ACTIVE LEARNING BY PERSONALIZATION
Lessons Learnt from Research in Conceptual Content Management

Hans-Werner Sehring, Sebastian Bossung, Joachim W. Schmidt
Hamburg University of Science and Technology, STS - Software Systems Institute
Harburger Schlossstraße 20, 21071 Hamburg, Germany

Keywords: Content-based and Context-based Learning, Research Systems, Knowledge Management, Personalization.

Abstract: In this paper we argue that the potential of e-learning systems for active and autonomous knowledge acquisition and use can be substantially enhanced by exploiting the personalization capabilities of concept-oriented content management.

Content and implementation personalization are essential services provided by research-oriented content management systems. Personalized concept understanding as well as concept-oriented content acquisition and use are key to most learning situations. Therefore, learning and research systems should cooperate with the common goal of exchanging and sharing content and enabling processes which transparently span system boundaries. In this paper, we discuss how personalization can be used to enhance both, autonomous learning activities and research-oriented workflows.

Personalization and content coupling technologies are at the heart of one of our operational web-based application systems, the Warburg Electronic Library. This system is successfully used in a number of research as well as learning projects, during which advantages of joint research and learning systems have been identified.

1 INTRODUCTION

Essential goals of research-oriented content management systems – in short, *research systems* – and *e-learning systems* overlap. Both system classes support autonomous user activities such as acquisition and exploration of concepts as well as creation, enrichment, publication, and sharing of content. As a consequence, a close coupling of both system classes is considered as mutually beneficial. Furthermore, key requirements are present in both, most prominently personalization. Research support systems focus on the representation of facts by content. It is important, however, that they do not impose a specific interpretation of content on users. As there is generally no agreed-upon single interpretation, such systems need to allow users to work with personal interpretations. Moreover, associating content with a fixed sets of a priori categories is inappropriate because every researcher needs to focus on aspects specific to the work at hand.

In addition to content organization, storage and retrieval, research systems have to support three types of research workflows: (1) personalization of given content and structures, (2) sharing of personalized content amongst users, and (3) making the views of users available to the general public. According to our findings many of these requirements can be met by means of personalization.

E-learning systems generally support learners in finding and studying content appropriate for their learning needs; content is packaged in learning units stored in e-learning systems. Such learning units can often be parameterized to better suit the learners' previous knowledge or their preferences with respect to learning styles, (Guttomsen Schär and Krueger, 2000). An integral part of learning, however, is putting the heard into practice to gain a thorough understanding of the subject area at hand, e.g., (El Saddik et al., 2001). To allow learners to work seamlessly during their entire learning activity, systems also have to support autonomous environments for active learning. We have found that active participation of users is also enabled by means of personalization.

In addition, there is a need for content linking and exchange between research and learning systems: Many of the research results of today evolve into learning materials of tomorrow.

We have gained many of the insights presented here through our operational system, the *Warburg Elec-*

Sehring H., Bossung S. and W. Schmidt J. (2005).
ACTIVE LEARNING BY PERSONALIZATION - Lessons Learnt from Research in Conceptual Content Management.
In *Proceedings of the First International Conference on Web Information Systems and Technologies*, pages 496-503
DOI: 10.5220/0001235404960503

tronic Library (WEL). The WEL research system emphasizes the support of research by flexibility in both structure and content, as well as for the respective processes. Both can be personalized to match the researcher's intentions. Since 2000, the WEL system is successfully used in a number of research projects. Because of the similar requirements we have also been able to employ it as a learning system, demonstrating the advantages of joint research and learning systems. User groups include researchers in art history, school teachers, and university students.

The paper is organized as follows: We begin with details about personalization (section 2) and show in section 3 and section 5, respectively, how it is employed in research and learning systems. Section 4 gives an account of our experiences with an implementation of the concepts presented in this paper. In section 6, we provide a closer look at the coupling technology for research and learning systems. We conclude with a summary and outlook in section 7. Related work is discussed where appropriate.

