A comparative study on LMS interoperability

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ABSTRACT

A Learning Management System (LMS) plays an important role in any eLearning environment. Still, the LMS cannot afford to be isolated from other systems in an educational institution. Thus, the potential for interoperability is an important, although frequently overlooked, aspect of an LMS system. In this chapter we make a comparative study of the interoperability features of the most relevant LMSs in use nowadays. We start by defining a comparison framework, with systems that are representative of the LMS universe, and interoperability facets that are representative of the type integration with other broad classes of eLearning systems. For each interoperability facet we categorize and identify the most representative remote systems, we present a comprehensive survey of existing standards and we illustrate with concrete integration scenarios. Finally, we draw some conclusions on the status of interoperability in LMSs based on our study.

1. INTRODUCTION

Interoperability is the ability of different computer systems, applications or services to communicate, share and exchange data, information and knowledge in a precise, effective and consistent way (Martínez & Navarra, 2007). In the eLearning field this topic is extremely important since there is the need for all systems that typically compose an eLearning environment to communicate and share data consistently.

The LMS plays a central role in any eLearning architecture. Choosing an LMS can be a challenging task for an organization. Several studies have been conducted to analyse and evaluate these types of systems from pedagogical and institutional perspectives (Pantel, 2007; Britain & Liber 1998). However, we are not aware of any study to evaluate the interoperability of LMSs with other systems typically found in an educational institution.

A major issue in LMS interoperability is the eLearning standardization. The concept of course, student, educational resource, summary or grade must be formally described in order to be shared among all the systems in an educational institution. For instance, the difficulty to reuse of a course in schools with LMS from different vendors (or even from the same vendor) is an apt example of the problems found currently in the majority of the LMSs. These interoperability issues affect the flexibility of the teaching-learning process and lead to a decrease of end user satisfaction and learning success.

In this chapter we make a comparative study of the LMS support for interoperability. This study is part of an effort to select an LMS on which to base the development of eLearning systems integrating heterogeneous components. We chose two LMS vendors - Moodle and Blackboard - since combined they a have a significant share of the LMS market and they follow different approaches to LMS development, namely open source and commercial. We analyse the interoperability features in these LMSs split in two

facets reflecting the broad classes of systems of a typical LMS operational environment. These broad classes are Learning Content Management Systems and Academic Management Systems.
This chapter starts by tracing the evolution of LMSs. We proceed with the selection of the systems representative of the LMS universe and of a methodology for comparing them based in interoperability facets. The following two sections analyse separately the learning management content facet and the academic management facet. For each facet we categorize and identify the most representative system, the existing standards and the interoperability issues regarding the communication with the LMS. In the final section we draw conclusions on the results of this study.

2. LMS EVOLUTION

The evolution of eLearning in the last decades has staggering, from the early monolithic systems developed for specific learning domains to new systems featuring reusable tools that can be effectively used virtually in any eLearning course. These types of systems evolved from Content Management Systems (CMS). The CMS was introduced in the mid-1990s mostly by the online publishing industry. This type of system can be defined as a data repository that also includes tools for authoring, aggregating and sequencing content. The main goal of these tools is to simplify the creation and administration of online content (Nichani, 2009). CMS are focused on content with the main purpose to store information and provide access to it. CMS content is organized in small self-contained pieces of information to improve reusability at the content component level. These content components when used in the learning domain are called "learning objects" (LO) and the systems that manage them are called Learning Content Management Systems (LCMS).
Nowadays, an LMS plays a central role in any eLearning architecture and can be defined as software application for the administration, documentation, tracking, reporting of training programs, classroom and online events, and training content (Ellis, 2009). Typically it is used by two types of users' groups: learners and teachers. The learners can use the LMS to plan their learning experience and to collaborate with their colleagues; the teachers can deliver educational content and track, analyze and report the learner evolution within an organization. There are open source systems, such as Moodle, Sakai, .LRN or Dokeos, and commercial systems such as WebCT/Blackboard or Desire2Learn.
They all feature general tools for delivering content and for recreating a learning context. From a course/discipline perspective they provide tools for handling assignments, managing chat rooms and forums, evaluating multiple-choice tests and quizzes, among others. From a learners' management perspective they provide tools for keeping grade books, managing groups of students, and browsing logs. Ashford-Rowe and Malfroy (2009) organize these tools in four groups, namely:

- **Content -** Unit/Course online, Lecture and Tutorial notes, Media (i.e. lectopia, podcast, videocasts), links to scholarly information (readings), links to content resources (i.e. websites), interactive resources (.swf .fla .flv and other file types);
- **Communication -** Chat, Announcements, Discussion Board, Email, Blogs and Forums;
- **Collaboration -** Wikis, Virtual Classroom and Voice-based communication;
- **Assessment -** Quizzes, Reflective learning journals, Portfolios, Grades, Surveys, Practice activities and past exams.

Recently the eLearning community started valuing more the interchange of course content and learners' information, which led to the definition of standards for eLearning content sharing and interoperability. Standards can be viewed as "documented agreements containing technical specifications or other precise criteria to be used consistently as guidelines to ensure that materials and services are fit for their purpose" (Nichani, 2009). In the eLearning context, standards are generally developed for the purposes of ensuring interoperability and reusability in systems and of the content and meta-data they manage. In this context, several organizations (e.g. IMS GLC, IEEE, ISO/IEC, ADL) are developing specifications and standards (e.g. IMS CP, IMS CC, IMS DRI, LOM, SCORM) in the last years (Dagger & O'Connor & Lawless & Walsh & Wade, 2007). These specifications are closely related with the learning object concept as context independent, transportable and reusable pieces of instruction that are digitally managed and delivered (Rehak & Mason, 2003). There are other definitions for Learning Objects (LO). Rehak & Mason (2003) define a learning object as: "a digitized entity which can be used, reused or referenced during technology supported learning".

