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KNOWLEDGE STRUCTURES AND PROCESSES: TEACHING AND LEARNING IN THE CONTEXT OF "PRODUCT INNOVATION"

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Abstract

The paper deals with the need of investing on an integrated process from content production to content exploration by the learners. The specific approach for this issue of the Center of Product Design is presented. It encompasses the structuring, delivery, and management of learning content. Moreover the need of facilitating the user-interaction within a learning environment is touched to guarantee the effective exploration of the learning content by the user in accordance with an appropriate pedagogical model. The application of an Integrated Learning System (ILS), the results with respect to the structuring of content and the development of a Learning Content Management System (LCMS) are explained . The paper also discusses the need of an appropriate user-interaction model and the capture of informal (implicit) knowledge generated in the interaction process.

Keywords*: Integrated Learning Systems (ILS), e-Learning, Knowledge Structures & Processes, Content Structuring, User-Interaction, XML, Learning Content Management Systems (LCMS), Learning Management Systems (LMS), Navigation, Socio-Constructivism.*

1. Introduction

The printed book still is one of the most important publishing media for information and knowledge. The structure of a book is fairly simple: the table of contents defines a certain sequence of information or knowledge units and, together with the indices, it facilitates the reader's navigation through the content. Books have been important media for storing knowledge and thus valuable learning resources. Their publication processes are well established and include collaborative work developed by authors and editors, guaranteeing high quality standards.

Knowledge structures and processes in IT-systems are somehow comparable with the ones in the world of printing, the Gutenberg Galaxy. However, the situation changes in at least two dimensions:

- The publishing process in IT-Systems is more flexible and faster. A mouse-click in a professional editor-software publishes the content in any chosen format. This flexibility invites the user of such systems to skip processes of validation and reviewing.
- The probably most important features or elements of hypermedia publications are hyperlinks which allow to load documents instantly into the web-browser. Instead of going to the library and searching for books a person can have the required documents loaded into his or her personal computer shortly after a mouse-click.

Today, with the help of information technology learning content is being offered to students online. Authoring Tools (AT), Learning Content Management Systems (LCMS) and Learning

Management Systems (LMS) effectively support structuring and processing of online courses starting from the first draft versions on to the reviewed and published courses. However, in order to guarantee effective learning results, an overall structure which generates an integrated process from content production to content exploration by the learners has to be developed and settled up.

This paper discusses how the Centre of Product Design (CPD) deals with this issue. The first section presents the overall architecture of an Integrated Learning System (ILS). Next, the implementation of a Learning Content Management System (LCMS), which defines the structuring of all learning contents and allows the metadata tagging of Reusable Learning Objects (RLOs) on different levels from elements such as pictures or drawings to whole documents is discussed. Major concepts of a research program on user-interaction in the near future are also presented. It is argued that an effective interaction with the learning content via pedagogically appropriate learning activities and tools, together with a suitable navigational model is paramount to generate learning.

2. Integrated Learning Systems (ILS)

Institutes that provide their students with online resources tend to use a learning management system (LMS). The typical functionalities of an LMS include the presentation of structured course content (courses), user administration tools, and communication tools such as blackboards for threaded discussions and chat rooms.

With every course offered via an LMS, one has to deal with a large number of files in various formats (as there are with all web-based information systems) – text files, images, animations, videos, presentations, etc, mainly in the original form of the author or the derivates for the LMS. These files have to be maintained. However, the amount of resources needed to edit and maintain these files – i.e. to ensure that they are orthographically and grammatically correct and that their content remains appropriate – increases exponentially with the increase of publication media and elements used. For example, if a part in a technical drawing needs to be corrected, it has to be re-inserted into all compound documents (e.g. Word documents, PowerPoint presentations). Often the layout also has to be redone before PDFs and HTML (web) pages can be re-created.

