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# Task-Model Driven Design of Adaptable Educational Hypermedia

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**Abstract:** Usability is widely recognized as being as important as functionality for the success of interactive computer systems. However, even where usability is considered seriously in the context of learning environments, there is no clear definition of usability criteria bringing together the important situational factors and learner characteristics. Therefore, a generic framework is introduced, which helps to structure the main dimensions of the learning process and focus on the most vital matters of learners and learning tasks. The framework allows covering all important usage aspects of the context of use of the learning environment during the design process and link this design knowledge with domain knowledge. Therefore, it supports the design team in framing, storing and communicating knowledge items.

## 1. Introduction

The process of lifelong learning changes the requirements and demands on usability of educational environments for different user groups and different contexts of use. Software designers have to find concepts and techniques to make software as flexible and interactive as to adapt to these altering demand levels [1]. There has been a rapid evolution of learning technologies in the past decade. This involved design innovations. Many of them are linked with instructional principles, learning theories, methods of framing the learning process or presentation principles for hypermedia. These principles and methods, even if they are at an abstract level, are valuable design knowledge.

There is a lot of design knowledge available, which covers a high potential for developing more effective, efficient and usable educational environments. Nevertheless, we lack effective methods to capture, represent, communicate and apply this knowledge. Therefore, a systematic conceptual representation of design knowledge is needed to deal with it during the design process. Furthermore, design knowledge should be available for re-use during run-time. To achieve this it is necessary to pay more attention to its nature and development and to use this knowledge to bridge the gap between the design and the usage phase. A solution seems to be a model-based approach to support the design and implementation of educational hypermedia able to adapt to different types of usage. In this context different types of users and relevant task models have to be identified. Even if the identification of these classes of design knowledge might be a problem in itself for other application domains, it is available for the learning domain.

The experience of the authors is based on two projects in the context of development of web-based course material for virtual universities. The first project is called “Virtual University of Applied Sciences” www.vfh.de (1998-2003) (funded by the German Ministry of Education and Technolgoy). It aims at establishing a location independent university with a curriculum for multimedia systems and for business engineering (Bachelor, Master). The authors are involved in the production of web-based courses, in the design of user-centered learning spaces and in the support of the design process (usability recommendations and quality management). The second project “Multimedia-Based Distance Education in Medical Computer Science” (funded by the German Ministry of Education and Technology) aims at providing a complete course of studies (offered by the Virtual University of Hagen, Germany) based on a multimedia learning environment for the specialization of students in medical computer science. The project starts from a paper-based tradition of teaching and learning, from where course material has to be enriched with multimedia components, given added value by interactivity and integrated into the cooperation platform of a virtual university.

## 2. Media environments for Learning

One of the problem designers have to face in projects dealing with the development of learning environments is that they have to start from a paper-based tradition of teaching and learning. Content authors write a kind of book, which has to be transferred to the web in the first stage of development. Of course the conceptual model of the author on how the book will be used by learners is another one than the conceptual model behind the use of a hypertext. Hypertext is not necessarily viewed in a linear and hierarchical way and therefore needs added-value hypermedia functionality, especially for helping the learner to keep orientation and to explore the hyperspace. Another situation of learning will come up with the integration of time-based media (multimedia course) and also with interactivity (interactive CBT), where active involvement of the learner

is necessary, e.g. when doing interactive exercises or when inserting parameters into simulation and exploring what happens. By media use there are added-value functions, which were not considered by the content author. Furthermore, the learning material will be integrated into and used within the context of a virtual university, where cooperative learning with other students, e.g. in working groups, and interactions with teachers or tutors are enabled by technology. Again this kind of cooperation and communication environment will shift focus and result in variations of use for the learning material.