As every kind of software, LMSs continue to evolve to meet market demands. In relation to interoperability the main trend for the next LMS generation is service-oriented architectures (SOA) (Dagger & O'Connor & Lawless & Walsh & Wade, 2007). In these architectures LMSs expose their functions as services and consume services from their operational environments, improving their interoperability with other eLearning systems. In fact, the last few years brought us several initiatives (Smythe, 2003; Wilson & Blinco & Rehak, 2004) to adapt SOA to eLearning. These initiatives, commonly named eLearning frameworks, have the same goal: to provide flexible learning environments for learners worldwide. Usually they provide a set of open interfaces to numerous reusable services organized in genres or layers that can be combined in service usage models (Queirós & Leal, 2010).

Other trends result from new market demands such as Web 2.0, Talent Management, Mobile Learning, “Software as a Service” and Open Source Software. With the recent appearance of *Web 2.0* tools and the popularity of social networking tools like Facebook and Twitter, there has been a great demand to use similar tools in the LMS to enhance the communication among teachers and students. *Talent Management* software systems are an extension of traditional human resource management systems. Some researches (Bersin & Howard & O’Leonard & Mallon, 2009) shows that in 2009 more than 70% of large companies have an LMS already and almost 1/3 of these companies are considering replacing or upgrading these systems with integrated talent management systems (Levensaler & Laurano, 2009). With more students working at distance, there has been also a strong demand to make eLearning applications accessible through mobile devices (e.g. Smartphones, PDA) know as *Mobile Learning* or m-*learning*. Using LMS *Software as a Service* (SaaS) schools can relieve the financial burden of maintaining their LMSs by outsourcing the hosting service. Commercial LMS (e.g. Blackboard, WebCT) have dominated the education market in previous years, but as costs increase, schools and companies are now looking for other options such as *open-source* solutions (e.g. Moodle, Sakai) that are financially more attractive.

3. COMPARISON FRAMEWORK

The goal of this work is to analyse and compare LMS interoperability features. Given the number of LMS vendors it would be impracticable to study them all. Therefore we selected two LMSs that we consider representative of the LMS universe. This selection is based on their prominence in the LMS market and the fact that they cover the open source and commercial development models.

Interoperability is in general a complex concept that can be analysed in multiples perspectives and this is surely the case with LMSs. To organize our study we identified two broad classes of systems that usually integrate the operational environment of the LMS. Thus, we considered two facets in LMS interoperability, regarding communication and data sharing with these classes.

3.1 Learning Management Systems

A good number of LMSs that were developed in the past fifteen years are still in use and under active development. For the purpose of our study we must concentrate on a few systems that are representative of the LMS universe in terms of their characteristics and market share.

A simple categorization of this type of systems is according to their development model. There are fundamentally two: open source systems, such as Moodle, Sakai, .LRN or Dokeos; and commercial systems such as WebCT/Blackboard or Desire2Learn. Figure 1 presents a timeline of the development of several initiatives grouped by their development model.

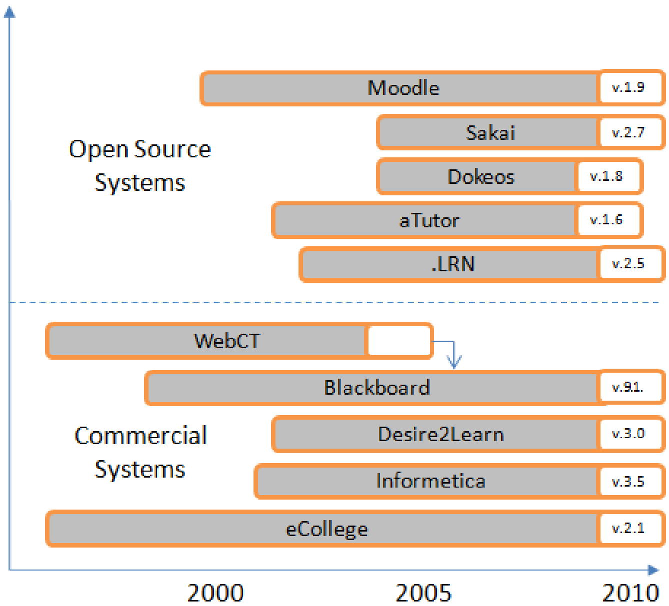

Figure 1. Timeline of development of major LMSs.

The Figure 1 shows that the first major LMS adopted a commercial development model but since the beginning of this century there has been a shift towards open source systems. In fact, this shift was already recognized as a trend in LMS development (Davis & Carmean & Wagner, 2009). In spite of the growing popularity of open source, commercial systems are still relevant and they must be included in any representative sample of LMSs.

In these two categories we decided to select the most popular systems taking as reference the available data on global LMS usage (Davis & Carmean & Wagner, 2009). As part of this study we conducted a survey on eLearning systems usage on Portuguese higher education institutions. We received responses from 20 different institutions and the results for LMS usage are shown in Figure 2. The two most popular LMSs in these institutions follow the global trend, which reinforces our choice of the reference systems for our study.

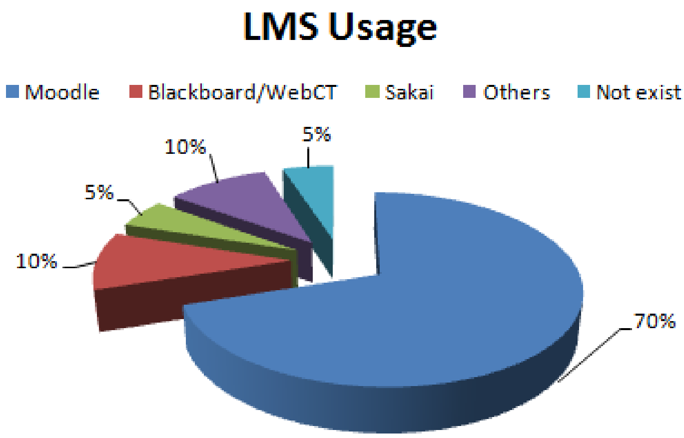

Figure 2. LMS usage in Portuguese higher education institutions.