Once all the corrections have been made, the various publication formats have to be re-entered into the LMS. These processes are extremely time-consuming – and also tedious for those working on them. Institutes that have recently begun to produce online courses and services related to web-based learning are now feeling the need for a content management system so called learning content management system (LCMS) in-between the authoring System and the learning system [1].

Learning systems consist, basically, of three subsystems, authoring tools, a learning content management system (LCMS), and a learning management system LMS). In this ideal-typical representation of functional subsystems of a learning system the LCMS is placed in the system architecture between the authoring tools, which are used by authors to produce content, and the LMS or other output systems (e.g. MS PowerPoint, printers, etc.). However, if one were to select a subsystem from a real system architecture, one would likely find that certain LCMS functions are covered by the LMS or in some cases even by the authoring tools. The boundary between the LCMS and the LMS is in fact fluid, and if one were to randomly select an LCMS and an LMS, one would find that some of their functions overlap while others are absent. In the functional area of learning content management certain standards have been established. Two types of standards can be identified: metadata standards and structure de-

scription languages in SGML (Standard Generalized Markup Language) or XML (Extended Markup Language).

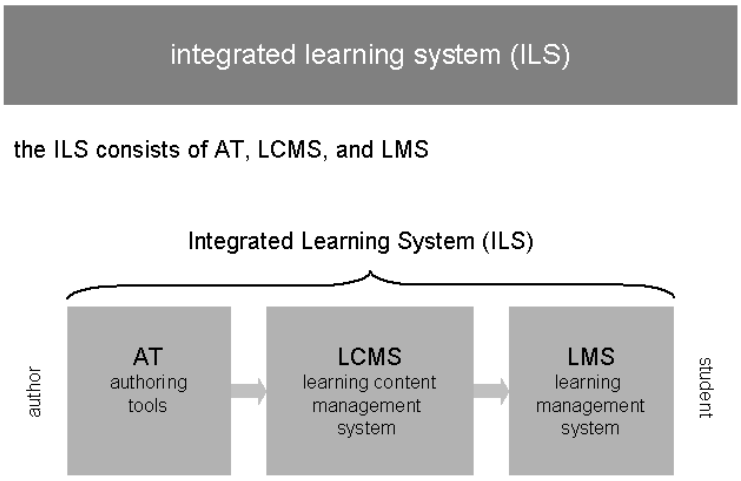

Figure 1: Building blocks of an integrated learning system

A LCMS is focused purely on managing and delivering the appropriate e-learning content. It provides an infrastructure for rapid input, modification and management to meet the needs of changing education requirements. Learning content management is the process of coordinating and managing the flow of information and knowledge related to learning content development. Ideally a LCMS closes the gap between information and learning by storing information in a wide variety of original formats. The main objectives are to facilitate modularizing, elaborating upon, sharing, re-using, managing and presenting the information in the context of educational units like online courses, an online reference library, presentations or other forms of educational utilization. Therefore it is not a surprise that LCMS's are very often tightly integrated with a Learning Management System (LMS).

A Learning Content Management System should therefore include the following functionalities:

- Interfaces to content creation tools, application interfaces to third-party content creation tools, and templates that separate content from layout and allow content to be deployed in different formats.
- Capabilities for meta-tagging content to support cataloging, intelligent retrieval, dynamic personalization, and ongoing maintenance and management of content in a repository.
- Management of the life cycle: work-group development and collaboration, process automation of content development (distributed authoring, project management, review processes).
- Multi-channel delivery of content to e-Learning application platforms, printed media or electronic media like CD-ROM. In the near future even the access of Learning Objects from wireless handheld devices (tablet PC's or PDA's) might be desirable.
- The LCMS must provide as a central feature many siltaneous user roles. It ensures that all contributing users have access to or may work with the latest version of the infor-

mation or content. A record locking is essential to prevent clashing changes from simultaneous users.

- Archives of older versions of content must be managed for a possible roll-back. It also should maintains date / time stamped history (audit trail) of content changes.

