Chapter X
The DEKOR System: Personalization of Guided Access to Open Repositories

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ABSTRACT
Due to the wide diversity of learning styles and learner characteristics, delivering learning material from modern ICT-based learning must also be conducted in a diverse manner rather than with a "one-fits-all" approach. By focusing on content aspects, the majority of adaptive Web-based educational systems are only able to deal with closed repositories and therefore only pre-defined content alternatives for limited learner characteristics are manageable. One possible solution is to enable and technologically support students’ freedom to select appropriate learning content of their own choice. The WWW as an extensive repository of diverse content has gained considerable interest as an open-ended learning environment, but most students cannot cope well with such open accessibility. To overcome this, the authors have started research towards a system of personalized access to open repositories. In this book chapter, they introduce the evolution of their linked approaches and discuss the findings in the context of learner characteristics.

INTRODUCTION
Modern society has become significantly more globalized and knowledge-driven in recent decades. Consequently, modern citizens have high expectations for their ever-changing society. Keeping pace with changes and effectively dealing with knowledge is vital for the success in this
modern environment, and continued learning and training are therefore also fundamental for today’s human beings. According to Bransford et al. (2000), the objectives of and expectations for the learning process have changed dramatically from repetitive learning to learning with understanding to move towards being independent in the learning process, strengthen meta-cognitive skills and link knowledge acquired in cultural context. In order to meet the requirements of educational goals for the 21st century, several aspects of learner-centered, knowledge-centered and assessment-centered environments must be considered. In this context, information and communication technology (ICT) can be very useful in educational settings such as in general schools, universities and in vocational education centers.

By further focusing on the knowledge aspects or more precisely on the learning content within the learning process, it is commonly agreed that from modern ICT-based learning settings much more is expected than simply delivering learning material to students in a “one-fits-all” approach. Learning activities and learning content must be well-tailored to (1) the individual needs of the students including the knowledge or competence state, preferred learning style, motivation, problem-specific and cultural context, (2) group aspects such as student-student and teacher-student interactions and collaborations, (3) teaching objectives including didactic concepts and (4) environmental aspects such as physical learning environment and front-end devices. (Germanakos et al., 2007; Gütl, 2007b; Hodges, 2004) There is no doubt, however, that it is time consuming and expensive to prepare such personalized learning activities or to focus specifically on the learning content. To overcome this problem, some approaches have been developed such as reusable learning content (Conlan et al., 2002) and collaborative content creation (Kortemeyer, 1999). Despite the existence of such interesting approaches, the great variety of individual needs can hardly be met and the ever-changing knowledge in the subject domain will lead to a Sisyphean task in keeping pace with this situation. (Thyagarajan & Nayak, 2007).

To overcome the situation stated so far, we have developed the Dynamic E-learning Knowledge Repository System (DEKOR System). The initial idea was motivated by the goal to supplement e-learning systems lacking personalization features with a background repository of resources that are automatically compiled for different knowledge levels by means of an information retrieval system. The first proof of concept was described in (Dietinger et al., 1998) and developed into a first prototype called E-Help System (García-Barrios et al., 2004). The findings from implementation and evaluation of E-Help led to a second prototype called Concept-based Context-Modeling System (CO2 System) which provides students with content from different types of information sources based on the learning context (Safran et al., 2006). Further enhancements led to our DEKOR system, which delivers personalized content from different sources based on user and group information (Gütl, 2007).

In this book chapter we want to outline the three systems mentioned above and explore the extent to which they can support different cognitive and learning styles.

BACKGROUND

Tailored learning and teaching activities can hardly be considered as new concepts developed in our modern knowledge society. Such concepts can be traced back to at least 4th century BC. In those days, adapted instructions were seen as a primary success factor. To give another example, tutoring given by adaptive instructions was a common method of education until the mid-1800s (Park & Lee, 2003). In the 20th century, instructional design and technology emerged, enabling the analysis of learning and performance problems to improve the learning process in diverse learning environments.
settings (Reiser, 2001). According to Bransford et al. (2000), the development of the science of learning itself began in the later part of the 19th century, when systematic attempts were made to study the human mind through scientific methods. Since that time, different theories and notions have emerged (Bransford et al., 2000; Sampson et al., 2002; Santally & Senteni, 2005). Active research in this area has shown that students’ individual learning is strongly influenced by numerous dimensions.

Consequently, research on learner characteristics and their influence on the learning process has been an active research topic for a long time. It is out of the scope of this work to discuss this aspect in detail; however, to illustrate the complex situation, a selection of important characteristics and aspects are given in this section. The selected categorization of learner characteristics was strongly influenced by Schulmeister (2006) and Jonassen & Grabowski (1993). Many other categorization approaches exist in literature, however, and some of the characteristics in one category may address or include aspects of characteristics in other categories.