We decided to focus our study on Moodle and Blackboard. We chose them since they represent the two main development models used by LMS vendors (open source and commercial); and combined they have a significant share on the LMS market (33.2% on the international market (Davis & Carmean & Wagner,

2009) in 2009 and 80% on our own recent survey). The following paragraphs provide an overview of the selected systems.

Moodle (version 1.9.9 - 8th June 2010) is a free and open-source LMS written in PHP and created by Martin Dougiamas. Its name is an acronym for Modular Object-Oriented Dynamic Learning Environment. In early January of 2010, Moodle had a user-base of 46,624 registered sites with 32,464,992 users in 3,161,291 courses in 209 countries and in more than 75 languages (Cole & Foster, 2007). The most common functions of Moodle are the course information and documentation, documents repository, announcements, synchronous and a synchronous communication (email, chat room, discussion forum) and assignments.

Blackboard (version 9.1 - 1th April 2010) was developed by Blackboard Inc. in 1997 and is an online proprietary virtual learning environment system that is used by over 3700 educational institutions in more than 60 countries. In February 2006, the virtual learning environment called WebCT (Course Tools) was acquired by Blackboard Inc. (Blackboard, 2005) and, as part of the acquisition terms, the Blackboard brand was assumed until now.

3.2 Interoperability facets

The interoperability features of a system reflect the operational environment where it is expected to be deployed. The operational environment of an LMS includes different systems and services with which it may have to communicate and exchange data. As depicted in Figure 3 we identified two broad classes of systems that usually integrate the operational environment of an LMS, each corresponding to a different facet in LMS interoperability. We identified also a layer of infrastructural systems and services that are domain independent but that play an important role in LMS interoperability.

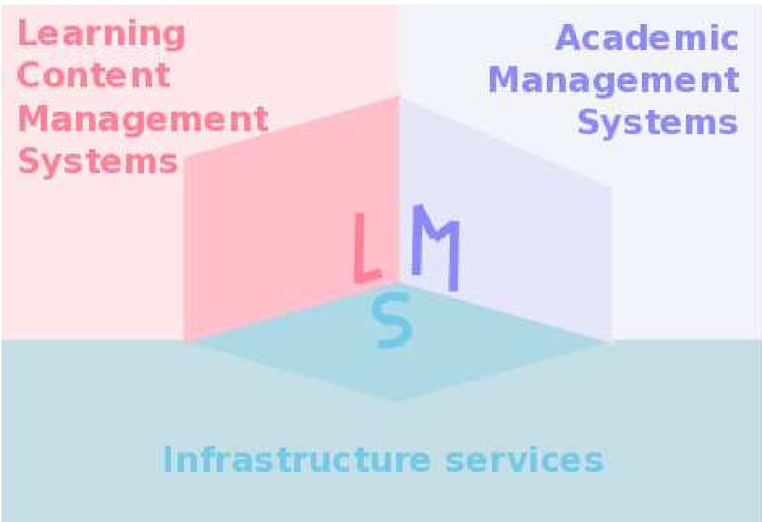

Figure 3. LMS interoperability facets.

For the purpose of this study, the broad classes of systems that we identified as part of the operational environment of an LMS are the following:

Learning Content Management Systems (LCMS) are used for the development, management and publishing of digital learning content (e.g. Learning Objects) that the LMS delivers. Examples of these systems are the Learning Object Repositories, e-Portfolio Systems, Authoring Tools, Specialized Evaluators and others.

Academic Management Systems (AMS) are used for managing academic data information of an educational institution. Typical features of these systems are the management of courses, classes and students, the enrolment of students in courses, the submission of summaries and grades by teachers, among others.

Apart from these facets the LMS is supported by *infrastructure services* providing basic functions that are not specific to eLearning, such as directory services for authentication and authorization or printing services. We consider also as part of this infrastructure the web or application server, the database engine and the operative system. In many cases this infrastructural layer is used for implementing *ad hoc* interoperability solutions.

In the following sections the selected systems are analysed and compared regarding these two facets. We categorize and identify the remote systems in each facet, the existent standards and the interoperability issues regarding LMS communication with those systems. There is a huge asymmetry among these facets and this is reflected in the structure of the following sections. Of the two facets, the first has a larger number of systems and mature standards. The systems in second facet are mostly home-grown with few and immature standards to regulate both content (e.g. academic records, course forms, grades, summaries) and communication.

4. LEARNING CONTENT MANAGEMENT FACET

The Learning Content Management facet focuses on the interoperation with systems that provide pedagogical content and services delivered by the LMS. We start by identifying their main types, followed by the existing standards for content and communication, and ending with an example of system integration in this facet.

4.1 System types

The content delivered by an LMS can be created, obtained, gathered or evaluated in several types of systems such as Learning Objects Repositories, E-Portfolio systems, Authoring Tools, Specialized Evaluators or Quizzes. In the following sub-subsections some of these system types are detailed.

4.1.1 Learning Object Repositories

A repository of learning objects can be defined as a “system that stores electronic objects and meta-data about those objects” (Holden, 2004). The need for this kind of repositories is growing as more educators are eager to use digital educational contents and more of it is available. One of the best known repositories of LOs is Merlot (Multimedia Educational Resource for Learning and Online Teaching) which provides pointers to online learning materials and includes a search engine. A non-exhaustive list of learning object repositories is presented in Table 1 (JORUM team, 2006).

