

Content Production for E-Learning in Engineering

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Abstract—The didactic quality of learning materials can be improved by enriching learning material with didactic information. Such content elements assist self-directed learning processes in virtual learning environments effectively. In order to develop didactically motivated for flexible use, e.g., at different terminal devices such as PC or PDA, a structured procedure is required. We propose the selection and identification of didactically relevant information prior to enrichment of highly structured content with didactical information. It can be achieved by using the CoDEx method (Content Didactically Explicit), and a mapping scheme to the learning-technology standard conform XML content structures. Furthermore, aspects for multi-channel content delivery in the application field of engineering have to be taken into account. In this paper we refer to the objectives and results of the EU-funded ELIE project (E-Learning In Engineering) to demonstrate the proposed procedure's effectiveness for content engineering.

Index Terms— content engineering, e-learning, m-learning

I. INTRODUCTION

Recent approaches for self-directed and learner-centred knowledge transfer stress the importance of engineering-based approaches for content production [1], but neglect concepts to derive, specify or implement didactically relevant content elements beyond standards in e-learning environments. According to Dijkstra et al. content elements relevant for didactically sound knowledge transfer should be identified prior to the definition of Learning Objects (LOs), since the latter are considered *crucial for effective e-learning* [2]. They represent those entities e-learning environments should be built on from the content perspective [3, 4]. However, content development should not only result in structures that can be processed by technical means. As Schulmeister points out for *didactically motivated pieces of learning content*, so-called “didactic content types” such as definitions, examples, exercises, etc., they should become part of interactive components for effective learning support [5]. Farmer and Hughes [6] argue to that respect “there is a need to shift focus from the structural aspects of design towards holistic, socially-informed aspects for *effective design of learning objects* (..). Learning object design goes beyond the structural

and ontological representation of learning materials”. Consequently, the didactic value of the learning material has to be considered as a 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” [7].

Content engineering requires a structured procedure to succeed with material supportive for learners. As Kerres [8] and Euler [9] point out effective content production based on didactic knowledge has to go beyond structuring of content, complemented by Mirabella et al. [10]: “Most of the efforts for supporting 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 the learning material development”. Content development should allow instructional designers to apply different strategies for adapting content to individual learner needs, as learners have different *skill levels* and *learning styles* (Stamley and Saunders [11]). A key enabler is the *multiple and dynamic representation of knowledge*, since it enhances the requested flexibility of learning resources [4, 12, 13].

In this paper we introduce a structured procedure for content development, and demonstrate its effectiveness in terms of a socially-informed implementation. As showcase an engineering course at the University of Applied Sciences has been supplemented with e-learning components. The work has been performed within the ELIE (E-Learning In Engineering) project funded by the EU in the Interreg IIIc REGINS programme. The development of engineering content is particularly challenging due to continuous changes in technology and its intertwining with tools (enabling interactive learning experience). As a consequence, enhancing flexibility of learning resources requires proper update management in addition to multiple representations of content, and

typing content elements according to didactic guidelines.

In section II the procedure for content engineering is introduced. It is based on the CoDEX method comprising document analysis and reflective interviews. In this way didactically relevant information can be elicited from experts. In section III the enabling e-learning platform SCHOLION is sketched, in order to reveal the complexity of enabling technologies for socially-informed e-learning environments.

The ELIE environment is one instance of the platform among others (cf. www.mobilearn.at, eBuKolab.jku.at). In section IV we detail some lessons learnt in the ELIE project. Section V concludes the paper.