2 PERSONALIZATION

By personalization we mean the ability of a system to adapt to the individual needs of each user. Personalization can be broken down into two aspects: schema *openness* and system *dynamics*. An open schema is one that users can change on-the-fly and at any time, thus guaranteeing best correspondence with their information needs. Information systems are dynamic if their implementation follows any on-the-fly modification of a schema dynamically.

Such personalization happens on two levels: *content* and *structure* personalization. The former refers to the ability of a system to let users change content according to their needs or opinions, the latter enables users to change the schema of the content. (Rossi et al., 2001) refer to content personalization as information personalization.

Note that this personalization is more general than what one is used to from contemporary web applications, where personalization usually covers presentational aspects only. (Koch and Rossi, 2002) also share this broader definition of personalization.

Another important aspect of personalization is the ability of users to re-integrate their changes with the content base of a larger community (fig. 1). This allows for iterative enhancement of the content. Personalization is used to achieve a number of goals: (1) Adaptation of content to personal views or intents, (2) securing of privacy, and (3) handling of large amounts of data by filtering out what is not of interest, (Niederée, 2002). Also see (Riecken, 2000) on personalization.

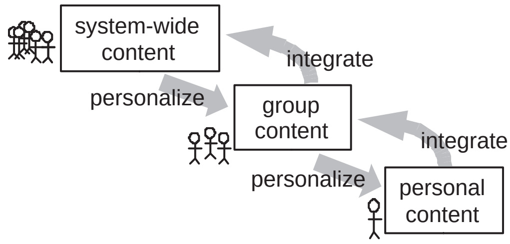

Figure 1: Personalization allows local change and re-integration of content.

2.1 Content Personalization

Research work is explorative and often subjective. It follows open and dynamic processes (see above, or (Sehring, 2004) for more details) in which every user has an own – possibly changing – view on the content. This personal view is reflected by individual modifications of the content. Users can – at least for some time – deviate from the opinion of the community by changing a piece of content. Personalization allows them to modify existing content, but those changes will only be visible to the user who made them. This approach is therefore called content personalization. Content personalization can be used to explore the implications of a hypothesis.

Note that presentation personalization (e.g., changing the background color) is a special case of content personalization as configuration data can be treated just like ordinary content.

2.2 Structure Personalization

Content personalization allows users to modify content according to their current needs without interfering with others. However, in many situations this is not sufficient, as it can handle uniform content only.

Structure personalization comprises two aspects: (1) Changing the structure of content by means of creating variants of the content's schema as well as (2) (re)categorizing content with the option of creating new categories. As with content personalization, there need to be means that allow users to re-integrate their changes with the community. Structure personalization is a dynamic application of schema evolution, e.g. (Banerjee et al., 1987).

For example, often users create a new attribute, to capture newly found aspects. In addition, they might also want to modify the categorization of content.

2.3 Implementing Personalization

Personalization as required by research and learning systems is not covered by contemporary information

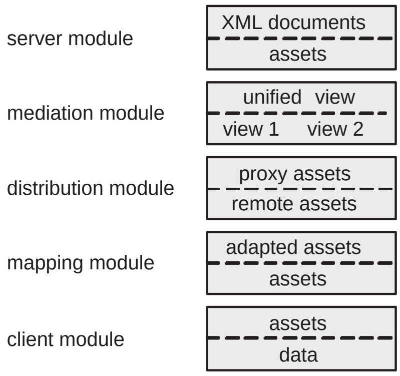

Figure 2: Modules interface with each other in a layered architecture.

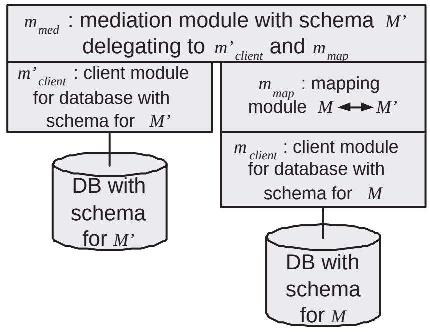

Figure 3: Sample configuration of a personalization from schema M to M'.

systems (ISs). Since ISs are usually based on database technology they share its typical constraints, the most crucial being that databases rely on one static schema. The schema is adapted to users' information needs by means of views or the application layer of a multi-tier application.