**Learner Characteristics**

The category of cognitive styles addresses variables describing the ways in which learners organize stimuli and construct meaning. They include: (1) perception by sensing (observation and gathering of data through senses) or intuition (unconscious perception, e.g. speculation, imagination, hunch), (2) modality input for effective perception (e.g. visual, auditory, kinesthetic), (3) organization of information preferred by learners, which can be either inductive (facts and observations are given, underlying principles are inferred) or deductive (principles are given, consequences and applications are deduced), (4) processing of information by either active experimentation (activities in the real world e.g. experimenting, discussing, testing) or reflective observation (e.g. introspectively examining and manipulating information), (5) understanding built either by sequential learning (following a linear reasoning process) or holistic learning (following a more global or conceptual way), and (6) selective attention by field independence (analytical, competitive, individualistic or task-oriented) and field dependence (group-oriented, sensitive to social interactions and extrinsically motivated). (Bloch et al., 2003; Felder & Silverman, 1988; Hall, 2000)

The category of cognitive control addresses how an individual coordinates himself within his environment by variables that describe motor skills, perception, memory and other basic quantitative forms of cognitive functioning. Variables include: (1) field dependence vs. independence, (2) cognitive flexibility (constricted vs. flexible control expresses the ability to ignore distractions of the environment), (3) cognitive tempo (impulsivity vs. reflectivity), (4) focal attention (scanning vs. focusing), (5) category width (breadth of categorizing), (6) cognitive complexity vs. cognitive simplicity, and (7) automation (strong vs. weak automation). (Jonassen & Grabowski, 1993)

**Personality** is a category with more general aspects: (1) anxiety (negative and positive effects, which motivate and facilitate as well as disrupt and inhibit cognitive actions as learning), (2) ambiguity tolerance (willingness to accommodate or adapt to handle ambiguous situations or ideas), (3) frustration tolerance (quality of a person’s performance in a task after frustration occurs), (4) extroversion vs. introversion (thinking and behavior that are directed either outwardly or inwardly), (5) locus of control (individual’s feelings about the placement of control over his or hers life’s events), (6) achievement motivation (individual’s willingness to achieve), and (7) risky vs. cautious behavior (individual’s preference to choose high-payoff/low-probability or low-payoff/high-probability alternatives). (Jonassen & Grabowski, 1993)
Prior knowledge addresses the knowledge, skills or abilities that students bring to the learning process. This category includes the following characteristics: (1) knowledge and skills in domain (the knowledge and skills the students already know related to the contents and which are necessary to understand new information), and (2) general knowledge and skills (domain-independent knowledge and skills, such as language skills, technology skills, social skills as well as cognitive strategies and meta-cognitive strategies). (Jonassen & Grabowski, 1993; Blochl et al., 2003; Bransford et al., 2000)

Further, Schulmeister (2006) has also outlined the category mental abilities, which addresses aspects of psychology of intelligence analysis. Mödritscher (2007) highlights the category constitutional attributes and states, which addresses physical properties of the body (e.g. age, special needs) and short-term states (e.g. emotion, tiredness, concentration).

From the aforementioned great number of learning characteristics, it can be concluded that learning is a very complex and highly individualized process. Therefore, a learning style model helps to classify students according to the way they receive and process information. Such models also support obtaining a better understanding about diverse learning processes. Efficient and effective knowledge transfer requires well-tailored instructional methods which must correspond to the individual’s preferred learning style. Further, teaching style models help to classify instructional methods with respect to those learning style components that an instructional method addresses (Felder & Silverman, 1988).

(Un-)Successfulness of General Solutions

Knowledge about the great diversity of learning methods has led to the concept of personalized instructions. Since the beginning of the 20th century, various approaches and methods of adaptive instructions have been developed and attempted. Three highly relevant approaches that have strongly influenced computer-based systems for personalized learning are: (1) macro-adaptive approach (supports the selection of alternatives for main components of the instruction such as instructional goal, depths of curriculum content and delivery system), (2) aptitude-treatment interaction (ATI) approach (adapts instructional methods and strategies to specific student characteristics), and (3) micro-level approach (adapts to instructional prescriptions based on learners’ needs during instructions). Since the early days of the computer era, computer media have been used for didactic purposes. Even computer-based personalized systems were already available at that time. Some worth mentioning are Computer-Managed Instructional (CMI) systems, Intelligent Tutoring Systems (ITS), and Adaptive Educational Hypermedia (AEH) systems (Brusilovsky, 2000; Park & Lee, 2003; Reiser, 2001b). Web-based AEH systems (based on concepts of link, content and presentation adaptation by using appropriate models) have gained increased interest since the mid 1990s (Brusilovsky, 2000; De Bra et al., 1999; Koch & Rossi, 2002).

In spite of the substantial interest in e-learning from diverse research and industrial sectors that has been evident for decades, just a few systems and projects can truly be seen as real success stories. The reasons can be found in both the high complexity of the subject domain itself and also in failures in the project management domain (Romiszowski, 2004; Wopereis et al., 2005). Given the great number and diversity of learner characteristics, it is virtually impossible to consider all of them in concrete implementations in terms of wagering system functionality, capturing appropriate information about the users, and providing a useful set of content alternatives. Nevertheless, some evaluated successful adaptive e-learning systems exist, but they have concentrated only on very specific learner characteristics or adaptation methods for specific student groups (e.g. Papan-
ikolaou et al., 2002; Brusilovsky, 2004; Kelly & Tangney, 2006). Furthermore, Brusilovsky and Peylo (2003) have conducted a review of modern adaptive and intelligent Web-based educational systems (AIWBES) and found potential benefits for teachers and students of five classes of adaptive technologies: (1) Adaptive Hypermedia (AHM), (2) Intelligent Tutoring (IT), (3) Adaptive Information Filtering (AIF), (4) Intelligent Student and Class Monitoring (ISCM), and (5) Intelligent Collaborative Learning (ICL).

Content-Based Aspects

Regarding the content delivered by adaptive e-learning systems, the majority of these systems are only capable to deal with closed content repositories. This closed content has to be designed especially for such a specific system and covers usually an entire learning unit. The adaptability of such a learning unit is embedded directly into the content or is computed at run-time by the system. Furthermore, although adaptive techniques may support the achievement of specific educational goals, these goals are restricted for the majority of existing systems to the domain scope of the available content (Brusilovsky et al., 2007; Meccawy et al., 2007). In addition, authoring tools help to create specific content alternatives (Sasakura & Yamasaki, 2007), but it is practically impossible to take the aforementioned complex situation of learner characteristics into consideration.