Together, the authoring tools, the LCMS and the LMS make out an Integrated Learning System or ILS (see Figure 1).

In autumn 2000 the CPD started the development of an integrated learning system, very similar to the system layout shown in figure 1. The initial procedure for the production of content basically used standard tools like MS Word and MS Powerpoint including export filters for the generation of html-files. As a standard LMS the widely used software WebCT was chosen, which guaranteed a fast implementation of contents and a very stable environment for accessing content and other material. In 2001 the CPD began the development of a Learning Content Management System (LCMS) on the base of an Product Data Management System (PDM) – the Cora-LCMS.

3. Implementation of the Learning Content Management System

The development of the Cora-LCMS was initiated as a further important building block of the learning system. This, however, implies the switch to another authoring tool, namely to Adobe FrameMaker. This is necessary to realize the concept of content structuring. For the provision of a content management functionality (change management, version management, database for metadata) professional systems like Axalant in connected with an Oracle database have been selected. Moreover specific macros have been developed to facilitate repetitive tasks related to export or manipulation of data during the editing process. The overall framework of the LCMS is shown in figure 2.

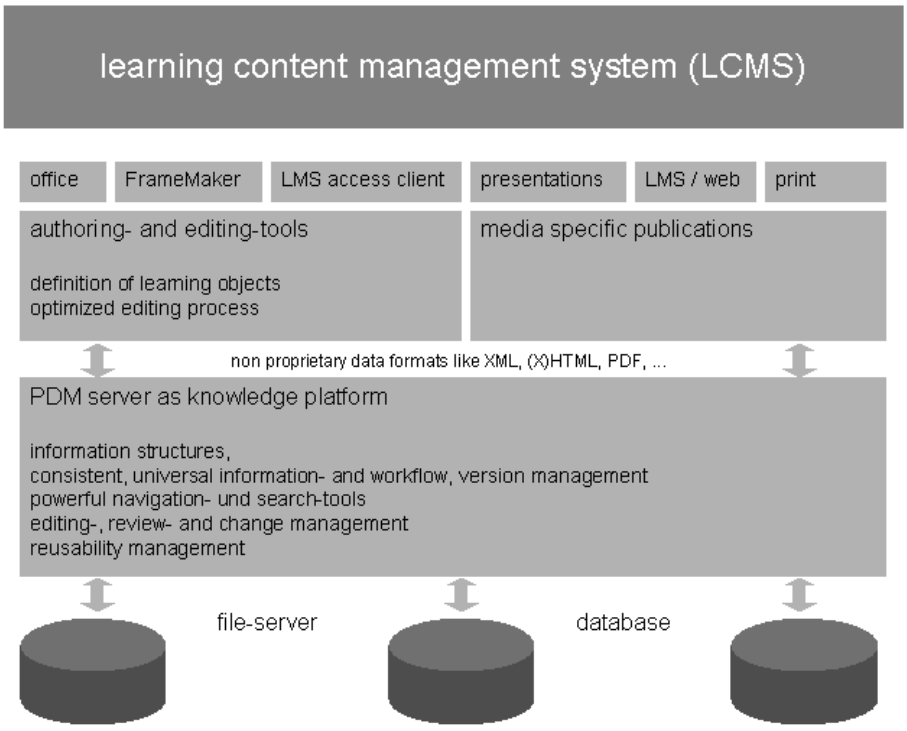

Figure 2: Overall system framework of the integrated learning system developed by CPD

3.1 Structuring of knowledge elements

One of the key responsibilities of higher education (universities), simultaneous to the obligation for doing research, is teaching with the objective of achieving a successful learning process. In the process to achieve this objective, teaching staff produce various types of teaching material, such as lecture notes, study guides, handouts, presentations, case studies, etc.