A static schema prevents dynamic processes, as all parts of an IS – data, application, and presentation layers – refer to that schema. Changing it leads to modification of the whole application. Since this requires manual changes to the software, it cannot be done by end-users. The same is true for view changes. Hence the demand for openness is violated.

After first experiments with monolithic multi-schema applications which enable openness and dynamics by means of complex application code we now favor a new approach to IS construction. This approach is based on a conceptual modeling language for content and concept schemata as described in (Schmidt and Sehring, 2003). This language introduces the notion of an asset as an indivisible union of perceivable content representing an entity and a set of expressions describing it abstractly. Conceptual expressions include values of fundamental properties of entities, relationships between (otherwise independent) entities, and constraints governing rules and regulations which entities follow.

From definitions given in the asset definition language, by end-users, open dynamic systems are generated by a technology that resembles model-driven architecture approaches, (Sehring and Schmidt, 2004). It consists of a *model compiler* and a *modularized architecture* for asset-based systems, which can be used to create research and learning systems.

Users can express their information needs in the asset definition language without regard to implementation constraints. The model compiler establishes openness by generating software systems meeting those requirements.

In our approach the architecture of the generated research and learning systems achieves personalization by the ability to enable dynamic systems evolution. For this it allows the open redefinition of assets and the dynamic invocation of the model compiler.

A system consists of a set of components reflecting one schema each. These are broken down into modules, which are the output of the model compiler. For our current purposes we identified five kinds of modules (see fig. 2); each module of a component is of one of the five kinds. By introducing module kinds we achieve a *separation of concerns* which makes addition and substitution of modules possible.

Personalized content is stored in third party systems, databases in most cases. Mapping asset schemata to schemata of such systems is done by *client modules*.

The functionality of a component is defined by a module *configuration*. Therefore a central building block of the architecture of most applications is the mediator architecture presented by (Wiederhold, 1992). In our approach it is implemented by modules of two kinds, namely *mediation* and *mapping modules*. Fig. 3 shows an example of a configuration which enables personalization. The component is accessed via mediation module m_{med}. It distributes requests according to a personalization strategy, e.g., to create and manipulate content objects in a user's private storage (via m'_{client}) while retrieving content from both the public (via m_{client}) and the private store. The mapping module m_{map} converts requests formulated according to the personalized schema M' to ones according to a global schema M.

As can be seen in fig. 3 the public component (m_{client} and the corresponding database) is integrated into a personalized component unchanged. This is the key to dynamic personalization, here changing the content structure from M to M'.

By use of *distribution modules*, components spread out over several systems. They are accessed via *server modules* using standard protocols.

3 RESEARCH SYSTEMS

The support of research activities is esentially a content management task, because information is retrieved as a basis to research and new content is created as its result. Software which supports research has – in extension of common content management systems – to provide content in a cooperative and personalizable way. The software has to meet requirements which go beyond those of common content management systems and will be discussed in section 3.1.

Very roughly, doing research can be broken down into two parts, which are shown in figure 4. The first is working with existing knowledge and facts to derive new findings from them. This is shown in the inner cycle. In a research support system, this typically involves customizing existing content and then changing it to reflect new ideas.

The outer cycle in figure 4 describes the interaction with the scientific community. After a number of iterations in the inner cycle, researchers will publish their results. This serves two purposes: Making their findings known to the world as well as receiving feedback from the world.

An integral part of research is the discovery and construction of new concepts. These make it possible to put the new findings into relation with existing knowledge, thus aiding the understanding of new discoveries. To this end, it is important to note that retaining existing concepts and content structures will be hindering at best. The old structures were devised in previous research iterations and can only be used to store information the corresponding structures. Especially the categories will fit the new findings only partially.