To reduce the efforts of the course compiling process and to prevent multiple creations of the same content assets, Courseware Reuse Systems (CRS) have emerged to provide access to open content repositories, e.g. ARIADNE and PROMETEUS. Indeed, reusing content or educational objectives would help to reduce these efforts, but most of the systems are not designed as flexible as to support such a reuse and support only a limited content integration from open content repositories. (Brusilovsky et al., 2007). To overcome this problem, adaptive systems’ design has made progress regarding the integration of static content or simple interactive content, e.g. questions. (Meccawiy et al., 2007) Further, to manage rich interactive content in adaptive e-learning environments, the approach of adaptive services for e-learning has emerged, e.g. Adaptive Personalized e-Learning Service (APeLS), Knowledge Tree Architecture (Brusilovsky et al., 2007).

Thus, although there is a significant development towards reusability and reduction of effort in the content creation process, there are still at least three serious problems: (1) content alternatives are pre-defined by the content author or teacher, and hereby, students are not adequately involved to improve their self-directed and life-long learning skills; (2) the rapid and ever-changing knowledge of our modern society requires a conscious update of learning content, which in turn causes a continuously hard-to-manage effort to create appropriate content alternatives and to ensure their quality; and (3) due to the limited number of content alternatives and of user characteristics in practical use, such approaches can only focus on very specific learning style options and motivational aspects.

Open-Ended Learning Environments

To overcome the aforementioned problems, one solution approach is to enable and technologically support students’ freedom to select appropriate learning content. Stary & Totter (2006) emphasize that students should be able to take learning control according to their needs, learning styles and other preferences. Web-based teaching enables to pass this control from the teacher or program designer to the student, which implies a higher flexibility regarding information exploration and access (Lin & Hsieh, 2001). On a more general level, learner control in computer-supported learning includes control over object type (e.g. exercises or questions), content, sequence, presentation, learning pace (speed and time), and learning context (Schulmeister, 1997; Sims & Hedberg, 1995).
The importance of learner control is stressed by various motivational theories, e.g. the effect of learning outcomes and the possibility to take choices makes students feel more competent and increase intrinsic interest (Lin & Hsieh, 2001). In this context, the results of many studies conducted over decades have shown that learner control can incur benefits, but that it can also cause a variety of problems, and all this depends on factors such as experiences and cognitive skills of students (for details see Lin & Hsieh, 2001; Schulmeister, 1997; Sims & Hedberg, 1995).

Web-based learning environments can provide a great variety of material for students, and further, the range of support can address both novice and experienced learners. Lin & Hsieh (2001; pp. 380-381) emphasize that the wealth of the Web “provides an experiential space for learners to follow their own thoughts and insights. The web also provides access to experts and cases that can provide virtual hands-on experiences”. As a concrete example, consider that Simkins (1999) proposed to use the Web as a repository of additional learning content in economics education to actively support the students’ engagement in the learning process and to generate a broader interest in the subject domain. The World Wide Web (WWW) as the most prominent and widespread hypermedia information system, provides an extensive repository of diverse content in various media types to students and information retrieval systems support the access to relevant ones. Therefore, we consider the WWW to be an Open-Ended Learning Environment (OELE).

Hill & Hannafin (1997) conducted a study about cognitive strategies and learning from the WWW and showed that five key factors affect open-ended learning strategies: (1) meta-cognitive knowledge (awareness of student’s cognitive processes), (2) perceived orientation (awareness of strategies and actions needed), (3) perceived self-efficacy (student’s judgment of one’s capability to perform actions), (4) system knowledge (prior knowledge and skills with information systems), and (5) prior subject knowledge (existing knowledge and expertise in the subject). According to the study, meta-cognitive knowledge seems to be the most influencing factor, and weaknesses herein result in disorientation, discomfort and confusion. Further, the lower levels of perceived self-efficacy, system and subject knowledge affect the strategies applied to find and deal with information. Shapiro & Niederhauser (2003) also found out that learning from hypertext requires meta-cognitive functions, e.g. choosing the content to read or the reading path. Regarding navigational strategies, students with less prior knowledge are comfortable with well-defined structures, but they face the “lost in hyperspace” problem at more complex structures. If increased meta-cognitive activities take place, however, these activities can contribute positively to hypertext-based learning results.

For the purpose of at least partly solving the aforementioned problems of an OELE (defined by the WWW as open content repository and by the available information retrieval services as selectors and finders of relevant learning content), we have developed a solution approach which we call Dynamic E-learning Knowledge Repository (DEKOR). Based on the background knowledge given in this section and that which will be described in the next sections, this solution approach goes along with the current trends regarding personalized e-learning systems, and thus, it represents a contribution to the modern requirements of technology-enhanced teaching and learning.

THE INITIAL APPROACH: E-HELP

The idea of developing a dynamic e-learning knowledge repository for personalized learning activities was born from the identified need to solve some problems of closed-content, non-adaptive instructional systems. The encountered solution integrates the OELE principle and aims at supporting personalized learning activities through an
automatic assignment of query-based hyperlinks (pointing to relevant content in the OELE) to the closed-content resources. The search keywords behind each hyperlink are directly related to the domain concepts of the resource. Thus, each concept points to topical and context-relevant resources enables an OELE approach, e.g. a Web content-based one. This section outlines the evolution of this idea and the evaluation results of the first developed prototype solution, the E-HELP system. For the purpose of developing E-HELP, a concept-based approach was chosen to describe the semantic associations between the content of a course resource and a (dynamically generated) set of resources relying outside the closed course repository. To clarify the fundamentals of the proposed solution, the next two sub-sections focus on two critical aspects: dealing with closed-content and dealing with concepts.