The level of complexity of teaching material (structure and form) varies due to the specific learning needs and background (knowledge) of the learners:

- undergraduate students need to get a first insight into a knowledge domain,
- graduate students need a deeper view into the knowledge domain with a certain degree of specialization,
- practitioners from industry need the access to a knowledge database for information retrieval.

Therefore, the structure of the learning content provided by an LCMS has to meet several requirements with respect to depth in content, structure and diversity of media channels and must also consider various learning situations (e.g. self learning, lecture, preparation for exams).

The analysis of existing learning content with respect to structure leads to the following conclusions:

- Content should be formulated and structured as unambiguously for later utilization.
- Content should be stored in a non-proprietary data format.
- Pure content and layout should be defined, described and stored separately.

Several institutions are currently working on concepts, which finally will lead to the required tools. For example the LMML (Learning Material Markup Language) of the Institute for Information Systems and Software Engineering (IFIS) at the University of Passau [3] is an XML-based description language for learning content.

DocBook is a standard DTD (Document Type Definition) [4]. It provides mark-up tags for technical manuals and document collections. It is available in SGML and XML versions. DocBook was initially developed for document collections (books and specialist articles) on computer hardware and software. However, the structure of a document collection can also be applied to learning content. Of course, the tried-and-true conventional way of structuring of knowledge used for books is also adopted. The newest version of DocBook supports the Dublin Core Standard Version 1.0.

As an alternative to these solutions, the CORA DTD has been developed by the Centre of Product Design at ETH Zürich. on one hand it was created on the basis of existing content. The content typically consists of formulas, illustrations, and videos in the thematic field of mechanical engineering. On the other hand it was developed in anticipation of the future use for flexibly configurable industry courses. The DTD is written in XML, and it operates with Adobe FrameMaker 7.0.

The CORA concept was created and applied for the learning content for the subject “product innovation” [18, 21, 23]. This knowledge domain involves processes, methods and tools in product design, engineering, machine elements, structural analysis, manufacturing technology, materials, and so on.

