

# An Architecture for Web-based e-Learning Promoting Re-usable Adaptive Educational e-Content

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### ABSTRACT

This paper addresses the issue of re-usability in personalised web-based learning environments. The paper focuses on the work of the European IST Project KOD “Knowledge on Demand”, towards the definition of an architecture, and the implementation of a system that promotes re-usable adaptive educational e-content. The proposed architecture is presented, and the elements of the KOD prototype system in use are demonstrated.

### Keywords

Adaptive educational e-content, re-usability, learning technologies specifications

## 1. Introduction and Background

The objective of the KOD project is to address the up-rising and pervasive needs originating in knowledge-based economy for the effective and efficient distribution of electronically published content available on-line, and the provision of personalised and on-demand training services in order to favour life-long learning and knowledge transfer experiences through the Web. In this context, the KOD project aims to address a number of different categories of users and market actors involved in the e-Learning business framework, including (Figure 1):

- *e-Learning assets publishers*, aiming to version their learning assets for different online learning solutions in a re-usable and interoperable way;
- *e-Learning platform providers*, mainly interested in providing architectural solutions for e-Learning at different levels, e.g. learning management systems, assessment systems, performance support systems, etc;
- *e-Learning service providers*, mainly using existing e-Learning platforms in conjunction with their own, or third-party learning content, to support service provision in the e-Learning arena.