II. STRUCTURED CONTENT ENGINEERING

The procedure for structured content engineering comprises five major phases: preparation phase, initial document analysis, structured interview, in-depth document analysis and mark-up of content

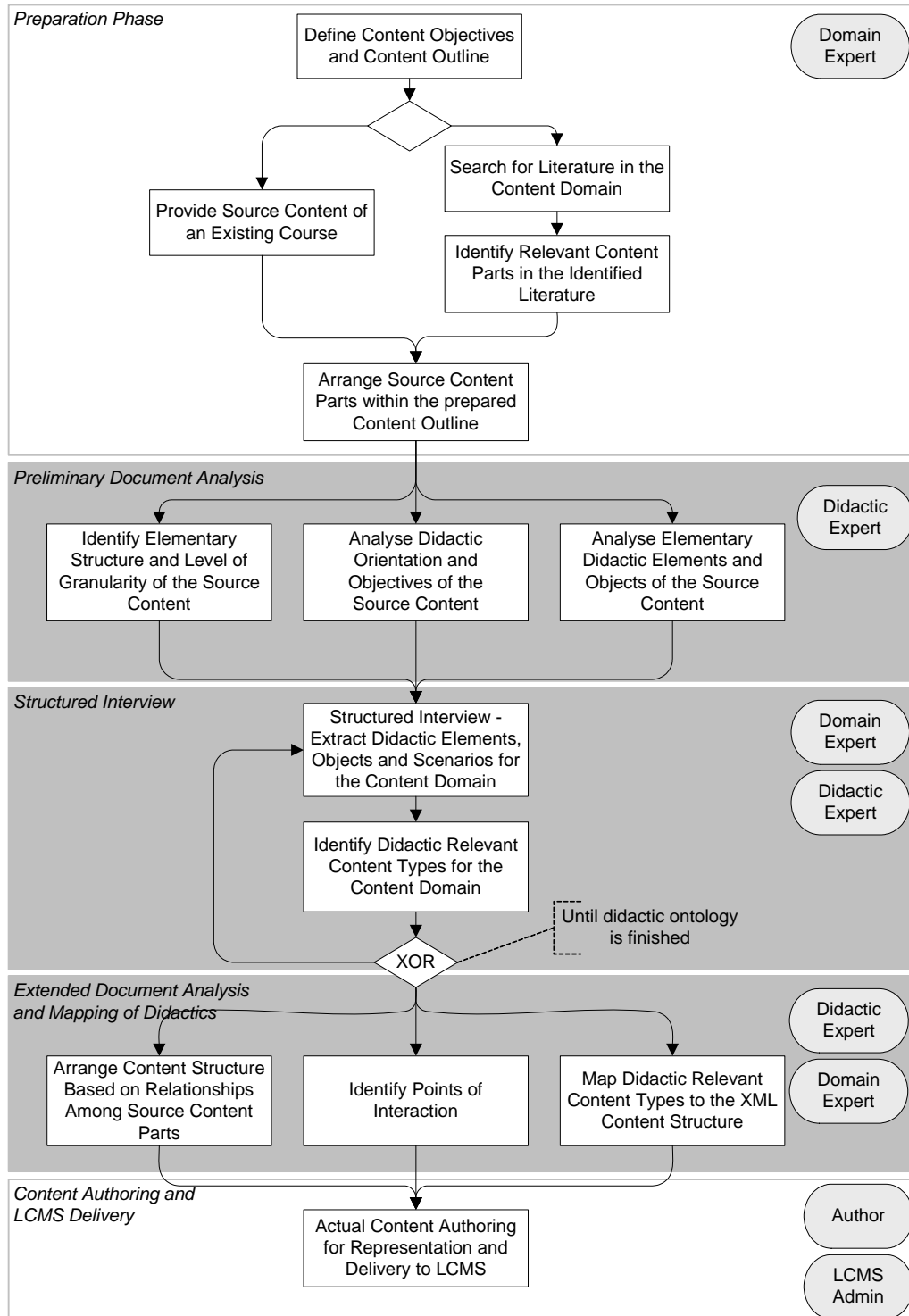


Figure 1. Content Engineering Procedure

with didactic information, 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, are traditionally involved in this multi-staged procedure (Figure 1). The procedure aims to identify didactic aspects of transferring content that can be mapped to information elements representing didactically enriched learning content. The three steps following the preparation phase have been termed as CoDEx (Content Didactically Explicit) method [14, 15].