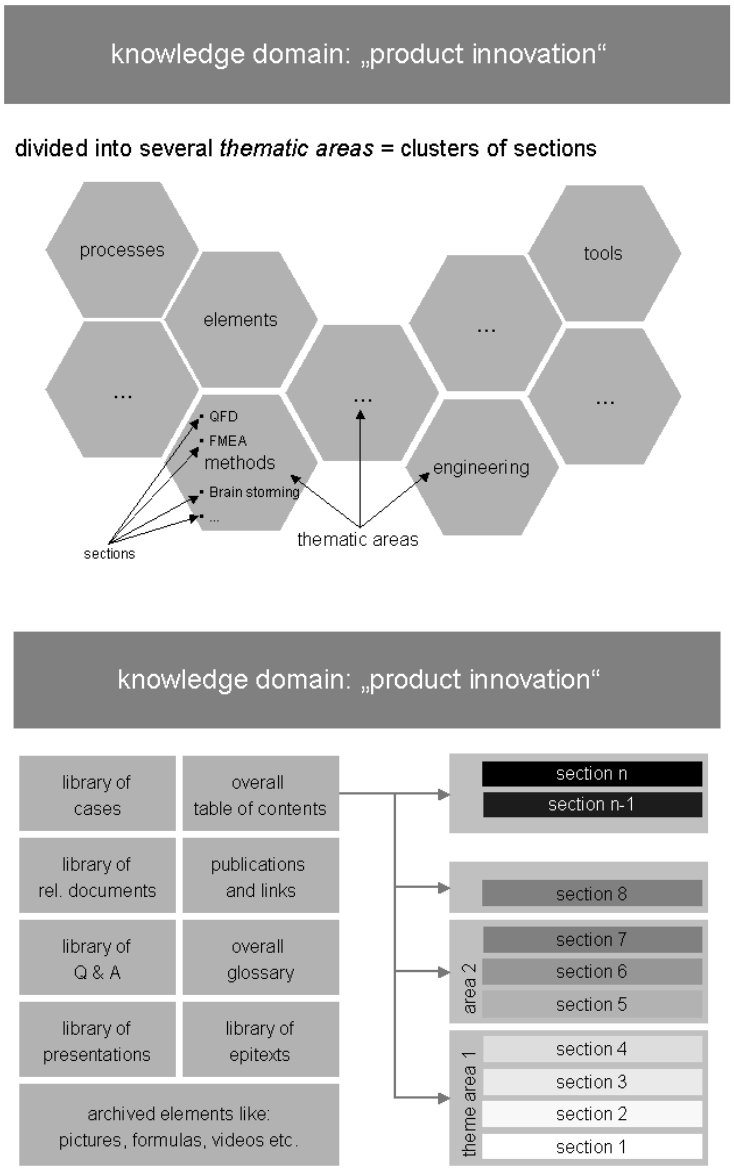

Figure 3: Learning content structuring in Cora: domain, thematic areas, sections, recombination of sections [22]

The knowledge domain is structured in several hierarchic levels. The top structure level in the CORA concept represents thematic areas, the first sub-level contains sections (see Figure 3).

The section itself also has an internal structure with the following elements:

- an introduction,
- several chapters with the main content (structured in main chapters, chapters and sub-chapters),
- a summary,
- a list of publications and links.

Each section contains didactic elements such as learning targets, a relevant motivation case, questions for immediate reflection and several case studies taken from industry (see Figure 4).

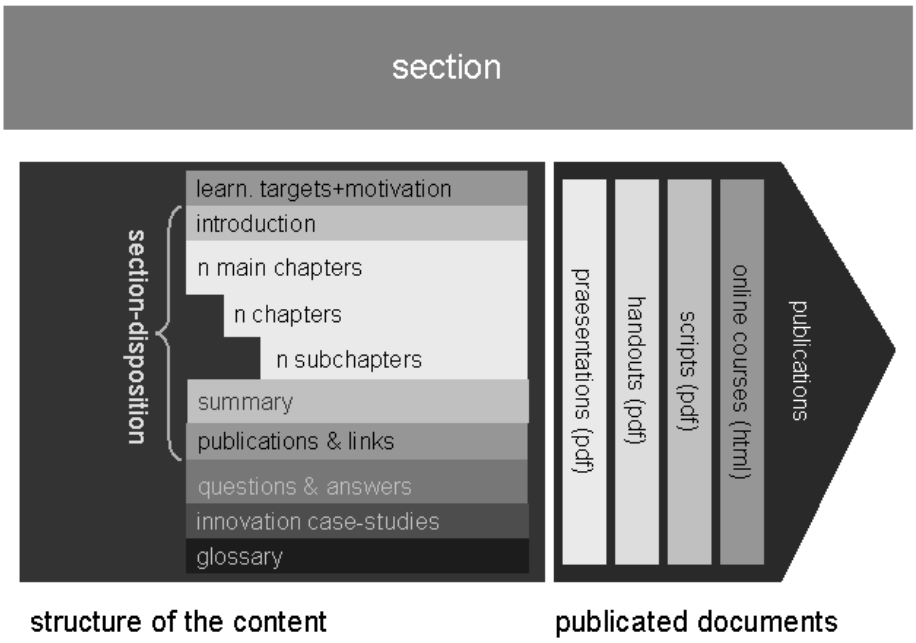

Figure 4: Reference structure of a section in Product Innovation [21,22,23]

In the CORA DTD learning content components are added to a chapter structure. The knowledge depth corresponds to the chapter level. Thus administrators can compile and publish specific courses with different knowledge levels. A certain group of students might then receive all main chapters but not the chapters and subchapters.

Currently, the limitations of the CORA DTD are that not all data format is XML yet, especially:

- it does not define the content of presentations, and
- it describes all other Office documents as one package without any internal structure.

