INTERNATIONAL DESIGN CONFERENCE - DESIGN 2006
Dubrovnik - Croatia, May 15 - 18, 2006.

DESIGN 2006

TOWARDS A DESIGN METHOD-SUITABLE, COMPUTER-SUPPORTED LEARNING ENVIRONMENT

J. Jänsch, S. Weiss and H. Birkhofer

Keywords: design methods, computer-based learning, design education, learning environment

1. Introduction

There is the need for a design method-suitable learning concept and environment. The ***pinn**gate* project of the department product development and machine elements (pmd) at the Darmstadt University of Technology offers an approach to set up a flexible product development system that represents product development contents in a modular shape, in order to provide user-suitable product development knowledge for teaching, training and applying design methods. This paper aims to give an overview of the possibilities of this system to provide a suitable environment to learn design methods with a cognitive (user friendly) learning process. Cognitive processes play an essential role in designing and applying design methods and need to be considered when teaching designing and design methods [Jänsch 2005]. Therefore, modern learning theories, e.g. cognitive apprentice ship, are taken up to give an effective approach for a design method-suitable and user friendly learning process. Starting with this approach, requirements for the ***pinn**gate* system are formulated and the concept of technical implementation is described.

2. Modern Learning Theories Applied to Design Methods

There are many modern learning theories suggested by cognitivism and constructivism. They are called situated cognition, anchored instruction, cognitive apprenticeship and flexible load theory. All these theories are based on problem-solving, learning, and stress the context, flexibility, as well as complex and realistic problems. These learning theories are also very practice-oriented, which is also an important aspect when teaching design methods. For this they seem very useful because we are dealing here with complex problems, instable situations and the urgent need for action. In this discipline we must provide teaching material and a high variety of application possibilities to meet the high requirements of teaching design. These teaching theories address the challenges to overcome teaching and learning issues with these kinds of materials in which the aspect of transfer and flexibility is decisive.
In order to understand the most important aspects for a user-suitable and design-suitable learning environment, the different learning theories are briefly introduced in the next four paragraphs.

2.1 Situated Cognition

The approach of situated cognition (Laves 1988, Rogoff 1990) emphasizes the context relationship of the learning environment, which means the learning environment should be as similar to a real working situation as possible. Important elements in this theory are the complex task, the degree of flexibility, the authenticity of the task, multiple views, possibility of reflection and the connection to existing knowledge.

2.2 Anchored Instruction

This approach (Vanderbilt 1990) focuses on multiple tasks and the fact that the initial problem situation is the anchor to integrate the new knowledge into existing knowledge. The theory of anchored instruction also stresses the need for multi-perspective views on the task, authenticity, and complexity of the task. Furthermore, it is suggested to teach the theory with the support of video sequences and to train certain aspects on different but similar tasks.

2.3 Cognitive Apprenticeship

Cognitive Apprenticeship (Collins et. al. 1989) emphasizes authentic activities within the learning processes and the introduction of expertise. The suggested teaching methods in this theory are modelling (introducing adequate behavior in certain situations), coaching (giving tips and advice during the learning process), scaffolding (offering different action possibilities and initiating reflection processes). These support mechanisms in the beginning of the learning process should be reduced during the learning process.

2.4 Cognitive Flexibility Theory

This theory proposed by Spiro (Spiro et. al. 1990) suggests that the learning environment should present different contexts and tasks. Moreover, the theory stresses the importance of the clarification of the aim of the task and a suitable guideline for the first steps within a new task.

2.5 Further cognitive-based teaching advice

Further important teaching advice based on cognitive and constructive learning and teaching research concerning problem-solving are given in the following paragraph.

The first important aspect, especially if one tries to set up a computer system, is that it is useful to divide teaching advice into process-oriented and object-oriented advice. Process-oriented teaching advice refers to the processes within the learning content. So, considering design methods as learning material, process-oriented teaching advice would contain aspects of the processes within the application of design methods; they would, for example, demonstrate available action possibilities and their characteristics. Object-oriented teaching advice basically addresses technical solutions in different design stages or descriptions of design methods, e.g., explanations of different working principles of solutions and structures and forms of design methods.

The second aspect that needs to be addressed by teaching advice is the comprehension of the design task. This advice has to emphasize the essential parts of the design task and if necessary put them on a higher level of abstraction. Thirdly, the search for solutions should be supported by advice that points out possible action and thought processes. A further important aspect is the support won by learning to find the relevant information in their (whose?) background knowledge and in new learning content. Also, a teaching advice should aid the perception of connections between learning contents.

