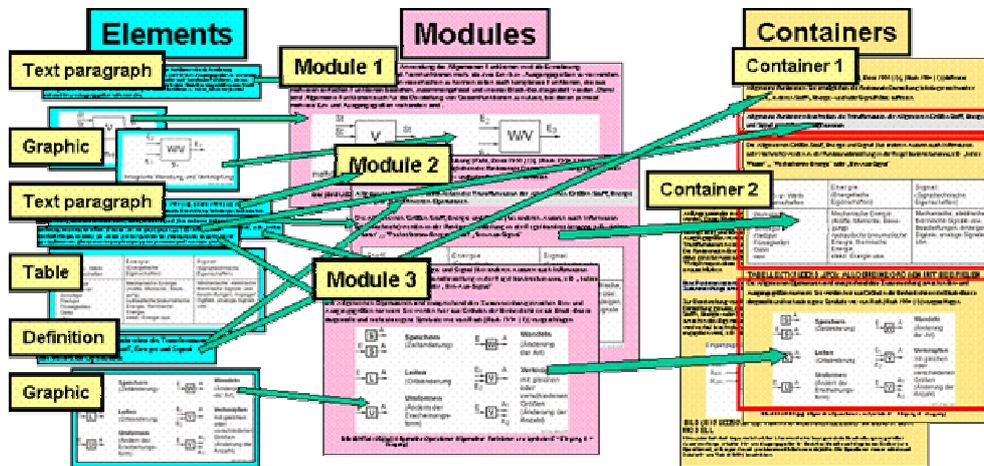


Figure 1 Content units of the modularisation approach (scheme)

The largest content units are called containers, which deliver information on broader areas of knowledge and support didactic processes in teaching design knowledge. They are adapted to specific teaching and learning situations and different kinds of presentation. Typical examples of containers are the main chapters of course scripts, methods with explanations and guidelines, or the complete slides for a lecture. Containers can be composed of several modules, individual elements, but also of complete sub-containers. Similar to modules, containers are stored by linking the corresponding contents in the database. Containers are considered to represent the final documents for teaching, learning and application, so different formations and presentations have to be supported.

#### 4.2 Structure, linkage and description of the content units

Appropriate representation of the content units within the database is fundamental for a successful effective and efficient application. Besides a defined structure and linkage of the content units, it is necessary to have a sufficiently detailed description of the content units. Users with multiple motivations, various practice with the system and different knowledge of the stored contents should have a highly flexible and quick access.

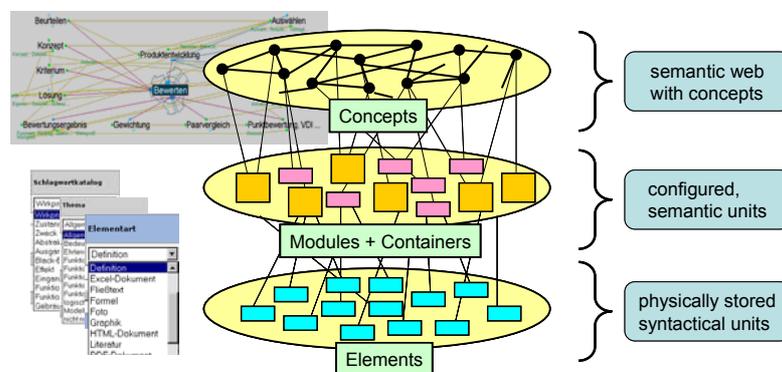


Figure 2 Representation model of modularised contents

Therefore the representation model includes three different levels (Figure 2): On the first level, the elements as syntactical units are stored physically. On the second level, the modules

and containers as semantic units are represented. On the third level, a semantic web for integrating and structuring concepts within the thematic context is represented [10].

There are two kinds of linkages between the content units: First the so-called configuration linkages, they link elements to modules, modules to containers and so on, to compose the semantic units. Second so-called context linkages exist, they link concepts out of the semantic web to modules or containers. Furthermore modules or containers can be linked to other semantic units within the same or similar context.

For the description of each content unit, an approach using metadata attributes is applied, adapted to the metadata standard LOM. This metadata standard (LOM - Learning Objects Metadata) has been adopted especially for teaching and learning objects [8] with the purpose of exchanging learning objects between different e-learning platforms.

The descriptive metadata are separated into two categories, one regarding content and the other regarding formality. First, descriptive metadata regarding content for example are name of the content unit, topic and keywords, out of a pre-defined topic structure or a glossary. Second, regarding formality metadata are also stored, e.g., data of the author, dates of creation and access. Some of these attributes are established automatically by the system at the time of content creation. Others, such as the attributes regarding content, must be set up by the author.