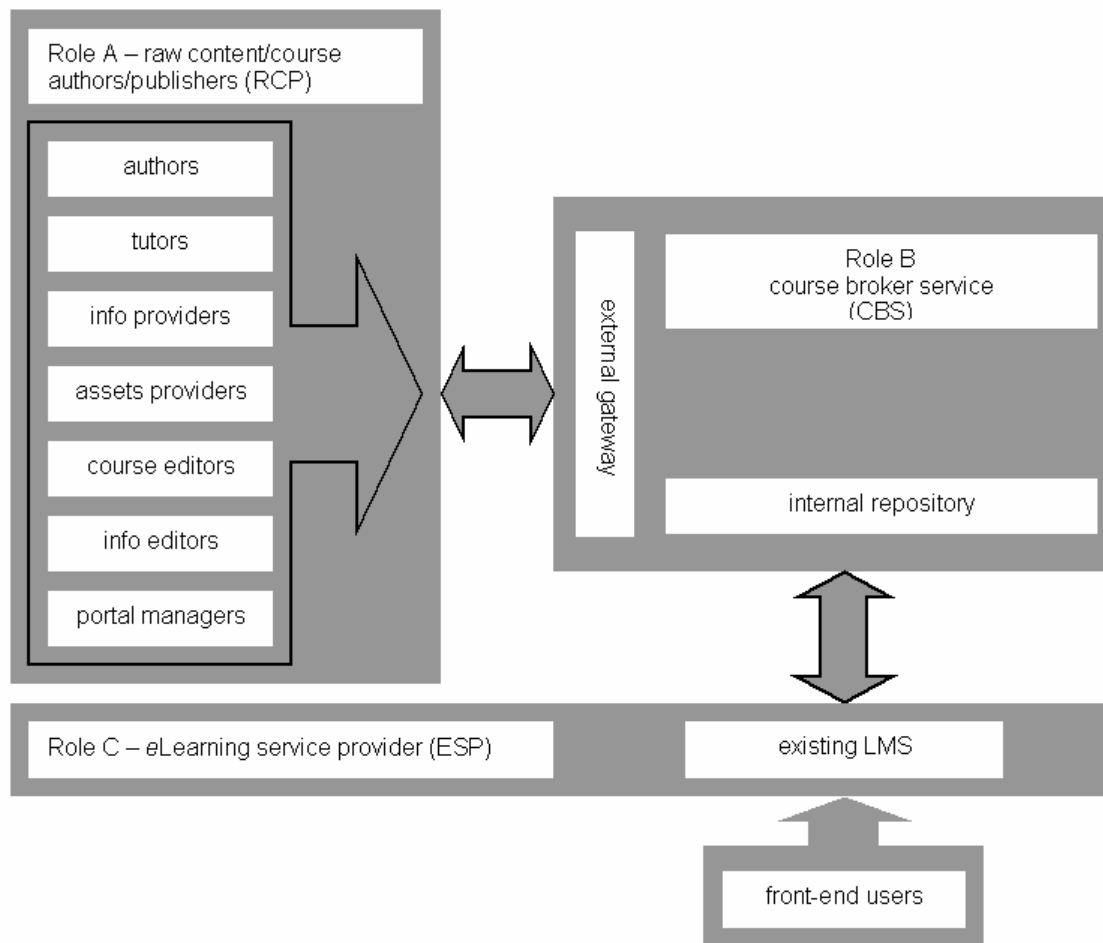


Figure 1. The KOD Business Model

In general, these users need to be able to publish to (or access from) knowledge repositories learning material (either “single” learning assets, or “learning packages”), so that it can be easily interchanged across different applications and services. This, in turn, requires that learning material is described and published in a *common format* (Sampson et al, 2002b).

This need has resulted in a number of international standardisation activities aiming to define common learning technologies specifications that can ensure interoperability in the *e-Learning* arena. The main initiatives in the area are the IEEE LTSC (Learning Technologies Standards Committee, [ltsc.ieee.org](http://ltsc.ieee.org)), the European CEN/ISSS Learning Technologies Workshop ([www.cenorm.be/iss/Workshop/lt/](http://www.cenorm.be/iss/Workshop/lt/)), the IMS (Instructional Management Systems) Global Learning Consortium Inc ([www.imsproject.org](http://www.imsproject.org)) and the US ADLnet (Advanced Distributed Learning Network, [www.adlnet.org](http://www.adlnet.org)) (Bachich et al, 1999).

These efforts have, in turn, already resulted in a number of specifications for *e-Learning* applications and services. In fact, current specifications already encompass (or will, in the next future) most aspects of a standard *e-Learning* architecture (e.g. the IEEE LTSA, Learning Technologies Standard Architecture), from the description of learning objects meta-data based on shareable XML-based data structures (e.g. through the IEEE LOM specification) to the assessment of user performances (e.g. through the IMS QTI, Question and Testing Interoperability Schemas). That is, existing specifications enable the common description of learning units, questions and tests, learner profiles, etc, so that they can be easily interchanged between different applications (Wiley, 2001).

Moreover, existing specifications enable users (learning material authors, tutors, publishers, e-learning platform and service providers, etc) to describe in a common format *content packages*, i.e. collections of learning objects, through the IMS Content Packaging Specification (IMS, 2001a). Each content package can be described in a common format, and can be “packaged” in a single zip file, which includes:

- all the learning objects included in the package;

- a manifest XML file, which describes the structure of the learning objects; the manifest file includes a number of “organizations”, each one including, in turn, a number of learning resources (see Figure 2).

However, the current content packaging specification enables only the description of table-of-contents like structures: “It is possible to imagine organizations that will take into account such approaches as hierarchical ‘branching’, indexes, custom learning paths utilizing ‘conditional branching’, and complex objective hierarchies. While many content organization approaches may be developed, a default approach is included as part of this specification. This default approach to content organization is referred to as a ‘Table of Contents’ scheme and is encompassed in a <tableofcontents> element” (IMS, 2001a). *That is, through existing learning technologies specifications we can re-use learning material; however, we cannot re-use adaptive learning material, i.e. learning material which is described in such a format so that a learning management system can select different learning objects for different learners.*

In this context, this paper presents an architecture which aims to facilitate the definition of *adaptive* educational e-content which is described in a *common* format, and can thus be easily re-used. The idea behind the architecture is to extend the manifest XML file of each content package, to include the necessary information for defining adaptation rules which determine how learning objects should be selected for different learner profiles. In particular, the KOD project has identified a procedure for describing adaptive educational econtent in a common format, which includes the definition of (Karagiannidis et al, 2001):

1. the concept ontology of the learning material to be presented,
2. the learning resources, i.e. the learning units that are to be communicated to the learner,
3. the competencies which are related to each node of the concept ontology,
4. the questions and tests that define when a learner has acquired a specific competency,
5. the different user profiles of the user groups that are expected to be interacting with the system, and finally
6. the navigation rules which define how different learning objects are selected for different learners; these “rules” specify the “matching” between the learner profiles and the learning content, that is the “learning path” that is appropriate for each different learner profile.

