Learning in the age of global information technology: development of a generic architecture for an advanced learning management system

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Abstract

This paper briefly introduces the trends towards e-learning and amplifies some examples of state of the art systems, pointing out that all of these are, to date, limited by adaptability and shareability of content and that it is necessary for industry to develop and use an inter-operability standard. Uses SCORM specifications to specify the skeleton of an architecture to develop an advanced learning management system.

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1. Introduction: computer-based training and online learning

Developments in information technology (IT) have led to huge increases in the use of computer-based training (CBT). Computer performance has, generally, been doubling annually, when taking into account the increased use of extensive hypermedia. Fast computers, with modern sound and graphics hardware have become cheap, allowing home-users to benefit from high performance software solutions using high-resolution graphics and video. The birth of the World Wide Web (WWW), in 1991, opened up a new dimension to CBT, as delivery was now possible over a network of computers. This enables trainees to learn online anywhere, anytime and provides possibilities for huge cost savings in corporate training. When the training can be done from an office local area network (LAN) or from a home computer, the travel, accommodation and off-the-site costs are reduced significantly. This applies most significantly to large multinational companies where employees are commonly sent abroad for courses.

Course authors of learning materials and technology soon changed focus from the development of standalone learning applications towards authoring Web-enabled content, which could be published on the Internet and viewed with a standard browser. An individual may now log on to the Internet and access training anywhere and anytime, learning online. Online learning has created excellent opportunities to access learning and new ways for collaboration have emerged. However, even though the benefits of the CBT are clear and the courses are designed to be highly interactive (Chen and Ford, 1997), they often suffer from the lack of direct contact with course tutors and fellow trainees, isolating the student from the human-to-human experience. Studies of computer mediated communications (CMC) systems in educational online environments have shown positive results on learning. CMC allows trainees to collaborate in a network using chat and conferencing tools

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regardless of their physical location. By using asynchronous applications, such as discussion forums, students are allowed to collaborate regardless of the time. Students can send questions, thoughts about the training material and problems they may have experienced to a discussion forum or answer/comment on messages from fellow students. Asynchronous CMCs allow more time to process the information and respond, it can be particularly effective for people with English as their second language and can result in more thorough processing of information. It provides opportunities for group work between distance learners, whereas traditionally this would have been only possible using phone, fax or post. (Stuart *et al.*, 1999). Academic research has begun further to investigate ways for distance learning students to collaborate and has resulted in the development of Web-based problem solving applications where students are able to collaborate to find a solution for an exercise.

Online learning is recognised as a key part of the future of educational culture. A whole new e-learning industry has been formed; vendors have developed learning content, authoring tools and delivery/tracking systems. Today, e-learning is a buzzword that is commonly used to express some form of IT-based learning that can be either online or traditional offline CBT. It is an umbrella definition that gathers together Web-based training (WBT), online learning, computer managed instruction (CMI), technology-based training (TBT) and many others. The value of the e-learning market in Europe is set to reach approximately £2.6bn by 2004. This equates to a 96 per cent compound annual growth rate, with the UK, the Netherlands and Sweden leading the way. International Data Corporation (IDC) has predicted the worldwide corporate e-learning market to be worth £16.7bn by 2004, compared to £1.4bn at year-end 1999.

2. Learning management systems

Historically, the basic form of an online training system was often a series of Web sites, but the industry required a more manageable system; one which could monitor the trainees' learning, measure it and provide reports on learning efficiency. This requires constant tracking of the trainees' actions and results of online tests. A range of learning management systems (LMS) emerged, such as Blackboard, Docent, Saba and WebCT. Even though they all provide a wide range of different features to enable online learning, all of them aim to deliver four main features:

(1) delivery training content;
(2) tracking of student performance;
(3) management of online learning (courses and trainees); and
(4) provision of tools for student collaboration.

A basic LMS is a Web application where the trainee logs on and accesses the courses allocated to her/him. While the trainee is going through the courseware, the LMS stores information about the trainees' interactions, such as scores and answers to the questions. LMSs use this information to analyse how well the trainee is performing, and are able to provide reports to the managers and course tutors; identifying how well individuals or groups are performing in a course or curricula. An LMS commonly contains an interface for managing users, adding/deleting new trainees, organising trainees into a hierarchy and allocating access rights/courses to the users and user groups. It is estimated that there are a few hundred LMSs, each with varying features. Some of the common features of the most popular LMSs are listed below:

- content/assessment authoring;
- assembly of the curricula from existing learning content;
- student collaboration tools;
- delivery of instructor lead online learning (video-conferencing);
- competency management (skills/gap analysis); and
- e-commerce payment component (sometimes additional module).

Soon after vendors began to develop and release LMS products, the e-learning industry was faced with a problem regarding interoperability between various systems. The customer needed to use content from different vendors in their LMS. LMS and content vendors required a common way to develop their products so that they could be combined in their customers' e-learning solutions. Different organisations started to work towards open interoperability standards that would enable use of content from different vendors in an LMS that supports the same interoperability specification. The aviation industry CBT committee (AICC) worked to develop an interface to enable run-time communication between the content and the LMS, and the IMS Global Learning Consortium Inc. developed XML-based meta-data schemes to define the course structures, tests and learners. IEEE and ISO participated in work to develop the emerging specifications to an official standard, and the US Department of Defence (DoD) created the advanced distributed learning (ADL) initiative to facilitate the development of common e-learning interoperability standards by different organisations. With a number of different organisations producing their own e-learning specifications, it has been a difficult task for the industry to follow developments in the area and integrate new technologies into their products.

Another key problem of the modern LMS is that it does not exploit the potential of Web delivery to personalise training content for individuals (Grigoriaddou *et al.*, 2001; Brusilovsky, 2001; Sampson *et al.*, 2002). This research reviews the available solutions for online training delivery and examines infrastructures that enable the integration of an intelligent tutoring component that facilitates an adaptive learning experience.

2.1 Examples of intelligent tutoring systems

Weber and Brusilovsky (2001) have been the pioneers in the area of Web-based ITS research as a result of a half-decade effort on developing the ELM-ART for supporting learning programming in LISP. ELM-ART is an intelligent educational system that provides all learning material online in the form of an adaptive, interactive textbook. ELM-ART is based on a stand-alone ITS called ELM-PE (1996), which was later converted into the fully Web-based ITS. Unlike most of the adaptive hypermedia systems which have been produced, ELM-ART has been in use for several years, supporting introductory LISP courses in the University of Trier, where it has received a positive welcome from students.

