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Knowledge Management Challenges in Web-Based Adaptive e-Learning Systems

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Abstract: A number of recent studies have contributed to Knowledge Management (KM) and E-learning integration. They are mainly based on organizational learning analysis. In this paper, KM is discussed from the viewpoint of adaptation in e-learning systems. The main components of adaptive e-learning system are discussed with respect to the KM processes. We analyze users and developers of adaptive e-learning systems and the knowledge, with which they operate. We present our view of knowledge and meta-knowledge concepts in the context of adaptive e-learning systems. The role of meta-knowledge as a contextual knowledge is emphasized for adaptation in e-learning. The paper discusses the challenges of KM in adaptive e-learning systems and analyses the main KM processes that should be introduced in adaptive e-learning systems.

Keywords: Adaptive e-learning systems, personalization, knowledge management, contextual knowledge, user interfaces

Category: H.5.1, H.5.2, H.5.3, H.5.4, H.3.5, H.1.2

1 Introduction

Recent research reveals great interest to introduce Knowledge Management (KM) ideas to e-learning systems. It is argued that KM can facilitate an e-learning system [Ravet, 02]. The joint studies of KM and e-learning point out the same fundamental goal: facilitating organizational learning. Researchers try to analyze the similarity of the goals, methods of assessment, and some knowledge sharing processes both in KM and e-learning. An e-learning system within KM is traditionally analyzed as a knowledge resource repository, where the KM methods can be implemented to increase the effectiveness of knowledge dissemination [Ponce, 03]. The special track "Integration of Knowledge Management and (e)Learning" at I-KNOW'04 conference and the special issue [Lindstaedt, 05] that followed the track overview up-to-date research on the crossroads of KM and (e)Learning, and consider integration of KM aspects with e-learning including issues of knowledge transfer through synchronous e-learning [Münzer, 05], knowledge sharing instruments and their use for e-learning,

and a work-process oriented learning environment [Köhler, 05] as an index to virtual communities of practice networks.

In this paper we present an analysis of KM challenges in adaptive e-learning systems. An adaptive e-learning system is considered as a personalized e-learning system, which supports adaptive interaction and adaptive course delivery [Paramythis, 04], and which works according the principles of adaptive multimedia systems [Brusilovsky, 01]: the system receives data about a user, constructs her/his user model and performs adaptation according that model. We recognized that the existent research related to adaptive e-learning systems discusses KM mainly with respect to content adaptation [Marshall, 03]. Ponce in [Ponce, 03] has analyzed the following KM applications that can enhance e-learning systems: content management, advanced collaboration support, user profiling, data mining, and help-desk. User profiling (user modelling) is usually used in adaptive systems to store information about the user, his tasks and goals. Ponce does not use the concept of adaptation, but she discusses adaptation of learning materials based on user's tasks and needs. Ponce argues that data mining methods can be used in e-learning systems to "detect unknown patterns in user learning behavior, learning resources and knowledge mastering bottlenecks". The necessity of KM techniques to collect information after learning event is discussed in [Ravet, 02]. Collection and analyzing of information about the last interaction process is one of the approaches being used in adaptive systems.

In this paper we analyze the use of KM processes in e-learning systems from the standpoint of adaptation. Traditionally knowledge concept is analyzed from the student's point of view, and learning materials are treated as knowledge. However, from the point of view of adaptation in the e-learning system the concept of knowledge has different meaning and it is related to the information on *what*, *how* and under which *context* can be adapted. The focus of this paper is on the role of meta-knowledge (or contextual knowledge) for adaptation of e-learning systems.

The rest of the paper is organized as follows: Section 2 discusses the general view on adaptive e-learning system architecture. In Section 3 we consider *knowledge* concepts in the context of adaptive e-learning system. Section 4 considers main KM processes that are important for the organization of adaptation in an e-learning system. In Section 5 we conclude with a brief summary and directions of further research.

2 Adaptive e-Learning Systems

According to [Paramythis, 04], an e-learning system is considered to be adaptive "if it is capable of: monitoring the activities of its users; interpreting these on the basis of domain-specific models; inferring user requirements and preferences out of the interpreted activities, appropriately representing these in associated models; and, finally, acting upon the available knowledge on its users and the subject matter at hand, to dynamically facilitate the learning process." We want to add to this definition that an adaptive e-learning system is acting according the meta-knowledge that specifies the context of adaptation, i.e. how, where, and when the system could be adapted.

The following types of learning environments adaptation are recognized in [Paramythis, 04]: content discovery and assembly, adaptive course delivery, adaptive

interaction, and adaptive collaboration support, which are shortly described below.