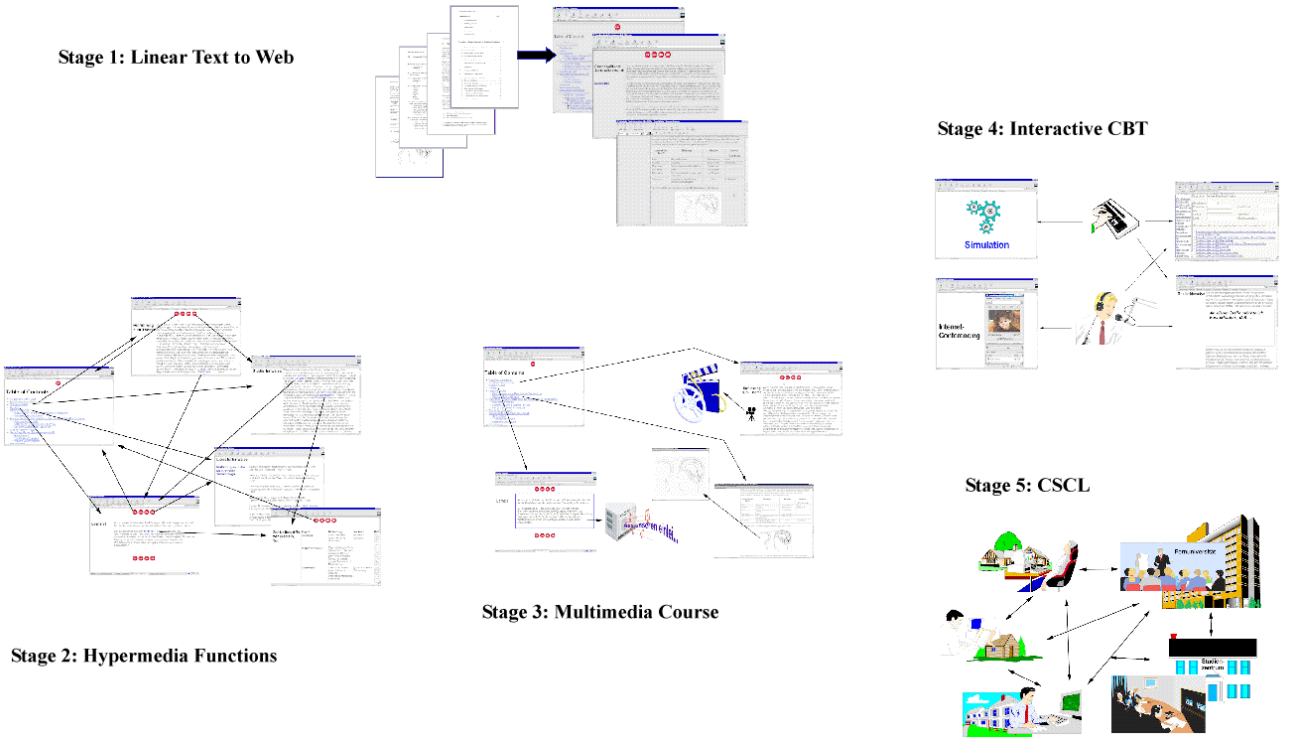


Figure 1: Different conditions of media use for Learning Environments

Normally, at each stage there are different conceptual models of the future user and of the situation of learning. Content authors normally start from writing courses as text documents that organizing knowledge in a hierarchical structure, which is are later on transferred into the associative web structure. The structuring is possibly done with authoring the hierarchical structure as guided tour into the hypertext. Although our common way of organizing knowledge hierarchically, is not the proper way for structuring hypermedia, which is centered around associations. Furthermore, the courses are enhanced with time-based media which need a careful look for example on knowledge presentation. Interactivity as a quality of action and interaction needs another pedagogic conception which go beyond models of instructional delivery of knowledge modules. Finally, in the cooperation environment, different kinds of use of the learning material can be imagined e.g. as background material for tele-teaching lessons.

Learning environments which are developed under these conditions need a media conception which considers usability. However, a user and usage-centered perspective is not easy to take, because there is a team of developers where each team member occupies a different role with different responsibilities in the design process.

## 3. User and Usage-Centered Design Perspective on Learning Environments

In the last years there has been a shift from user-centered to usage-centered design in the field of usability engineering. User-centered design represented a shift of focus from technology to people. To design actually usable tools, however, it is not only users who must be understood, but usage [2]. If we adopt this idea for the development of educational environments, which can be regarded as a special case of software development, this aspect seems to be rather important in itself, because the main purpose of this software is to support the task of learning in an effective way. However, as it gets clear from the considerations of chapter two learning environments differ according to media use. Therefore, depending on the media other kinds of learning environments with different use conditions will be developed.