The result is the *knowledge packaging format* (Karagiannidis & Sampson, 2002), i.e. an extension of the IMS content packaging specification which facilitates the description of adaptive educational e-content in a common format (see Figure 2).

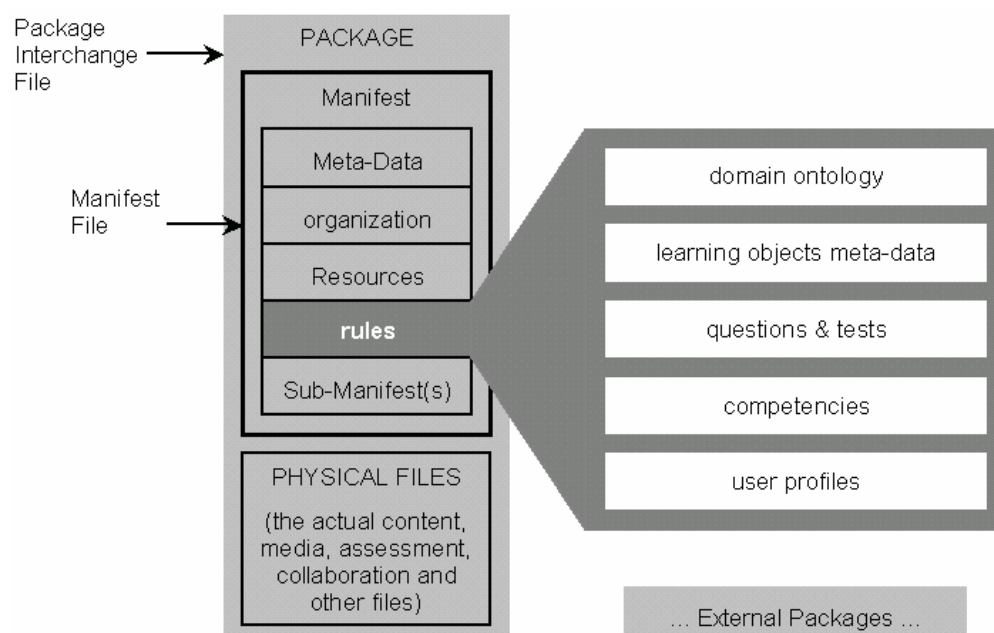


Figure 2. The KOD Knowledge Packaging Specification  
Extensions over the IMS content packaging specification are shown in dark grey

The following section presents KOD architecture, while section 0 discusses elements of the KOD system in use.

## 2. The Proposed Architecture

The architecture (shown in Figure 3) includes a *Learner Interface*, which facilitates access to the learners' functionality. The Learner Interface supports all the features that are available in existing state-of-the-art *e-Learning*, *e-Publishing* and *e-Knowledge* tools. In addition, it facilitates access to PL services, i.e. enabling the user to authenticate himself, and subsequently to define, review and modify his/her user profile, so that the PL environment is adapted to the user's requirements, preferences, interests, goals, etc.

In the following paragraphs, the "KOD Factory" is described, i.e. the components of the architecture which enable the definition of adaptive educational material. The description is given in terms of a scenario of use, describing the steps that need to be performed by an "editor", i.e. a person responsible for defining adaptive content so that it can be interchanged across different PL environments.

