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Creating cost-effective adaptative educational hypermedia based on markup technologies and e-learning standards

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Abstract

This paper addresses the problem of developing a cost-effective, flexible Web educational environment focused on the learner. Our project, called <e-Aula>, has three main goals: (1) to simplify the creation of a virtual class environment, (2) the reuse of previously existing educational content and, (3) to enable content adaptation to meet individual needs.

The design of <e-Aula> is based on recently developed e-learning standards (such as IMS, EML and ADL/SCORM) and courses are developed according to the Learning Object model. We use markup technologies (i.e. XML) to streamline the way the system is built and how it handles information. XML's metadata and related technologies are used not only to mark up the course material so that content can be adapted and reused, but also to mark up all data needed to manage different activities involved in the learning process (such as managing student information or system use). <e-Aula> also includes synchronous and asynchronous tools for communication between students and tutors.

Keywords

Educational hypermedia, virtual class, adaptive multimedia, e-learning standards, markup technologies.

Introduction

For many years, computers have been used for educational purposes but now, with the development of the information and communication technologies (ICT), their role is changing. Just a few years ago, this educational use was described by terms like 'interactive learning environments', 'computers-assisted instruction' or 'educative multimedia'. With the widespread adoption of Internet and web technologies as delivery platforms, new forms of educational applications are appearing. These new teaching and learning tools, usually described with terms like 'virtual clases/campus' or 'web-based learning/training', make full deployment of the new

capabilities added by global communication networks. Maybe the most remarkable being the possibility of real co-operation and interaction among people and the simplification of the access to the information. Also, the web provides real independence of place, time and pace. Communication no longer depends on time or place either: e-mail, lists servers, discussion groups make possible communication among students and tutors anytime and anywhere.

At the same time, learning paradigms are changing. As social pressures increasingly demand a change in educational institutions, instructional methods are shifting to a more student-centered educational model. Nowadays, education needs to give support to part time and lifelong learners. The market demands highly qualified professionals with little available time for training and whose knowledge and skills are permanently updated. Not only learning anytime and anywhere is required, but also flexible learning environments that permit students fill their educational needs considering their prior knowledge and competencies and adapt the environment according to their personal preferences.

Nevertheless, despite the new possibilities offered by ICT, developing web educational tools is a complex process with several problems to overcome. We are specially concerned about three aspects of the development and implementation of web learning environment: cost effectiveness of the learning environment construction, cost effectiveness of the production and reuse of educational contents, and personalization of contents to suit individual learners.

In fact, cost effectiveness is one of the main identified and unsolved problems when trying to spread multimedia training through the higher education market (Bélisle et al 01). In the last years, we have seen several technologies come and go. Content that was made available in a specific format is no longer usable, unless large investments are made for conversion: the design is often too closely tied to implementation-specific aspects. Therefore, we think that a key problem to be faced when adopting Web learning environments for educational purposes is assuring platform and system independence for content. This will permit content reuse in several different senses, such as among different systems or in the same system for different courses, and ideally avoiding vendor "lock-in".

We think that markup technologies (i.e. XML and related technologies) can play an important role in simplifying the development of educational applications and in making content reusable (Fernandez-Manjon 97). First of all, they enable the definition of platform-independent protocols for data exchange so the information can be displayed in the way each individual prefers. The technique, however, is not simple and requires agreements about the standards to be used (i.e. IMS). Markup also simplifies the reusability of educational content and instructional components, which is often limited because developers do not know that certain components exist or because they cannot be easily obtained for integration. Markup technologies allow the identification of and search for these components as well as their decontextualization.

On the other hand, markup technologies offer the possibility of providing the user with relevant and customized information. In education this creates the possibility of personalization: the adaptation of content, sequence, navigation and presentation format to a person's preference or knowledge requirements (Brusilovsky et al 98, Fernandez-Manjon et al 98).
In this paper, we describe how we have used XML and related technologies for the development of a web-based learning system focused on the learner that provides an easy and cost-effective way to reuse content.

The following section presents an overview of the project. After that we discuss content production, content reusability and content adaptation and the use of the learning standards in current implementation of the system. Then we describe <e-Aula> as a learning management system. Finally, we present some conclusions and future work.