III. PREPARATION PHASE

In the course of preparation the source material for content development has to be identified and selected for further processing. This task is traditionally performed by a teacher or coach in the role of a domain expert. Initially, the objectives and a content outline, including learning goals, target learner group, depth and granularity of content and similar fundamental data as well as keywords are identified. Secondly, the actual content resources are collected and reviewed for reuse. In most cases, existing material can be reused at least partially. Therefore, scripts, presentation slides, books, animations or scientific papers are collected in this phase. If these documents do not capture the subject sufficiently, additional material is reviewed and checked for inclusion. Finally, all relevant sources are integrated in a draft source document in a text processing format, such as HTML. It serves as reference document for further activities in the content development process.

IV. CODEX – REVEALING DIDACTIC INFORMATION

The CoDEx method has been developed to elicit and represent relevant didactic knowledge of domain experts for content engineering. It should enable the assignment of didactic information to content elements captured as mark ups transparent to learners (as described in section II.III).

Initial Analysis of Documents. In this step a didactic expert scans the sources of information to identify the level of granularity information can be presented, basic (encoded) didactic principles and content-related orientation and navigation. In addition, the potential for enriching content with didactic information is identified. These objectives are met by walkthroughs and inspections of all material.

Hereby, the level of granularity of the documents can be quite different: source material may range from presentation slides to well elaborated textbooks for self-studying, animated or interactive elements for self exploration. For instance, slides may offer information at a low level of granularity in contrast to textbooks. Depending on the envisioned use of the content and the intended learning scenarios, different levels of detail may be considered effective.

For each source material, the (envisioned) context of use should be captured. It helps to understand and develop transfer scenarios, such as the linear presentation of content elements due to the nature of a curriculum. Didactic objectives might also be inferred from the source content. They are required to tune the paradigm of transfer (behaviourist, cognitivist, constructivist transfer or any combination), its overall objectives, and the didactic elements to achieve the overall objectives.

The source content structure might already follow didactic principles and contain dedicated transfer elements, such as motivation, definitions, explanations, case studies, examples or theorems etc. Such elements should be separated from the others and revisited for integration, as soon as overall content structure for a course or a lecture has been established. At that stage the following information should be available: (i) the rationale for each document to reflect its inclusion into the final content; (ii) the conceptual relationships between the source elements; (iii) generic content types/elements/objects; (iv) (alternative) ways for navigation or patterns of navigation (stemming from source content). This information can be (re)presented by means of a semantic network. Such a representation is a valuable input to the structured interview with domain experts.

Reflective Interview. According to Flechsig [16] each didactic entity needs to be well reflected in terms of an in-depth analysis of target groups that can be addressed, the learning culture where it might fit into, its organisation, the learning program it is part of, the resources needed, the demands it can meet, the requirements to implement it, and the knowledge and competences it addresses. Most of these issues concern content engineering. Hence, they are part of the structured interview that should be performed with a coach or teaching domain expert. The interview is structured as follows:

Organisation. This part addresses organisational issues, such as structuring content, traditional learner profiles, and the organisation of the learning environment, as the partial list of items shows:

- How many coaches teach the content currently, and how many learners are involved in the transfer?
- Are there didactic or subject-related content parts that constitute modular structures or learning objects?
- How can the content structure and the didactic approach be described in terms of the type of knowledge transfer: normative, by variants, adaptable to situation context?
- Which of the following criteria should be met by transferring the knowledge addressed by

the content, and why: (i) high quality of the content; (ii) high productivity of the transfer itself; (iii) high degree of flexibility to capture a variety of transfer situations, in terms of scope and amount of information; (iv) intense transfer of skills; (v) intense transfer of concepts; (vi) reflection support of competence; (vii) high learner satisfaction; (viii) innovation in transfer?