Content Discovery and Assembly applies adaptive techniques in the discovery and assembly of learning materials (learning content) from distributed sources and repositories. *Adaptive Course Delivery* tailors a learning course to the individual learner. The examples of adaptations in this category are: dynamic course (re-) structuring; adaptive navigation support; and adaptive selection of alternative (fragments of) course material [Brusilovsky, 01]. *Adaptive Interaction* adapts the user interface, without adaptation of the e-learning materials content. The examples of adaptive interaction are: adaptation of position of the presented information; adaptation of the graphical/colour schemes and font sizes; adoption at the lexical level of interaction (to user preferences, requirements or (dis-)abilities); adoption at the syntactic level of interaction (by reorganization or restructuring of interactive tasks); adoption at the semantic level of interaction (by using of alternative interaction metaphors). *Adaptive Collaboration Support* adapts communication used in learning processes. The main goal of this type of adaptation is to facilitate the communication/ collaboration process, and ensure a good match between collaborators. [Paramythis, 04].

Being able to offer the above types of adaptation in an e-learning environment requires many kinds of expertise and its inclusion into the system as meta-knowledge which is used to make adaptation more effective and efficient. We suggest the general architecture presented in Figure 1 for an adaptive e-learning environment. In figure, the arrows emphasise information flows most relevant to the adaptation process. On the left hand box in the figure the main collaborators bringing in their expertise are named.

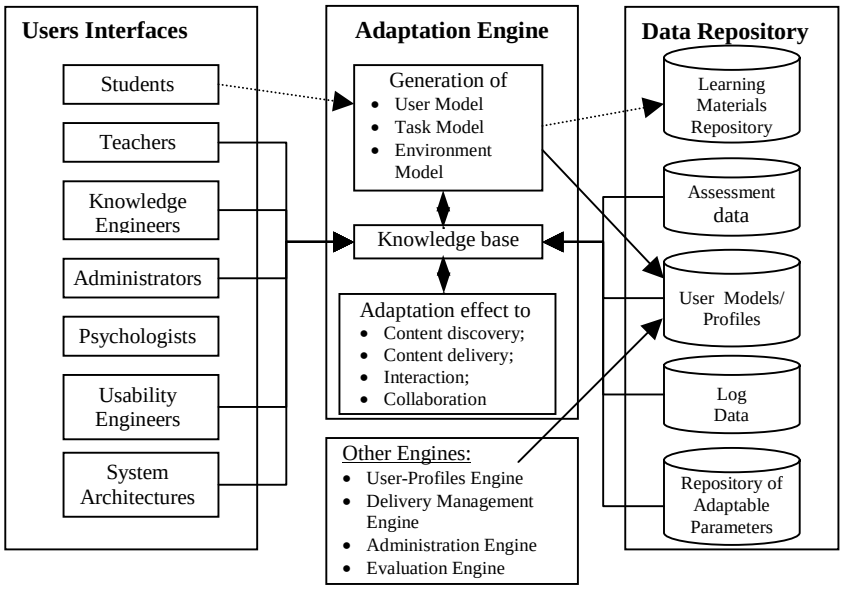

Figure 1: The general architecture of adaptive e-Learning system

Among the main contributing participants of any e-learning system are students, teachers, knowledge engineers, usability engineers, system architectures (developers), administrators, and psychologists. All they have their own perspective to the e-learning environment. Knowledge about users (students) is usually, at least mainly, collected using monitoring [Paramythis, 04] while the other participants mainly use other interfaces to deliver their contribution.

On the right hand box in Figure 1 the main data repositories needed in the system are named. Beside the learning material itself the system needs several types of knowledge and meta-knowledge to be able to adapt effectively and efficiently. In figure these include assessment data, user models/profiles, data log, and knowledge about adaptable characteristics. In the middle part of Figure 1 we have named beside the adaptation engine itself some other engines offered to main participants for keeping repositories updated.

The general architecture (Figure 1) is planned to be able to offer the types of adaptation suggested in [Paramythis, 04]. For content discovery and assembly knowledge about users is collected by monitoring and further included in the user models/profiles repository using software tools and meta-knowledge created by the system architects, knowledge engineers, and teachers. Meta-knowledge for adaptive course delivery is mainly acquired from teachers, and usability specialists. The role of adaptive interaction meta-knowledge is to point out the context in which the adaptation should be performed. The meta-knowledge for this type of adaptation is mainly formed on the base of knowledge, which could be acquired from usability specialists, psychologists, and from the experimental studies of the interaction between the user and the system. Adaptive collaboration support type of adaptation emphasizes the "collaboration" approach to learning by using communication between multiple persons, cooperative learning, communities of learners, social negotiation, and apprenticeship in learning [Paramythis, 04]. For this type of adaptation the meta-knowledge could be acquired from psychologists, usability engineers, and communication experts.