### 4.3 Different user roles

Requirements for the modularisation of product development knowledge must be defined from the “customer’s” point of view. Target groups, who will be working with, creating, using and accessing modularised contents, are classified into three user groups: authors, configurators and customers (Figure 3).

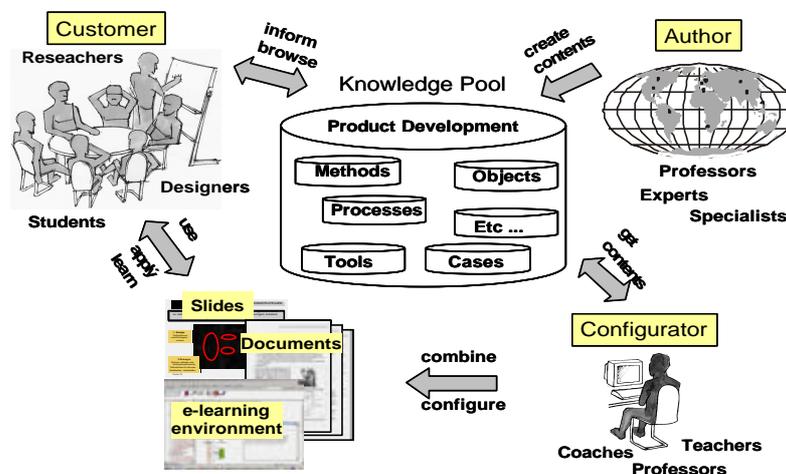


Figure 3 Different users and their competences

The first group are the authors, who 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 creation of so-called sample containers is of special importance. A sample container is defined as a pre-defined collection of contents. The author makes a suggestion 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. All contents, created by one author, will be reviewed by a Quality Board and will afterwards be placed at the disposal of all users.

The second group of users are the configurators, who arrange documents (e.g., scripts, slides, method collection) suitable to their own needs. The configuration takes place on the basis of existing and released contents, for example sample-containers. Typical configurators are professors or tutors, who have to prepare for example 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. Configurators are responsible for their arranged documents, because they have to decide, what to teach to their customers, for example students of their lecture. Because of this, the specific containers will not be examined by the quality board, but they also will not be placed at everyones disposal, to avoid information overflow within the database. In case of wishing to publish the arranged documents, the configurator has to change his role to an author to proceed the whole authoring process described above.

The third group are the customers, who are the final users of the available modularized contents and arranged documents. 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.

#### 4.4 Prototype database for modular contents

Experiences and first results in configuring and adapting individual and situation specific documents have been made at the department product development and machine elements (pmd) of the Darmstadt University of Technology.