Dealing with Closed-Content

Regarding the overall scope of knowledge provisioning, e-learning systems often provide the capability to store and administer courseware through so-called learning repositories. Such a repository is usually a static entity in these systems, e.g. previously uploaded content is stored there as long-term static data. Further, these repositories may allow teachers to structure their materials for example in chapters, sub-chapters and other sub-divisions. Even more, some systems provide the possibility to store additional materials in background repositories, such as libraries or glossaries. Considering then the point of view of learners and teachers, such additional background repositories might be seen as static background knowledge because the resources are considered not to change over a learning journey (or even over several years). Therefore, it is up to the teachers and the course authors to ensure the topicality and domain-relevance of these resources.

Regarding this circumstance, many problems may arise, as already depicted in the previous section. So why not take advantage of the increasing amount of relevant knowledge resources on the Web and dynamically integrate them as an additional background library? For the retrieval of such resources, a smart search engine could help. Knowledge acquisition and learning processes can be supported by information retrieval techniques, as stated for example in Baeza & Ribeiro (1999) and Liaw et al. (2003). Furthermore, some problems related with the freedom in and chaotic growth of the Web (e.g. censorship of information as well as reliability, accuracy and topicality of resources) can be solved through methods such as a white list of servers (Lenon & Maurer, 1994) and the Quality Metadata Schema approach discussed in (Gütl et al., 2002).

Dealing with Concepts

In general terms of adaptation, biological and artificial life-forms tend to build their own internal representations of their environment by means of the inputs from their sensory components. This internal view is well modeled by neuronal networks in human beings on the one hand, but on the other hand, it can be modeled in software systems by artificial intelligence methods such as connectionist or logic-based knowledge bases. Taking a closer look at human beings, they tend to simplify, unify and cluster traits in phenomena (e.g. observations from environment, or complex systems and processes) as well as to inter-relate them into semantic structures for their thoughts and notions. Considering this latter aspect and analyzing research work in the fields of cognitive science and social science, the idea of dealing with concepts can be identified (see e.g. Gütl & García-Barrios, 2005b). Concepts and their relations may describe statements and assertions for particular situations or knowledge domains. While learning, new concepts and relations are either built or integrated into prior knowledge (i.e. existing concepts and relations can be adapted). This might be induced by stimuli and information
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in everyday life as well as initiated by an active knowledge transfer process applying different styles such as declarative and constructivist approaches (Gärdenfors, 2001; Chieu et al., 2004).

From the teaching perspective, the use of concepts supports the identification and description of syllabi, topics and main subjects within courses and lectures. In addition, course content itself can be modeled through concepts and relations which in turn can help to identify or define learning paths. From the learning perspective, concept relations have the power to structure perceptions and insights, to allow expressing knowledge about a specific situation, and to make it possible to detect and explain dependences to and influences by other concepts. Thus, concept relations provide the means to develop applications, for example to codify prior knowledge and to modify or adapt knowledge through concept map tools. Concept relations also provide the means to discover or generate knowledge from unknown or hidden relations by using co-occurrence analysis. Further details for this context can be found in (Gütl & Garcia-Barrios, 2005b).

The First Prototype

In order to give learners the freedom to discover new knowledge in open (but domain-relevant) information spaces, we implemented a first prototype solution called E-HELP (Garcia-Barrios et al., 2002). The E-HELP system presents a set of domain-relevant hyperlinks to learners, and these links are attached to used learning materials and might be followed in order to explore additional materials residing outside the mandatory (closed and static) learning repository. These hyperlinks are defined in advance by teachers through concepts, but these concepts are not directly connected to specific Web resources; rather they are used as keyword definitions for queries of search engines. E-HELP provides a communication layer to the information retrieval systems xFIND (http://xfind.iicm.edu) or Google
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(http://www.google.com). Thus, each hyperlink (as a specialized search query) brings learners to relevant, topical and context-relevant resources. Within the E-HELP system, the data structure to internally represent and compute such a hyperlink is called a Concept, which is also the term used by learners for the E-HELP hyperlinks in their front-end user interfaces.

For learners, E-HELP provides the possibility of choosing (a) the personal level of expertise regarding the knowledge domain of a given course, and (b) one of four available viewing modes for displaying E-HELP concepts while navigating through the course contents. Specifically, these four viewing modes are: In File (whereby the concepts are displayed within the text of a course page, as shown for the term “intranet” in Figure 1); After File (the E-HELP concepts corresponding to the page are appended at the end of the page); After Chapter (the concepts are listed at the end of each chapter); and After Content (a new page is generated at the end of the course with a list of all concepts).

The general architecture of the E-HELP system is presented in Figure 2. The background knowledge accessible through the Information Retrieval System (IRS) is abstracted as a set of Concepts, which are basically defined within expertise level groups (novice, regular and expert). Furthermore, each concept is assigned to one or more course sections each of which is said to define its Context. Therefore, this set of contextualized concepts represents the core of the E-HELP System. Depending on the chosen viewing mode, a course page requested from the Web Client side is dynamically adapted by E-HELP for the Learning Management System. Clicking on a delivered E-HELP hyperlink will trigger a search request to the IRS using the pre-stored and concept-specific Query. This process is symbolized by the long arrow on the top of Figure 2.