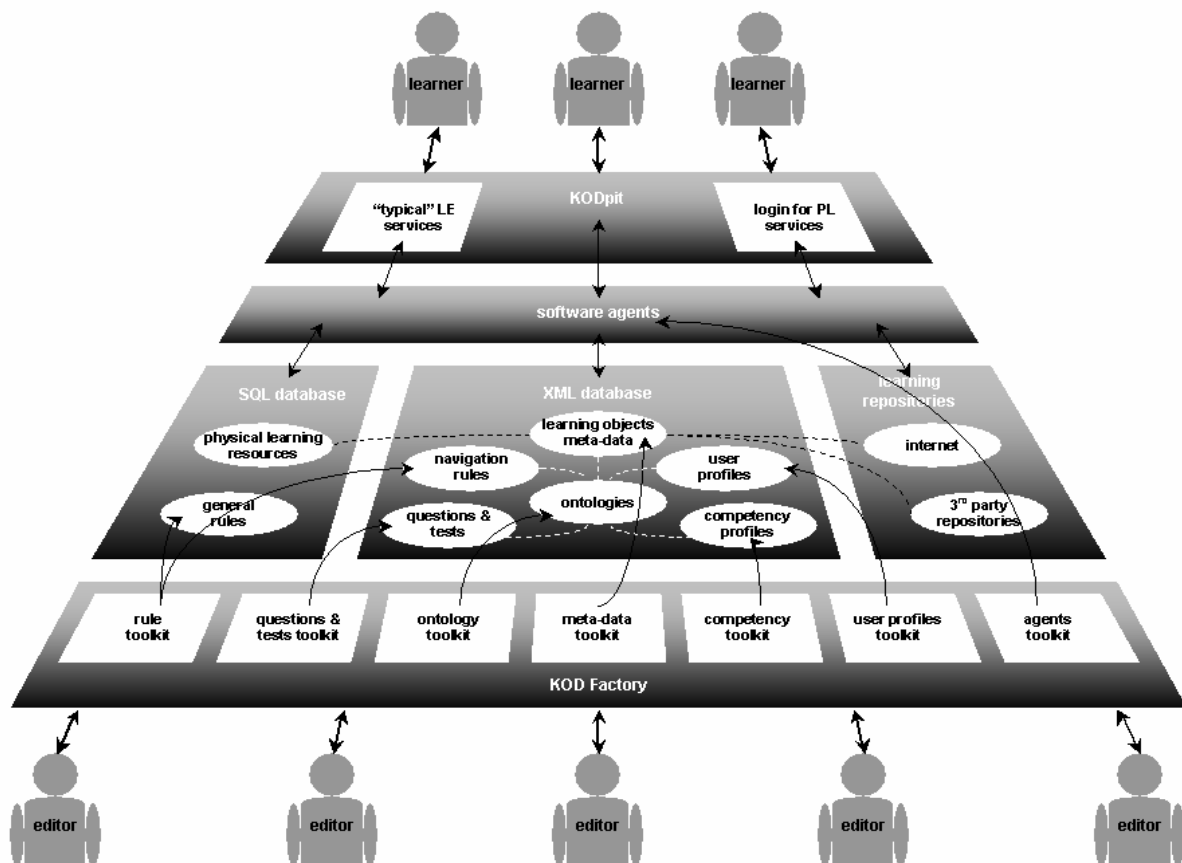


Figure 3. The KOD Architecture

### 2.1. Ontology toolkit

First of all, editors need to define the content to be presented to the learners. To this end, the first step in the definition of a "knowledge route" (i.e. the output of the PL environment) is the definition of the *ontology* that describes the concepts to be communicated. It should be noted that this ontology contains a factual description of the learning concepts (e.g. computer science is composed of operating systems, programming languages and databases), which is *independent* from the learning process. This ontology can be provided by a content expert, who is being interviewed by an editor. In this context, the Editor Factory includes an *Ontology Toolkit*, which assists editors in this process. The Ontology Toolkit employs a specific *knowledge representation* technique for storing the ontology, and provides as output XML files (*Ontology Profiles*), which are maintained in the *XML database* of the PL environment.

## 2.2. Meta-Data Toolkit

Following the above process, editors need to define the learning material / resources that are available for each “atom” of the ontology (i.e. the leafs in the ontology structure). In this context, the Editor Factory includes a *Meta-Data Toolkit*, which assist editors in defining the meta-data of the learning resources that are available. The Meta-Data Toolkit stores the meta-data as XML files (*Meta-Data Profiles*), which are also included in the *XML database* of the PL environment.

## 2.3. Questions & Tests Toolkit

In addition, the ontology should be “enriched” with questions and tests, which can specify when the learner has mastered a concept in the ontology hierarchy, and can therefore proceed with the next concept. The process of defining these tests is assisted by a *Question & Test Toolkit*, which enables the editor (with the help of the content expert) to define the questions and tests that are related for each concept in the ontology hierarchy. The Question & Test Toolkit stores *Question & Test Information* this information into XML files, maintained into the *XML database*.

## 2.4. Competencies Toolkit

Based on the ontology, editors then need to define the competencies that are related to each node of the ontology. In this context, the Editor factory includes a *Competency Toolkit*, assisting editors interviewing content experts, and storing this information into XML files (*Competency Profiles*), maintained in the *XML Database*.