- Which target groups can be addressed through content adaptation?
- What is the professional orientation of the learners (technical, business, language etc.)?
- Are there specific targets encoded into the content provided to the learners, such as introducing a novel field, deepening understanding, put existing knowledge in a global context?
- In which way is the content brought to the learners currently, ex-cathedra, in a self-directed way, via classical distance learning media?
- Can the learners be considered as a homogeneous or heterogeneous group with respect to previous experiences and knowledge, including participation in synchronised virtual learning sessions, interest in the subject matter, media-literacy and -acceptance?

Individual Approach to Transfer. This part should clarify the individual approach of content-providers or teaching authors to knowledge transfer.

- How much time does the coach actually spend on knowledge transfer activities?
- What are the basic didactic principles of the coach (e.g., less is more)?
- Which teaching techniques does the coach prefer?
- Depending on teaching techniques: What is the effect on the design of learning material: no effect at all, for teachers or learners individually, for both of them, for additional learning resources, for mobile scenarios, for content development etc.?

Knowledge transfer. This part deals with organisational activities during knowledge transfer activities and the representation of relevant learning material.

- In which of the phases is the coach active? In the course of
 - Preparation, e.g., selecting content elements, establishing didactic concepts, consulting learners
 - Implementation, e.g., classroom teaching, collecting feedback, checking quality
 - Assessment
 - Evaluation
 - Enhancement of learning material (based on evaluation results)
 - Improvement of didactics
 - Development of (web based) tools?
- Which didactically motivated content elements and objects are used to design learning material?

How are they encoded: in text, pictures, multimedia, drawings, content types such as examples, use cases, definitions, directives, or interactive elements?

- How can the structure of the learning material be described, as linear sequence, (hyper) linked, hypermedia, hierarchically structured, or hybrid?
- Is all the relevant content available in the learning material? If not, how shall learners receive missing information in a didactically relevant form, e.g., by self-directed search?
- How has the process of transferring knowledge being organised so far (as collective experience, task-specific scenario etc.)?
- How is the feedback of coaches delivered to learners, including the grading and examination results?

Communication. In this part the communication patterns among coaches and between coaches and learners in the context of knowledge transfer are revealed. Social interaction and social skills should become evident.

- How often are coaches in contact with other coaches in the course of knowledge transfer?
- How often are teachers in contact with learners in the course of knowledge transfer?
 - Are there special points of reference to social interaction that can be identified in the learning material, such as elements that always lead to discussions?
 - Are there specific content types which require interaction?
- Does the coach communicate with learners in a virtual setting, e.g., via e-mail?
 - How often are coaches in contact virtually with learner?
 - Which issues communicated virtually: appointments and other organisational issues, learning hints, additional information etc.?
 - Which tools are preferably used for communication or interaction: e-mail, discussion boards, chat etc.?
 - Who initiates virtual communication?
 - Who administrates and moderates communication and interaction?
 - What are the implications of virtual communication between coaches and learners: less face-to-face meetings, higher skill level, increased interactivity?
 - Are there specific content elements virtual communication facilities should be directly linked to?
 - Should the virtual communication be context-sensitive?

- Should it also be possible to link communication to content?

Technical support. In this part the current and future technical support of the knowledge transfer shall be clarified.

- Which kind of ICT-tools are used for knowledge transfer: content management systems, ERP-systems, office tools etc.?
- Is the world wide web used for particular purposes: download of material, increased availability of peers etc.?
- Are there any technical interfaces between two or more tools (for data interchange) to support the knowledge transfer process?
- How could web-based learning concepts be effectively applied for knowledge transfer: individual profiling to trigger navigation, highlighting information in views on content etc.?