In any case, the CORA DTD can be transferred to other domains of knowledge, as it is based, like the DocBook DTD, on the structures of (technical) document collections and books.

3.2 International Metadata Standards

Some of the most important metadata standards for learning content and content components [5–16] are:

- the Advanced Distributed Learning (ADL) Network with its Sharable Courseware Object Reference Model (SCORM),
- the Alliance of Remote Instructional Authoring and Distribution Networks for Europe (ARIADNE),
- the Dublin Core Metadata Initiative,
- the Gateway to Educational Materials,
- the PROmoting Multimedia Access to Education and Training in European Society (PROMETEUS),
- the IMS Global Learning Consortium,
- the Learning Technology Standards Committee (LTSC) of the IEEE,
- the Learning Object Metadata Working Group of the LTSC or
- the Aviation Industry CBT Committee (AICC).

Of these standards the Dublin Core seems to be the most straightforward, and SCORM seems to be the most promising, because it results from some of the most important standardization projects and thus represents a sort of meta-standard. Metadata standards make particularly good sense when an institute is working with the concept of reusable learning objects. If an institute decides to engage in the resource-intensive task of designing and writing RLOs and of entering these into an LCMS, then these RLOs need to be retrievable – both by the institute itself and by other institutes. Metadata guarantee not only the reusability of learning content but also the basic usability of RLOs [17].

4. User-Interaction

So far, the focus of the work of the CPD has been on providing the students with well structured knowledge or learning content. This knowledge is validated by the authors and is referred to as "formal knowledge". However, we are conscious that the knowledge which is generated via the user interaction (see Figure 5) with the learning content is also very important. We call this type of knowledge "informal knowledge", as it does not go through a formal process of validation. In this section, we discuss how to promote an effective user-interaction with the learning content, which generates and allows the capturing and integration of informal knowledge.

A good learning content is as good as the way the learner is able to make use of it. It is very important to provide high quality learning content, which is well structured, reliable and reusable. But to allow learners to make effective use of this learning content and learn from it should be the ultimate goal. Therefore, the way the learner interacts with the learning content and with the learning environment as a whole has significant importance. Thus, the learning content needs to be accessed via a coherent navigational approach, within a coherent user-interaction model.

The user-interaction model allows the description of the visual appearance of the system, including user interface elements, information shapes and organisation. The user-interaction model will guide the design of the environment, determining:

- the organization of the content presentation;
- the character of the different parts within the learning environment;
- the hierarchy of information;
- the forms of navigation through the environment.

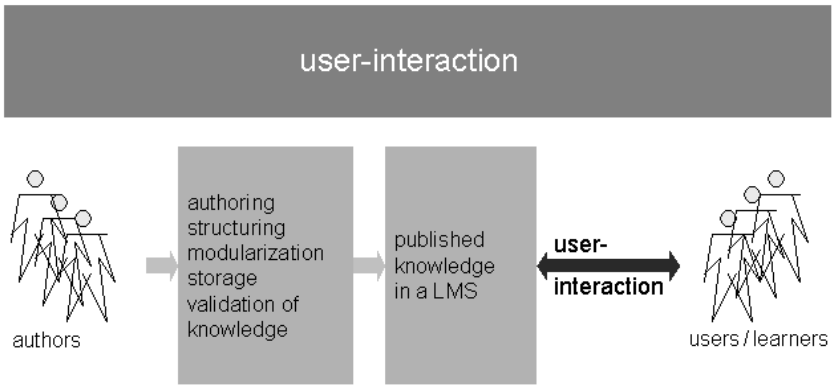

Figure 5: User-interaction

An online learning environment can be imagined as a physical environment, in which users walk through, finding and interacting with learning content in the form of objects. Within this context, the user-interaction model adopted will determine the quality of the users' experience in this environment, the way the various 'spaces' are organised, how they are accessed and by whom. According to the users' needs there can be private and public spaces, for example. The "navigation", in its turn, is the process of walking through the different spaces, via different routes, looking for different ways of interacting with the learning content.