Evaluation Results

An extended evaluation of E-HELP conducted in 2004 focused on the examination of the following aspects: (a) functionality of the system from the authoring and teaching points of view; (b) usefulness of the system from the learners’ point of view; (c) knowledge acquisition improvement; and (d) comprehension improvement regarding distinct types of learners (students, research staff, and project employees). The main findings of the evaluation regarding the learner type students are described in this sub-section.

Figure 2. Overall architecture and functionality of the E-HELP system
The DEKOR System

The evaluation was conducted as an observed online lesson within the lecture Information Retrieval at Graz University of Technology (summer course, 2004). Attendees of this lecture represented the test subject group. Details about this evaluation can be found in García-Barrios et al. (2004a). Participants of the experiment (in the following, subjects) were requested to take the online lessons using their own laptops and Web browsers (the IRS Google was chosen to be used in E-HELP). The subject group consisted of 14 males. Furthermore, 28 distinct concepts were prepared whereby each course chapter was assigned a certain number of these concepts. The experiment included the following steps (the time period for each step, in minutes, is given in parentheses): introduction into the learning platform and E-HELP (15), pre-questionnaire (15), online lesson (120), post-questionnaire (15), and short written exam (15). Within the context of this book, the most relevant general findings of this evaluation can be summarized as follows.

At that time, the subjects expressed their preference to learn from lecture notes and books on paper, but they were very interested in acquiring additional (relevant and up-to-date) background knowledge and using these additional resources for their learning activities. Regarding the usefulness of E-HELP, it could be extracted from the analysis of the post-questionnaire that the system was rated with an average of 1.9 points, where 43% of the subjects gave it the grade of ‘1’ (1 best, 6 worst). A positive feedback could be also gained from the post-questionnaire, for example when asking for the efficiency of the information retrieval process through the system. The subjects stated (among others) in the free-text section the following:

- **I particularly liked:** cross references directly embedded in text; idea of graded information behind entries according to user’s expertise; ease of use.
- **I did not like:** the hyperlinks within the text are intrusive; I had to modify queries manually to find more useful information.

- **For improvement, I recommend:** reducing hyperlinks because a large number of embedded hyperlinks is confusing; modifications in the index of the search engine may represent a risk, because one may get wrong documents in the future; delivering search results in user’s language; providing other relevant resources from online-lexica (e.g. Wikipedia or dict.leo.org) and separating them from the results of Google.

In addition, the students were asked for their opinion about the benefit of using E-HELP. A positive tendency may be concluded from the personal estimation about the improvement of learning activities through the system: the average rate was 2.6 (from 1: good, to 6: bad). Regarding user interaction preferences, the evaluation showed that it is highly important for E-HELP users to keep control over individual settings. In the special case of E-HELP, users wanted to explicitly choose and change the settings for their expertise level and viewing modi by themselves. Furthermore, when requested for the personal benefits of using E-HELP, subjects stated in a free-opinion manner that the system gives user-tailored and up-to-date hints about relevant and additional literature, provides up-to-date information and other perspectives on the subject, enables corrections of individual knowledge gaps (e.g. expertise knowledge, foreign words), supports autonomous investigation activities, enables a rapid retrieval of specific terminology, and that it refreshes the forgotten. Finally, referring to the overall functionality of E-HELP, the subjects stated (among others) that:

- **I particularly liked:** that explanations appear in the place where they are needed; the possibility to change personal settings; that E-HELP works as an activator, deviating from the reading monotony.
- **I did not like:** that E-HELP hyperlinks appear in the text; irrelevant documents were
also found in the search results; the search results are too global.

- For improvement, I recommend: improving the design of E-HELP links in the text; using tool-tips; moving concepts without an influence on topicality to a static glossary; restructuring concepts if too many concepts defined (e.g. in End of Chapter viewing mode).

As stated in García-Barrios (2007), the use of such a system should represent a guided motivation and controlled starting point to leave the mandatory repository and discover new knowledge at one’s own pace.

THE CO2 APPROACH

The last section presented the results from an evaluation of E-HELP. Based on these findings, an improved second prototype has been developed. This section focuses on this second solution approach.

The Need for Improvements

The main problems and most relevant recommendations from the evaluation of E-HELP motivated us to start a new project for the development of an enhanced version of the system (see also García-Barrios, 2006a or 2006c). Some of the conclusions from this evaluation can be summarized as follows.

Too many concepts displayed within the text of a course page represent a usability problem because overwriting content with too many added-on styles leads to subjective acceptance troubles and was evaluated as too obtrusive. The problem is the noisy redundancy of concepts if appearing often in a page. Furthermore, adapting the content of a long page may be time-consuming for the server side of a system, and thus, unacceptable waiting time periods for the user may be the result. In addition, using only the global interface of a search engine (as done during the evaluation) may lead to the appearance of irrelevant (i.e. not context-relevant) search results, which in turn leads to the necessity of time-consuming query refinement.

Essentially, the efficiency of utilizing E-HELP concepts is dependent on the didactical goal of a teacher and on the learner’s expectation at the moment the recommended concept is detected. Consequently, the pragmatic value of concepts is much higher than the semantic value (i.e. intention before meaning). For example, from the teacher’s perspective, a concept is created because it is considered to be relevant within specific course segments and thus, it will be assigned accordingly (through keywords) to some search results considered to be useful. In the teacher’s mind, learners should follow the hyperlinked concept when they have a knowledge gap, i.e. when they need an explanation. And at this exact point, the problem from the learner’s perspective appears because the current intention of a learner (just before following the hyperlink) may be distinct from the defined didactical need (the expectation of the teacher). This means that when learners depend on the current situation, they expect distinct explanations behind the hyperlinks, for example a translation, definition, graph, or a statistic table, etc.