Free	**Payed**
CAREO	Sentient Learning
Wisconsin Online Resource Center	Harvest Road Hive
BELLE	Learn eXact
POOL	teknical
CLOE	KaiNao Ltd
MERLOT	Luminas
Maricopa Learning Exchange	The Learning Edge
Connexions	
EducaNext	
The Learning Matrix	
MIT OpenCourseWare	
DLearn	
EdNA Online	
ARIADNE	

Table 1 - Repository tools by category

The Jorum Team made a comprehensive survey (2006) of the existing repositories and noticed that most of these systems do not store actual LOs. They just store meta-data describing LOs, including pointers to their locations on the Web, and sometimes these pointers are dangling. Most of the current repositories are specialized search engines of LOs and with little support for interact with specialized eLearning systems, such as evaluation engines and experimentation environments. These systems require both complete interoperability and specific metadata. They need service oriented repositories of learning objects, fully compliant with the existing interoperability standards, and supporting new definitions of learning objects for specialized domains. An example of a specialized repository of LO is crimsonHex (Leal & Queirós, 2009), the repository developed as part of the EduJudge project to act as a programming problem repository service to the Evaluation Engine (EE) and the LMS.

4.1.2 ePortfolio Systems

An electronic portfolio is a digital collection of student work (artefacts) usually managed in ePortfolio systems and displayed for specific audiences and purposes. The ePortfolios systems usually include (or link) a repository where students organize their artefacts typically for the purpose of assessment. The benefits of an ePortfolio system in an educational institution are shared by students and teachers. Students are able to reflect on their educational experiences and showcase their work in a repository. Teachers are able to evaluate the student progress and provide concrete evidence of the students' learning.
Helen C. Barrett (Barret, 2008) organizes the ePortfolio tools in two categories: individual and institutional. Both are presented in Table 2.

Individual		**Institutional**	
Authoring tools	Web Services	Software – Server	Hosted Services
Mozilla Composer Dreamweaver Microsoft Office Adobe Acrobat Movie Maker	Google Docs Zoho Writer WikiSpaces	Elgg Mahara OSPI Moofolio, MyStuff (embedded in Moodle)	Digication iWebfolio Epsilen GoogleApps for Education

Table 2 - ePortfolio tools by categories

In the individual category we can use *authoring tools* to author portfolios offline (requires web server space to publish online) or *web services* to create online and publish a presentation portfolio allowing interactivity (Web 2.0). In the institutional category we can use a *software-server* where an institution installs on their own server to provide space for hosting portfolios or *hosted services* that an institution adopts (no server required) that host portfolios.
In the survey we conducted on Portuguese high education institution no one indicated to be using a ePortfolio system. This fact allows us to conclude that the dissemination of these tools in the educational institutions, at least in Portugal, is still low.

4.1.3 Authoring Tools

The growing popularity of learning objects lead to the development of specialized editors supporting eLearning metadata. These tools, either open source, freeware or commercial, export the content to SCORM packages and other formats such as IMS CP, IMS CC, HTML, PPT, PDF and Flash. The most important authoring tools grouped by their development model are presented in Table 3.

OpenSource	Freeware	Commercial
eXe Xerte ScenariChain Opale LOMPad	Hot Potatoes MyUdutu MOS Solo Reload Courselab	Camtasia Captivate QuizCreator Wondershare PPT2Flash PowerQuizPoint

Table 3 - Authoring tools by categories

The majority of the authoring tools support multiple application profiles. RELOAD is arguably the most mature of these projects and is available both as a standalone Java application and as an Eclipse IDE plugin. It supports a broad range of metadata formats but cannot be extended to support specialized formats. The SHAME project (2006) - Standardized Hyper Adaptable Metadata Editor – stands out from the rest since it is actually a metadata editing and presentation framework for RDF metadata with support for all kind of metadata based on a previous mapping for the RDF syntax. Some of these tools are specialized in a certain type of multimedia format (e.g. Captivate for video) or activities (e.g. Hot Potatoes for quizzes) and are the best place for the users to create the respective content.

4.1.4 Specialized Evaluators

Examples of eLearning systems that provide content can be drawn from different domains. At the heart of a system with automatic evaluation resides an Evaluation Engine (EE). This is an apt example of a specialized eLearning service, performing a specific task and reusable in different scenarios. An EE can supply its services not only to LMSs but also to other specialized application services, such as quizzes and contest management systems. Desktop based applications also fit in this approach.
This model of combining specialized services can be extended to competitive learning in other domains such as business training, for instance. In this domain teachers use business simulation games to improve the strategic thinking and decision making skills students in particular areas (e.g. finances, logistics, and production). Through these simulations students compete among them, as they would in a real world companies. A business simulation service fulfils a role similar to that of the EE in programming exercises and it also requires a repository containing specialized LO describing simulations. An example of a evaluation engine is the UVA Online Judge EE (Regueras & Verdú & Castro & Pérez & Verdú, 2008), the EE developed as part of the EduJudge project to act as an evaluator of programming problems submitted by students.

4.2 Standards

In this subsection we introduce several standards related to learning objects. We structured these standards in four groups: packaging, metadata, organization and communication.

4.2.1 Packaging

Packaging is crucial to store eLearning material and reuse it in different systems. The most widely used content packaging format is the IMS Content Packaging (IMS CP, 2007). An IMS CP learning object assembles resources and meta-data into a distribution medium, typically an archive in zip format, with its content described in a manifest file in the root level as shown in Figure 4.

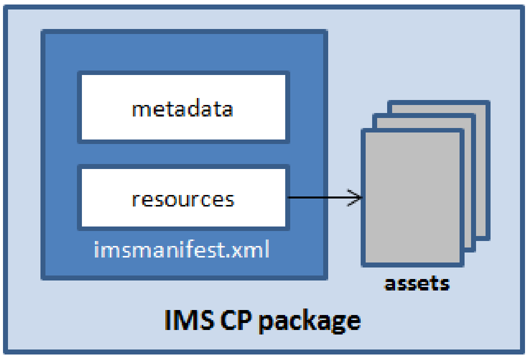

Figure 4. The IMS CP package.

The manifest file - named imsmanifest.xml -adheres to the IMS CP schema and contains the following sections:

Metadata - describes the package as a whole;
Organizations - describes the organization of the content within a manifest;
Resources - contains references to resources (files) needed for the manifest and metadata describing these resources;
Sub-manifests - defines sub packages.

