Ubiquitous Access to Learning Material in Engineering

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Abstract. Advances in mobile computing allow new ways of any-time and any-where, networked and dislocated knowledge transfer. Such new ways of instant learning access are especially required in the field of engineering, due to its increasing complexity and diversification of tasks, and the resulting skill profiles of engineers. Qualification support has been achieved by providing an integrated e-/m-learning solution in the ELIE project (E-Learning In Engineering). It adapts didactically relevant content to both, the technical properties of multiple devices, and the situation of the learner. The structuring process for content is based on elicited experiences of coaches. In this way, it ensures high didactic value of learning material. Since this expert knowledge can be encoded into content directly, self-directed transfer processes can be triggered and managed effectively. The procedure for content development we propose enables coaches not only to follow the implementation of their knowledge in a transparent way, but also to reuse content, either as marked as didactic entities, redesigning them, or re-assigning didactic qualities to content. As technical enabler XML data structures have been developed for the encoding at the environment level. Both, in the web and the mobile learning setting, data are displayed sensitive to the user, the transfer situation, and the device at hand. In addition, users might link content elements to individually selected communication elements, such as entries in a discussion forum. The evaluation performed so far indicate several benefits for learners and coaches.

Keywords: mobile learning, didactics in e-learning, content management.

1 Introduction

By establishing the information society lifelong learning has become complementary to formal education, primarily driven by occupational needs. It is expected to qualify its members for a time of continuous changes, in particular with respect to skills they need to accomplish work tasks. Communication technologies and personal mobile devices enable access to information at any time at any location. Of particular interest in this context is the field of mobile learning (m-learning), as mobile networked applications might transfer knowledge effectively at the right time at the right location in the right way. Mobile learning is expected to facilitate lifelong learning [1], and leads to learning activities embedded in everyday (conversational) scenarios [2][3]. As mobile computing devices are available in different flavors, such as PDAs, smart

C. Stephanidis (Ed.): Universal Access in HCI, Part III, HCII 2007, LNCS 4556, pp. 481–490, 2007.

phones and portable computers, taking advantage of them has brought up a variety of facilities for interaction, navigation, and presentation of information. In addition, computer systems can be used in environments where they could not been used so far. Such a high degree of diffusion requires novel concepts, such as location awareness and context sensitivity. Taking into account user needs, work and situational context has to be considered as a prerequisite for m-learning, otherwise the challenges of achieving intelligent content delivery and engaging learning experience [4] cannot be met.

A recent survey study performed in the UK and Italy reflects the attitude towards m-learning of a total of 128 learners [5]. According to the study's results, mobile learning is considered unique due to its capability to enable learning effectively anywhere, anytime, *and* in a personalised way. Furthermore, mobile learning helps learners to identify areas where they need assistance and support. To that respect, adequately prepared content and highly self-contained, but motivating learning material could help, in addition to effective communication facilities. Tuned content and communication would allow focussed interaction within the peer group, and help contacting tutors and coaches.

Reflecting the findings so far m-learning can be considered a key advancement in the field of learner-centred knowledge acquisition and self-directed learnering. Recent approaches to m-learning stress the importance of a structured procedure to produce proper content, and suggest engineering-driven approaches for content production [6]. Unfortunately, these approaches lack concepts for identifying didactically relevant content elements in m-learning environments, as well as their context-sensitive specification and implementation. According to Dijkstra et al. [7], content structures need to meet didactic requirements to become Learning Objects (LOs). LOs are considered crucial for effective learning in distributed learning environments. Although current research in the field of advanced distributed learning stress the importance of modular content motivated by domain-specific didactics in academic environments [8, 9], LO development is driven by technical means and needs rather than didactic experiences and concepts. However, the didactic value of learning material is *the* decisive factor for online learning: "The material provided through online learning must have a high didactic value, since it is primarily intended for self-paced training" [10].

Developing material of high didactic value is a challenging task. As Kerres [11] and Euler [12] point out, bridging the gap between technology-centred development and didactically relevant content management, requires more than content structuring, namely the recognition of didactic expertise and situational parameters in the course of development: "Most of the efforts to support the preparation and deployment of accessible web-based learning material propose guidelines that prevalently address technical accessibility issues. However, little or no consideration is given to the didactic experts, and thus their didactic experience, in learning material development" [13]. Consequently, enabling multiple and dynamically generated representations of knowledge requires more than shifting content from conventional e-learning to m-learning environments: "Developing learning materials specially for mobile learning is better than re-using material developed to a PC".