Second Prototype

The improved version of E-HELP, called Concept-based Context Modeling System (CO2), was developed within the AdeLE research project (Adaptive e-Learning with Eye-tracking; http://adele.fh-joanneum.at, http://adeledemo.iicm.edu). As E-HELP, the CO2 system aims to provide accurate background knowledge and thus, it assists users in their teaching or learning activities. Within the AdeLE system, in contrast to the E-HELP solution, the CO2 concepts are provided solely through one viewing mode, namely as additional
Navigational elements. As depicted in Figure 3, the CO2 concepts are visualized under the area Background Knowledge (bottom left-hand side of the figure). One of the concepts for the current learning page is visualized as Service-Oriented; for this concept, three information retrieval services (IRS) are registered, one of them being Wikipedia (Castellano). Clicking on the hyperlink leads to the additional window in Figure 3 for which the keyword SOA was added to the search query of the Spanish version of Wikipedia.

Concerning improvements and within the scope of this chapter, the major distinctions between E-HELP and CO2 can be explained as follows. The E-HELP system delivered each concept as a hyperlink to one IRS. Analyzing the outcome of the system evaluation, it becomes clear that distinct learners expected distinct results behind one concept (e.g. a translation, a textual explanation, or even images). It is highly relevant to mention at this point that this problem cannot be accurately predicted and thus, it can hardly be solved through fully adaptive techniques. To overcome this problem, a teacher may register more IRSs in CO2, and in turn define distinct specialized queries for each concept. Through this way, solving the problem of predicting the distinct (momentary) clarification needs of the learners was expected.

Hence, instead of trying to personalize towards a single helpful hyperlink, we decided to place a variety of information services at the disposal of the learners, information services from which learners can choose the more suitable one. In other words, the solution principle was shifted to somewhat of an instantaneous just-in-time customization because the intention of an individual learner before following a hyperlink appears instantaneously and is dependent on the current state of the learner’s mental model and thus, it is meant to be unpredictable. The main problem here is that a need for clarification can have different reasons which depend on the learning journey within the already delivered page. In other words, the learner switches among different contexts within the elements and domain granularity of the page rather than simply being in a known context. Therefore, the decision of selecting a certain hyperlink is transferred to the learner, whereby the variety of selectable hyperlinks is given by the teacher (e.g. depending on didactical goals or expectations). According to the example shown in Figure 3, (a) if the learner needs an explanation in Spanish, “Wikipedia (Castellano)” could lead

Figure 3. Web-based user interface of the AdeLE system
to the corresponding solution, (b) if the learner needs results from a specific information space (i.e. needs a smart search service that works on a white list of relevant servers), “xFIND (smart search)” may help, or (c) if the learner needs more graphical hints related to the concept, “Google (images)” could lead to accurate results from the Google Images search service.

From the architectural point of view on the CO2 system, as shown in Figure 4, the main distinction to E-HELP relies on the additional internal management of various Information Services. In this way we generalized the E-HELP notion of Information Retrieval System to break the limitations of dealing only with traditional query-based search services. CO2 is a fully service-oriented solution and is capable of communicating with other information services through distinct Web-based interfaces (e.g. Web Services, REST, native SOAP, etc).

The CO2 system has been also evaluated to corroborate the usefulness of the improvements of and differences to its first approach, the E-HELP system. The next sub-section summarizes some relevant aspects of this evaluation.

**Evaluating Cognitive Styles**

The evaluation of CO2 was conducted within the course Software Development in Distributed Systems (IICM; winter semester 2005/2006; sixty students participated). The time schedule for this evaluation consisted of three phases for four different groups of learners (two of them were assigned a common time slot). The learning part of the evaluation (i.e. the lesson) had the title Adaptive E-Learning Technologies. During this lesson, for which we provided one hour of time, the learners had to consume 3 main lesson sections with a total of 14 pages, including 3 assessment pages for each main section. For these pages, 32 concepts were defined, and for each concept at least 3 information services were included. For each page, 2 different versions of content have been created, one with more textual information and another with more images. Within the AdeLE project, we were also interested in the possibilities of personalization with respect to the cognitive styles of Riding’s WAVI model. This model considers the cognitive styles Wholist, Analyst, Verbaliser and Imager (Riding & Cheema, 1991; Riding & Watts, 1997). Due to this research interest, the main focus of attention in this evaluation was set on eye-tracking technology and personalization. For the sake of simplicity, the following paragraphs just summarize the relevant findings in the scope of this book.

Regarding the WAVI model for cognitive styles, we could corroborate that there is no difference on learning performance for verbalizers...
or imagers if they consume textual or illustrative information; see also Bajraktarevic et al. (2003). On the one hand, the subjects were requested at the beginning of the evaluation to give feedback about their styles through indirect questions. On the other hand, as a last step of the evaluation, the students completed the VICS v2.2b to measure the real individual WAvI factors. This is a recognized psychological test to retrieve WAvI parameters (Peterson et al., 2003). It is worth mentioning at this point that according to Phillips (2005), students are bad judges of their own styles: assessing the WAvI factors of two different psychological tests (VVSR, CSA) and of a questionnaire for self-assessing these values, Phillips (2005) found out that all three results did not correlate, whereby the self-assessment differed particularly strongly from the calculated values of the two tests. Please refer to Mödritscher (2007) for more details about the overall evaluation of the AdeLE system.