Another important advice for the learning material is to structure it according to cognitive knowledge structures (schemata) of human beings. Furthermore, the learning advice and the composition of the learning process should attract the motivation of the learner.

In summary, one could say that there is the need for teaching advice concerning the problem, the solution search, examples, structure and existing knowledge.

2.6 Requirements for a suitable learning environment

All in all, there are five main aspects that need to be implemented in the ***pinn****gate* system (see figure 1).

- Design tasks and examples of solved design tasks (processes and objects)
- Real design contexts
- Different kinds of advice

        - Different perspectives on situations and problems
- Questions in the form of dialog
    - Support for reflection
    - Support to gain information about existing knowledge
- Shown possibilities of actions and thinking

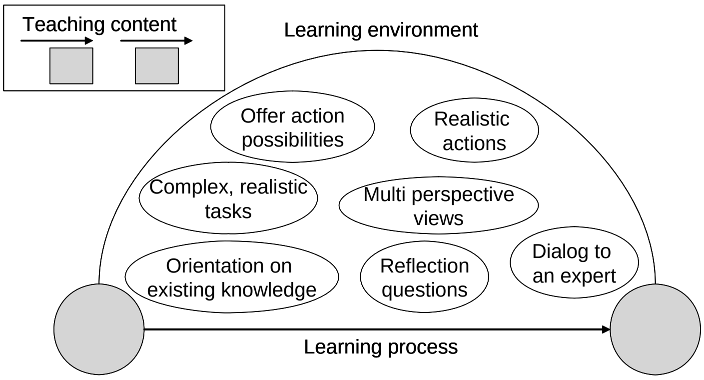

Figure 1. Requirements for a user-suitable learning environment

2.7 Basis structure for a suitable learning process

In order to deliver a problem-oriented learning process, a certain basis structure of the learning process has to be provided. According to Seel [Seel 2003], there are five important phases of a learning process that need to be supported by adequate learning aids and the learning environment. This basis structure of the problem-oriented learning process is presented in figure 2.

In the first step of the learning process, the problem identification is inevitable. Especially in design, problem identification is essential in order to meet the customers requirements and identify the essential problem during the design process.

The second phase is to structure the problem properly. This phase is also very decisive for the design process. In this phase, the design task will be assessed and decisions of what design methods will be applied and how much time will be needed, etc., will be made.

The third phase encompasses the search for methods and aids for solutions. In this phase, the application of a design method and/or changes in solution approaches and methods might occur.

In the fourth step, a solution will be found and then controlled and evaluated. This is not only an important step to assess the quality of the solution, but also for learning.

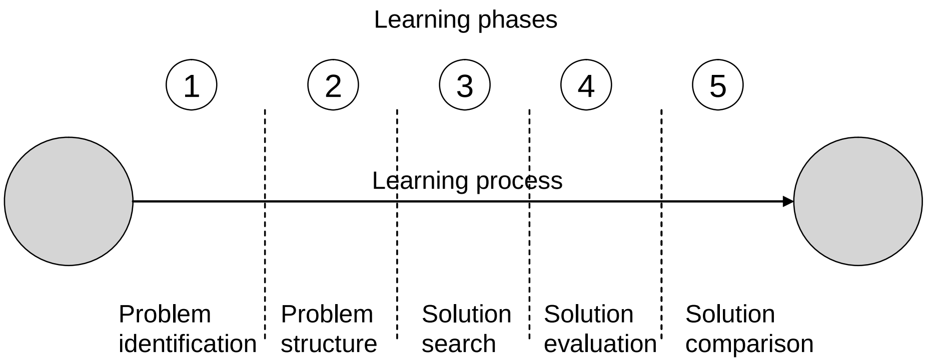

Figure 2. Learning phases for problem-oriented learning

This is very similar to phase five, in which the opportunity is provided to compare the existing solution to other solutions and maybe to other approaches towards/types of solutions. It is very useful to see what other possibilities there have been and which of them are better or worse than the existing one. This can also demonstrate the use of other design methods that could be useful in this problem.

2.8 Requirements for implementation of the *pinngate* system

Putting the requirements from the learning theories and the phases of problem-based learning together one sees that there are many steps left before having a complete system. On one hand, there is the generation of the learning material (design tasks, examples, modularized contents, etc.) and on the other, the implementation of the system (creating links, storing data, asking questions, processing information, adapting content, etc.)