Usability engineers, teachers, knowledge engineers, psychologists, and last but not least developers define what can be adapted in the system. In KM one of the main problems is storage and re-use of the knowledge that is accumulated with experience. In e-learning systems such knowledge can be accumulated both by the system itself and by the participants of the e-learning environment. For example teachers can analyze students' performance as well as the statistics of students' interaction with the e-learning system (e.g., how long the student has studied certain material, or how many mistakes were made in the test, etc). This knowledge allows the teacher to restructure the learning material, and to refine learning scenarios and test tasks.

The key issue here is that KM specialists can be involved in the development of an *adaptive* e-learning system. They can import traditional KM techniques that would motivate to organize and maintain basic KM processes in e-learning systems for adaptation purposes. In next section we consider main KM processes with regard to adaptation context.

3 Knowledge in Adaptive e-Learning Systems

The e-learning systems use and process great amount of different data, information, and knowledge which is necessary to be analyzed before KM methods can be applied. We suggest one such new vision of the KM applied with e-learning systems.

The role of the range and dimensions of knowledge and their place in KM is emphasized in [Spiegler, 00]. According him reality is related to entities whereas data represents, records, stores, and maintains attributes of the entities. He considers information (*knowing-that, knowing-what*) to be the result of processing data with such operations as sorting, organizing etc. Further knowledge (*knowing-how, knowing-why*) is "consequence of information processing operations" [Spiegler, 00, p.14]. Beside this division into data, information, and knowledge the concept *meta* is often used with data and/or knowledge. We use *meta data* in the ordinary meaning "data about data" and interpret *meta knowledge* here as contextual knowledge. In Table 1 these concepts are in the rows of the table while in the columns we present both the traditional view with e-learning systems and our suggestion as a new view related to the context of adaptive e-learning systems. We discuss the latter view more deeply below.

Dimensions	**Traditional view**	**Adaptation Context**
Data	answers	students data, learning materials
Meta-data	data attributes	profile and model parameters
Information	about e-learning participants, results of assessment	structure of model, profile
Knowledge	learning materials	information on how to present the materials of the learning course to the users.
Meta-knowledge	keywords, material *A* is part of the course *B*	knowledge on what (or how) learning materials should be presented to the student with the particular characteristics and what should not be presented

Table 1: Dimension of knowledge in e-Learning: traditional view (2nd column) and adaptation context (3rd column)

In the case of an e-learning system learning materials can be seen to be data which maintains attributes of real and abstract entities. In an adaptive e-learning system also the data that represents the student profiles as the values of the users' characteristics, the set of adaptive elements' values, and data on the interaction processes with the system (quantity of the mistakes, amount of the help usage, etc) can be considered as data. Metadata is typically a definition or description of data, as names of the attributes and their structure. In an e-learning system the keywords of the learning materials can be treated as metadata and in an adaptive e-learning system also some characteristics of user and adaptation models can be considered as meta-data.

Information, the result of processing data, in an e-learning system is for example

the structure of the learning course enabling a person to define which parts of the learning material are included in a particular learning course. An example of information in the context of an adaptive e-learning system is for example a particular set of the user model's characteristics that is essential for adaptation.

Information on how to present the learning course materials is an example of procedural knowledge in an e-learning system. Correspondingly in an adaptive e-learning system the information on which of available course scenarios should be used for a user having a particular set of characteristics is considered as knowledge. Beside this *knowing-who* is important type of knowledge related to information about knowledge sources (e.g. individual experts, or networks) for acquiring or updating certain knowledge; *knowing-why* and *knowing-what-for* knowledge may help to explain the theory behind certain adaptation rule and reason of adaptation. Meta-knowledge (as contextual knowledge) gives insight into the characteristics of the context in which the knowledge can be used and in which it can not be used. Contextual knowledge may include *knowing-if*, *knowing-where*, and *knowing-when* contexts. The suggested classification of concepts enables the clear identification of the important role of contextual knowledge (meta-knowledge) in adaptation. An adaptive system stores the contextual knowledge, which specifies the cases in which the system should be adapted to the user. In the next section we will try to analyze the challenges of KM in adaptive e-learning systems.