Against this background, it can be stated that the usage of CO2 concepts for the distinct cognitive styles (in terms of quantity of hyperlinks followed) has not shown significant differences. Over the whole usage of the system (i.e. the total of clicks of all students on CO2 concepts) an average of almost 4.66 clicks on each CO2 hyperlink could be calculated from the log files. From the available set of information services, the online dictionary dict.leo.org was used most frequently (36.25% of total usage), followed by Google (20.8%). This is comprehensible when clarifying that the original course language is German, but the evaluation’s content was in English. The third group of subjects (15 students) showed to be more wholist than analyt, meaning that it preferred getting an overview of the whole content (e.g. navigation trees) rather than learning sequentially (step by step over the given learning path, e.g. just using the previous and next buttons). Taking these latter aspects into account and considering that the CO2 concepts have been provided in the navigational frame, this group has answered the question “Did the background knowledge mechanism help for or improve your understanding?” with a resulting average rating of 2.8 (1 very good; 6 very bad). In comparison, the overall rating from all the participating students was 3.4 in average. Further, the question “Do you think the position of the background knowledge mechanism is suitable in the navigation frame?” was rated with an average of 4.3 (1 very good; 6 very bad).

Summarizing, independent of the cognitive style, the subjects have left the given closed-content and used the hyperlinked CO2 concepts to explore additional information on the Web. Although the situation “I need a translation” appeared more often, all CO2 concepts for the other information services have been used as well.

Regarding the usefulness of the CO2 system, some of the subjects stated in the post-questionnaire phase of the evaluation that:

- **Positive feedback (PF):**
  1. The idea of automatically providing background knowledge is great (8 subjects)
  2. Interesting, relevant and helpful information from external sources (5)
  3. An extensive offer of help (5)
  4. Pre-defined queries are helpful; no refinement was needed (3)

- **Negative feedback (NF):**
  1. I use search systems as background source of information anyway (6)
  2. Please, not in navigation frame (3)
  3. Not enough links for all topics (3)

Let us mention at this point that an unexpected failure in the system led to performance problems for the first group of students (system’s cache was disabled; long delays in response time). Based on the explicit feedback of this first group, most of those students admitted having tried to get benefit out of the waiting time during the load of a page; thus, they followed the CO2 hyperlinks in the
meantime and found relevant additional resources outside the mandatory content. The fact is that none of them arbitrarily left the closed-content to explore the Web. This behavior could be explained if we assume that they knew that the concepts on the CO2 system had a tight relation to the context of the closed-content pages. In addition, some of these students confirmed having gained a previously non-existing pre-knowledge for new pages, which in turn has compensated the loss of time. The first three PF statements (see the first list above) come from this group of students which also shows their satisfaction with the idea. Essentially we assume that the fact of having problems with the system combined with the stress situation of having limited time to pass the assessment tests has led the students to develop a new strategy for learning, i.e. they took advantage of the CO2 mechanisms to acquire the needed knowledge. In other words, they have preferred the possibility of a guided exit from the closed repository. A positive acceptance of the CO2 system is underlined by the PF statements 3 and 4. Furthermore, the general assumption that wholists tend to preferably jump from one navigational element to another at one’s own pace is enforced by the first NF statement, which was given by six wholists. Even more, three of them expressed wanting more CO2 concepts (NF statement 3).

In the other direction, analysts (see NF statement 2) showed displeasure with the position of CO2 concepts in the navigation frame. Nonetheless, from all analysts, these three subjects have used each CO2 concept at least once. Within this evaluation, the system proactively hid the navigation tree (shown in upper left side of Figure 3) if the user was considered to be an analyst. The hyperlinks of the Background Knowledge segment, however, were always shown. Thus, as found out in (Bajraktarevic et al., 2003) and stated in (Mödritscher, 2007), the statement NF2 of analysts can be the result of a cognitive overload for analysts while being shown too many navigational elements.

Enhanced Exploratory Learning

As a key finding from the CO2 evaluation, it can be stated that the CO2 system can be successfully used for exploratory learning. According to diSessa et al. (1995), the theory of exploratory learning is related to adaptive e-learning through the following three premises:

- Learning can and should be done at one’s own pace.
- Learners may approach a learning task in very diverse ways.
- Learning does not have to be forced.

On the one hand, explorative learning enforces creativity. On the other hand, if the corpus of learning materials is too open (as in an open Web-based environment), problems may arise such as cognitive overload or the lost-in-hyperspace phenomenon (Garcia-Barrios, 2007). Hence, the application of the CO2 principle can be seen as a practical example of exploratory learning because it gives learners the freedom to discover new knowledge in open (but topic-relevant) information spaces at their own pace and through various ways. The third premise is not absolutely comparable, however. Through CO2 concepts, an analyst may feel forced to leave the close-content. But as stated in García-Barrios (2007), the CO principle minimizes the lost-in-hyperspace problem through the combination of exploratory learning with guided learning. This means that students may leave the closed-content through pre-defined starting points, in this case, through didactically prepared concepts. Within this particular context, a personalization-pertinent e-learning system aims at overcoming these difficulties of comprehension and disorientation by reducing and optimizing the material repertory of an open environment (García-Barrios, 2007). This was the main motivation to enhance the CO2 principle by a new personalized approach, as depicted in the following section.
THE DEKOR APPROACH

In the light of our experiences and of the findings discussed in the previous sections, the motivation arose to develop a Dynamic E-learning Knowledge Repository System with "personalization capabilities", called DEKOR. This approach and its implementation enable personalized concept-based information access applicable for knowledge transfer and learning activities. But moreover, as various information needs are caused by situations or activities given by very specific contexts, the DEKOR system can cope with this requirement as well, what we call context sensitiveness (Gütl & Safran (2006); Gütl (2007).