Overall, the structured interview should lead to explicit information about individual, organisational and technical aspects of the knowledge transfer process the interviewed person is involved in. In the core part of the interview, didactically motivated elements such as dedicated content types, interactive elements etc. should be elicited. Depending on the level of competence of the interview partner these content elements and their relations can be tuned with the content elements identified in the course of the initial document analysis. This activity does not relate to domain-specific structuring of content.

IV.1 MARK UP OF CONTENT

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

Content Structuring. The content structure we have developed in various e-learning projects enables content delivery at different user devices, namely PC, PDA, and Smartphone – cf. mobiLearn (www.mobilearn.at), and the eBuKoLab (www.jku.at/ebukolab). The overall content structure is described in Figure 2.

Levels of Detail. They are of crucial importance for content delivery for different devices or purposes. The LOD (Level Of Detail) concept allows content developers to produce material on three different levels of granularity. Consequently learners are able 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 on LOD1, a text book structured according to block types on LOD2, and additional information or further material (links, files in pdf, videos and the like) at LOD3. On LOD1 learners might retrieve essential information at a glance with minimal effort in navigation. In combination with a 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.

The learn space as shown in **Error! Reference source not found.** provides all features required for self-directed learning.

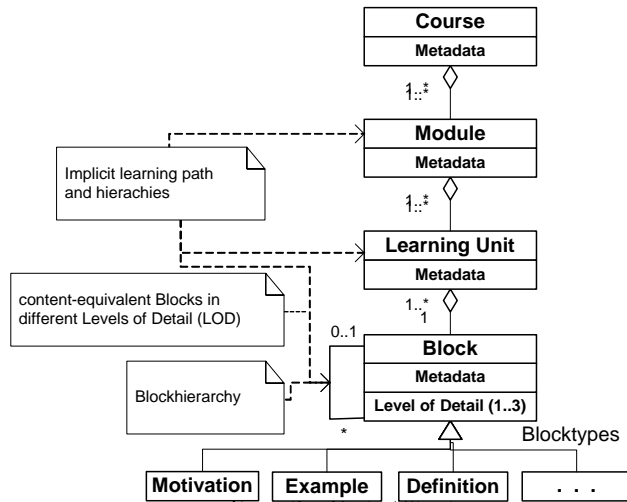


Figure 2. Content Structure

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, among them definition, motivation, background, directive, example, self test and other generic didactically relevant content structures. Additionally, some domain specific block types, such as source code, interaction etc. have been defined for the field of engineering in the course of the ELIE project.

Mapping Didactic Information to Content. So far, the block types and the content structure has been analysed in the course of document scanning and the structured interview. At this point, the source content is transformed to didactically relevant content, jointly by the didactic expert and the domain expert. In the ELIE project, the source contents were prepared in MS Microsoft-Word documents and the structures (learning units and blocks) as well as the block types were integrated into the reference document as comments and highlighted content elements. Furthermore, interactive elements and adequate interactive discussion issues were inserted at identified reference points for interaction into source content. In this way prepared documents become prerequisites for the actual content authoring and delivery to an e-learning environment, such as the ELIE system.