The manifest uses another standard - the IEEE Learning Object Metadata (IEEE LOM, 2002) - to describe the learning resources included in the package (c.f. Sub-subsection 4.2.2). Recently, IMS Global Learning Consortium proposed the IMS Common Cartridge (IMS CC, 2010) that adds support for several standards (e.g. IEEE LOM, IMS CP, IMS QTI, IMS Authorization Web Service) and its main goal is to shape the future regarding the organization and distribution of digital learning content.

4.2.2 Metadata

The content of LO packages is described by metadata. Its purpose is to support the interoperability and reusability of learning objects. As mentioned previously, the IMS CP manifest contains four sections and is precisely Metadata that provides an overall description of the package. Metadata can be used to describe file features in the Resource section. In the manifest the metadata element is used at two levels: package (overall description of the package) and resource (description of the resource and contained files). In both cases metadata information usually follows the IEEE LOM schema. The IEEE LOM is a data model used to describe a learning object. The model is organized in several categories that cover general data, such as title and description, technical data such as object sizes, types and durations, educational characteristics and intellectual property rights, among many others.

These categories are very comprehensive and cover many facets of a LO. However, LOM was designed for general LO and does not to meet the requirements of specialized domains. For instance, there is no way to assert the role of specific resources. Fortunately, IMS CP was designed to be straightforward to extend through the creation of application profiles. The term Application Profile generally refers to "the adaptation, constraint, and/or augmentation of a metadata scheme to suit the needs of a particular community". A well know eLearning application profile is the Sharable Content Object Reference Model (SCORM, 2009) that extends IMS CP with more sophisticated sequencing and Contents-to-LMS communication.

The IMS GLC is also responsible for another application profile, the Question & Test Interoperability (QTI) specification. QTI describes a data model for questions and test data and, since version 2.0, extends the LOM with its own meta-data vocabulary. QTI was designed for questions with a set of pre-defined answers, such as multiple choice, multiple response, fill-in-the-blanks and short text questions.

There are other metadata specifications, such as, the Dublin Core Metadata, which provides a simpler and a more loosely-defined set of elements useful for sharing metadata across heterogeneous systems. At the present, the Dublin Education Working Group is extending the Dublin Core for the specific needs of the education community.

4.2.3 Organization

Learning objects can be organized in items and an organization defines a path through those items. The IMS CP specification includes a manifest section called Organizations. This section can be used to design pedagogical activities and articulate the sequencing of instructions. By default, it uses a tree-based organization of learning items pointing to the resources (assets) included in the package. However, other standards could be accommodated in this section, such as IMS Simple Sequencing (IMS SS) and IMS Learning Design (IMS LD). These specifications aims to provide to the teachers mechanisms for coordination of the educational instructions based on students' profile making the instruction more dynamic and flexible.
The IMS LD specification is a meta-language for describing pedagogical models and educational goals. Several IMS LD-aware tools are available as players (e.g. CopperCore, .LRN) and authoring/export tools (e.g. Reload, LAMS). The IMS SS is a specification used to describe paths through a collection of learning activities. The specification declares the order in which learning activities are to be presented to a learner and the conditions under which a resource is delivered during an eLearning instruction. Despite all these specifications, the design of more complex adaptive behaviour is still hard to achieve.

4.2.4 Communication

The standardization of the learning content it is not enough to ensure interoperability, which is a major user concern with the existing systems. The definition of common protocols and interfaces for the communication among systems is also an issue that the major eLearning interoperability initiatives (e.g. NSDL, POOL, OKI, EduSource, IMS) try to address. As an illustration we present the communication guidelines defined by IMS, arguably the most developed ones in this category.
The **IMS Learning Tools Interoperability (IMS LTI)** provides a uniform standards-based extension point in LMSs allowing remote tools and content to be integrated into LMSs. The main goal of the LTI is to standardize the process for building links between learning tools and the LMS. The LTI has 3 key concepts as shown in Figure 5 (Gilbert, 2009): the Tool Provider, the Tool Consumer and the Tool Profile.

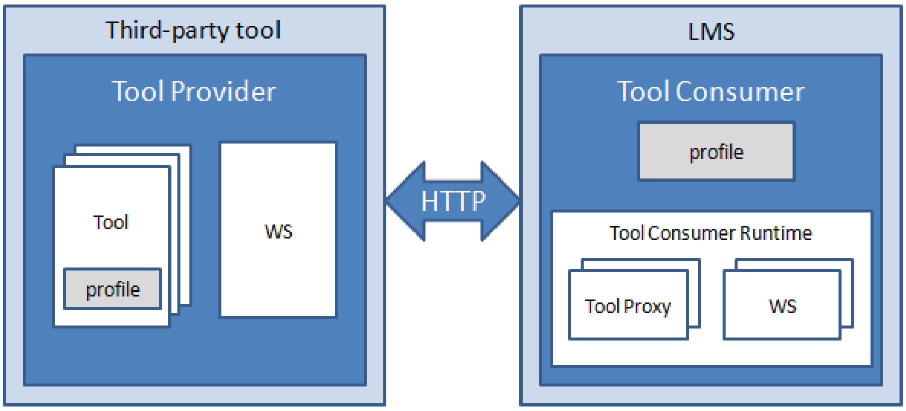

Figure 5. The IMS LTI framework.

The *Tool Provider* is a learning application that runs in a container separate from the LMS. Publishes one or more tools through the Tool Profiles. The *Tool Profile* is an XML descriptor that describes how a tool integrates with a tool consumer. It is composed by information about the tool metadata, vendor information, resource and event handlers and menu links. The *Tool Consumer* publishes a Tool Consumer Profile (XML descriptor of the Tool Consumer's supported LTI functionality that is read by the Tool Provider during deployment), provides a Tool Consumer Runtime and exposes the LTI services.