A Context-Sensitive Solution

In general, DEKOR enables to manage various contexts, such as courses (in a learning environment) or projects (in a working environment). For the purpose of a more fine-grained structure, a specific context can be composed by various sub-contexts that are modeled by different context items. In order to assign sub-contexts to a given information structure, context items can be linked to one or more content pages, such as learning objects, knowledge assets or workflow tasks. A flexible support of various information services is ensured in the DEKOR system by the use of query templates, whereby pre-defined queries can be created through a placeholder mechanism. Placeholders are used to replace parts of queries or to extend them, e.g. to fill a query with certain concept keywords or to enrich the query with user group or user information. Each DEKOR concept can be initialized with the default set of information services and pre-defined query templates, and some of them can also be deselected or rewritten. If appropriate, the template-generated query for an information service can be partly adapted or completely rewritten. For example, the keywords “creativity training,” “brainstorming” and “think tank” could be assigned to the concept “idea stage”, whereby a default set of information services (e.g. Wikipedia, Answers.com and Scholar Google) can be chosen to be available. Furthermore, to get more relevant results, the basic search query “think tank” for Scholar Google can be refined to “think tank” AND “project management”. For representation purposes, keywords and query instances for specific concepts can be logically clustered by structure elements and displayed by proper titles.

The system described so far addresses a generic, non-personalized level, as known from the CO2 system. To enable personalization capabilities, DEKOR can also deal with concept modeling on the group and user level. All functions from the generic level are also applicable on these two levels, i.e. specific information services, query templates and concepts can be managed for groups and for individual users. In addition, data from the generic level can be wholly or partly inherited and overwritten to the group and further to the user level. To illustrate the added value of this part of the system, consider a group of students that are members of a community “MyCommunity,” and thus interested in receiving background knowledge from the MyCommunity Digital Library. Thus, they can specify the portal and use query templates on the group level to easily get access to additional background knowledge without any further effort. On the individual user level, for example, a student may also need additional concepts from another Web-based information service which can easily be added and semantically linked to the course resources during the learning journey.

Figure 5 depicts the conceptual architecture of DEKOR, which consists of the Personalized Concept-based Context Modeler (PCo2) and the other surrounding systems. Information consumer services, such as a Learning Management System, send requests to PCo2, which include information about the context, the specific context item, the user ID and the result representation. The PCo2 returns a set of concepts and corresponding queries...
The DEKOR System

Figure 5. Dynamic e-learning knowledge repository system with personalization capabilities

The DEKOR System

Beyond Traditional E-Learning:
Applicability of DEKOR

The DEKOR system can be incorporated into the context of learning-on-the-job in order to place background information (e.g. from a meeting corpora) at the disposal of company workers during their learning or working activities. Note that in this case, the Learning Management System shown in Figure 5 represents just an instance of many possible Information Consumer Systems, e.g. a content management system, a workflow system, or a knowledge management system.

To give an example of this versatility of the DEKOR solution approach, the focus is brought back to e-learning in terms of learning-on-the-job (see Figure 6). According to Rosenberg (2001), e-learning includes three different focuses: training, knowledge management and performance support. Within the scope of this book, the last issue should be underlined. Rosenberg argues that performance support may indirectly assist humans to enhance their work by means of speed, efficiency and cost reduction. It is provided in different forms, such as books, mentoring, software tools, or checklists. The integrative usage of software solutions for this purpose combines hypermedia systems, expert systems, adaptive systems, real-time support systems and help of real experts.

Furthermore, a critical aspect of personalization systems in the scope of learning activities is given by the possibility that these activities may change continuously over time. Thus, the User & Group Modelers in such systems must be continuously aware of situational changes and require advanced and long-term tracking mechanisms to ensure or boost the confidence of inferences. Therefore, the innovative value of the DEKOR approach relies on the integrative character of its components, and therefore it represents a set of goal-oriented and configurable tools (or software modules) being able of supporting company
The DEKOR System

This chapter has outlined the evolution of the idea of developing a dynamic e-learning knowledge repository for personalized learning activities (the DEKOR system) by means of the evaluation results and respective enhancements of two previously developed prototype solutions (E-HELP and CO2).

In general, evaluation results and findings have shown that our DEKOR approach is technologically applicable for knowledge transfer and learning activities in various settings, such as in higher education, organizational learning and life-long learning. Moreover, students or employees (1) need access to content alternatives and additional background knowledge, (2) appreciate guidance to open repositories, and (3) require
The DEKOR System

even personalized access to open repositories. The introduced approach can support users in dealing with problems of open ended learning environments but they can also access to a broad range of topical content alternatives.

Towards a system of personalized, guided access to open repositories, the DEKOR approach (1) allows the flexible integration of the system with different information consumer services (such as knowledge management and learning management systems), (2) enables a personalized and guided access on the logical level of concepts and contexts to content alternatives from different information services, and (3) supports a simple way to define concept instances causing less effort because of the template mechanism.

Our intended future work will mainly follow three lines. Firstly, we want to explore the applicability of the DEKOR system by further experiments and by its implementation in real-life applications. Secondly, further research work should be conducted to find solutions on how to combine our approach with e-assessment to improve the user model of our system. Finally, an improved user interface based on Web 2.0 technology will be developed to simplify the creation and modification of concept instances for and through communities of learners.

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