## 2.5. User Profiles Toolkit

Then editors need to define which are different profiles of the users (learners) who are expected, foreseen, etc, to interact with the system. The definition of the user profiles (which is assisted by a content expert) is assisted by a *User Profiles Toolkit*, with similar functionality with the above tools. The User Profiles Toolkit stores *User Profiles* in XML format, maintained within the *XML database*.

## 2.6. Rule Toolkit

Finally, editors need to define how the learners will navigate the concepts of the ontology (i.e. viewing the learning resources, questions and tests, etc) that have been specified for each concept in the ontology, based on the user profile of the learner, as well as the competency level. Therefore, a *Navigation Rules Toolkit* is included in the Editor Factory, which assists editors to define the rules that determine the learning paths in the ontology that should be followed, and their matching to user profiles and competencies. It should be noted that these rules (*Navigation Rules*) are *dependent on the specific learning content* to be communicated, and are again stored in XML files within the *XML database*. The Rule Toolkit also enables the editor to define *general rules*, which are applicable to every learning context, and stored in the SQL database of the PL environment. All the above information form the basis for the definition of the different *knowledge routes* of the PL environment. Knowledge routes contain the ontology of the learning material, the learning objects and questions and tests that are related to each node in the ontology, the different user profiles and competency profiles, as well as the *navigation rules* which determine how the ontology is navigated for different learner profiles.

## 2.7. Agents Toolkit

The proposed architecture is based on software agents, which are the knowledge analyzing, monitoring, generating, adapting and delivering “pulse” of the PL environment. In this context, the Editor Factory includes also an *Agents Toolkit*, which enables the editor to construct new agents, destruct existing agents, modify agent parameters, etc. Agents are capable of presenting knowledge routes to learners, i.e. processing knowledge routes files. In particular, agents extract the information contained in the knowledge routes, and present learning material according to the learner profile. At each node of the ontology, agents are capable of identifying whether the user can understand the respective concept, or whether there is a need for presenting some “pre-requisite” concepts before. In case that the user cannot understand these concepts based on the learning material that is

available (i.e. the physical learning resources indicated in the knowledge routes file), the agent automatically searches for additional information, both from specific repositories (defined by the editor), and from the Internet. Also, agents provide assistance for the “verification” of the information that is encapsulated in the knowledge routes. For example, agents can notify the editor that the users that have accessed a specific knowledge route can be classified into more (or less) user profiles (employing data mining techniques).

### 3. The KOD Prototype

#### 3.1 Creating Adaptive Educational e-Content

Based on the above architecture, we are able to develop knowledge packages (as opposed to IMS content packages), i.e. adaptive educational e-content which is described in a common format. The knowledge packaging format is used as the interchange format within the KOD-based prototype vertical learning portal, which aims to support back-end users to design, develop, modify, publish, search, retrieve, broker, interchange and re-use adaptive educational e-content; as well as individual learners to have access to learning material in a personalised way.

The main tool available within the KOD prototype for the development of knowledge packages (i.e. collections of learning objects described through the knowledge packaging specification) is the KOD Packager (Cardinali et al, 2001). Figure 4 shows a screenshot of the KOD Packager, where the following features are shown:

1. at the left-hand side window, the KOD system user (author, publisher, tutor) can import learning objects, which can then be used for the development of knowledge packages; the learning objects can be imported both from the local file system, the KOD prototype repository, or from publicly available resources on the WWW;
2. at the middle window, the on-line content author can create a number of organizations (similarly to the IMS content packaging specification) for each “knowledge unit” (or concept) related to the domain of the knowledge package; in the example screenshot, the domain of the knowledge package is tele-radiology, and the following concepts have been defined: introduction, definitions, implementation, basic parts, image acquisition and management, display systems, communication networks, interpretation, image standards and compression;
3. at the right-hand side window, the KOD system user is able to edit the learning objects that have been imported; in this example, the user can modify a text file, including a definition of tele-radiology;
4. all previous steps are in line with the IMS content packaging specification; in addition, the KOD Packager facilitates the definition of navigational rules, for determining which learning objects should be selected for different learner characteristics;
5. this can be done through the Rule Editor; as it is shown in the screenshot, the user can define a number of rules for the same knowledge package; also, one rule can include other rules, thus allowing nesting of rules; for each rule, the KOD system user can define:
  - i) conditions: they are based on learner (profile) characteristics; examples include the learner’s learning styles, interests, goals, achievements, etc
  - ii) assignments: these are the post-conditions of rules; one rule may determine, for example, that the learner’s expertise in a concept is increased, after accessing learning material on this concept, or passing a relevant test;
  - iii) launch request: a number of actions can be initiated; for example, after a learner accesses learning material or passes a test on a specific concept, additional learning material can be proposed (e.g. based on the results of the test), new concepts can be presented to the learner, and so on.