Overview of <e-Aula> project

<e-Aula> is a research project for the development of virtual class environments. Initially, the main aim of <e-Aula> was to demonstrate the feasibility and cost-effectiveness of the production of a virtual class environment. It was also conceived as a framework to test and investigate aspects such as e-learning standards and the use of markup technologies as a way to personalize learning and adapt information to the user.

The design of <e-Aula> is based on recently developed e-learning standards (such as IMS, EML and ADL/SCORM) which define information models, and XML bindings for the data to be transferred into or between systems. Although e-learning standards and markup languages are surely becoming very popular in the e-learning community, their use is still not generally spread. We think it has come the time to learn about the benefits obtained by implementing XML enabled e-learning environments based on educational standards.

Therefore, two key objectives of <e-Aula> are:

Cost-effectiveness, in two different senses: affordable and easy development, and affordable and easy maintainability. Here, to simplify the production of high quality educational content, the system should allow reusing previously existing educational content, should be platform independent and should avoid vendor lock-in.

To provide tailored information to the student. <e-Aula> tries to adapt course content to the individual learner, taking into account different levels of granularity in the information and different student knowledge levels.

<e-Aula> is also an innovative educational project in the Complutense University at Madrid. We have already developed an <e-Aula> pilot course for the creation of graphical user interfaces in Java (the content is in Spanish and it was adapted from a printed book). This course will be tested next fall semester by third-year computer science students and will be a complement to classroom teaching.<e-Aula> prototype aims to asses features like student interaction with the learning environment and cost-effectiveness, as well as to test different implementation approaches for the information processing, such as the assessment of fat client or fat server processing (or even a mixed approach).

Content production, content reusability and content adaptation.

The key to success in e-learning is high quality educational content. But producing (quality) educational content is difficult and time consuming. Hence, in order to simplify this process and assure its outcome quality, we propose to reuse previously existing educational content.

Also, our intention is to increase learner motivation by providing tailored content adapted to his/her personal needs and, at the same time, to reduce the time spent in training with the maximum benefit. The idea is to offer students a learning tool easy to use and capable of being adapted to the user's preferences.

The power of markup languages relies in its flexibility. XML permits to separate content from the way it is processed (e.g. presented), which avoids the need of rewriting the same content that is to be displayed in different formats or devices. This feature makes adaptation easier and faster than ever before.

To accomplish our first objective of content reuse we have identified two main problems (Forte 97):

- Many times it is unclear whether there is any appropriate existing material that can be reused in the course.
- When the appropriate material is collected from various sources, it is difficult to integrate it in a unified whole.

Therefore, reusability has a number of consequences, among which we can mention: identification and search for parts and re-assembly of these parts. The implicit idea behind this assumption is that courses are not designed and built in a monolithic way, but as aggregates of independent parts (Merril 99). These parts are usually referred to as "learning objects". To make intelligent use of learning objects, information about its content and some other important issues must be somehow linked to the learning object as metadata using a markup language (usually XML). Additionally, the idea is that learning objects are stored once and delivered over the Internet so that any number of people have simultaneous access to them. This implies automatic update of the courses using one particular learning object.

The most common way of learning object's structure is depicted in Figure 1.

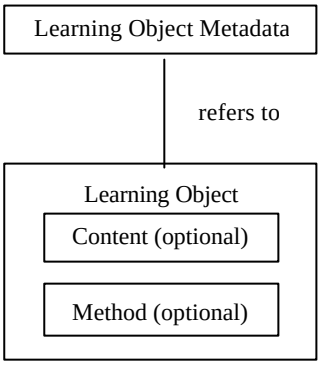

Figure 1. Learning Object structure

The learning object model and markup technologies also offer the possibility of personalization in an easier a more extensive way than before. This means that it is possible to adapt content, objectives, instructional method, navigation and presentation format to a persons' preferences or characteristics.

According to Rob Koper (Koper 00), there are two possible ways of personalization in a learning environment depending on whom has the control on the adaptation process:

1. Adaptive learning environments. In this situation the designer has control over the adaptation process.

2. Open and flexible learning environments. In these systems the principle that the student is central is fully implemented: students can define their own educational goals, influence the educational method and participate in the evaluation.

Therefore, the key question is whether the designers should always make the system adjustments, or users themselves be allowed to choose what they want.