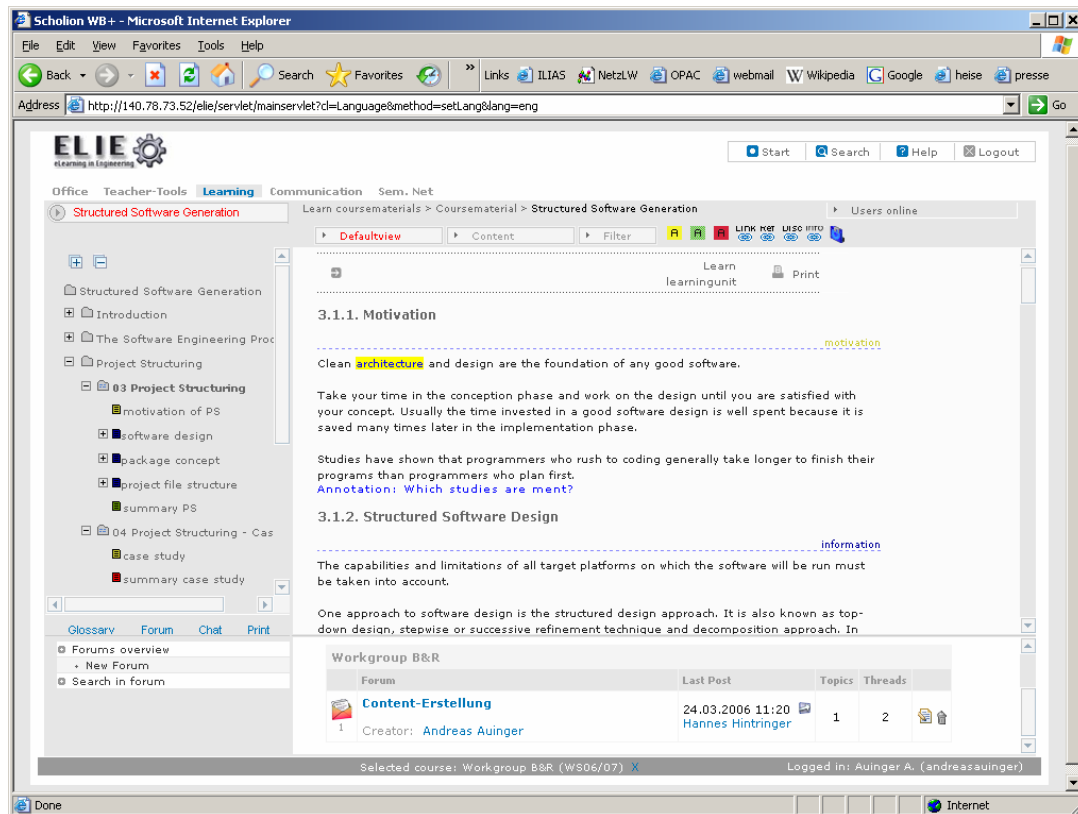


Figure 3. Delivered content at the ELIE platform in LOD 2

V. CONTENT AUTHORIZING AND DELIVERY

The content authoring was performed with a web-based XML Content Editor for the ELIE learning environment. The platform is one of the instances of the SCHOLION platform (scholion.jku.at). It can be considered as a second generation educational environment, since it overcomes current limitations of distributed hypermedia environments for continuous user-centered teaching and active learning support and it provides multiple content delivery for PCs and PDAs. It also provides individualized facilities for knowledge producers and consumers, as well as a common information space for focused interaction. The target user groups which are supposed to use SCHOLION instances are knowledge consumers, as well as trainers, lecturers and knowledge providers from (business) schools and universities (knowledge producers). The benefits are: Knowledge consumers 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.

The ELIE *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 individualize 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 ELIE, 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. The office area is a set of personalization features for each user. Users might create personal records, individual work spaces, and arrange their courses.

The annotation tool allows 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 individualization 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 environment annotations are stored in views that can not only be cascaded, but also transferred to other users (including the teacher) 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.