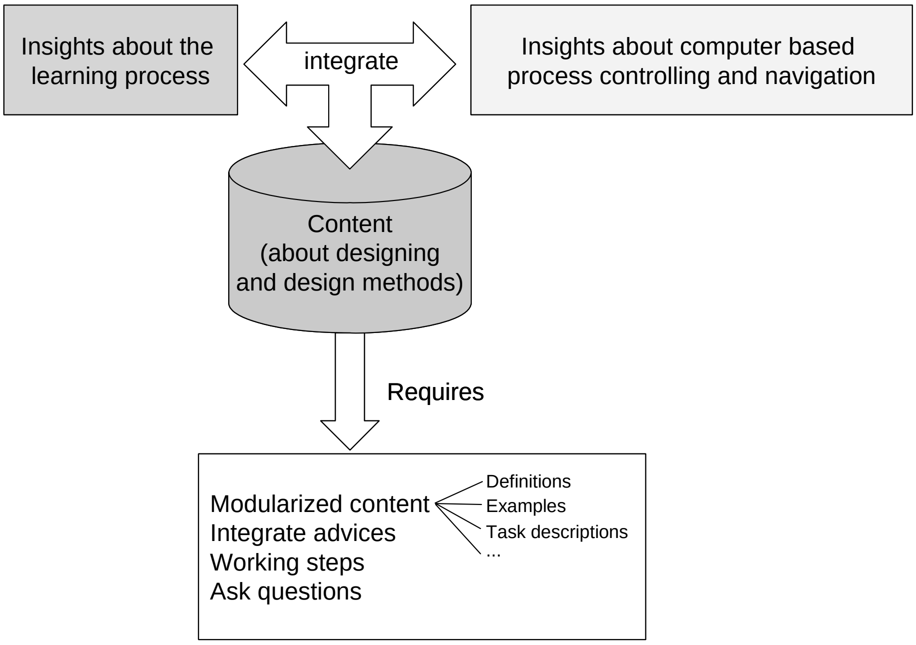

Figure 3. Integration of learning and computer-based research results and working steps

The next chapter will focus mainly on the implementation of the system.

3. Implementation

The formulated requirements of chapter 2.7 encompass five objects, which have to be realized within a computer system to support this approach:

- Modularized content: This section contains the real content, such as
    - Modular Definitions: A Modular Definition defines a concept and is internally represented as an object. First, Modular Definitions are the basis to create a glossary by the union of sets of all such objects. Second, Modular Definitions are the basis to automatically identify and highlight key concepts in any content and to support an on-click behavior.
    - Examples that describe either a process (the application of a design method) or an object (technical solution or stage of the design process).
    - The design tasks and its descriptions, which contain the problems and situations of a real design task.
- Process Structures can be used to define threads throughout any content. These structures can be branched or un-branched. They will be used to establish the working steps.

- Decisions Objects are objects that define conditional, configurable and user-influenced branches within Process Structures. They are used to establish interactivity between user and Navigator, which controls threads, for instance. So the Navigator, in the case of a branched structure, is able to ask questions in order to decide which way to continue.

3.1 The pinngate-approach

The scientific basis for the realization of the implementation of the objects mentioned is the ***pinn**gate*-approach [www.pinngate.de] [Berger 2004] [Berger et al. 2002] [Weiß et al. 2003] [Weiß and Birkhofer 2004] [Weiß et al. 2004].
Within this approach two levels have to be distinguished: the level of contents and the level of application (see figure 4). The level of contents defines and contains all the contents stored within the system. The level of application supports users with material retrieved from the level of contents in a well-structured way. These levels are separated by the so-called Navigator. The Navigator is a central unit that contains all the information about contents and their relationships, selects saved contents, considers the user's context, structures extracted contents and displays the results in the front-end [Weiß et al. 2003].