ELM-ART has been developed to provide a functional, versatile system that offers a range of features to aid the student in learning. It includes several interactive activities, such as live examples where students can actually execute LISP functions and follow the execution and responses line by line. It provides problem-solving examples where users can explore example problems and solutions and test their own ideas. ELM-ART pages also contain simpler questions and small programming problems to solve. The system can evaluate the correctness of an answer, provide feedback and hints for the student and provide editing support on the proper format of the code. Structured training content is adapted to the user's knowledge, preferences and interest to provide most the appropriate pathway. In addition, the adaptive presentation includes visual cues to help the trainees while they proceed through courseware. So far, the system seem to have succeeded in delivering a highly versatile Web-based ITS system yet, which has been proven to increase learning. (Weber and Brusilovsky, 2001). However, ELM-ART is a bespoke system for instructing programming in LISP. It does not address the issue of interoperability and reusability, thus it fails to address the needs of industry. Industry requires a solution where adding new content across a variety of problem domains is affordable; either by developing re-usable content using standard authoring tools or by buying existing third party content. Recently Weber and Brusilovsky (2001) have addressed the problem by developing NetCoach, an authoring system to create adaptive Web-based courses using ready-made templates:

> With NetCoach, authors can create fully adaptive and interactive Web-based courses without being required to program or to learn any programming language (Weber and Brusilovsky, 2001).
>
> This has been the approach of many others due to the inherent difficulties in developing generic domain ITSs (Mullier *et al.*, 1998).

Grigoriadou *et al.* (2001) developed "an intelligent system for personalised instruction in a remote environment" (INSPIRE), which is not tied to a specific problem domain, but instead provides a generic ITS for personalised learning. INSPIRE:

> ... dynamically generates lessons that gradually lead to the accomplishment of the learning goals selected by the learner. The generated lessons are adapted to the learner's knowledge level and learning style, and follow his/her progress (Grigoriadou *et al.*, 2001).

Even though INSPIRE is usable across a range of subject domains, it does not address the issue of interoperability and therefore does not take advantage of the existing learning content from different vendors. The learning material from the third party content vendor has to be converted or re-developed for the system, which is an important cost factor in publishing training material over the Web. The development of one hour of training material for the Web is estimated to take 100 hours of development time, even by the most modest estimations.

To accomplish intelligent functionality, an ITS requires an amount of knowledge throughout the subject domain to respond correctly to the user interactions and to provide the necessary help (Alpert *et al.*, 1999). ITSs developed through academic research have often resulted in the development of bespoke applications, instead of generic problem domain solutions. However this approach does not take advantage of interoperability specifications. There is a clear case for the development of a generic ITS methodology that caters for the dynamic scheduling of content from a learning object repository to fulfil the needs of the individual (Kuisma and Watson, 2002). While ELM-ART and INSPIRE represent typical examples of the ITSs that academia has been developing in the past decade, the "knowledge on demand" (KOD) project provides a contrasting example that aims to develop open standards and tools for personalised learning, by extending the existing interoperability specifications and standards to:

> ... facilitate the definition of adaptive and conditional navigation rules taking into account user-characteristics (user profiles, testing, sessions, etc.) (KOD, 2002).

Karagiannidis and Sampson (2001a) have designed the architecture for defining re-usable adaptive educational content. The research results are being actively disseminated in conferences; however, there is no system currently available for public testing. The project demonstrates that people have realised the importance of the interoperability between an ITS and other e-learning solutions. Henze and Nejdl (2001) developed an adaptive educational hyper-media system to facilitate the adaptation of distributed learning materials, and noted the importance of conformity to the interoperability specifications. The research goals of this investigation stem from the same principal aims as the KOD-project and the work done by Henze and Nejdl; to examine re-use of existing and third party vendor content in an ITS and adaptive educational hyper-media applications.

2.2 LMS design considerations

As intelligent tutoring functionality is traditionally an integral part of an LMS (Murray, 1999; Ritter, 1997). In this section we investigate design considerations and requirements for the LMS. A typical modern LMS will be used to demonstrate these in detail. A case demonstration of the LIBRIX performance management system (GlobalLearningSystems) will be used to illustrate the focus on key features and functionality that can be used to enhance utilisation of content. This sections also reviews the current interoperability specifications that can be used to create interoperable course contenta and goes on to describe the generic architecture of a system-based on the ADL SCORM specification that exploits inter-operability.

The number of LMSs has been increasing rapidly over the last five years and some believe that there are several hundred LMSs on the market. Clearly, the number of LMS products on the market shows that there are many different established solutions available to potential customers. However, selecting an LMS from the hundreds of available systems is a very difficult task. An LMS is a complex server-side software application that usually requires some amount of configuration to get it running. Owing to their inherent complexity, evaluation versions of LMSs are rarely available to test installation. Vendors commonly give users rights to access in their test environments for evaluation, or organise online conference type demonstrations, but still it is a time-consuming task for companies to find the right solution for their requirements. The selection process is not made easier by the fact that many LMSs are customisable products, which allows the LMS vendors and sales people to "promise the earth". Most vendors favour selling e-learning solutions along with consultancy, customisation and training, as opposed to an off-the-shelf LMS as a product.

We briefly comment on SmartForce and Blackboard before moving on to examine in more detail the LIBRIX performance management system.

SmartForce Global LMS is one of the leading e-learning companies in the world with more than 2,500 major corporate customers. It recently won the training company of the year gold award presented by Institute of IT Training, London. Global LMS is an access point to many features such as assigned learning, progress reports, search facilities, etc. The tutor and administrators have a separate interface that includes features not available to trainees, such as course management, user management etc.

Blackboard is an LMS very much favoured by academic institutions, and its customer base consists mainly of universities, colleges and schools. This is not surprising as, in addition to normal LMS functionality, Blackboard contains functionality for supporting teaching – such as distributing/grading course assignments and course reference material. Blackboard also contains functionality from a normal office application, such as Calendar and Tasks, which are linked to the scheduling of the learning events. It provides tools for the teachers to create new courses which include course collaboration tools.

Global LMS and Blackboard are marketed to different kinds of audiences and contain differing sets of features. While Global LMS is the base of a typical corporate e-learning solution, Blackboard contains features aimed mainly at academic educators. It is essential for a customer to understand their own requirements clearly and select an LMS to match them. To understand further the operation of the LMS and its functionality, we present a case study of the LIBRIX performance management system as a demonstration of a typical LMS for corporate training. Screenshots are used to illustrate some of the main functionality of this state-of-the-art LMS.

3. Case study: the LIBRIX performance management system

Maritz Learning provides a full learning solution service to its customers in the form of LIBRIX. Maritz's e-learning customer list contains many giant global companies, such as Philips, Panasonic Caterpillar and Minolta. They base their online learning solutions around the LIBRIX performance management system V3.0™, which provides a customisable suite of integrated tools for online learning with virtual catalogues, collaboration tools, performance reporting etc. Table I summarises the features of the basic LIBRIX package, providing an example of the typical features included in a modern LMS.

The core LMS can be extended with LIBRIX competency applications module to provide skills assessment, competency modelling and gap analysis features. Together with the LIBRIX performance management system V3.0™, they provide an effective package for an organisation to:

- describe the various job roles throughout the organisation;
- identify a set of competencies required to perform each job role;
- develop self and/or skills assessments to measure an individual's proficiency in each competency;
- deliver skills assessments online and automatically record results;
- produce instant gap analysis reports that identify an individual's areas of strength, as well as areas that need improvement;
- prescribe targeted development activities to address those areas in need of improvement; and
- create individual development plans consisting of prioritized development activities to streamline an individual's skills development and automatically track progress against those plans.