In conformance to these findings our research has been targeting towards didactically motivated and effective content development for web-based and mobile learning environments (cf. www.ce.scholion.at, www.mobilearn.at). In this paper we show in which way highly structured, didactically enriched content can be produced in a context-sensitive, but still efficient way. It has been effectively used in the field of electrical engineering, both in web-based e-learning and m-learning scenarios of use. As enabler a platform has been selected that allows for multi-channel content delivery on e-learning and m-learning devices. After detailing the didactics-driven content engineering process in section 2, we show the mapping of didactic elements to the XML content structures in section 3. In section 4 we briefly discuss the relevant features of the second generation e-learning platform SCHOLION that is required for the ELIE environment. Section 5 concludes the paper reflecting our results and indicating further research based on the practical experiences made so far.

2 Content Engineering Driven by Didactic Knowledge

The content engineering process for m-learning content comprises various steps. It is composed of 5 main steps: preparation phase, preliminary document analysis, structured interview, extended document analysis and mapping of didactic knowledge, and finally, the actual content authoring and delivery to a Learning Management System (LCMS). Different roles, including domain expert, didactic expert, author and LCMS administrator, should be involved in the process (cf. **Fig. 1**). The core process steps aim to identify how content can be handled conform to (domain-)didactic principles. The data to that respect are collected through interviews with domain experts. Subsequently, they are mapped to didactically enriched content elements. These three steps constitute the CoDEx method (Content made explicit from a didactic perspective) [14,15,16].

Preparation. In the course of preparation, the source materials for content development have to be identified. Based on their objectives and outlines, literature in the content domain and/or source content from existing courses are arranged to a concluding source document.

Eliciting Didactic Knowledge. The CoDEx method has been developed to make the relevant didactic knowledge of domain experts for content engineering explicit, and to map this knowledge to digital content. It requires the following steps.

Preliminary Document Analysis. Hereby didactic experts examine each source content. The levels of granularity, didactic components, such as definition, and means of orientation and navigation are identified. The level of granularity of the various sources may be quite different. Depending on the intended use of the content to be developed and the envisioned didactic scenarios, different levels of detail may be useful. Additionally, the didactic orientation and the didactic objectives of the source content should be examined. Finally, the following items should become transparent: (i) a reason to include the data into the digital content; (ii) relationships between the different sources of information; (iii) generic content types/elements/objects; (iv) alternative ways of navigation and navigational patterns.

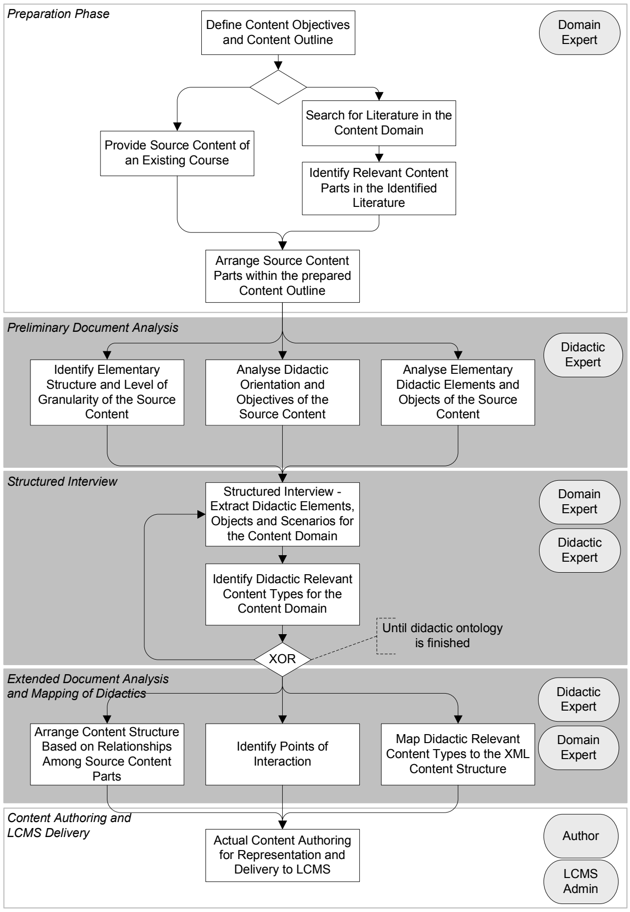

Fig. 1. The content engineering process (single iteration)