<e-Aula> tries to adopt an intermediate solution between both positions: by using our system students will be able to adapt content to their needs by choosing the knowledge level according to which the information will be displayed in a predefined way. In the current course working in <e-Aula>, we consider two different levels of granularity in the information and three the different student knowledge levels (beginner, intermediate and expert). In the first granularity level the system pre-selects and organizes the learning objects according to the student and the course requirements (i.e. different tables of contents are possible but there is always a default

learning path). In the second level, the content of the learning objects is adapted to the student knowledge level before the information is displayed.

The current prototype requires the explicit choice of knowledge level by the learner and, adaptation is based only on filtering out those contents considered too difficult for the student. We are currently working on improving content personalization and plan to automate this process based on the learner interaction and on his/her overall evaluation taking advantage of some capabilities already included into <e-Aula>.

In the next project stage, some more features will be added to the system to fully implement our initial personalization goals. The idea is to follow students during their education, and to adapt instruction to the wishes and requirements of the moment. The information about the student progress during the course will be stored in a personal file. Based on this data, the system will automatically change the initial value of his/her knowledge level and display the information according to his/her changing needs. Figures 2 and 3 show how the same content is presented for two different student knowledge levels (beginner- Figure2- and expert -Figure3-)a in <e-Aula>.

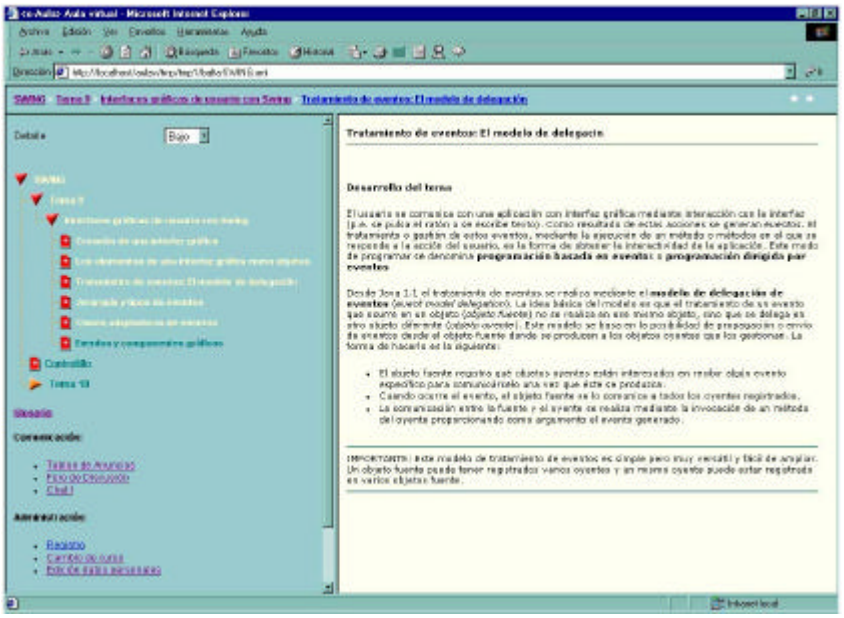

Figure 2 <e-Aula> presents the information about event-based programming in Java for a beginner student (so the detail level is fixed to low -bajo-). Only an introduction to the topic is presented wihtout the contents considered too difficult for the student.

Application of learning standards in <e-Aula>

Making content re-usable and avoiding “vendor lock-in” also require clear agreements about the standards to be used. To facilitate the adoption of the learning objects approach, the Learning Technology Standards Committee (LTSC) of the IEEE formed the Learning Object Metadata working group to develop and promote instructional technology standards. At the same time, several organizations began working on technical specifications to support the deployment of the learning object model. Among this initiatives are IMS project, ARIADNE, ADL/SCORM, PROMETEUS (Duval 01).

According to the definition of the IEEE LTSC (2001) a learning object is: “an entity, digital or non-digital, that can be used, re-used, or referenced during technology-supported learning”. It is now commonly agreed that this definition is too broad to be useful. In the first place, we will always refer to digital learning objects. <e-Aula> uses Wiley’s (Wiley 00) definition of learning object as “any digital resource that can be reused to support learning”.

The idea behind learning objects is clearly grounded in the object-oriented paradigm: independent pieces of instruction that may be reused in multiple learning contexts and that fulfil the principles of encapsulation, abstraction and inheritance. Therefore, they have been historically described as LEGO pieces, because as LEGOs do, learning objects can be assembled into lager instructional structures and reused for building other structures. But there is a substantial difference, learning objects are not at all combinable to any other learning object. It is very likely that assembling learning objects without any instructional model will hardly be educationally useful.