#### 3.2 Interchanging and Re-using Adaptive Educational e-Content

The KOD prototype aims to assist the interchange and re-use of adaptive educational e-content. That is, the knowledge packages that are created through the process and tools described in the previous section can be published in the KOD prototype system, so that they can be searched, retrieved and accessed by learners in a personalised way (see next section); or re-used by authors for the creation of new knowledge packages.

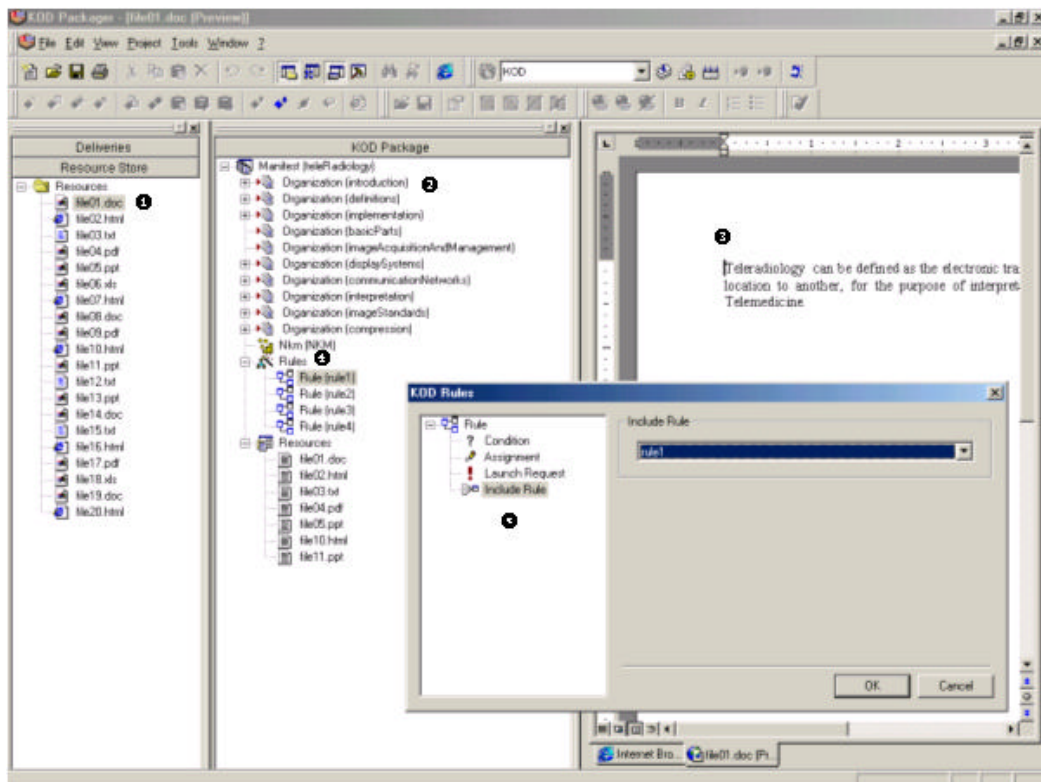


Figure 4. The KOD Packager for Defining Knowledge Packages within the KOD vertical learning portal

In addition, the KOD system facilitates the re-use of the “building blocks” of the knowledge packages. That is, within the KOD prototype system, authors can publish, search, retrieve, broker, interchange and re-use:

- learning objects,
- ontologies,
- questions and tests,
- competencies,
- learner profiles, and
- adaptation rules

which are related to a specific domain, so that they can be used for the development of knowledge packages in the same domain.