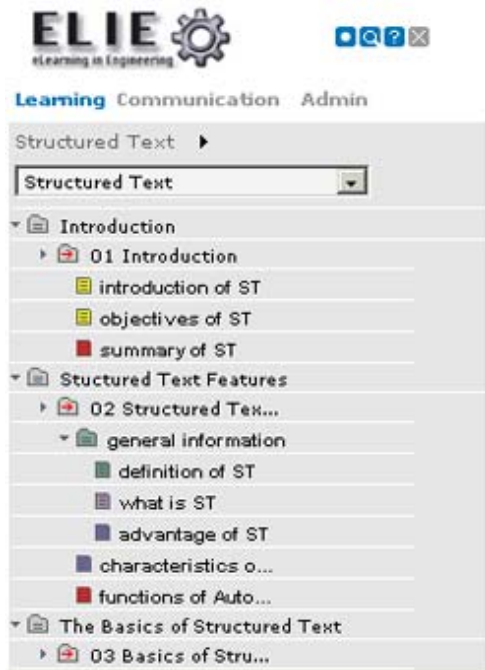


Figure 4. Content Navigation at the PDA Platform

All three main interaction spaces for knowledge transfer (content area with annotations, communications area and office area) have been prepared for web and to mobile device access, taking into account the limited availability of space for displaying information and its manipulation, and the functionalities provided by various current vendors [17]. The example in the figure shows content navigation at the PDA version.

VI. EXPERIENCES

This section reflects four scenarios of producing content for ELIE. The scenarios involve content in the fields of object-oriented modelling with UML, object-oriented programming, electro-technical basics and programming of automation software.

One scenario involved an introductory IT course for part-time students of the university. For this scenario, contents about UML (Unified Modeling Language) class models were based on a popular textbook and subsequently engineered according to the procedure described. Despite the high standard of the text, a number of changes and additions were required to provide a consistent structure of didactic elements. In addition, the LOD1 text had to be written from scratch. From the lecturer point of view, these aspects improved the presentation and allowed more flexibility for students, in particular for those with different background knowledge. The students were required to study the material and do the exercises before the end of the semester. They passed the exam on the material without additional

instruction. The students said they appreciated the detailed presentation on LOD2.

Sticking to the goal of reusing modules, the same material was used in combination with new modules on c# programming and other UML models for full-time engineering students. This scenario was implemented on a different LCMS (moodle). Some changes were required to the text as this LCMS does not support didactic elements. The students were asked to look at the content over the period of 10 days to get more information about topics as presented in lectures. When asked, all of these students fed back that if additional modules were provided they were likely to use the modules, even on a voluntary basis, but were not likely to look at the book (i.e. source contents without didactic annotation). They reported that the didactic elements (e.g., definitions and explanations) allowed them to find the information they required. This is also supported by the fact that students often did the self tests before they read the explanations. Based on this, further modules based on this didactic model are planned.

The second scenario involved a module on inheritance in c# programming, which was used with the UML materials described above. The content was taken from an existing script written by one of the teachers, which is available to students via the internet. The structure of the text was slightly adapted to the structure of didactic elements developed with the didactic expert. Only a few changes were required for the LOD2 text, such as adding motivation elements. Both the teacher and students appreciated the new structure. Based on the experiences, the content of the c# course will be modified using didactic elements. The third scenario involved an electrical engineering course. The content elements were taken from a script developed by the teacher. A new structure was developed jointly by the didactic expert and the teacher. The conversion to this structure proved to be very time consuming. Since it cannot be accomplished by persons not familiar with the domain, it is still under construction.

The final scenario involved programming of automation software developed by the company that developed the software. Three modules were developed based on an already highly structured material. Therefore the content engineering process was quite straightforward and less time consuming compared to all other scenarios. Subsequently, the materials were tested internally using 3 different teaching techniques. The feedback from learners was very positive. We intend to use the modules in training sessions for customers of the software. The larger the complexity of the material presented, the larger the perceived benefits.

VII. CONCLUSIONS

As self-directed learning requires specific didactic preparation of learning material, we have proposed to enrich learning material with didactically typed elements. On one hand, the categorization of content is driven by learning styles, on the other hand by domain-specific structures. In addition, content should be delivered anywhere. Information, navigation, and communication has then be available on a variety of devices, among them web-accessible PCs and PDAs. A particular transformation scheme ensures the quality of interaction and collaboration. Didactic quality requires the elicitation of teaching experience and domain structures. To that respect the CoDEX method (Content Didactically Explicit) has been applied successfully in several fields. The resulting solution has been tested in the EU-funded ELIE project (E-Learning In Engineering). It did not only provide insights into the content engineering process for newcomers to didactic-driven e-learning, but also for learners who are now willing to switch to this new form of knowledge transfer. In this way, not only the content providers can profit from new developments (the produced content can be re-used due to the didactic elements in XML format), but also students since they can keep track of their knowledge development, even in terms of the associated communication that is linked to the different types of knowledge.