In this sense, for the design of learning environments there is available a lot of design knowledge derived from learning theories and from teaching strategies, which has to be utilized for the design of learning environments. But furthermore, there are other aspects that will determine how and for what purpose the learning environment will be used. Model-based

approaches seem to be promising. They aim at finding declarative models that allow designers and developers to concentrate on relevant aspects of their work without being immediately immersed in analysis and implementation details. The framework discussed in this paper and the implementation of an authoring and generation tool on this conceptual basis offers an opportunity. Besides the philosophy of how people learn there are other things to be analyzed (e.g. user needs, problems to be solved, conditions of use, resources for use, kinds of knowledge in the learning material and so on), which need to be captured, represented, communicated in the design team, as well as considered and applied as relevant design knowledge.

## 4. Framework for Structuring Learning Environments

The first step in the development of software is the analysis of user and task [3]. For the field of developing learning environments this means the analysis of pedagogic goals, the organizational context, and the characteristics of the intended user group (learners). If this kind of analysis is done accurately, a lot of data will be gathered. In order to be able to use these data in context, it will be necessary to store the collected data in a structured way. For this purpose pre-structuring by scenarios is a useful method. The following object-oriented framework seems appropriate for structuring, storing and applying these data in the course development process for learning environments.

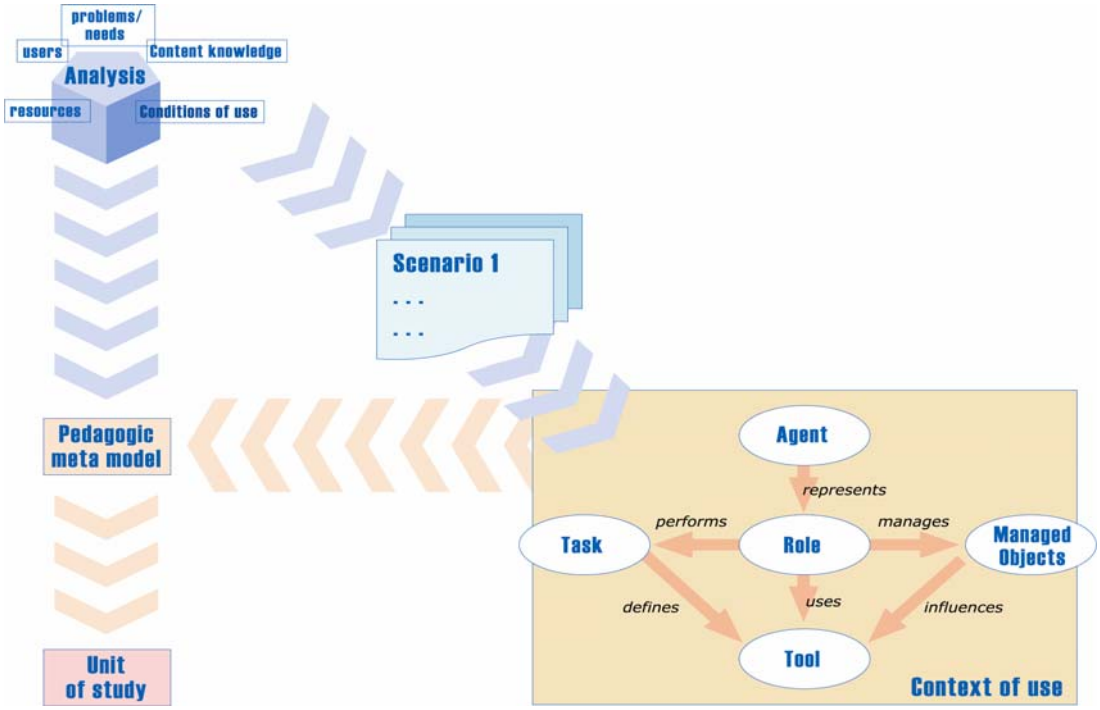


Figure 2: Analyzing and Modeling the Context of Use of Educational Hypermedia

The framework, which represents the context of use, is a generic model [4]. It proved to be useful for structuring the main dimensions of a learning environment and focus on the most vital matters of the learning process, teaching strategies, user characteristics and the conditions of use. It consists of the following application independent entities: Managed (Learning) Object, Task, Role, Agent and Tool.