4 Knowledge Management Process in Adaptive e-Learning Systems

In this section we consider key issues of meta-knowledge management aimed to organise a systematic process of meta-knowledge capture and refinement over time. The goal of this process is to make the use of available adaptation mechanisms more effective and efficient.

The KM process can be seen as a continuous process divided into five main stages: (1) knowledge creation and acquisition, (2) knowledge organisation and storage, (3) knowledge distribution and integration, (4) knowledge adaptation and application, and (5) knowledge evaluation, validation and refinement (Figure 2).

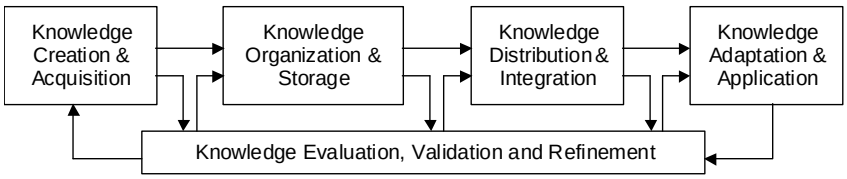

Figure 2: The knowledge management process

One common example of adaptation in an e-learning system is the adaptation of the learning materials' content presentation according the proficiency of the student in the subject area. The basic idea is that for the student, who has the sufficient background (an "advanced" learner), an e-learning system can present a brief summary of that material and hyper-links to the more detailed description of it. In the

case when the subject is unknown to the student (a "novice" learner) an e-learning system may present more detailed information in a smooth logical flow. In this example the information on how to present learning material in brief and detailed form is *knowledge*, while the context, which specifies the situations where each of the presentation forms should be used, is *meta-knowledge* or *contextual knowledge*. We analyze the main KM processes (Figure 2) on the given example. The given adaptation principle can be *created* by teachers and knowledge engineers (trying to analyze different mapping of course ontology with possible student background). This adaptation principle can be suggested also as a result of experience in knowledge structuring and different types of presentation for the different groups of students.

Meta-knowledge, on which adaptation is based, is *stored* in the e-learning system. It is commonly organized in the form of the logical rules, which are entered to the intelligent component of e-learning system via a special interface.

The meta-knowledge in the e-learning system is *integrated* from three groups of experts: from teachers, knowledge engineers, and usability engineers. In an adaptive e-learning system meta-knowledge can be also integrated from psychologists, department's administrators, and the e-learning systems or other web-based systems. These participants can use their knowledge and experience to integrate the meta-knowledge, which is used in adaptation, by adding new conditions and restriction. For example, psychologists can suggest to analyze the user's cognitive and learning styles for adaptation of the learning materials content presentation. The data on student's performance and interaction with e-learning system can also be integrated into the meta-knowledge, used in adaptation.

The *application* of discovered adaptation principle in e-learning system leads to estimation of its external *validity*. The evaluation of discovered knowledge through its application may naturally result in discovery of new interrelations and contexts. In turn, this leads to *refinement* of meta-knowledge since e.g. new important contexts are introduced or otherwise, inessential conditions of the adaptation rule are revealed. In our example, during the evaluation it could be discovered that the student's level of locus control plays an important role. Correspondingly, new context like "if *level of locus control* is *external* …" would be introduced.

It can be easily seen that all the activities related to the KM process concern the issue of knowledge sharing as by individual experts as by institutions as by different e-learning systems. Currently, there is little systematic sharing of learning content, context, and supporting materials [Norris, 03]. We can say that, unfortunately, the situation with motivation of meta-knowledge sharing is no better.

5 Discussions

Recent research has motivated the integration of KM paradigm into e-learning systems. We hope that our paper will also encourage the initiatives of KM techniques application into e-learning systems and will attract attention of KM experts to the problems of adaptation and personalization in e-learning. The involvement of KM practitioners, who can bring to the area of e-learning state-of-art KM approaches and motivate support of main KM processes, may have a significant impact on the development of personalization and adaptation in the e-learning systems.

In this paper we suggested a general architecture of adaptive e-learning system,

considered different dimensions of *knowledge* concepts and the organization of meta-knowledge inside our general architecture, and discussed knowledge management processes in an adaptive e-learning system aimed to make the use of available adaptation mechanisms more effective and efficient. Behind these suggestions is our belief that the support for the systematic process of meta-knowledge capture and refinement over time would improve e-learning system's adaptation and contribute to further research and development of adaptive e-learning systems.

Our further studies are directed towards the development of guidelines for adaptive e-learning systems design, addressing the issues of effective meta-knowledge creation, discovery, and acquisition; organization and storage; evaluation, revision and application for adaptation of content discovery, assembly and delivery; user interface and collaboration support.

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