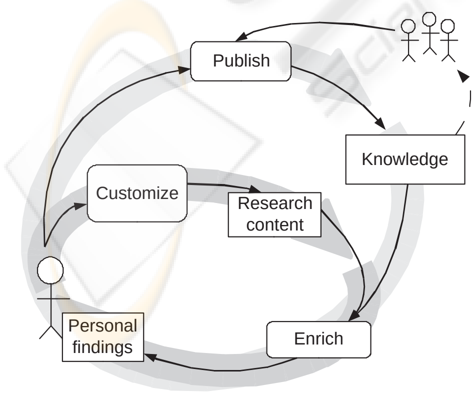

Figure 4: Research cycle showing personal actions of the researcher as well as interactions with the community.

3.1 Research System Requirements

In extension to typical demands to research systems (Yao, 2003), we identify additional requirements. Alltogether, researchers need to be able to:

- create new structures (i.e., both new concepts and new data structures to store findings) as well as new content, which represents the actual findings,
- categorize existing as well as new content according to their needs, which might involve changing the categorization of existing content or finding evidence (content) for existing categories,
- manage co-existing structures of concepts to handle personalized as well as public research results,
- enter a review process (e.g., by peer groups) which ensures consistency of the new findings with existing ones, and to
- republish their findings to the outside world once the research is complete.

A research system needs to have an additional property: It needs to ensure that intermediary steps in the research are only visible to the researcher and not to the outside world. Intermediary results hardly ever make sense to anybody but their creator. In many fields of research (e.g., in social studies) there are also privacy concerns.

Ordinary information systems are ill-suited as research support systems as they generally do not meet many of the requirements. Shared data is the communication paradigm of information systems (Goldin and Thalheim, 2000). These systems therefore allow neither changes in structure nor in content without making the changes visible to all users at the same time. Even if categorization is handled, on-demand re-categorization is usually not supported.

3.2 Personalization in Research Systems

By means of personalization one can create a system that meets the above requirements.

First of all, it allows the implementation of the inner cycle of fig. 4: Researchers can take existing content and change both its value as well as its schema. They can also restructure content on a larger scope, e.g., by changing or adding categorizations. This process can be repeated until the personal findings are in a consistent state.

Then researchers can choose to publish the findings to a larger community. This can happen in several steps, for example first to other members of the research group, and only later to the general public. Here again support is given by personalization, because it also includes an upward path that allows the

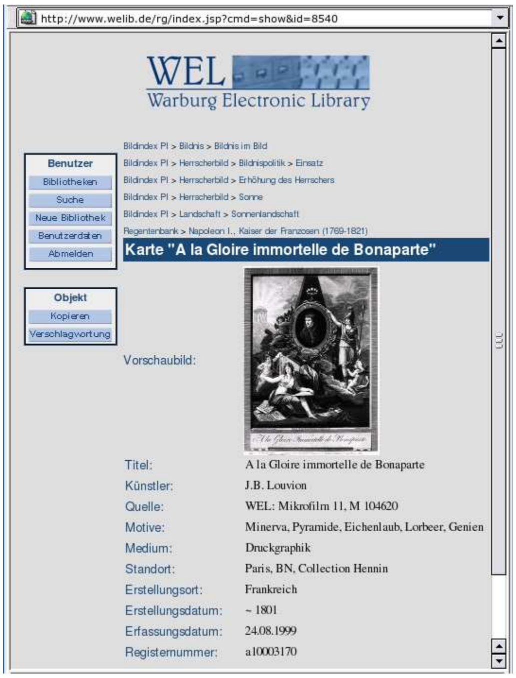

Figure 5: A view of the running WEL system.

reintegration of personalized content into the content that was originally personalized from, see figure 1.

Personalization is thus the outstanding feature that enables the conduct of research in the system.