Structured Interview. According to Flechsig [17] each didactic entity needs to be well planned and requires a broad analysis of target group, learning culture, organisation, learning program, resources, demands, requirements, knowledge and competences. The most of these analysis steps also affect the content engineering process. In the course of a structured interview with the coach (or domain expert), the focal points of the didactic analysis will be treated from his/her perspective.

- *Organisation.* Organisational issues including content profiles, learner profiles and the organisational learning environment are clarified in this interview section.
- *Individual Positioning.* This section should make explicit individual approaches to knowledge transfer: Techniques to teach and individual didactic principles are explored.
- *Knowledge transfer.* This part of the interview deals with organisational activities during knowledge transfer activities, and the representation of relevant learning materials.

- *Communication*. The communication behaviour of the interview partner in the context of knowledge transfer is clarified. Conclusions about the social interaction and about social skills of the interview partner are drawn.
- *Technical support*. Current and future technical support of the knowledge transfer is clarified: Questions about the use of ICT-tools, the www or learning environments in conjunction with learning material are asked.

The structured interview clarifies individual, organisational and technical aspects of the knowledge transfer process. In the core part of the interview, didactically motivated elements such as didactic content types, interactive elements etc. are identified. Depending on the preparation and knowledge of the interview partner (domain expert, coach or teacher) these content elements and their interrelations can be balanced with the content elements in the learning materials.

3 Structure Mapping

In this phase, the elicited didactic elements and structures are mapped to an XML content structure.

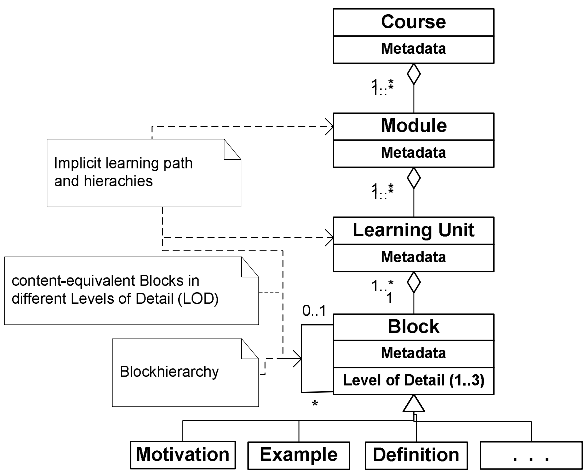

Fig. 2. Didactically motivated content structure

Content Structure. The content structure as described in Fig.2 comprises levels of details, domain-specific block types, and rendering levels for different device categories.

Levels of Detail. The LOD (Level Of Detail) concept is important for polymorph content delivery. It allows content developers to produce content on three different levels of granularity, and consequently, learners to retrieve differently detailed information of the same block type or on the same topic. A very common instantiation of that concept is to provide slides for presentation at LOD1, a text book structured according to block types at LOD2, and additional information or further material (links, files in pdf format, videos and the like) at LOD3. At LOD1, learners might retrieve essential information at a glance with minimal effort in navigation. In combination with the filter function, mobile access can be designed as effectively as stationary access. In this way, access to content ‘on-the-move’ provides added value to knowledge transfer in virtual environments rather than burden users with cumbersome navigation activities.

Didactic Blocktypes. In the content area the content is grouped according to didactic principles, forming so-called blocks. Currently, about 15 generic block types have been defined and implemented. They comprise definitions, motivation, background, directives, examples, self test and other generic didactically relevant content structures. Additionally, some domain specific block types, such as source code, interaction etc. were defined for the field of engineering in the course of the ELIE project.