Campus-Wide Information Systems
Volume 21 · Number 1 · 2004 · 4-21

Table I LIBRIX performance management system features

Core feature	Description
Online delivery and tracking of Web-based content, assessment tests and surveys	Both customized and off-the-shelf content can be available 24/7, using dynamic HTML, Flash, and other leading multimedia technologies for a highly engaging, interactive learning experience
Online tracking of off-line learning activities	Leader-led, videotape, CD-ROM and other off-line training media can be included in a user's catalogue, and the completion status updated through the Web-based administrative interface
Online virtual catalogues	Enables each user or group of users to view a unique catalogue consisting of any combination of online and off-line resources or groups of resources
Integrated follow-up activities	Enables users to receive reinforcement training automatically following any resource. The follow-up activity can be released to the user based on a variety of "triggers", such as upon assignment or completion of the original resource
Integrated e-mail messaging	E-mail messages can be created, scheduled and sent to selected users based on various criteria (e.g. user registers for a resource, administrator assigns a resource, user completes or fails a resource)
Integrated discussion groups	Enables users to read and respond to messages organised into discussion "threads" or topics. Discussion groups can be assigned to individual users or user groups and administered in the same manner as other resources
Extensive management reporting	User progress, test results, resource usage, survey results and numerous other management reports are available on demand, at the individual, group and enterprise level. Custom reports can be easily added
Distributed online system administration	The powerful and flexible group management capabilities of the LIBRIX system enable administration of users, resources, reports, discussions, etc. to be delegated to anyone with appropriate security privileges

Source: LIBRIX, 2002

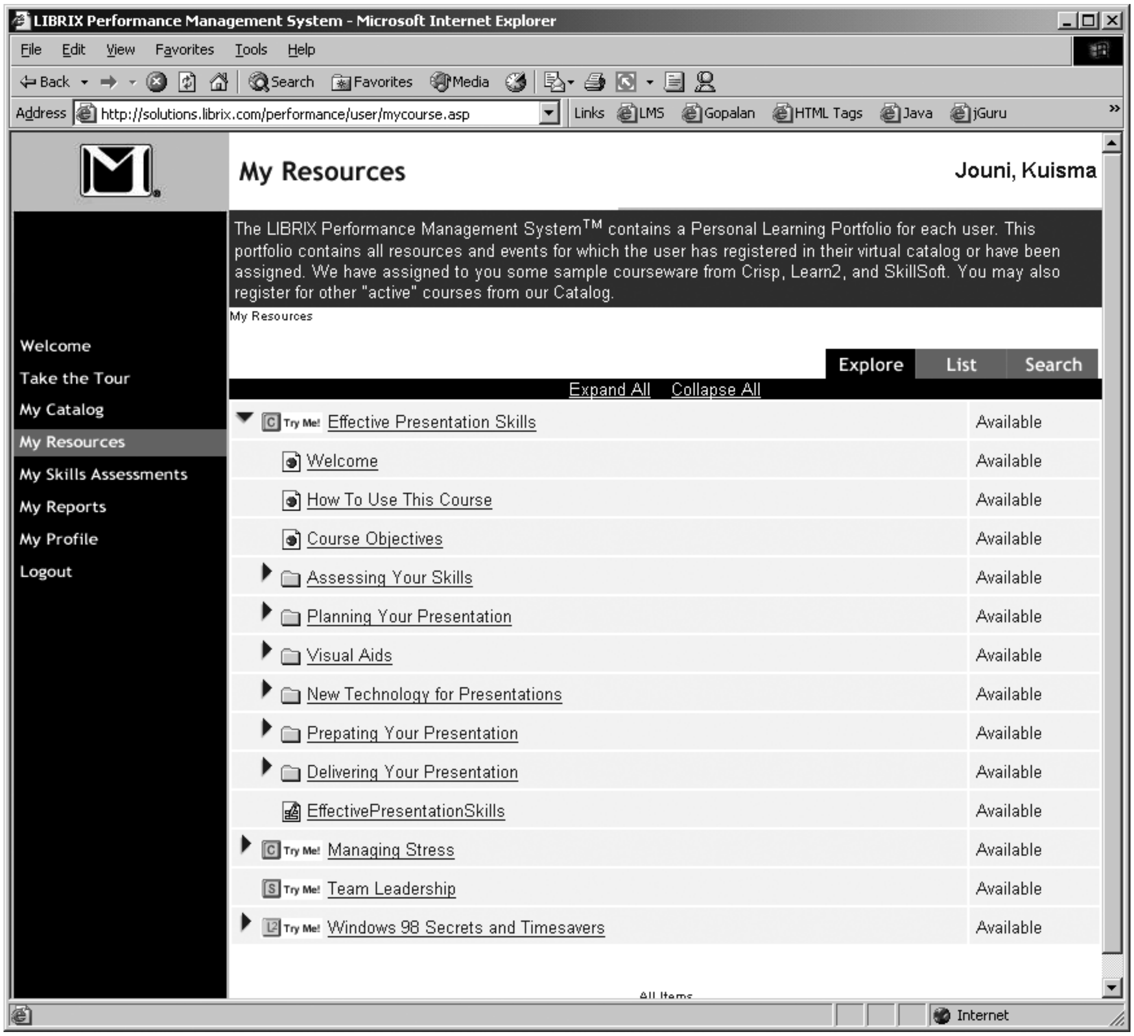
To understand better the role of the LMS in online learning, the perspective of the trainee will be demonstrated and illustrated using screenshots of the LIBRIX example implementation. First, the trainee logs into the system using a personal login name and password. The system identifies the user and provides the trainee with a menu-based interface that can be used to access tools allocated for the particular trainee. After logging in to the LMS, the user continues by clicking "My resources" – a menu that displays courses that have been allocated to him/her (Figure 1).

When the user selects a course, it is launched in the same browser window. Some LMSs use a different approach and launch a course into a new window or into a frame in the current window. Figure 2 demonstrates an example course launched by the LIBRIX. While the user proceeds through the course, the learning objects transparently communicate with the LMS, sending information about the trainee's performance and actions. The LMS commonly analyses this information and stores it to the database. This information is later used to provide reports about the trainee performance.

LIBRIX has a "My reports" menu that provides a comprehensive selection of different reports about the trainee's performance. This demonstrates the real importance of an LMS compared to a static Web page that contains instructional material. Online learning is possible through a standard Web page that contains links to other pages on the Internet. Trainees can browse through courses and learn at their own pace. However, there is no tracking of the student's performance and there is no possibility of monitoring student actions. For a company, it is essential to measure learning and provide reports on the performance of individuals or groups. Figure 3 illustrates a selection of the reports provided by the LIBRIX.