4 A RESEARCH SYSTEM IN E-LEARNING SCENARIOS

The *Warburg Electronic Library* (WEL for short[1]) has contributed much to the authors' insights into research and learning support systems, (Schmidt et al., 2001). It is publicly available as a web-based system since 2000. It is and has been used in several research and learning projects by a current total of over 700 users world-wide.

4.1 Research

The WEL software was originally developed for the project "Regent Base" which was carried out in cooperation with art historians from the research institute for Political Iconography at the University of Hamburg. Analyzing the demands of the humanities we soon discovered that they cannot express their findings in conventional databases since subjective views dominate those disciplines. Therefore the WEL has been designed as a personalizable digital library which follows the paradigm of reference libraries (Niederée, 2002).

The personalization methodology of the WEL is based on the understanding that many organizational paradigms for information, for example those of public libraries, reference libraries, and card indices, all share the same fundamental principles. Besides the amount of content, they differ primarily in the content schemata. The organizational structure is determined by the size – and thus the broadness of interests – of the addressed community.

The users of the WEL are organized in groups, which are laid out in hierarchical manner to allow researchers to capture their concerns in projects and subprojects. Group membership determines the content which is visible to the user. In combination with transparent personalization of content, this allows for individual research as well as collaborative work in groups. Groups exist for a range of projects with often different but sometimes overlapping content.

4.2 Learning

The WEL system has been used for e-learning purposes since 1998. Several seminars have been carried out with students of art history. A common task in such a seminar is to structure content from a given subject area, e.g., a regent, a geographical region, or an epoch. By relating content and finding subject terms describing the area at hand, students gather information on the political situation, a regent's goals, or the ways of mass communication by art. Finally, students give a presentation on their findings and write a text about them. Using the WEL system we experimented with employing a research system to systematically support such seminar work.

We used the chance to try different interaction patterns of users in different roles. The general approach of using the WEL's personalization in the seminars is depicted in fig. 6. This workflow meets the demands from (Maurer and Lennon, 1995).

At the beginning of each course the instructors prepare material for student groups working on different topics ("customize"). Using personalization they select WEL content and make it available to the groups as a starting point. In this first interaction pattern teachers communicate with learners using the WEL.

Students use the prepared content to start a personal card index for their topic. They structure additional content, which they either find in digital repositories available through the WEL or add by digitizing material from books or catalogues ("personalize").

While finding, structuring, and amending content ("(re-)structure and improve") the students are able to communicate with each other. By making content available to members of other groups on a peer-to-peer basis they are able to discuss results and bring

[1]Also see the web site: http://www.welib.de

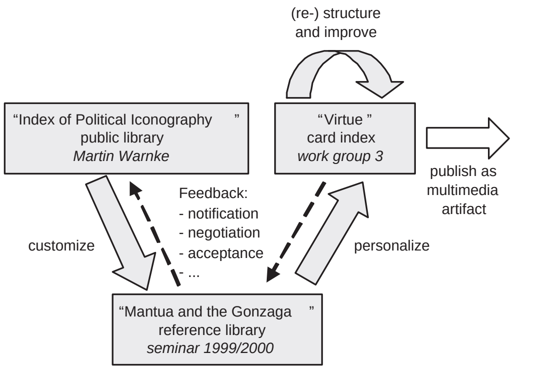

Figure 6: An example of the learning cycle with system support: the seminar process.

out interrelations of topics. This second interaction pattern allows students to jointly work on their topics. It trains their ability to work in teams and to participate in scientific discourse (Alavi et al., 2002).

While working on a topic, students can present material to their instructors since both are WEL users. Furthermore, instructors can monitor the progress of students and guide them. Both ways of communication form the third category of interaction patterns: learner-to-teacher communication.

When they are done with the acquisition of content, students demonstrate their findings by giving a talk. Normally they do this by taking attendants on one linear path through their structure, while showing content where appropriate. Using the WEL, they are able to visualize the complex structures they created, resulting in more in-depth discussions.

Finally, students prepare a medial presentation of their findings. All past seminars created a web page for this purpose, as indicated in fig. 7.