For example, an author may search in the KOD prototype vertical learning portal, and retrieve learning material which is related to the “definitions of tele-radiology” domain; learner profiles and competencies related to the tele-radiology domain; adaptation rules which are related to the tele-radiology domain; etc.

### 3.3 Accessing Adaptive Educational e-Content

The aim of the KOD system is to facilitate personalised access to learning material. That is, each learner can receive learning material which is adapted to his/her individual profile.

To this end, the KOD prototype maintains a profile for each learner, which is based on the IMS LIP (Learner Information Profile) Specification (IMS, 2001b). That is, upon entering the KOD portal for the first time, each learner is prompted a short questionnaire, for determining his/her characteristics. This profile is automatically updated, taking into account the learner’s interactions with the KOD portal, i.e. the knowledge packages that have been viewed, the assessment questions that have been answered, etc.

Subsequently, the learner can search the KOD portal, and retrieve knowledge packages in specific domains of interest. The KOD system adapts the results of this search according to the learner’s profile.

Figure 5. Initial Questionnaire for the KOD Learner Profile

The learner can then access the knowledge packages in a personalised way. That is, the KOD e-learning system can import knowledge packages, disaggregate them, interpret the rules included in them, and select to present the learning objects which are appropriate for the learner, according to his/her profile.

Figure 6 shows an example adaptation of a knowledge package in the tele-radiology domain. In the left-hand side, the KOD system suggests the “acquisition systems” section to be viewed next (indicated with the red arrow), since this is the most appropriate learning object according to the learner’s profile. It also suggests that specific sections and not yet ready to be viewed (indicated in dark grey); while, in the right-hand side picture, the suggestions have changed, after the learner has viewed the “acquisition systems” section, and answered correctly to a specific assessment question.

#### 4. Discussion and Conclusions

The emergence of the Knowledge Society and the Knowledge-based Economy signify a new era for education and training. Within this framework, knowledge and skills of citizens are becoming increasingly important both for the economical strength and social cohesion of the society, and the quality of citizens’ life. The structural and functional society transformations raise the demand for major reforms in Education and Training, aiming at reducing the risks for knowledge gaps and social exclusion.

An interesting social and scientific debate is thus continuing, on the paradigm shifts in the way that education and training is planned, organised and delivered, as well as the definition of concrete future objectives of educational systems. Typical demands include personalised training schemes tailored to the learner’s objectives, background, style and needs; flexible access to lifelong learning as a continual process, rather than a distinct event; just-in-time training delivery; new learning models for efficient integration of training on workplaces; and cost effective methods for meeting training needs of globally distributed workforce (Rosenberg, 2001).

Concepts	Learning asset	Format
Introduction - General Aspects	Introduction Movie	Movie
	Presentation slides	Powerpoint
	Web resource on General Aspects	HTML
	Web resource on Tele Radiology	HTML
Definition	"Teleradiology can be defined as ..."	HTML
	Telemedicine	HTML
	Still Images	Word Doc
	Service definitions	Powerpoint
Implementation	Possibilities of Tele Radiology	HTML
	Chapter 3 - Implementation	Word doc
	<b>Acquisition Systems</b> ←	Word doc
	Basic knowledge of multimedia data exchange	Word doc
	Example implementation	HTML
	Chapter 3 - Closure	Word doc
Basic Parts of a Tele-radiology System	The basic parts	HTML
	Types of radiology - analogue output*	HTML
Image Acquisition and Management	Walter the radiographer - part 1	Movie
	Image acquisition	Movie
	Walter the radiographer - part 2	Movie
	The Gammex Site	HTML
	Acquisition Systems	Word doc
	Film Digitizer Site	HTML
	Image standards being exchanged	HTML
	Standardisation Bodies	Word doc

Figure 6. Personalised Access to Learning Material within the KOD vertical learning portal

A number of R&D efforts have addressed the above demands, aiming to deliver flexible and individualised access to learning material. However, most of this technology – intelligent tutoring systems, adaptive educational hypermedia, intelligent pedagogical agents, etc (Shute & Psozka, 1995; Park, 1996; Brusilovsky, 1998) – is still not mainstream. The main barrier for the “under-exploitation” of these efforts, at least from a commercial point of view, is the difficulty in “re-using research results”: most existing systems follow customised approaches (for representation, reasoning, etc), which cannot be easily re-used across different applications (Brusilovsky et al, 2002; Sampson et al, 2002a).