Figure 4 contains a report showing how an individual has performed in the course. It shows that trainee "Kuisma, Jouni" has started this presentation skills course and has accessed the first three lessons, but he has not proceeded through the whole course and post-tests. He has completed the second lesson "Planning your presentation", but only

Figure 1 LIBRIX "My resources" display



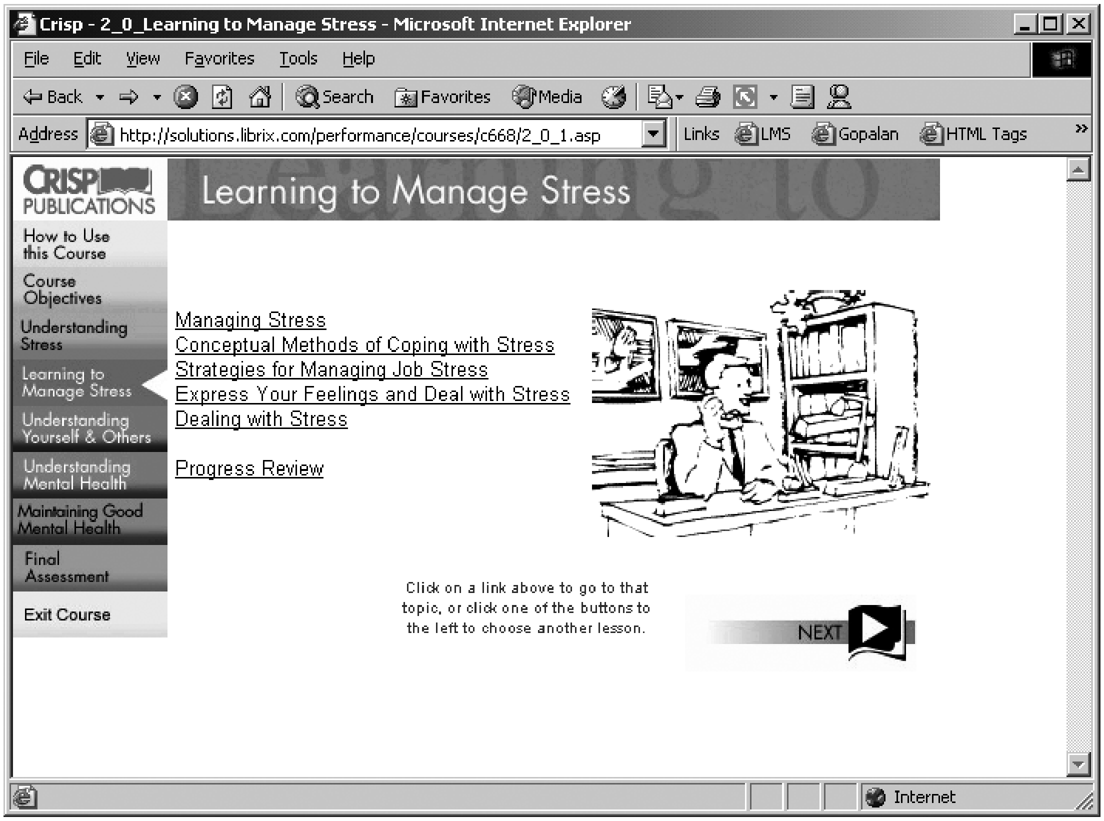
briefly accessed the first and second course. This demonstrates course communication as the LMS has stored details about which lessons or learning objects the trainee has accessed. Commonly an LMS will also store the final score of the lesson, based on test results and actions in exercises.

LIBRIX competency applications module provides features that are not commonly included in a traditional LMS; such as defining user competencies, self-assessment of trainee skills and providing gap analysis to identify what students have to study to acquire the required knowledge for a specific competency. LIBRIX provides skills assessments which can be used by the trainee to self-assess his knowledge or by the managers/tutors to assess the trainees.

Figure 5 demonstrates how student Kuisma is going through the self-assessment by answering some simple questions. This information can now be used by the gap-analysis component to identify which areas the trainee has to improve to match the requirements of the defined competencies.

Figure 6 shows a typical gap-analysis report identifying the required level of knowledge against the trainee's current level of knowledge, which can be a combination of self/manager assessments and test results. In this example trainee Kuisma is slightly lacking in the knowledge areas required for first four competency requirements, but has clearly passed the requirements for the "Windows 2000" skills. For the first four skills, the report is showing a link to the development