In a current WEL-project, the "Hamburg Media Index", the WEL system is taken to school teaching to explore the remaining fourth interaction pattern, namely teacher-teacher interaction. As school curricula are currently being reformed, teachers have to collect and create new learning material. With the help of the WEL, teachers can jointly work on new material and discuss it with colleagues. Individual teachers can also offer content to others. Personalization gives them control over the publication of their materials.

5 LEARNING SYSTEM REQUIREMENTS

As is witnessed by many taught courses, absorbing content and applying the learnt are essential parts of learning, see for example (Clancy, 1995). Constructionists interpret learning as the construction of knowledge and not its absorption, (Schroeder, 2002).

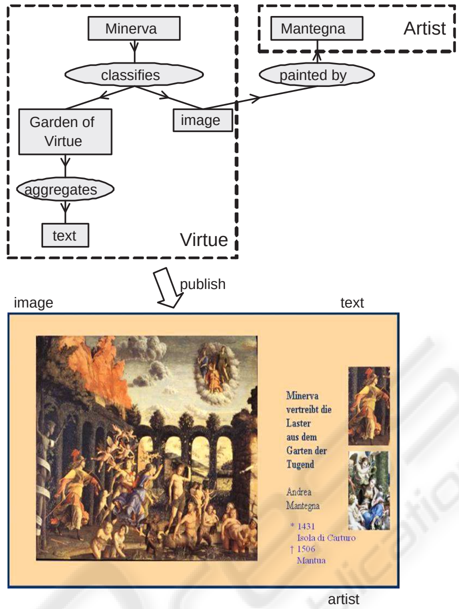

Figure 7: Multimedia publication of content.

Practical application facilitates the lasting storage of information by guaranteeing the incorporation of the appropriate association into the existing cognitive network. By means of this association the learnt can later be applied to different, more complex problems.

5.1 Learning Activities

Fig. 8 depicts this active way of learning. There are two levels, which differ in closeness to the learner as well as in speed of iteration. The inner cycle of purposeful action, getting results on the action, and incorporating those into the mental model focuses on active learning. It is usually carried out by one learner alone. The outer circle describes the interaction with others, learners as well as teachers.

Typical e-learning systems support a passive way of learning: There are usually a number of ways to present lessons to learners (Guttomsen Schär and Krueger, 2000). Interaction of learner and system is frequently limited to formal testing.

Unfortunately, the abilities of e-learning systems to allow the learner to solve problems inside the system itself are limited. Enabling this is crucial to support active learning, which is believed to be important to allow learners to gain a thorough understanding.

5.2 Personalization in E-learning

Ideally consumption of content in e-learning systems is augmented by making the content parameterizable. That is, users are allowed to view the same content in different forms. To this end, the content is parameterized and users can tweak its presentation according to

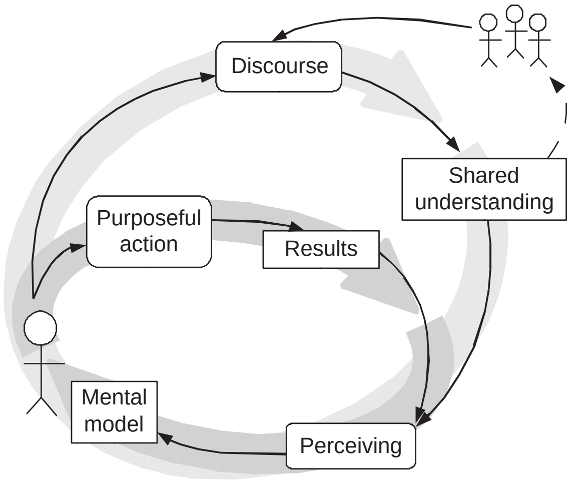

Figure 8: Learning cycle from the learner's point of view. Inspired by (Allert et al., 2004), but content is different.

their needs. Typical dimensions of parameterization include the language of presentation, the number of examples, or the degree of formalism.