The **IMS Digital Repositories Interoperability (IMS DRI)** specification deals with the communication with a specific eLearning system: the repository. Within eLearning, repositories are used to store, manage and share LO. One of such efforts was the IMS Digital Repositories (IMS DRI). The IMS DRI specification was created by the IMS Global Learning Consortium (IMS GLC) and provides a functional architecture, summarized in Figure 6, and reference model for repository interoperability.

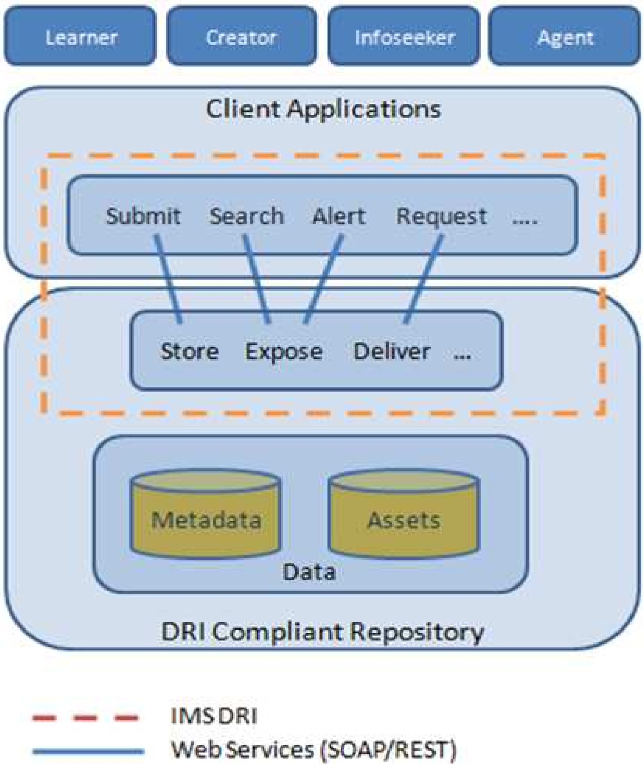

Figure 6. The IMS DRI specification.

The IMS DRI provides recommendations for common repository functions, namely the submission, search and download of LOs. It recommends the use of web services to expose the repository functions based on the Simple Object Access Protocol (SOAP) protocol, defined by W3C. Due to their growing popularity other web service interface flavours, such as Representational State Transfer (REST) (Fielding, 2000), should be considered, since they are not excluded from the recommendation. This will improve interoperability with systems that adhere to a more informal style of development.

4.3 Integration

In the majority of the cases an LMS integrates an organization infrastructure in conjunction with other systems. In the following sub-subsections we present the interoperability features of the reference LMSs with the learning content management systems usually found in educational institutions. An integration example between a LMS and one of these systems is also presented.

4.3.1 State of Art

The integration with eLearning content management systems can be implemented on the LMS data or business layer. In the former the integration uses the import / export features of both system and relies on the support of common formats. In the later the integration relies on the existence of compatible web services in both systems.

Data integration is the simplest and most popular form of integration in content management. For instance, the RELOAD authoring tool can be used to create learning objects in SCORM format and Blackboard supports and imports SCORM packages. Table 4 lists some of the most important eLearning content standards and specifications defined in the last years by educational organizations. For each standard we present the LMS support status.

	Moodle	**Blackboard**
IMS CP	yes	yes
SCORM	yes	yes
IMS CC	partial	partial
IMS QTI	yes	yes
IMS LD	no	no
IMS SS	no	no

Table 4 - Reference LMS support of eLearning content standards

The studied LMSs support almost all the LO package standards with exception of the recent IMS CC that is only partially supported. In relation to the design and sequencing of learning activities standards are not yet supported by these LMSs, probably due to their complexity.

Data integration assumes an important role in the LMS interoperation with system types that do not require a tight integration, as is the case with authoring tools. For instance, the Hot Potatoes system enables the creation of quizzes - interactive multiple-choice, short-answer, jumbled-sentence, crossword, matching/ordering and gap-fill exercises - in HTML format. Moodle includes an activity that imports the quiz (HTML file) previously generated in the Hot Potatoes system. It should be noted that although Moodle supports the QTI format for quizzes described previously, Hot Potatoes cannot export in this format.

It is possible also to integrate an eLearning tool with an LMS on the business layer. For instance, the *IMS Learning Tools Interoperability (IMS LTI)* provides a uniform standards-based extension point in LMSs allowing remote tools to be integrated into LMSs. Although this specification is still not explored by the major LMS vendors, obtaining the certified support for IMS LTI is already a major milestone in their development plan. Another integration approach is through Application Programming Interface (API). The LMSs include APIs to allow developers to extend their predefined features through the creation of plugins. Table 5 enumerates the approaches used by the selected LMS to address the interoperability issues regarding the integration with the system types referred in subsection 4.1.

	Moodle	**Blackboard**
Repositories	***Repository API***	Building Blocks API
E-Portfolios	Portfolio API	Building Blocks API
Evaluators	OPAQUE ws	no

Table 5 - Integration APIs in reference LMSs

Moodle version 2.0 (due in September 2010) includes several APIs to enable the development of plugins by third parties to access repositories and portfolios (c.f. the following sub-sub-section). Blackboard uses the Building Blocks technology to cover the integration issues with other systems. A Building Block is simply a web application that runs on the Blackboard application server. This technology allows third parties to develop modules using the Building Blocks API. For instance, the company Verbena Consulting LLC created a building block that provides a search user interface that allows searching in the MERLOT repository and returns matching results along with the metadata for each learning object.

4.3.2 Example of integration

In this subsection we illustrate the use of the communication APIs in Moodle, arguably the most popular LMS nowadays. Concretely we present the new file APIs of Moodle 2.0 and how it was used for implementing a plug-in for crimsonHex repositories (Leal & Queirós, 2009). The beta version of Moodle 2.0 includes support for different types of repositories. Two APIs are already available to enable the development of plug-ins by third parties systems, including:

Repository API for browsing and retrieving files from external repositories;

Portfolio API for exporting Moodle content to external repositories.