Figure 2 An example course launched by LIBRIX

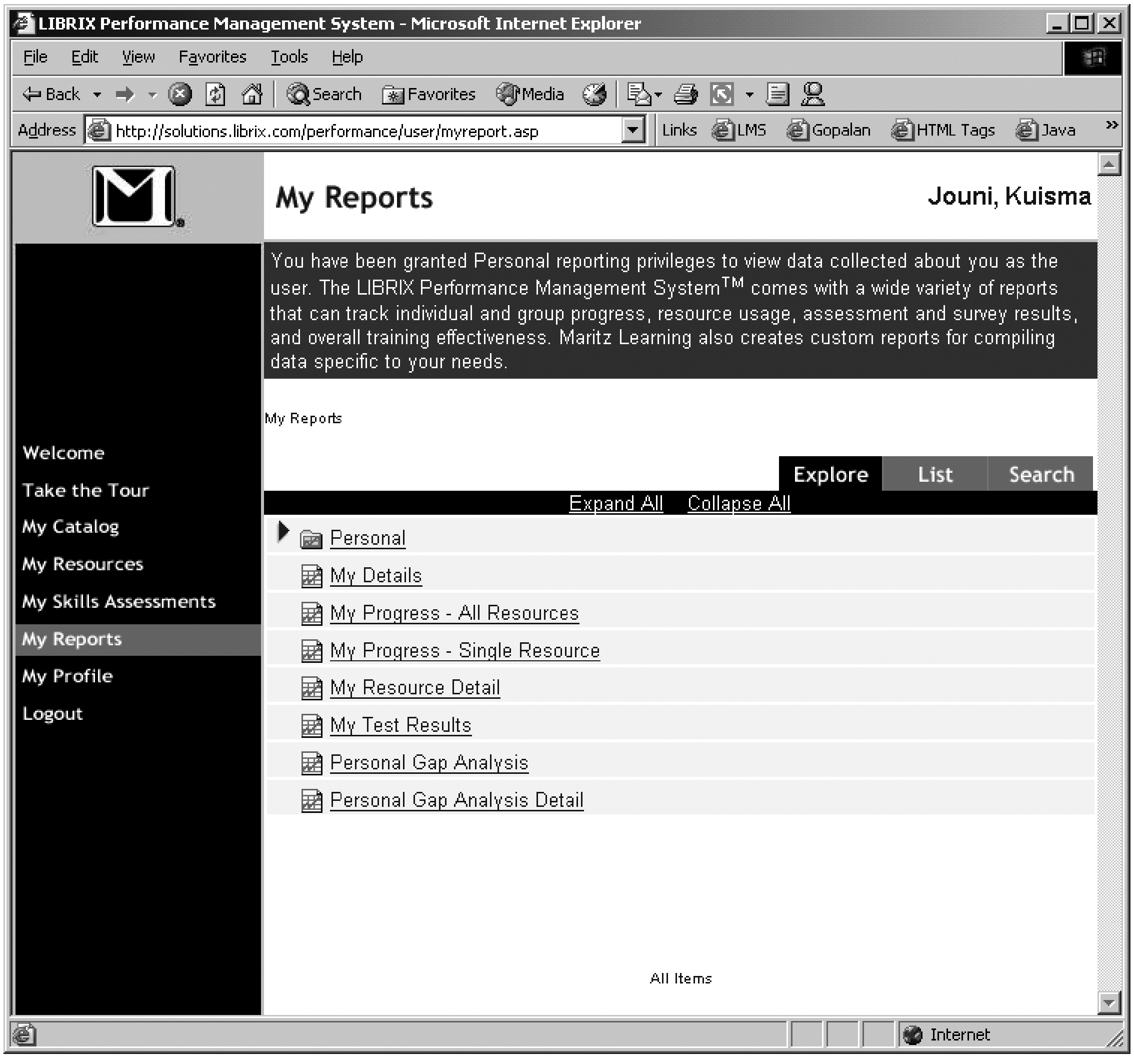


activities, which the student can use to select courses that would increase skills in the respective areas.

4 A generic architecture for adaptive and sharable content LMS

Whilst CBT has been used for some time, the development of e-based learning is relatively new. Success in e-based learning models is perceived to be critically defined by interoperability standards (primarily the ability to communicate and share content) (Arruarte *et al.*, 1996) and the ability of the system to respond to the specific learning needs of the "student", i.e. the ability to cater for learning preferences and styles (Brusilovsky, 1996; 2001). The need for e-learning standards has been one of the key issues in the industry for the last decade. As the number of LMS vendors and content developers has increased enormously, the requirement for interoperability has become increasingly important. This facet also holds implications for the second point because the choice of an LMS system holds long-term implications for an organisation's e-learning strategy. Choosing an LMS that restricts the organisation to the use of only the content or authoring tools from the same vendor is not viable long-term strategy because as the need for corporate competences changes dynamically, so must the content to reflect these changes. Moreover, by having a free choice of content from different vendors a company can reduce content costs dramatically by avoiding reinventing and customising the same content (Blumenthal *et al.*, 1996). This need for interoperability has been the main driving force of the e-learning standardisation process. These standards can also help to establish a base technology infrastructure with permanency (Duval, 2001). Rapid development of ICT can cause systems (LMSs, ITSs, authoring tools) to become obsolete, but if the specifications that define boundaries between the infrastructure parts are robust then longer term systemic viability can be ensured (Sampson *et al.*, 2001; 2002).

Figure 3 LIBRIX reports

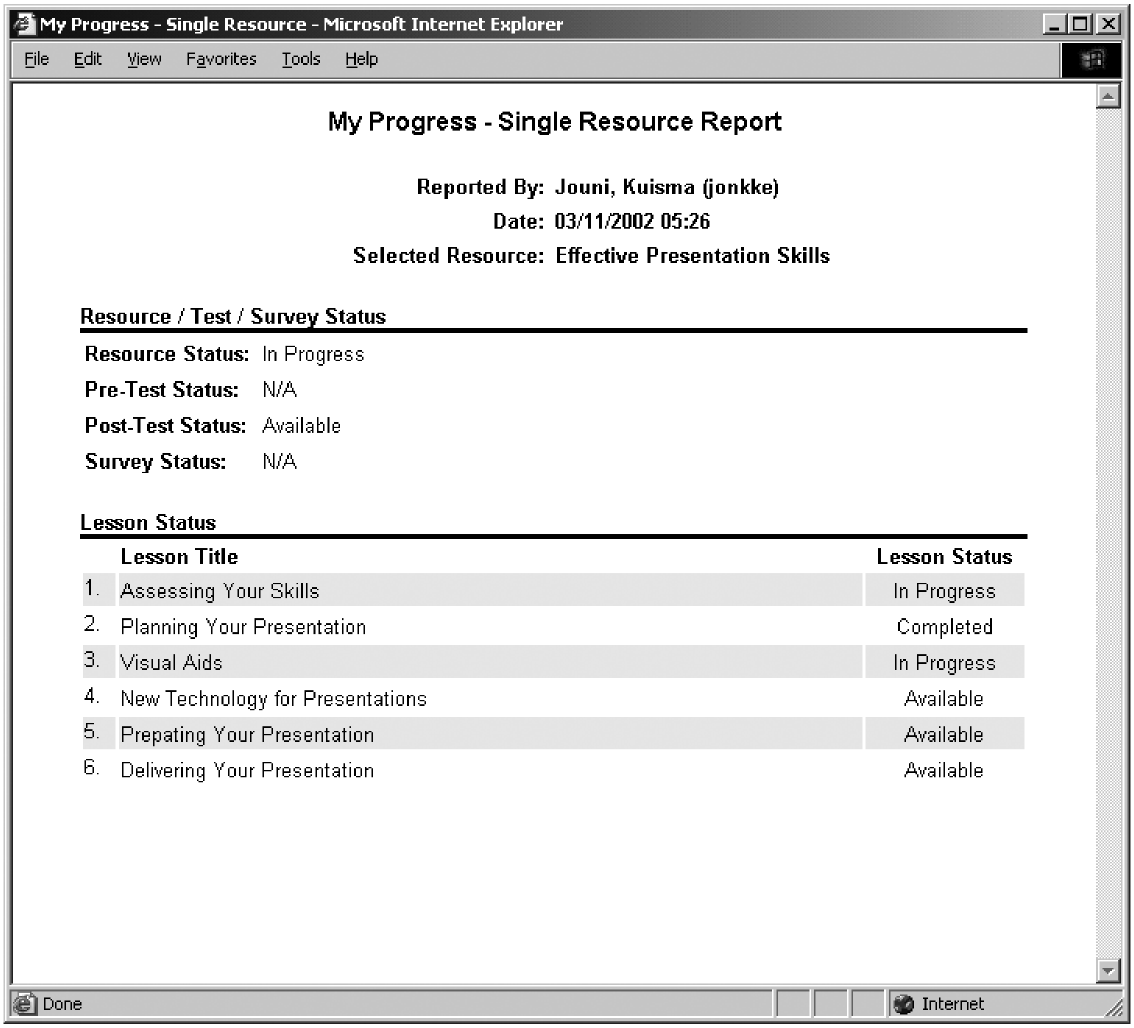


At the present moment there are no official open standards, but instead various specifications aiming to contribute to official standards. For the e-learning system developer this situation has lead to some confusion, since many in the industry have been developing their own standards, leading to the emergence of an abundance of buzzwords, such as "AICC certification", "SCORM compliant", "supports industry standards". Fortunately, many of the leading organisations have started to work together to develop an official standard, which provides an interchange capability with parts of each other's specifications. The main aim has been to incorporate eventually aspects from work done by different organisations into an official ISO standard. We elaborate on the generic model based on SCORM specifications because it is one of the leading standards specifications, towards which convergence appears to be progressing. SCORM as an infrastructure makes it possible to deliver dynamically personalised learning using re-usable learning objects. The specifications mainly address two specific problems:

(1) How to define the learning object and resource packages so that they can be imported into any LMS.
(2) How to enable content tracking and run-time communication between the content and the LMS.