### *Managed (Learning) Object*

The idea is to store the knowledge to be taught by the course in a modular way as basic knowledge objects of a certain topic. This modularization of knowledge provides flexibility needed during run-time, when a sub-set of knowledge items is planned to be presented to the learner. The actual selection of a sub-set of knowledge items at a certain stage of use depends on the characteristics of the learner (usually defined as characteristics of a learner group). Different learner groups might be distinguished in this context (see role). During run-time a certain sub-set of the knowledge items will be selected and presented to the learner as knowledge sequences built from a collection of structured knowledge items of a certain topic.

Furthermore, as different learners have specific characteristics, learning objects have to be structured and presented in learner-specific ways. To specify these relations there are connections to the entity tool (as teaching strategies) and to the entity role (as user group) in order to link relevant knowledge objects.

***Task***

Tasks are defined by the work to be performed by the user. In the context of learning environments tasks are defined as models of the learning process. Examples for tasks at a higher level of analysis “facts”, “exercises”, “rules”, “problem solving”. On a lower level there could be more concrete task specifications like “principles for the elaboration of a sequence of knowledge items” and offer elaboration strategies for the kind of knowledge at hand. In the context of the learning environment these tasks can be understood as steps performed to complete a learning process. On a lower level of task decomposition the naming of the tasks depends on specific pedagogic models (e.g. instructional model, constructive model). But the point of view on the task as a philosophy of learning seems not to be broad enough, because the task is embedded in the context of use and is therefore modified by the specific context of use at hand. For example, different media might influence how the task can be performed and also what kind of problem the user wants to solve with using the learning environment may play a role for the exact form of the task.

***Agent***

The entity “agent” covers descriptions of specific target groups and intended learner groups. User groups may be diverse, if learning environments serve the purpose of lifelong learning. For example, for courses offered in the learning environment of a virtual university on the web the following learner groups may be distinguished. There may be a learner group 1, which does basic studies comparable to traditional universities or schools. There may be a learner group 2, which is interested in further education. Another learner group 3 wants training on the job and fill knowledge gaps. A learner group 4 is characterized by having a concrete problem, which has to be solved by acquiring new knowledge. In order to do so, they need to study only specific knowledge items (learning objects) or collections of knowledge items. Furthermore, a learner group 5 may want to explore the learning modules without any shortage of time. Of course, other user groups may be relevant and characterized as well. The definition of user groups is very important for the development of a learning environment, because teaching always means to address a target group with specific needs. Therefore, the means and the teaching level have to be adapted accordingly.

***Role***

The role specifies the context of use given by a specific learner, his or her learning tasks and the learning context, derived from the learning history. The role realizes of concrete user characteristics [5] out of the potential user groups, which are specified in the entity “agent”.

***Tool***

The tool describes the learning environment and its user interface. This incorporates for example functionality which is sometimes called the learning space, browser and navigation tools. In a more sophisticated framework there will be different environments for specific learning tasks, situations and learner groups.

The framework allows designers and developers to concentrate on relevant aspects of their work by specifying and representing relevant design knowledge for learning environment. This design knowledge is derived from analysis of the complex real world situation (problems, user groups, conditions of use, kinds of content knowledge, ) where the learning environment is needed for example as a unit of study. The complex real world environment can be modeled with the framework and the model is integrated into a pedagogic meta model for the unit of study. Compared to many other pedagogic meta models the basis of modeling is not restricted to cognitive theories of teaching and learning but covers as many relevant aspects of the situation of learning as possible.