The problem is that there is a lack of instructional design information in the learning object model specified by the current version of the Learning Objects Metadata Working Group standard. To allow the automatic combination of learning objects in a way that makes instructional sense (“sequencing”) some information about the educational context in which the learning object can be used, ought to be included. The current specification neither provides a way to express the semantic relationship of the types of objects in the context of educational settings, nor does it provide a model of the structure of the content. Recently, IMS has created a new working group to propose a standard for instructional design based on EML (Educational Markup Language).

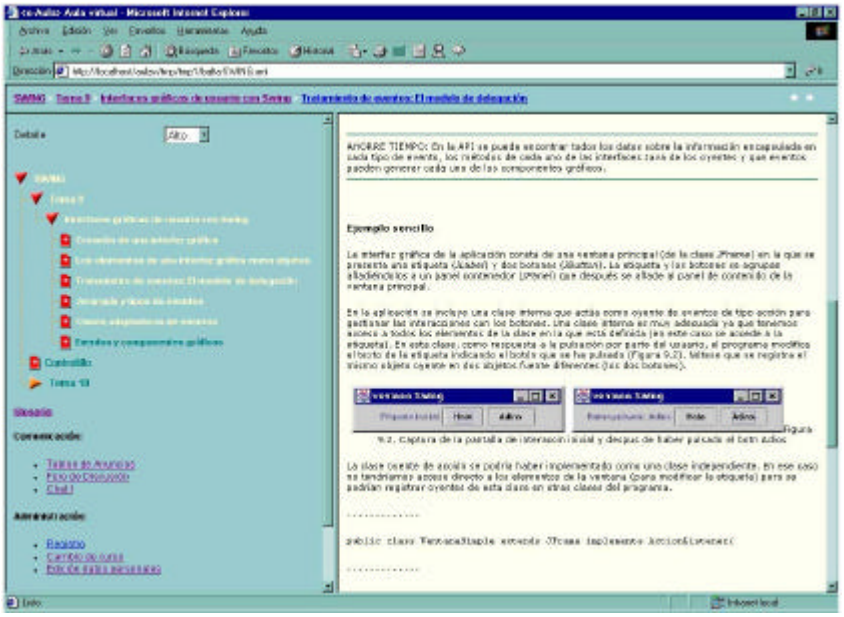

Figure 3. <e-Aula> presents the same information of figure 3 for a student with a good understanding of the event-based programming (so the detail level is fixed to high -alto-)

Learning objects are entities that may be referred to using metadata. The metadata itself are separate from the object it refers to. The metadata specification is described in the IEEE LOM standard specification (IEEE LTSC, 01). IMS provides a binding in XML.

Metadata are used by <e-Aula> to accomplish the two key objectives of the project: content reuse and content adaptation.

To identify reusable educational content, course designers have access to the metadata stored in the digital library. Based on the information provided, the learning object itself can be included in the course: metadata permits to locate an item very quickly without browsing all the individual items in the digital library. Our system does not currently include any automatic search and sequencing tool. Our intention is to use EML in a future version to test the automatic sequencing.

For adapting content to user's prior knowledge, <e-Aula> uses XML at two different levels (one of the aims of the pilot currently being tested by students of the Universidad Complutense, is to asses whether this more refined adaptation of content compensates for the increase in complexity):

1. Learning object level. This metadata set informs if an e-learning object is suitable for a particular student (there are two possible values: visible and not visible).

2. Content level. Enriching content with additional metadata will allow adaptation in a more extensive way. The document (or any other kind of learning object) is organized into sections, and each section includes information about to the kind of users it is suitable to. For the currently working course, only adaptation based on prior knowledge of students is considered .

The learning object authoring is currently done by an XML commercial editor (XML Spy). For course and learning objects definition the DTD used includes the three sections defined in IMS content package specification version 1.1.2 (IMS CP_BIND 01):

1. Metadata section, with general information describing the course as a whole.

2. Organization section, an XML element to describe the hierarchical structure of the course, if there exists any. It also includes co- requisites, pre-requisites and personalization features for a particular item (LO) defined in the structure. The personalization features included at this granularity level are reduced to whether to display or not the learning object to a particular user.