SCORM V1.2 defines the SCORM aggregation model and the SCORM run-time engine (SCORM, 2001; 2002). Each of these is next described in more detail to define the

Figure 4 Single resource report



generic model architecture for an advanced LMS.

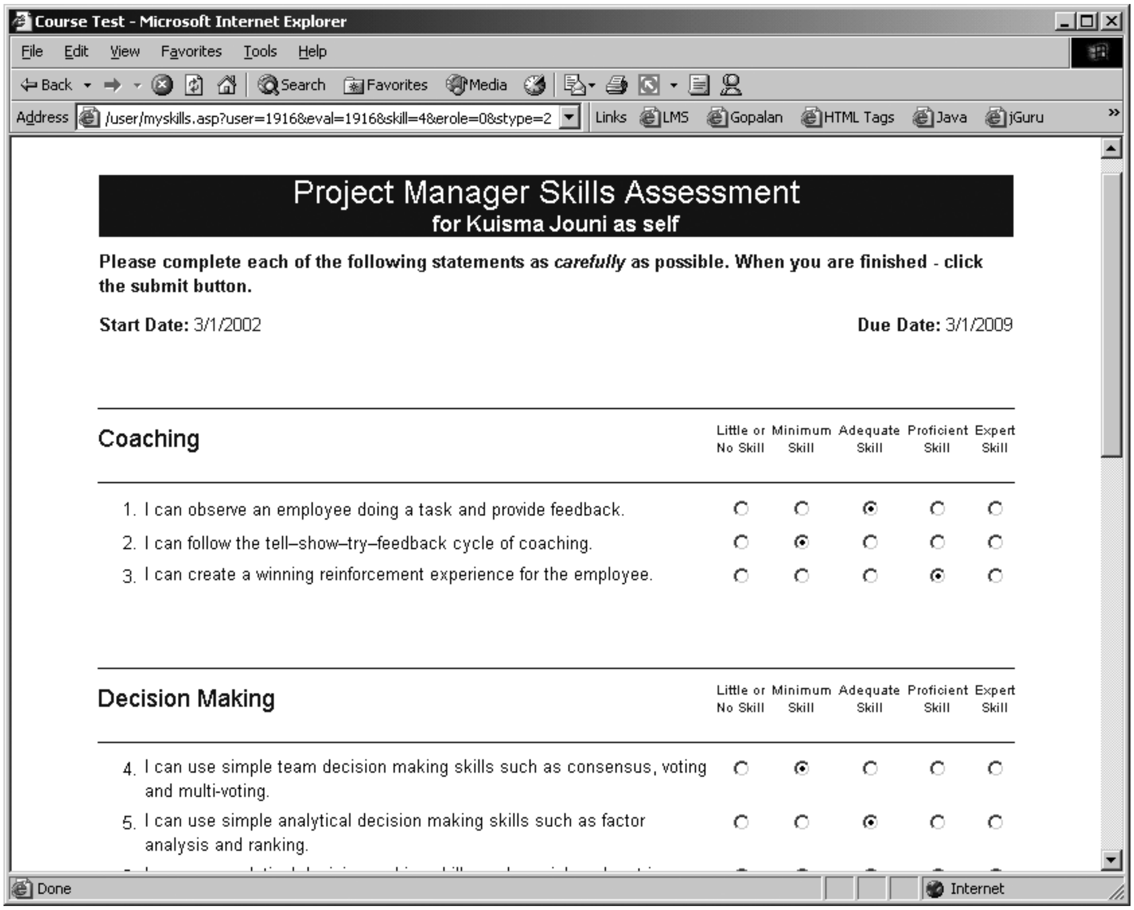
4.1 The SCORM content aggregation model

The SCORM content aggregation model (CAM) defines how learning resources are defined with the XML meta-data. CAM consists of three different parts:

(1) *Content model*: defines three low-level sharable/reusable SCORM components.
(2) *Meta-data*: mapping of IEEE LOM elements to content model components.
(3) *Content packaging*:
   - content structure – how to represent the intended behaviour of a learning experience; and
   - content packaging – how to package learning resources for movement between environments.

The content model defines three different types of low-level, sharable and reusable SCORM components: assets, sharable content objects (SCO) and content aggregations and how these components are aggregated to units of instruction. An asset is a simple learning resource, e.g. text, image, sound or Web page that can be shared between a number of SCOs, which are collections of one or more assets. Content aggregations are maps of content structure that define units, chapters and courses. Each of the components is defined using asset meta-data, SCO meta-data and content aggregation meta-data respectively. Meta-data represents a mapping and recommended usage of the IEEE-LTSC learning object meta-data elements for each of the components.