## 5. Using Task Models to Adapt Hypermedia Learning Environments

The potential of learning environments adapted to learners has been put forward by studies interested in user centered design [6], [7]. The framework introduced above covers relevant aspects of user-centered as well as usage-centered design and helps to structure, represent, communicate and apply these analysis data as the context of use for the learning environment. The context of use covers also media aspects as discussed in chapter 2, e.g. in the specifications for the object "tool" Specification of details within the framework is free and left to be individualized by designer needs and conceptual models on users and usage.

The task model is useful for designing more user-oriented interactions, because they will be structured according to the user’s conceptual model of possible activities. Therefore, to really meet this potential of adaptation it is important to avoid inconsistencies between what has been specified in the task model and what can really be done in the implementation of the learning environment.
The framework is planned to be implemented with a relational database, XML-based data sets and a web-front-end [8]. This technical basis is capable of meeting the requirement of using design specifications (user characteristics and usage

information) for the adaptation of the hypermedia learning environment during run-time. The collection of hypermedia nodes presented to the concrete learner in the web-front-end is a customized collection of knowledge objects fitting the specific user needs and usage situation at hand. The criteria for the selection and presentation of the knowledge items to the learner has to be built-in meta information (specifications on the learning tasks, on teaching strategies relevant for learner types and user groups in the entities described above, together with other relevant analysis data) and linked during the design process.

Contrasted with cognitive models of the learning process covered by many adaptive hypermedia systems [9], the framework described above is capable of covering a model of the context of use for the learning environment. The context of use model covers and represent analysis data on an adequate level of abstraction to be represented. As far as the task model is concerned for example it is not only necessary to capture cognitive states of the user compared with the domain model, as in many adaptive hypermedia systems, but other aspects also. For example, learning tasks are a sort of chain, where burden and demands alter with the change of mental states. In order to initiate successful and effective learning processes it is most important to find an adequate demand level. It causes positive mental states like happiness, motivation, increase in performance and, in the long run, even qualification and positive development of personality. On the other side, inadequate demand levels cause negative and undesirable mental states, e.g. a feeling of tiredness, drop in performance, frustration, and even psychosomatic illness. Relevant information for the adequate demand level may not only come from the users cognitive state of knowledge acquisition, but also from other aspects defined by the context of use. The kind of the problem to be solved, the kind of media environment used for it, or problems with the user interface may among others play a vital role for the definition of the demand level. Therefore, information on these aspects of the learning environment should be available as well. The framework descrived above seems to have a potential to cover such aspects and therefore it helps to cover essential information for adaptation of the learning environment.

## 6. Development of a Learning Environment in Distributed Teams

The implementation of the framework allows to specify all relevant information on user and usage during the design process and re-use it during run-time. It also allows distributed teams to work together during the development phase [10]. There are several reasons for it. As the implementation is web-based it can be used with a web-browser by distributed teams. Furthermore, object-oriented techniques for data-modeling allow even the handling of large data collections. Designers identify classes of information, such as “all learners”, “learners of group 1”, “sub-group within learner group 1” etc.. Then these classes can be freely combined into “views”, which are needed by different members of the design team at different development stages. Object-oriented techniques like generalization, abstraction or inheritance are used. Attributes of the most general object are inherited by all following objects and therefore included in the respective view. Techniques like under-specification and refinement make the handling of large object sets easier. They allow all members of the design team to start with rough sketches of concepts and refine them during the lifecycle of the system developed. The use of a database supports the complete lifecycle of the course unit and makes all information and design rationales available for maintaining or updating the course.

## 7. Conclusions

The framework described above helps designers solve design problems, since the navigation through information space with unstructured and dynamic nature of multimedia data poses complex problems which have to be solved in a structured way. The object-oriented model described above allows to address different design considerations at the proper level of abstraction. The levels either concern user characteristics, learner's tasks, content knowledge or interface considerations. And as the design decisions and the reasons for the design decisions (coming from analysis) are recorded, they can be traced backward and forward in the design process. This methodology is especially helpful for team use, when for example different media considerations (see stages in the production of learning environments as described in chapter 2) are to be considered. Furthermore, it is also intended to bridge the gap between design knowledge and re-use of design knowledge in the implementation of the hypermedia learning environment. Although the implementation is ongoing, it seems to be rather promising for a task-model driven design method.

## Acknowledgement

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