3. Resources section, containing information about all the items described in the organization section.

Another important issue when designing a course is how big a learning object should be, usually referred as the "granularity" problem (Wiley et al., 99). The problem of the scope of learning objects can be viewed as a trade off between the benefits of reuse and the expense of the increase in complexity that it implies. In our opinion, the question should be: who is more aware of the benefits of reusing instructional material? The answer is clearly course designers. This is the reason we have left to course designers the decision of what is to be defined as learning objects in <e-Aula>.

<e-Aula> as a Learning Management System

It is becoming more and more evident that the requirements of a commercial learning environment are too diverse to be provided by a single monolithic system. First, we need a number of systems related to the content production, which needs to be created by an authoring system, to be stored in a content repository, described, catalogued and searched for in a repository. Then this contents have to be put together into courses and delivered to learners through a Learning Management System (LMS), which also has to provide support for communication and collaboration between students and teachers. Finally comes the student modelling (or student profile) systems which will carry rich and detailed information

concerning student progress through the course, and which needs to be linked to the LMS. Therefore these environments are more likely to be produced as an integration of a number of specialized systems (Olivier 00).

Hence, the scope of constructing a complete and working learning environment is too vast to be approached by a single project. Also the e-learning standards are too complex and not mature enough to be fully implemented in a research project with limited funding. Our intention is to provide a cost-effective solution for:

- Content authoring, storing and retrieval (through its metadata repository). This feature will be addressed in the next project stage, for the current system, contents are developed manually according to their DTD. Right now, data's primary format is done by any file editor (like MSWord) and we do not provide any specific editor to translate to XML. This work is currently done by programmers under the supervision of the educational specialist.

- Learning management system with support to: synchronous and asynchronous teacher-student and student-student communication through chat, forum and e-mail systems.

- Tools to simplify the management and operation of the system, such as the management of the student profile records or student and tutor registration.

- Front-end users (students) application, through which learners will be able to navigate easily through the available courses, and inside a specific course. As described in the previous section the contents presented to the student are filtered according to his/her prior knowledge.

The diagram of figure 4 gives some idea of the inter-relationships which <e-Aula> supports. The solid text boxes represent features that are already operational in <e-Aula>, the rest are to be implemented in the next project version.

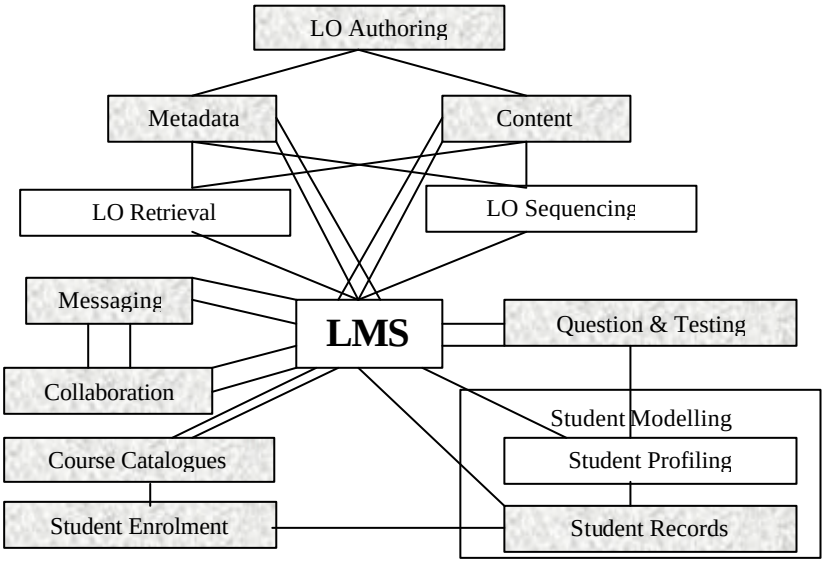

Figure 4. Outline of the blocs of a Learning Management System and their inter-relationships.

We use markup technologies (i.e. XML) because they streamline the way the system is built and how it handles information and also ease future integration with other systems. XML's metadata and related technologies are used not only to mark up the course material so that content can be adapted and reused, but also to mark up all data needed to manage different activities involved in the learning process including student information or general information for internal system

use (like the complete catalog of courses with information about students and tutors of every course). Even <e-Aula> asynchronous tools for communication between students and tutors (e.g. the forum) make use of XML. All the messages to the forum and their replies are constructed according to a simple XML DTD, in order to simplify the future use of the students contributions in the next versions of the course.