Figure 5 LIBRIX self-assessment



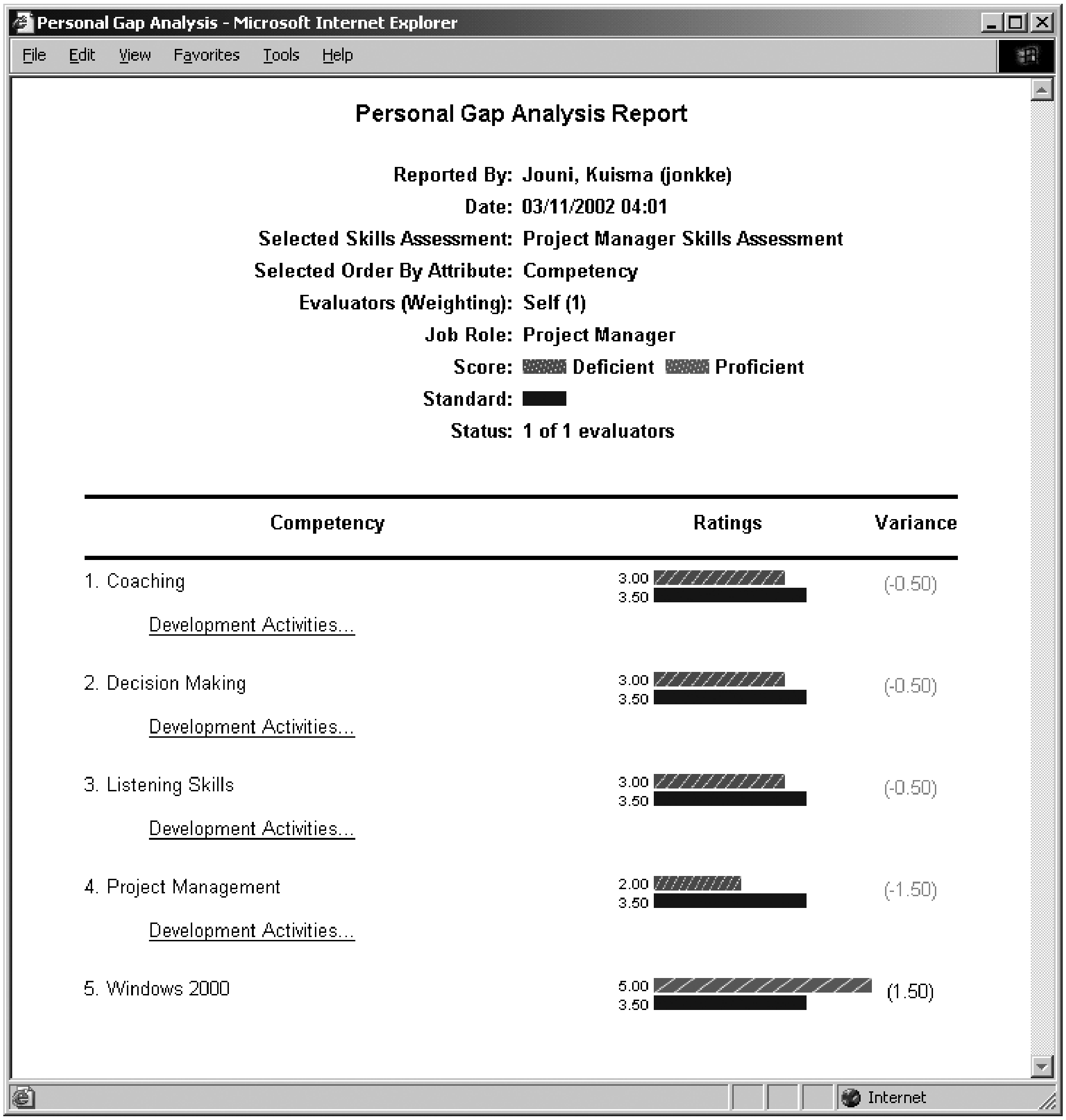
SCORM meta-data defines guidance of how to apply the meta-data to the learning resources by using the SCORM meta-data information model (MdIM). It references the IMS learning resource meta-data information model, which itself is based on the LTSC LOM that was developed as a joint effort between IMS and ARIADNE (IMS CP, 2001; ARIADNE, 2002). SCORM MdIM also references the IMS learning resource meta-data binding specification, which provides an XML representation of the information model.

MdIM describes the data elements used in the XML files that define the learning resources. It is broken down into nine categories:

(1) general;
(2) lifecycle;
(3) meta-metadata;
(4) technical;
(5) educational;
(6) rights;
(7) relation;
(8) annotation; and
(9) classification.

The general category contains general information that describes the resource. The lifecycle has information about the features related to the history and current state of the resource. The meta-metadata does not contain any features linking to the resource itself, but instead it defines data about the metadata itself. The technical defines the technical requirements and characteristics of the resource while the educational groups define the educational and pedagogical characteristics. The rights contains elements that relate to the intellectual property rights and conditions of usage of the resource. The relation contains information about the relationship between this resource and other targeted resources. The annotation contains comments on the

Figure 6 The gap-analysis report and suggested development activities



educational use of the resource and finally the classification describes how this resource is categorised. Table II demonstrates all items from the MdIM together. For this research, it is more important to understand how the run-time environment works as opposed to exploring the meaning of all elements in the MdIM.

SCORM meta-data XML binding defines how the elements of the MdIM are described in the actual XML file. Some of the elements are represented as XML elements while some are attributes of the elements, etc. Binding specification also describes minimum or maximum permitted values for some elements.

Content packaging (CP) provides a standard way to exchange learning resources between different systems and tools, such as LMSs and content authoring tools. CP can also define the structure, or organisation of the collection of learning resources. It defines:

- a manifest file describing the package;
- meta-data about the package;
- optional organisation section;
- list of references to the resources in the package;
- how to create XML-based manifest; and

Campus-Wide Information Systems
Volume 21 · Number 1 · 2004 · 4-21

Table II SCORM meta-data information model elements

Category		Category	
General	Identifier	**Educational**	Interactivity type
	Title		Learning resource type
	Catalog entry		Interactivity level
	Catalog		Semantic density
	Entry		Intended end user role
	Language		Context
	Description		Typical age range
	Keyword		Difficulty
	Coverage		Typical learning time
	Structure		Description
	Aggregation level		Language
Lifecycle	Version	**Rights**	Cost
	Status		Copyright and other restrictions
	Contribute		Description
	Role	**Relation**	Kind
	Entity		Resource
	Date		Identifier
Meta-metadata	Identifier		Description
	Catalog entry		Catalog entry
	Catalog		Catalog
	Entry		Entry
	Contribute	**Annotation**	Person
	Role		Date
	Entity		Description
	Date	**Classification**	Purpose
	Metadata scheme		Taxon path
	Language		Source
Technical	Format		Taxon
	Size		Id
	Location		Entry
	Type		Description
	Requirement		Keyword
	Type		
	Name		
	Minimum version		
	Maximum version		
	Installation remarks		
	Other platform requirements		
	Duration		

- directions of how to package manifest and all related physical files into a zip file or on a CD-ROM, etc.

CP specification consists of two separate sections: content structure and content packaging. SCORM content structure is derived from the AICC CMI specification and it states that it provides the content developer with the means to author collections of learning resources into cohesive unit of instruction, apply the structure and associate specific behaviours that can be uniformly reproduced across LMS environments. Content structure is simply the map used to sequence through the learning resources defined in the content package. It consists of:

- content hierarchy (tree-based representation of navigation through material);

- context specific meta-data (additions to context independent meta-data); and
- sequencing and navigation (simple linear sequencing information, which will be extended in the next version of SCORM).

Content hierarchy defines organisations and items to describe different parts of the course structure. The organisation can be considered as a course with the items as lessons or chapters. Figure 7 illustrates the behaviour with an example of a course with two chapters. Bottom level items reference to resource, which can be either SCOs or assets.

The SCORM content packaging information model references the IMS content packaging specification. Content packaging application profiles describe how the IMS content packaging specification will be applied within the overall context of the SCORM. There are two SCORM packaging application profiles:

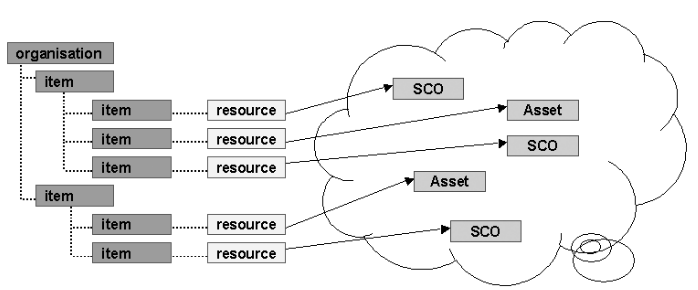
(1) resource package – defines a mechanism for packaging learning resources (e.g. assets and SCOs); and
(2) content aggregation package – defines a mechanism for packaging course structures including all referenced physical files (e.g. assets and SCOs)

4.2 SCORM run time environment (RTE)

The three main parts of the RTE are:

(1) *Launch* – defines a common way for LMS to start Web-based learning resources.
(2) *Application programmable interface* (*API*) – communication mechanism for informing the LMS of the state of the learning resource.
(3) *Data model* – standard set of elements used to define the information being communicated.