Rendering levels. Basically, content in the different Levels of Details can be used at various delivery platforms (PC, PDA and Smartphone). The content developer should only care about multimedia files and pictures. Hence, different display resolutions, different media players, and different capabilities of delivery platforms have to be considered and implemented in different, so-called rendering levels, which are also part of the content structure. Only specific combinations of LOD and delivery platforms have turned out to be effective for learning so far (cf. Table 1).

Table 1. Scenarios using content on different Levels of Detail and devices

Level of Detail	Granularity of Text	PC	PDA	Smartphone
LOD 1	presentation style	X	X	X
LOD 2	full text	X	X	
LOD 3	additional information	X		

Mapping of didactics to content structure. At this point, source content and didactic elements are mapped to the content structure jointly by the didactic expert and the domain expert. In the course of the ELIE project, the source contents were prepared in MS Word documents. The learning units, blocks, and block types were integrated in the document using comments and highlighted. Furthermore, interactive elements and adequate interactive discussion issues were inserted directly into the source content at identified points of interactions. Preparing source documents in this way was the precondition for the actual content authoring and delivery to the ELIE environment.

4 ELIE - Powered by SCHOLION

The ELIE environment is one of the instances of the SCHOLION platform [14], similar to mobiLearn (www.mobilearn.at). As a second generation educational environment it overcomes current limitations of distributed hypermedia environments for continuous user-centered teaching and active learning support. It provides individualisation facilities for knowledge producers and consumers, as well as a common information space for focused interaction.

The architecture reflects this open access concept based on a central data repository. The system tiers decouple the processing logic from data management and user interaction. The target user groups which are supposed to use the ELIE environment are knowledge consumers in companies, as well as trainers, lecturers and knowledge providers from educational departments, (business) schools and universities (knowledge producers). The benefits to be expected for both user groups are: Knowledge consumers are enabled to leave their passive role and become an integral part of the knowledge transfer process. This immersion of learners into the transfer process is achieved through telecommunication facilities and individual knowledge navigation and annotation.

Architecture. The technical architecture is based on 3 tiers, providing database-management-system independency for the data management, presentation and business logic (model, view and controller). Most instances of the platform use a Oracle 10g database capturing all data (including all media files and slides stored in BLOBs) and Tomcat 4.1.31. The application's servlet technology is based on Java 1.4 and generates a XML meta language, similar to HTML, but independent from styles and web-browser specific characteristics, that is rendered to XHTML 1.0, DOM 1.0 and CSS 1.0 (2.0). The architecture enables the personalisation of the graphical user interface as well as annotations and individual views.

Based on the model view controller paradigm, the architecture establishes a strict separation of presentation, business logic and data management by the use of XML and XSLT. The goal of MVC design is to separate the application object from the representation at the client-side and from the way in which the user controls it (Fig. 3). The architecture grants the following benefits:

- Re-use of model components: The separation of model and view allows multiple views using the same model.
- Enabling high design complexity
- Support for new types of clients
- Clarity of design
- Efficient modularity

Interaction facilities. The facilities of the ELIE environment have been decomposed into prominent areas that are relevant from a function and user perspective: The *learn space* has been designed as an easy-to-access content area to navigate within modules and to work within the learning units. It also comprises specific tools, such as a multimedia library, search features, and annotations. Using the annotation tool, users can individualise their content as well as mutually interact in a context-sensitive way - each content element might be directly linked to asynchronous or synchronous communication elements (chat, discussion forum entry etc.). Communication is supported by both synchronous and asynchronous tools. The chat forum and the Instant Messenger allow for synchronous communication within the platform, whereas the discussion forum and the information board support asynchronous communication. Both types of tools also enable users to collaborate for exchanging content or comments, and to form groups as they like. Finally, the office area is a set of personalisation features for each user. Users might create personal records, individual work spaces, and arrange their courses.