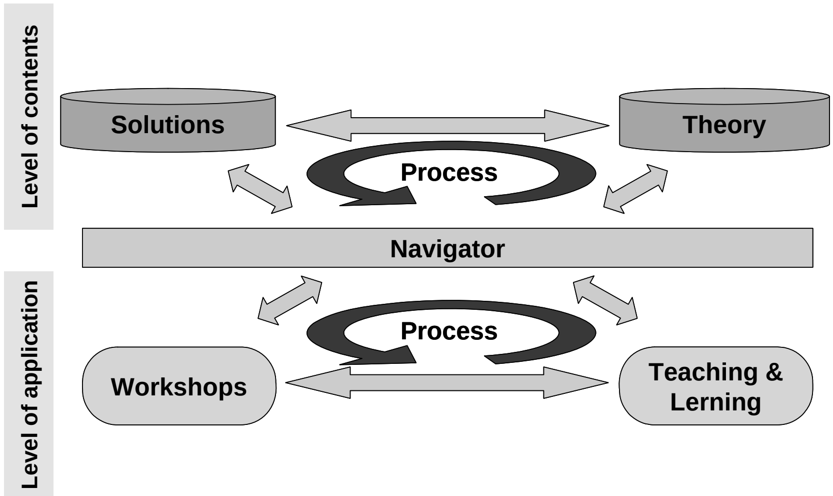

Figure 4. The *pinngate* overall concept

In general, the level of contents supports different classes of contents, such as theory, literature and other material concerning engineering design. Here, the level of contents is used to establish content such as definitions, examples and task descriptions. But these classes of contents have to be presented differently, depending on the users aim (e. g. teaching, learning, applying).
Within the teaching scenario, different parameters define the real appearance of contents, such as the user's level (e. g. novice, intermediate, expert) and aim (e. g. gaining an overview, mastering tests, closing gaps, becoming an expert). Thus, topics have to be presented with respect to the user's situation. For this, proportions of text and pictures, the layout and the extent (among other things) of the final documents may vary.
Consequently,

- different documents have to be available
- these documents may be used within different contexts
- different processes have to be supported.

To master the (re-)configuration of different documents in an individual and flexible way, a modularization approach is used. This approach describes content as modularly constituted units [Berger 2004] [Weiß et al. 2004]. The pure content (here texts, pictures, equations), its structure (ordinal level) and layout (position and format) have to be separated [Bullinger 2001].

3.2 Contents

With the ***pinn**gate*-approach, content is implemented by so-called Self Link Objects (SLO) [Weiß and Birkhofer 2004] [Weiß 2006]. Self Link Objects are objects defined by the pure content, its structure, its layout and a set of metadata describing the object. The metadata section carries data describing the object and its content and supports data concerning the processing of the objects. So, the SLO have potential interfaces defined by metadata, which link SLO's of similar content to each other by algorithms following the key-lock principle. The Self Link Object property of automatic conglomeration is used to arrange groups of similar objects, such as definitions or examples concerning similar topics. The main benefits of the SLO approach are

- the sequential and fast definition of SLO
- its automatic linking by an algorithm running in the background
- the iterative integration of modular definitions
- the modularly constituted objects, and consequently,
- the fast and flexible (re-)configuration of the objects concerning content, structure and layout, as well as the possibility of an iterative combination of all objects.

By means of the Self Link Objects concept, modularized content has been implemented according to the requirements formulated in chapter 2. The defined Self Link Objects have now to be put in a procedural context. Thus, threads have to be defined in order to guide users through the content carried by Self Link Objects.

3.3 Processes

A sub-concept of the ***pinn**gate*-approach is the concept of the Process Navigation Objects (PNO) [Weiß 2006]. In general, the PNO-concept was developed with respect to the implementation of procedural structures. Furthermore, two specific classes of PNO's can be used to implement branched Process Structures within ***pinn**gate*. Process Structure Objects arrange processes (transformations of initial states into final states over time [Heidemann 2001]) according to their logical sequence. Decision Objects define conditional, configurable and user-influenced branches within Process Structures.

By means of the Process Navigation Objects concept, Process Structures and potential branches have been implemented. Thus it is possible do define user influenced threads concerning navigation.

3.4 Navigation

As ***pinn**gate*'s central interface, the Navigator links SLO and PNO to each other, manages user requests and controls the front-end. It has an external and an internal component. The external component establishes the interface for the user. The internal component provides various procedures and algorithms to achieve the desired system behavior. For instance, it contains algorithms concerning the automatic linking of SLO and PNO [Weiß et al. 2003] [Weiß 2006].

Among other things, the Navigator provides Standard Structures and a Search Engine. Standard Structures enable organized and direct access to appropriately defined classes of content, such as definitions, examples and design tasks. The Search Engine provides access to Self Link Objects by metadata and full text.

Moreover, the automatic generation of a front-end and the configuration of a web-server is provided. So, the complete structure consisting of SLO and PNO can be published via the internet automatically.