The organisation of these 'spaces', as mentioned on the cited metaphor, will be determined by:

- the "organisation" of the learning content – its qualities regarding its size or "granularity", "type of information it brings", and its "connectivity" to other pieces of information or "relational attributes";
- the possible "paths" available or which can be generated by the learner;
- the learning activities which are available to the learner and provide guidance during the learning process.

A lot about the organisation of content has already been said in section 3.1 of this paper. However, the importance of relational attributes for the definition of navigation processes has to be emphasized. A good example is shown by the structure proposed for the 'product innovation' material, shown in Figures 3 and 4.

Very important in the determination of a coherent interaction model within a learning environment is a sound pedagogical approach. We opted for a "socio-constructivist" pedagogical approach for being in line with the most recent developments in educational research and for its applicability into networked learning environments [19]. Within this approach, the proposed interaction model should favour not just learner-oriented processes, but also collaborative learning. It is important to provide the learner with a choice of learning processes, via which she/he is able to interact with the content in a manner that is more adequate to her/his learning preferences and needs. Moreover, learning activities that can be developed by the learner alone and in collaboration with other learners should be provided, allowing for the development of individual and social cognition [19], [20].

The navigation in a learning environment should, therefore, be structured in different levels. One top navigational level should define the main areas of the environment and provide spaces where students can explore different types of learning (e.g. problem-solving, collaboration, reflection.), via the use of different tools and activities. General tools for exploration of the whole environment should also be available.

In e-learning, where the focus is more on the learning process than on teaching, a learner-tailored exploration of the content should be allowed, in a level where the user can choose among possible learning paths (see Figure 4). Therefore, embedded in the forms of navigation, there should be options to facilitate the access of the content according to learners' preferences, such as the following:

- There are learners that prefer having an overview of a sequence of information, before choosing to go deeper into a specific part of the content. These users would be able to choose to see all the "overview" parts of a series of learning content "sections", for example, those that contain the overall "learning targets", the "motivation" part and the "introduction" to the section. Options could be: 'see all overviews' or 'see all summaries' or 'see all Q&A exercises', 'see all images'.
- Other learners are more visually oriented and they should have the option of browsing all the images of a learning theme, looking at "elements" pictures such as diagrams, and simulations, for example ("elements").

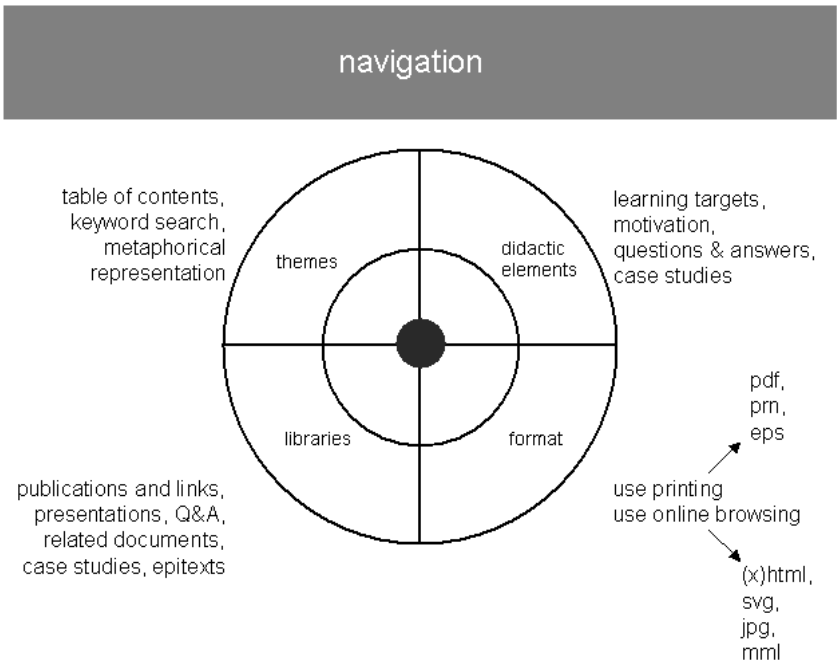

Figure 4: content navigation areas

5. Summary and conclusions

Several changes occurred in teaching and learning, due to the application of information technology (IT). The use of IT in education poses new questions which need to be answered, in order to guarantee the quality of the learning process. Paramount is the use of an integrated solution.