REFERENCES

- [1] Vrasidas, CH. (2003); Glass, G.V.: Distance Education and Distributed Learning. Information Age Publishing. Eurospan. London
- [2] Dijkstra, S.; Jonassen, D.; Sembill, D. (eds.) (2001): Multimedia Learning: Results and Perspectives. Lang. Frankfurt, Berlin, Bern, Brussels, New York, Oxford, Vienna
- [3] Schlupe, S. (2005): Modularization and Structured Markup for web-based Learning Content in an Academic Environment. Shaker, Aachen 2005.
- [4] Taylor, J, Slay, J and Kurzel, F (2006): Learning Object Applications & Future Directions. Chapter accepted in Learning Objects, Informing Science Press (in press)
- [5] Schulmeister, R. (2003): Lernplattformen für das virtuelle Lernen. Evaluation und Didaktik. Oldenbourg. München
- [6] Farmer, R. A., Hughes, B. (2005) : A Situated Learning Perspective on Learning Object Design. In: Proceedings of ICALT05, IEEE
- [7] Leidig, T. (2001): L3 – Towards an Open Learning Environment. ACM Journal of Educational Resources in Computing, Vol. 1 (1) Article No. 5
- [8] Kerres, M. de Witt, C, Stratmann, J. (2003): E-Learning. Didaktische Konzepte für erfolgreiches Lernen. In: Schwuchow, K.-H., Guttman, J.: Jahrbuch Personalentwicklung & Weiterbildung 2003. Luchterhand
- [9] Euler, D.(1992): Didaktik des computerunterstützten Lernens : Praktische Gestaltung und theoretische Grundlagen. (Hrsg. Band 3: Holz, H.; Zimmer, G.) BW Bildung und Wissen. Verlag und Software. Nürnberg.
- [10] Mirabella & Kimani & Catarci (2004): A No-Frills Approach for Accessible Web-Based Learning Material. Conference Proceedings of the WWW2004, New York

- [11] Stanley, J.W., Saunders, B.T. (2005): Designing Intelligent Learning Objects. In: Proceedings of ICALT05, IEEE
- [12] Kurzel, F., Slay, J. (2003): The Development of a Personalised Learning Environment. 4th International Conference on Information Communication Technologies in Education. Samos Greece 3-5 July. 2003
- [13] Kurzel, F., Slay, J. (2002). The Adaptive use of Hypermedia Learning Objects. E-Learn 2002 Montreal, Canada, October 15-19, 2002.
- [14] Auinger, A., Stary, C. (2005a): Didaktikgeleiteter Wissenstransfer. Interaktive Informationsräume für Lern-Gemeinschaften im Web. Deutscher Universitätsverlag, Wiesbaden
- [15] Auinger, A.; Stary, C. (2005b): Effektive Content-Produktion für selbstgesteuerten, polymorphen Wissenstransfer. In: O.K. Ferstl, E.J. Sinz, S. Eckert, T. Isselhorst: Wirtschaftsinformatik 2005 – eEconomy – eGovernment – eSociety. Tagungsband zur 7. internationalen Tagung Wirtschaftsinformatik 2005, GI, Physica-Verlag, Bamberg
- [16] Flechsig, K.-H. (1996): Kleines Handbuch didaktischer Modelle. Neuland, Eichenzell
- [17] Stary, C., Auinger, A.: Navigation Design for Mobile Access to Knowledge-Transfer Platforms. In: Salvendy, G. (eds): Human Computer International 2005; 11th International Conference on Human-Computer Interaction; Lawrence Erlbaum Associates, Las Vegas 2005

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