The KOD project aims to contribute in this direction, and address on-demand, personalised access to learning material *in a re-usable way*, based on the existing learning technologies specifications. Moreover, the KOD project aims to extend these specifications, to facilitate the description of *adaptive* educational e-content in a common format, so that it can be easily re-used.

As a result, when a learning management system imports a knowledge package (i.e. as opposed to a content package), it can disaggregate it, interpret the rules included in it, match them with the learner profile of each individual learner, and select different learning objects for different learners (Figure 7). Therefore, each learner can have access only to the learning material which is appropriate for his/her individual requirements, interests, skills, etc, thus personalised access to learning material can be supported.

Future work within the KOD project involves the development of three demonstrators:

- one involving a “learning organisation”, interested in providing to its employees personalised access to internal organisational e-knowledge materials;
- one representing a seminar-based, life-long learning scenario; and
- one addressing a “typical” vocational training scenario,

aiming to assess the KOD business model and the KOD prototype vertical learning portal in different scenarios of use and e-learning contexts.

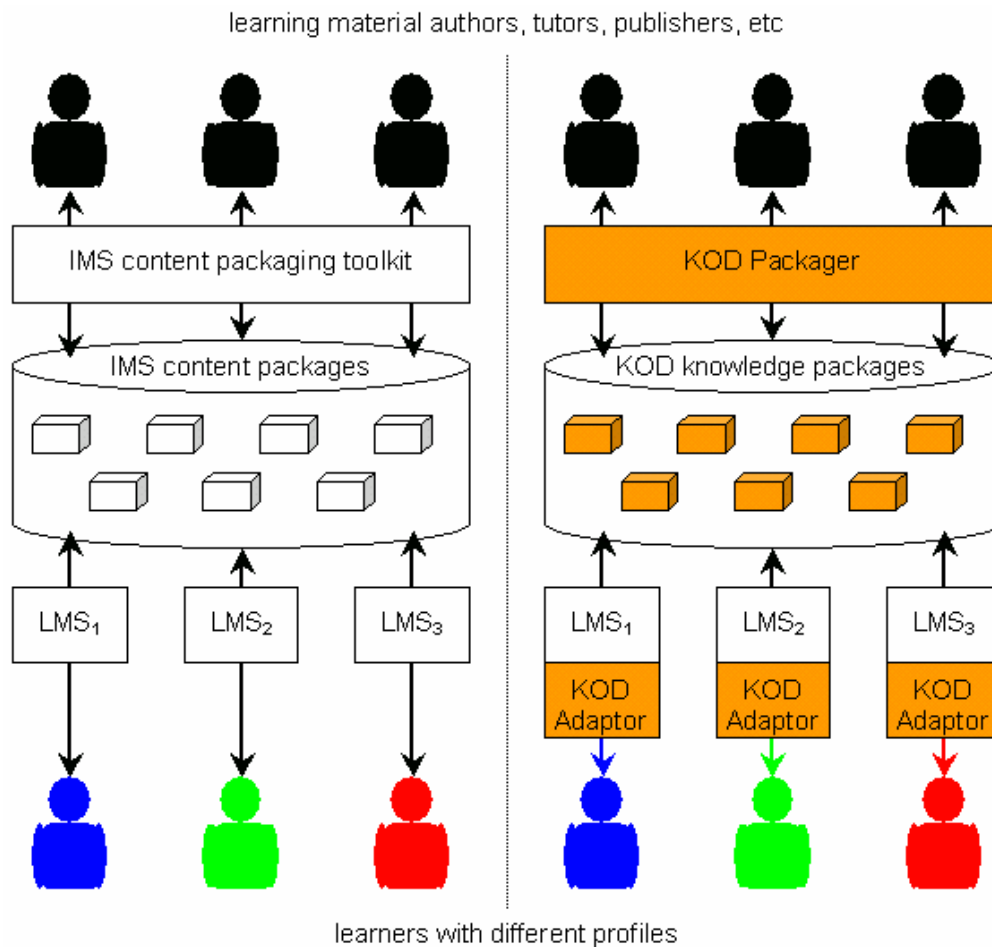


Figure 7. KOD versus existing IMS content packaging-compliant Approaches

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