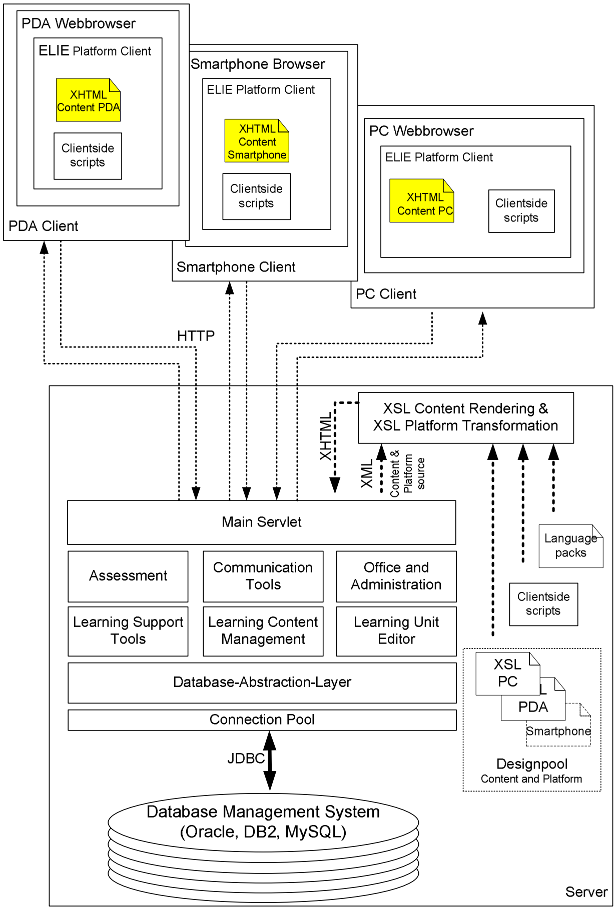

Fig. 3. ELIE Architecture for PC, PDA and Smartphone

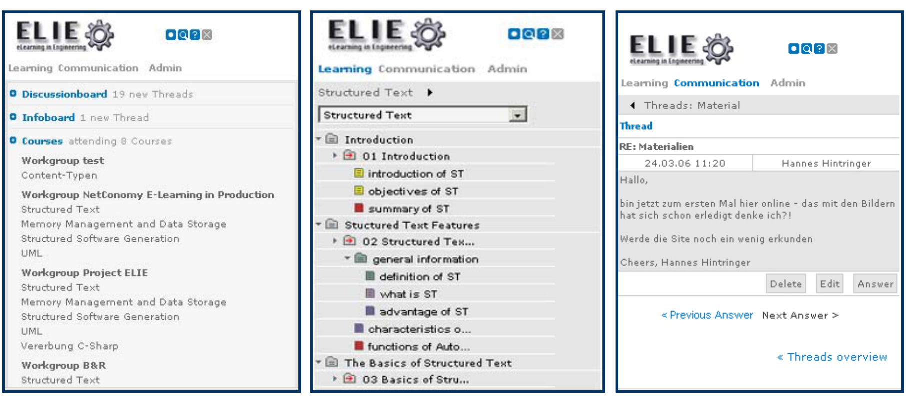

Fig. 4. ELIE PDA environment; left: startscreen; middle: content tree; right: discussions

The annotation tool enables the individual design of content and the learn space in the course of knowledge acquisition within a module. Learners can choose from a variety of functions: Individualization of textual content elements; Navigation within a module; Formatting and marking of text. Typical examples for individualisation are textual note taking, multimedia attachments, links to internal or external sources of information, underlining/ coloring of text, and direct links to entries in the discussion forum. In the platform annotations are stored in views that can not only be cascaded, but also transferred to other users (including coaches) or used as shared memories in work groups. The content figures display typical learning situations, both, at level of detail 1 and 2. All annotations are stored to user-individual views.

All main interaction spaces for knowledge transfer (content area with annotations, communications area and office area) are available for type of device (PC, PDA and Smartphone), taking into account the limited availability of space for displaying information and its manipulation, and the functionalities provided by various current vendors. The example in the figure shows content navigation using the PDA version. Further information on the PDA version can be found at [18].

5 Conclusions

Effective learning via mobile devices requires didactic preparation of content. Didactically typed elements and specific structures for multi-channel delivery on PC, PDA and Smartphone enable anywhere and anytime learning, information, navigation, and communication. The ELIE experiences in engineering have learners qualified in using novel forms of navigation and content-sensitive communication. Although high motivation and increased quality in knowledge transfer has been recognised so far, further empirical data have to be collected in a more systematic way.

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