While content personalization can be used to implement parameterization, personalization itself covers a much broader scope. Parameterization mainly applies to teaching, while personalization covers all aspects of the learning circle in figure 8. It supports discourse through exchange of personalized content and structures with a limited group of peer learners. Most importantly, users are enabled to take action in the system itself and learn through the results of their action. They can recombine artifacts to solve learning problems. This applies to the subject under study (which is represented in the system in one form or another through content) as well as learning objects (the course lessons which deal with the subject).

This allows a new approach to e-learning in which learners can structurally rework or even extend the subject matter. For example, a lesson could start with a given partial content structure that the learners are to complete. In doing so, they apply what they previously learned. Thinning out the content is again achieved through personalization (the left-out pieces are of course not deleted globally), as the whole system is likely to provide a much higher level of detail in the given area, for example to also support more advanced learners.

6 COUPLED SYSTEMS

Active participation of the learners is an important part of the learning process. Practical experience has shown that this in general can be enabled by means of personalization.

While the need for personalization is shared by both learning and research systems, the feature – content as well as structure personalization – is used in different ways in each kind of system. It is a critical part in the learning process to enable active work by learners, to allow learners to share knowledge in groups, and to enable teachers to cooperatively develop learning content. In research systems personalization allows users to formulate hypotheses, develop them in isolation, and finally share them with the community in a controlled manner.

Research and learning systems can be linked on a technical level since they share the same understanding of personalization. Therefore research and learning processes can be coupled, allowing the exchange of research results and learning content. Joint processes can transparently span system boundaries. Combining research and learning processes allows for various synergies not possible with unrelated systems.

Findings obtained through research systems will eventually make it into teaching. Joint processes support such a migration by keeping a link from course material to research content. This link is lost when content is copied manually from one system to another, discarding information about, e.g., authorship and data provenance, see (Buneman et al., 2001).

Occasionally, advanced learning content contributes to research. For example, the students' results from the seminars reported on above caused parts of the project's content to be refined. Similar results can stem from Master's or PhD thesis work which link back to research content. Tracking the life-cycle of content from a research system into a learning system and back is not feasible without system support.

7 SUMMARY

The success of research and learning systems relies heavily on their support for active processes in open and dynamic environments. To our findings, such systems are largely based on personalization functionality for content, structure, and the processes attached. The required personalization exceeds the capabilities of traditional information systems. Implementation and application experience shows that advanced personalization can be successfully employed for both research and learning purposes.

To extend the approach presented here towards Intelligent Tutoring Systems (ITSs), models of the learners and teaching strategies are required in addition to the model of a domain. The asset definition language allows the open formulation of these models comparable to, e.g., user models capturing expertise in research systems by keeping track of their interests, contributions, and ratings by others. By means of ITSs, models of learners can be used to give feedback and to dynamically adjust learning modules to the learners' abilities. How to make use of a set of learner descriptions to determine typical obstacles is currently being researched.

Future work will extend the principles discussed in this paper essentially in two dimensions. First, we seek to extend the interaction patterns of the WEL system by designing and evaluating the teacher-teacher communication discussed above and group-oriented student-student interactions. Second, we see a need for interoperability with other e-learning systems through standardized e-learning formats such as LOM, SCORM and the like. Furthermore, the use of exchange formats based on XML will also allow general sharing of any content. In our approach XML schemas are dynamically generated out of user defined asset models. A first prototype implementation of an XML schema generator exists.

In a varity of application projects we are seeking additional learning and research scenarios to acquire further user demands that will challenge the architectural decisions for our personalizable conceptual content management systems.

ACKNOWLEDGEMENTS

We would like to thank our colleagues from the Art History Department of Hamburg University, first of all Prof. Dr. Martin Warnke, for the extraordinary patience of a highly experienced user community. Furthermore, we thank Hamburg County for its continuous financial support of the Warburg Electronic Library Project (WEL grant) and Deutsche Forschungs Gemeinschaft (DFG) for its WEL-related grant on "Geschichte der Kunstgeschichte im Nationalsozialismus".

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