4. Results

Design contents have been implemented by means of the Self Link Object concept as a part of the ***pinn**gate*-approach. The objects can be (re-)configured depending on parameters like user level and aim or context.

By this, a set of different objects representing the contents have been defined. These objects are ready to be processed by the Navigator (interaction between user and machine). By means of Process Navigation Objects, threads and Process Structures, which may be influenced by the user, have been established. In this way, content can be read within a specific context selected by users. Thus, with this computer-based implementation of the requirements of problem-oriented learning theories, a user-suitable learning environment with adequate learning aids can be provided.

5. Conclusion and Outlook

The high requirements of teaching and learning designing with design methods can be decisively supported by the ***pinn**gate* system. It is necessary to gain experience in how to modularize contents and examples quickly and adequately, as well as how to continuously update the contents. The system needs to be tested in universities and practical situations.

It must also be enhanced and adapted with other insights about the learning process within design. Adequate design tasks, examples and situations need to be formulated and put into the system.

References

Berger, B.: Modularisierung von Wissen in der Produktentwicklung – Ein Beitrag zur einheitlichen Aufbereitung und individuellen Nutzung in Lehre und Praxis. Dissertation, Fortschritts-Berichte VDI, Reihe 1, Nr. 376, Düsseldorf: VDI-Verlag, 2004.

Berger, B., Birkhofer, H., Walter, S.: Modularisation of Knowledge. In: Proceedings of the International Design Conference, DESIGN 2002, Dubrovnik, 2002.

Bullinger, H.-J.: Internet- und intranetbasiertes Content Management. In: Bullinger, H.-J. (Hrsg.): Content Management – Systeme und Anwendungen. Stuttgart: Fraunhofer IRB, 2001.

Heidemann, B.: Trennende Verknüpfung - Ein Prozessmodell als Quelle für Produktideen. Dissertation, Darmstadt, 2001.

Jänsch, J., Birkhofer, H., Walther, J., "The Development of Design Methods and Expertise", In: Prodeedings of the International Conference on Engineering design ICED 2005, Melbourne, 2005.

Seel, N, M., „Psychologie des Lernens", Erst Reinhardt Verlag, München, 2003.

Vanderbilt, C. a. T. G. a. 1990. Anchored instruction and its relationship to siutated cognition, Educational Researcher, 19 (3), pp. 2-6.

Collins, A., Brown, J. S. und Newman, S. E., Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics In: Knowing, learning, and instruction, Resnick, L. B.(Ed.) Erlbaum, Hillsdale, NJ, pp. 453-494. 1989.

Spiro, R. J., Feltovich, P. J., Jacobson, M. J. und Coulson, R. L. 1991. Cognitive flexibility, constructivism, and hypertext: Random access instruction for advanced knwoledge acquisition in ill-structured domains, Educational Technology, 31 (5), 24-33.

Lave, J., "Cognition in practice: mind, mathematics and culture in everyday life. Cambridge: Cambridge University Press, 1988.

Rogoff, B. "Apprenticeship in thinking: Cognitive development in social context", Oxford University Press, New York, 1990.

Weiß, S.: Navigation on Modular Contents in Engineering Design (working title). Dissertation, Düsseldorf: VDI-Verlag, 2006 (expected).

Weiß, S., Berger, B., Birkhofer, H.: Topology of Modular Knowledge Structures in Product Development. In: Proceedings of the International Design Conference, DESIGN 2004, Dubrovnik 2004.

Weiß, S., Berger, B., Jänsch, J., Birkhofer, H.: COSECO (Context-Sensitive-Connector) – A Logical Component For A User- And Usage-Related Dosage of Knowledge. In: Proceedings of the International Conference on Engineering Design ICED 2003, Stockholm, 2003.

Weiß, S. Birkhofer, H.: Auto-Generation of Dynamic Cross-Links Among Modularized Contents. In: Proceedings of the International Design Conference, DESIGN 2004, Dubrovnik, 2004.

Dipl.-Wirtsch.-Ing. Judith Jänsch
Research Assistent
Darmstadt, University of Technology, product development and maschine elements (pmd)
Magdalenenstr. 4, 64283 Darmstadt, Germany
Tel.: + 49 (0) 6151 16 3055
Fax.: + 49 (0) 6151 16 3355
Email: jaensch@pmd.tu-darmstadt.de
URL: http://www.pmd.tu-darmstadt.de