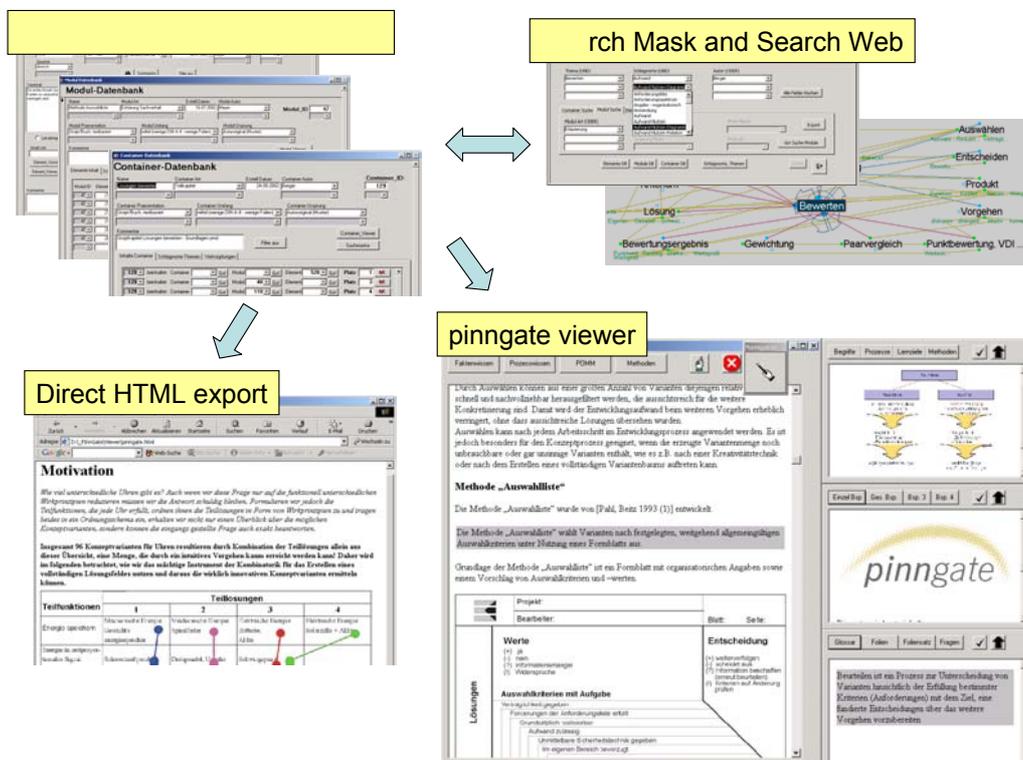


Figure 4 Screenshots of the IT-prototype components for modular contents

An IT-prototype database for handling the modularised contents has been developed and modularised contents out of the range of conceptual design in product development have been worked out and stored within the database (Figure 4).

The IT-prototype enables the following functions: a) storing elements and describing them with given metadata attributes, b) configuring modules and containers, storing and also describing them, c) searching for and accessing to content units by using keywords or browsing through a semantic web, d) formatting and exporting of content units to HTML-pages and e) working with a specific viewer to access different contents of the database in parallel respectively to browse through contents.

## 5 Influencing factors for a successful transfer of modular contents

Realising the technical aspects of configuring documents out of modular contents by implementing and using a software, such as the IT-prototype described above, is a necessary prerequisite. But nevertheless a lot of additional influencing factors and best practice procedures are fundamental for a successful, individual and flexible configuration of documents for teaching, learning and applying product development knowledge.

For a better understanding and illustration of influencing factors for working with modular contents, two exemplary scenarios typical for situations at university shall be looked at. First assuming there is a group of students in the early beginning of their studies in a lesson for product development, the context for example shall be “evaluating methods”. Second scenario assumes a student, who is at the end of his studies working on his diploma thesis. One task of the thesis is to evaluate several principle solutions. Both have different education backgrounds, lets say high and low, and different aims. On the one hand learning and understanding, on the other hand problem solving of a concrete task. Furthermore both scenarios differ for example in available time, suited kind of presentation or the required profundity. Out of this, different requirements result obviously, although the subjects and main aspects of both are the same.

### 5.1 Acquisition - Information resources for modular contents

Concerning the information resources, product development knowledge is covered by a huge collection of new and established documents, e.g., scientific papers, educational literature, scripts or guidelines for the description of methods. Furthermore research in product development was carried out by different schools with many different approaches, mainly in Europe [3]. Thus, building up and complementing a high quality modular database requires to consider the “right” information resources as basis for deriving and defining modular contents. Aspects such as completeness, redundancies and similarities with existing contents have to be double-checked very carefully, to be sure of having enough and suitable modular contents to cover the thematic context sufficiently.

For the IT-prototype database, especially contents out of fundamental educational literature [5][9] and course scripts have been analysed, structured, modularised and described with attributes. Concerning the scenarios of the students, especially methods, definitions, explanations, checklists or guidelines for evaluating and selecting solutions, have been acquired. Positive experiences have been made by identifying and defining the granularity of the units, i.e. elements and modules. Furthermore these units could have been integrated quite good within a predefined thematic context structure and described with metadata attributes, such as keywords.

Concerning the included information resources, it became obvious, that mostly within relative few sources there is already a certain saturation of contents, but the process of double-checking still takes place manually. An approach to develop in future could be an automated comparison of the metadata attributes of identified elements and modules. Being aware, that

this research area is quite challenging in general [12], the existence of already defined and described modular content units is considered to be a useful prerequisite.

## 5.2 Delivery – presentation of learning and teaching documents

Within the context of providing and presenting product development knowledge there are many possibilities. On the one hand established ways of teaching, such as lectures or seminars are state of the art. On the other hand, within the increasing usage of computer-aided systems, many e-learning platforms have reached a high level and are accepted as well [6][4]. The requirements here are the existence of web sites, but also communication tools such as white board, chat-room or e-mail are of very high importance. To deal with this broad range of different presentations, technical aspects as well as didactical aspects, such as readability, arrangement and format of contents have to be considered.

To fit the technical aspects, software features and automated export filters have to be implemented to create different kinds of documents and presentations. In case of our scenarios, especially slides for a beamer presentation, a script and exercises as paper print are required for the first group, which participates the lesson. The second student working on his thesis for example requires short information in the internet as web pages or pdf-document, because of easy and quick access. To fulfil these requirements, one powerful characteristic of the modularisation approach is, that the content units are stored in a neutral format, so different kinds of presentation can be created using the same content basis. At the moment, the IT-prototype is able to create individual formatted HTML-pages to provide them as web pages. In the near future it is also planned to implement export possibilities for printed-out documents (e.g., pdf-files) or even presentation slides.