This paper focuses on the need an integrated process from content production to content exploration by the learners. These issues encompass the structuring, delivery, and management of learning content, together with the need for developing a user-interaction within a learning environment, which guarantees the effective exploration of the learning content by the user, according to an appropriate pedagogical model.

The use of an Integrated Learning System (ILS) is an important step towards the achievement of the desired integration of processes. The overall architecture of a ILS and as well the implementation of a Learning Content Management System (LCMS) have been discussed. The proposed LCMS defines the structuring of all learning contents and allows the metadata tagging of Reusable Learning Objects (RLOs) on different levels from elements such as pictures or drawings to whole documents. This guarantees the efficient organisation of content, which is easily separated from presentation, favouring reusability and flexibility of use.

Regarding the use of the content by learners, other aspects need to be considered. The user interaction with the learning content depends on two main aspects: the definition of an appropriate user-interaction model and the appropriate integration of the informal knowledge produced by this interaction. These aspects generate an important focus of research.

In order to guarantee effective learning results via the use of ICT, an overall structure, which generates an integrated process in the production and use of the learning content must be achieved. New applications of ICT will continuously bring new challenges, but the applica-

tion of flexible and well-thought solutions shall minimize the effort for updating and development.

References

[1] *http://www.learningcircuits.com/2002/dec2002/greenberg.htm*

[2] E. Maler, J. el Andaloussi, Developing SGML DTDs. From Text to Model to Markup; New Jersey (Prentice Hall), 1996

[3] *http://www.lmml.de/index?text=23*

[4] *http://www.docbook.org/*

[5] http://www.elearningmag.com/elearning/article/articleDetail.jsp?id=5043);

[6] http://www.fnl.ch/

[7] http://www.adlnet.org

[8] http://www.ariadne-eu.org/

[9] http://www.dublincore.org

[10] http://www.geminfo.org/index.html

[11] http://www.prometeus.org/

[12] http://www.imsproject.org

[13] http://ltsc.ieee.org

[14] http://ltsc.ieee.org/wg12/index.html

[15] http://www.aicc.org/

[16] http://www.w3.org/TR/xslt

[17] http://interactiveu.berkeley.edu:8000/rdhyee/stories/storyReader$349

[18] Product Development as a Structured and Interactive Network of Knowledge ; Birkhofer, Lindemann, Meier; Workshop ICED Conference 2001

[19] Pereira, M. A. Pedagogical Principles in Web-Based Learning; Proceedings of the Telematica 2001 Web-Based Education, 18-21 June 2001, St. Petersburg, Russia.

[20] Crook, C. Computers and the Collaborative Experience of Learning. London, Routledge, 1996.

[21] http://www.product-innovation.ethz.ch

[22] W.J. Elspass, An Integrated Learning and Information Environment for Product Innovation, e-Technologies in Engineering Education, a United Engineering Foundation Conference, 11-16 August 2002, Davos, Switzerland

[23] W.J. Elspass, M. Meier; Learning, information and training environment for product innovation, Syllabus 2000 Conference on new learning technologies, July 2000, Santa Clara, CA, USA

[24] Wilfried J. Elspass; Product Innov@tion – the Implementation of a new Learning, Information and Communication Environment for Product Innovation, 4th International Conference on New Educational Environments, May 2002, Lugano, Switzerland

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