We chose the Repository API since it is the most stable of the two. It is organized in two parts: Administration, for administrators to configure their repositories, and; File picker, for teachers to interact with the available repositories.

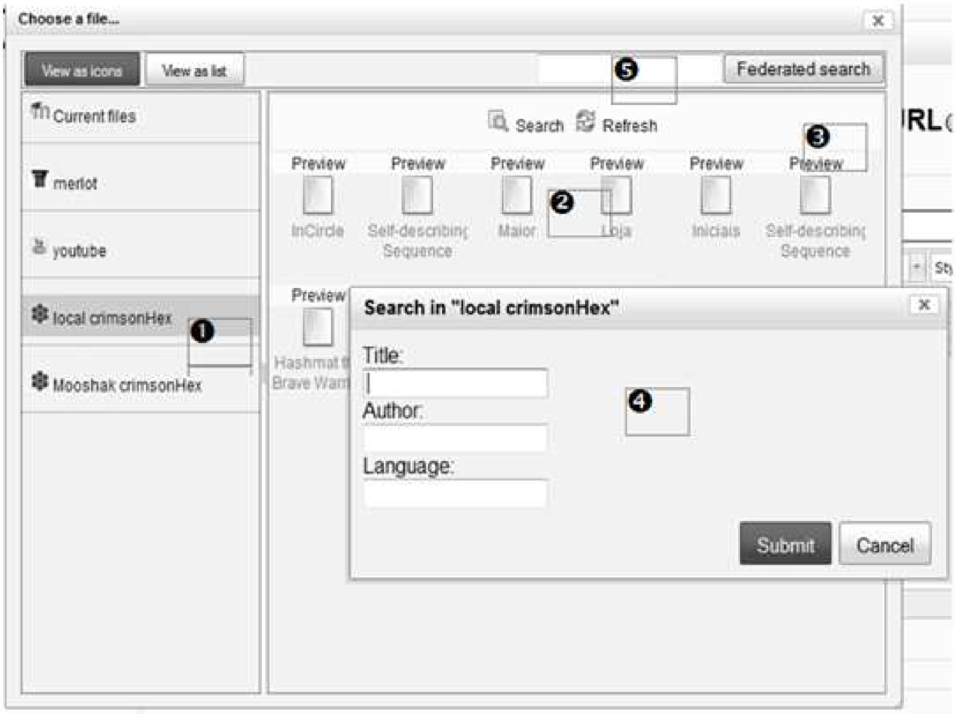

Figure 7. crimsonHex plugin interface.

Figure 7 presents the file picker GUI of the crimsonHex plug-in. On the left panel are listed the available repositories as defined by the administrator. Two crimsonHex repository instances are marked with label 1. Label 2 marks the default listing of the selected repository. Pressing the "Preview" link marked with 3 presents a preview of the respective LO. Pressing the "Search" link pops-up a simple search form, marked as 4. For federated search in all available crimsonHex repositories is used the text box marked as 5. The development of this plug-in was straightforward. In terms of programming effort we spent half a day to produce approximately 100 new lines of code.

For Moodle each repository is just a hierarchy of nodes. This allows Moodle to construct a standard browse interface. The repository server must provide:

- a URI to download each node (e.g. a LO);
- a list of nodes (e.g. LO and collections) under a given node (e.g. collection).

In addition to these requirements, a repository can optionally support authentication, provide additional metadata for each node (mime type, size, related files, etc.), describe a search facility or even provide copyright and usage rules.
Each feature of the plug-in is implemented by a method in a PHP class. A typical method includes: a repository invocation (SOAP or REST), the parsing of its response (using a PHP function to parse the XML data), a selection of the pertinent data (using XPath) and an iteration over the new results (for instance, populating an array with the relevant data).

5. LEARNING CONTENT MANAGEMENT FACET

In this section we analyse the Academic Management facet. The main system type on this facet is the Academic Management System (AMS). An AMS aggregates all the information regarding administrative, financial, technical or scientific processes usual in educational institutions. Examples of these processes are the enrolment of students in courses, the management of grades or the payment of fees. This interoperability facet is not as mature as the one analysed on the previous section and there are still few standards available. This fact burdens the integration of academic management systems with LMSs that must resort to *ad hoc* solutions based on the infrastructural layer.

5.1 Integration

Unlike in content management, there is a sole type of system in this facet - the AMS - and apparently with very few vendors. We were not able to find in the literature any study on AMS usage. For this reason our analysis is based on the use of AMSs by Portuguese higher education institutions as reflected in the survey we conducted for this study.
As mentioned before, the questionnaire inquired on vendors of different types of eLearning systems in use at each institution. We received responses from 20 different institutions and the results for AMS are presented in Figure 8.

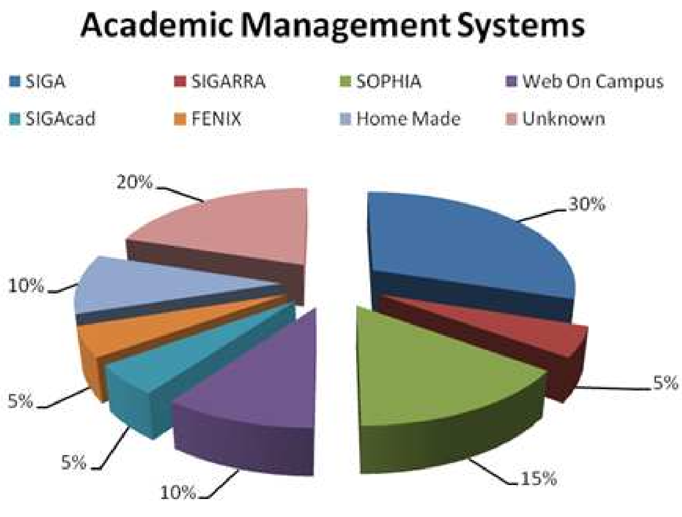

Figure 8. AMS usage.