## 5.3 Configuration – specifications for different users and situations

With regard to the customers for a successful transfer of knowledge, different kinds of users in various situations and their specific requirements have to be considered. Students learning basics need different documents compared to a product developer solving practical problems. As demonstrated in the both exemplary scenarios, even at university, there are various situations, such as lectures, seminars or design tasks.

Specific configured documents differ concerning structure or extent, but they also contain same or even similar content units. Regarding the exemplary scenarios, first the extent and profundity of required documents will differ: Students in a lesson like a coherent and detailed script whereas the student working on his thesis prefers a short and terse essay. Second the didactical structure of required documents will be different: For the students group aspects, such as learning aims, motivation or overview are important, while for the older student a step-by-step instruction will be helpful. Third the main content units vary: For learning and understanding the context of evaluating solutions the student groups needs basics, specific information, explanations as well as examples. The student solving a concrete task will be more interested only in specific information, hints and links to similar cases.

Working out different documents by configuring the modular contents, positive experiences have been made using the IT-prototype. For some exemplary situations at university for example short or long versions of one context, step by step instructions or case oriented explanations could have been derived out of the same modular database. The configuration process, the access to the content units and especially the granularity of the elements and modules seems to be suited for an individual and flexible creation of documents. Though a more professional software is considered to save much time and expenditure for the configuration. For future research it is planned to define user and situation profiles, including

requirements and needs. Using these profiles and resulting guidelines, the configuration process will be supported systematically and efficiently.

## 6 Integration within a holistic learning and teaching system

Looking forward to a holistic learning, teaching and training system, besides the modularised contents using elements, modules and containers, further interactions between several other integrated components are of high importance. Therefore the project *pinngate* was launched at the department of product development and machine elements (pmd). *pinngate* bases on the project *thekey* [3], described above, and can be seen as the continuation especially for the Darmstadt University of Technology. The aim of *pinngate* is to develop and implement an integrated information, teaching and learning system for use i.e. for the education of students of mechanical engineering as well as to support product developer in practice [3]. To realise this, the *pinngate* system consists especially of three main parts: content part, application part and the navigator (Figure 5).

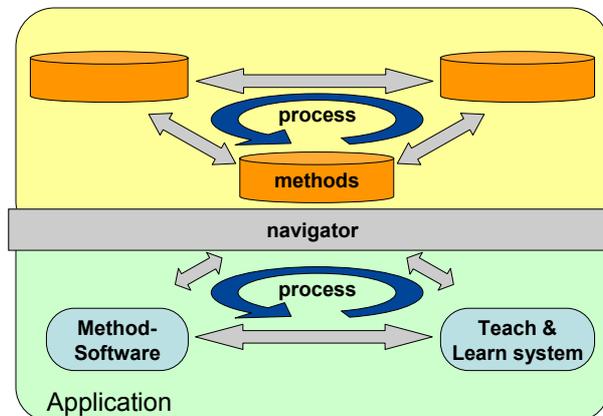


Figure 5 The *pinngate* approach – schematically – and its components

Within the content part modularised contents of three domains are stored and accessible: Documents include first of all learning contents, such as explanations, definition and examples. Methods include descriptions and guidelines of product development methods, also modularised using a standardised model for representation, the so called “process oriented method model” (PoMM) [2]. Objects include part and overall solutions according to defined steps within the product development process. Within the application part software tools will be developed and implemented. The teach & learn system is considered as a e-learning platform using modularised contents out of the content part. Method software will be supportive tools for product development method application and documentation. To integrate all the components of the *pinngate* system, a navigator connects them and supports the user by guiding through contents and applications. The aim of the navigator development is to provide a context sensitive and user adaptive navigation.

## 7 Conclusion

To provide an adaptive and flexible learning, teaching and training system, an appropriate modularisation of product development contents is essential. On the one hand, technical aspects, such as the right granularity, linkage and access of the modular content units, have to be focused. The application of the modularisation approach using the IT-prototype is considered to be suitable for gathering first experiences in working with modular contents:

identifying, storing, describing, accessing and configuring. For the near future it is planned to develop and implement an improved software version for reducing the expenditure and saving time for handling and configuring the modular contents. On the other hand, didactical aspects concerning user profiles and learning and teaching situations, e.g., structure and extend of information or kind of presentation, have to be considered for configuring individual and specific suited documents. Therefore further research for defining user and situation profiles, deriving requirements and needs and, thus, adapting specific configured documents will take place in industry and at university.

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