The actors of the learning process are:

- Students, tutors and system administrators (front-end users of the learning system).
- Content creators and knowledge providers (back-end users).

<e-Aula> aims to be a student centered learning environment. This means, on the one hand, that students should have open access and possibly choice of study time, place and tempo and, on the other hand, that learning should be adapted to the student knowledge gaps and learning objectives (<e-Aula> provides tailored information according to three different educational levels -low, intermediate and expert-). At the same time, we offer students a clear perspective of where they are at every moment of the learning process and provide a default learning path. Also we allow the student to get to any other location in the learning environment (that do not break any of the prerrequisites of the course) through uniform and easy navigation tools.

Tutors have access to tools to simplify the management of course related information. This: information includes detailed data about students (like learning status, marks obtained in the tests, time spent connected to the system) that is stored in student personal files. Course tutors are also allowed to modify the course structure and its content (currently with the help of the system maintenance programmers).

The tools currently available for communication and collaboration among students and tutors are e-mail service, discussion forum, chat and a general purpose section which is dynamically controlled by the tutor and that includes the latest news about the course, bibliography and related web sites.

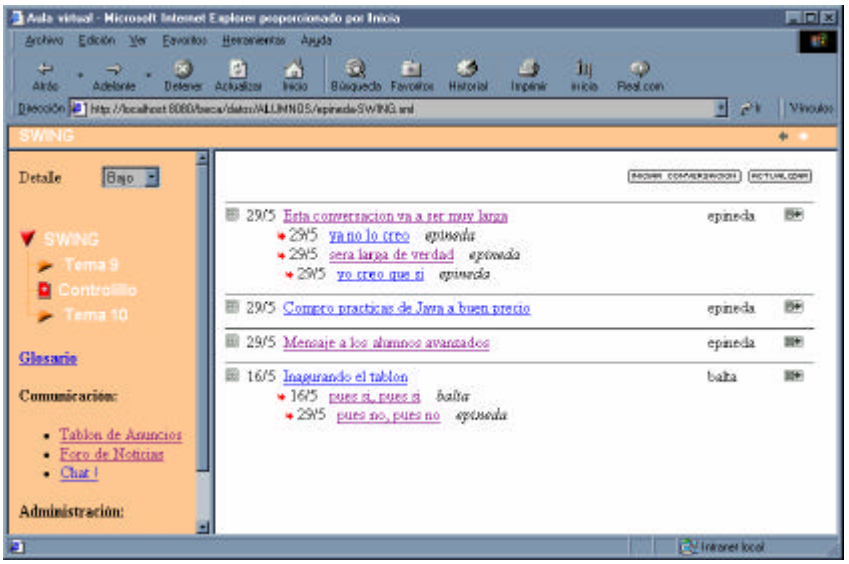

Figure 5. Asyncronous communication using a forum. The contributions agree with a simple DTD to allow their future integration in the next version of the course.

Conclusions and future work

Even though the e-learning community agrees in considering XML and educational standards the way to make content interchangeable and reusable, there is still a long way to go to reach real interoperability. Now there are many international standarization projects taking place, such as IMS, EML and IEEE LTSC. Therefore at the moment it is uncertain which standard will emerge as a "lingua franca" to create interoperable educational contents.

<e-Aula> is a research project that aims to investigate the use of learning standards and markup technologies applied to content reuse and personal adaptation in a real learning environment. Aspects such as cost-effectiveness and feasibility of the implementation are priorities of the project.

This semester a first pilot <e-Aula> course is being used by students of third year of computer science of the Complutense University of Madrid as a complement to classroom teaching. We intend to evaluate the main features of the system (like cost-effectiveness and content adaptation), the results obtained by students and the educational objectives reached.

We believe that for the next project stage it will be useful to include instructional design information for learning objects as a first step to implement an automatic sequencing tool for learning objects. Therefore, our intention is to adapt the system to comply the new IMS specification for instructional design which is based on EML. We will also take into account the IMS Learner Information Packaging (IMS LIP 01) as model for the student modelling information.

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