This data shows that no system is clearly preferred by Portuguese educational institutions. The choices are divided by the systems SIGA, SIGARRA, SOPHIA and Web on Campus. It should be noted that most of these evolved from home grown systems and are in use in different schools from the same university or polytechnic institute. In some cases spin-offs were created to develop and commercialize these systems but the size of these companies cannot be compared with those developing other types of systems related to eLearning, such as LMSs.

5.2 Standards

An AMS manages different kinds of information. The concept of course, student, summary or grade should be described formally in order to be shared among all the systems included in a educational institution. As far as we know, there are few standards that formalize these content types and how they are communicated to allow the AMS to share data with other systems. Table 4 enumerates these standards and the respective support by the selected LMSs.

The **IMS Learner Information Services (IMS LIS)** is the definition of how systems manage the exchange of information that describes people, groups, memberships, courses and outcomes within the context of learning. The IMS LIS, like its predecessor (IMS Enterprise specification), is focused on the connection between an LMS and an AMS.

The **IMS Learner Information (IMS LIP)** specification addresses the interoperability of internet-based Learner Information systems with LMSs. It describes mainly the characteristics of a learner. The learner information is a collection of information about a learner (individual or group learners) or a producer of learning content (creators, providers or vendors).

	Moodle	**Blackboard**
IMS LIS	partial	in development
IMS LIP	no	no

Table 6 - LMS support of academic content standards

5.3 Integration

There is an obvious gain in integrating AMS and LMS: avoiding the duplication of processes. For instance, course management is required in both systems and with a tight integration it can be performed in just one of them. Several processes can be performed in only one side and reflected in the other such as: course management, enrolment of students, grades management, summaries management, exams schedule, absences management.

In general, educational institutions use *ad hoc* solutions to implement this type of integration. The most common strategies are:

- **portals -** aggregating content from multiple sources with a common presentation layer;
- **database replication**: different applications but sharing content;
- **features share**: presentation independent but sharing some features (e.g. authentication).

The diagram in Figure 9 summarizes three main integration strategies. Integration usually includes at least one web application, and these are typically designed based on the well known three-tier architectural pattern. There is a potential for integration in any the three classical tiers: presentation, logic and data.

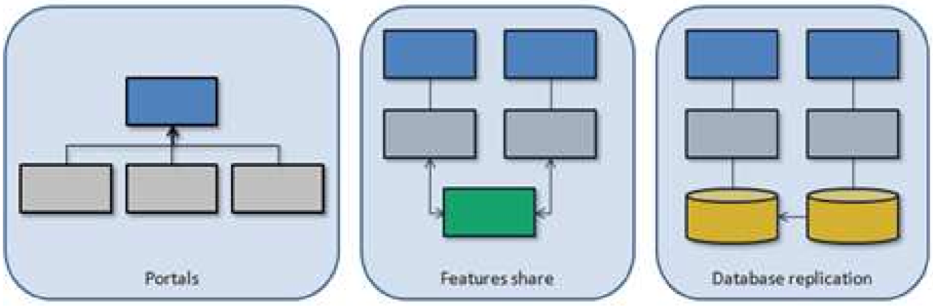

Figure 9. Three integration classic models.

The portal strategy integrates at the presentation tier, providing and unified web interface to a number of independent subsystems, including eLearning systems. The major advantage of this strategy is the fact that it gives users a sense of unity, sometimes at the cost of compromising consistency.
Feature sharing is integration at the logic tier and is becoming increasingly popular as more systems expose their functionality using web services. Moreover, there are a number of infrastructural services, using or not web services, which can be exploited by eLearning systems. User authentication based in directory services, such as LDAP, is an apt example of this type of integration.
Finally, integration may occur at the data tier, and partial database replication is arguably most common example. For instance a LMS may import data on students, courses and student enrolment in courses from administrative systems to avoid the burden of entering this data manually. These integration models are usually combined. For instance, a portal that provides and unified presentation may also adhere to a single sign-on mechanism shared with other services.

6. **CONCLUSION**

This chapter presents a comparative study on LMS interoperability. Given size of this category we focused on a couple of representative systems - Moodle and Blackboard - since combined they represent a significant market share and cover both the commercial and open source development models.
We proposed a framework for analysing LMS interoperability by distinguishing two different facets in the way theses systems communicate with their operational environment: learning content management and academic management. We characterized the types of systems that communicate with the LMS trough each facet. Standards are the corner stone of interoperability. Thus we made a comprehensive presentation of the existing standards. We completed the analysis with illustrations of system integration for each facet.
The main conclusion of this study is that there is still a long road ahead in LMS interoperability. In general it is not straightforward to connect an LMS to another system. A lot of work has already been done in defining standards but many of them are supported neither by the LMSs nor by the system that surround them. The content management facet is much more developed then the academic management facet. Content formats, especially those of learning objects, are already mature and widely supported by the analysed systems. The notable exception is the recent Content Cartridge of IMS that is not yet supported, as is not its companion specification - the Learning Tools Interoperability - that is still being implemented in Moodle and Blackboard. This specification promises to be a major step towards content interoperability among eLearning systems. Meanwhile, to integrate LMSs with content management systems we must resort to system specific APIs. An example of using Moodle 2.0 Repository API was presented to illustrate this type of integration. On the academic management facet there are no AMS system standing out from the crowd and most of those in use, at least in Portuguese higher education institutions, are home grown systems. Standards in this facet are few and immature and not widely supported by existing AMS systems. As a consequence, the integration of LMS and AMS relies on infrastructure services. We presented a set of integration strategies that are commonly used for implementing these *ad hoc* integrations.
This study is part of an effort to select an LMS on which to base the development of eLearning systems integrating heterogeneous components. Unfortunately, from that viewpoint we cannot conclude on the superiority of any of the analysed systems.

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