Figure 7 SCORM content hierarchy terminology

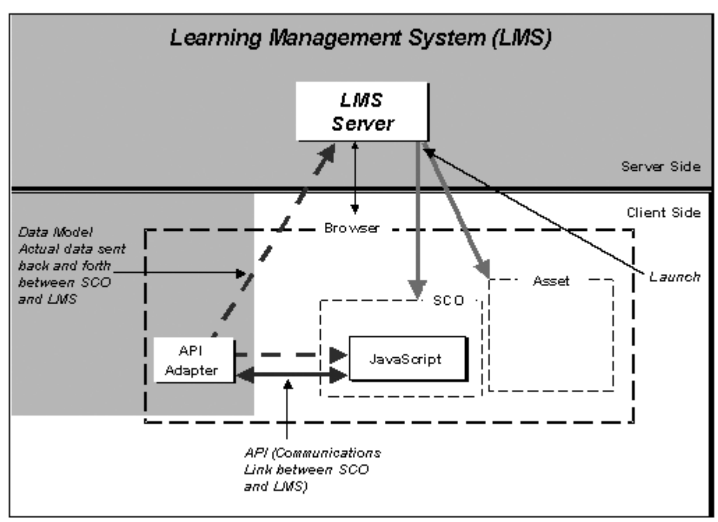


Source: SCORM, (2002, p. 2-106)

Figure 8 illustrates the operation of these three elements. The LMS is responsible for scheduling the course content and launching the learning resources. The LMS can use any process to determine the sequencing order, i.e. intelligent/ adaptive functionality. Launch can initiate two out of the three types of SCORM content model components: assets and SCOs. For assets, the LMS simply launches the resource using HTTP protocol and no run-time communication is provided between the LMS and the asset. For SCOs, there are a few restrictions; the LMS can open only one SCO at the time and the SCO cannot initiate other SCOs. The LMS must launch the SCO in a browser window that is a child window or a child frame of the LMS window that exposes the API adapter as a document object model (DOM) object (DOM L1, 2000). It is the responsibility of the SCO to search recursively for the API Adapter from the parent/opener window frame hierarchy. After the SCO has found the API adapter, it is ready to start the communication with the LMS (SCORM, 2002, pp. 3-7).

The API provides a standardised way for the SCO to communicate to the LMS. API exposes a set of functions that a SCO can call (Table III). These functions are divided into three categories: execution state, state management and data transfer. Execution state functions are used to initialise and terminate the SCOs. State management

Figure 8 SCORM API, data model etc.



Source: SCORM (2002, p. 3-3)

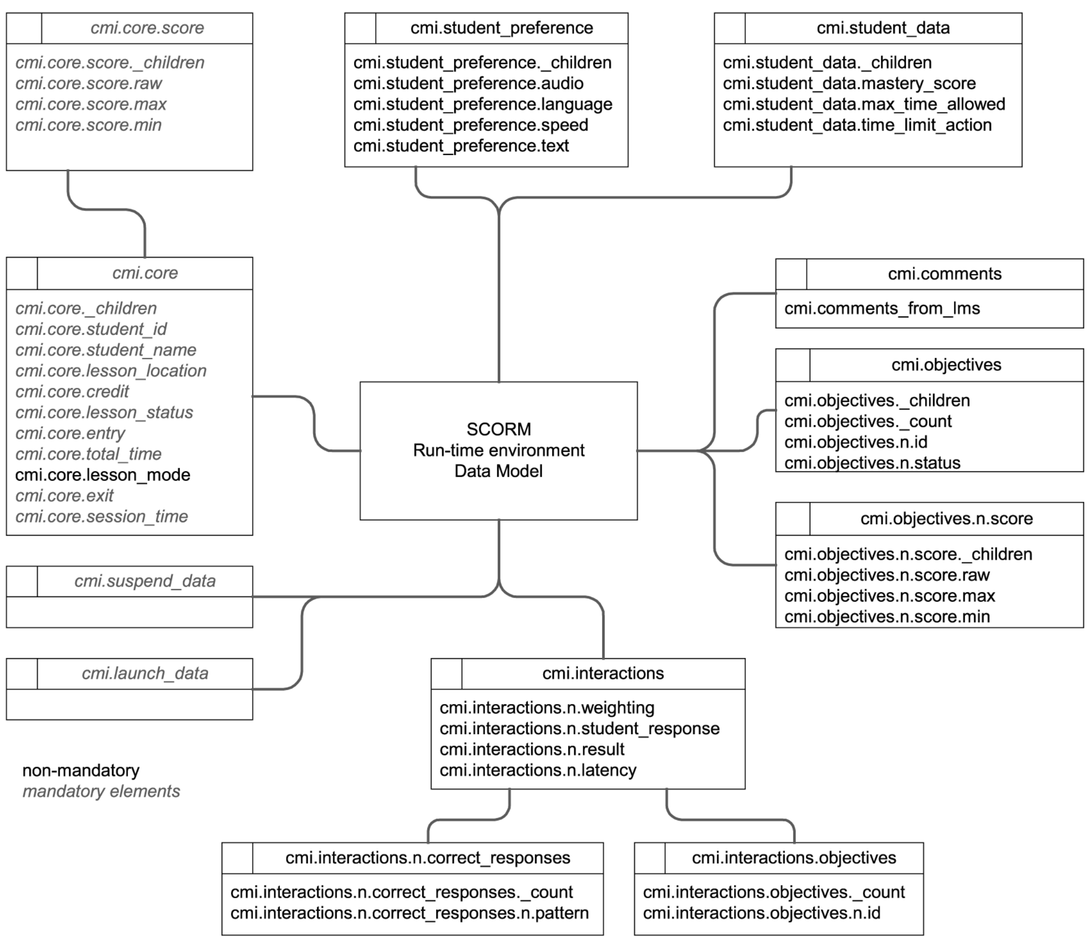
Table III SCORM API functions

Function	Operation
Execution state	LMSInitialize (" ")
	LMSFinish (" ")
State management	LMSGetLastError ( )
	LMSGetErrorString (error number)
	LMSGetErrorDiagnostics (error number)
Data transfer	LMSGetValue (data model element)
	LMSSetValue (data model element, value)
	LMSCommit (" ")

functions are used to check the state of the LMS after an execution of other functions. If error occurs during the execution, the LMS sets its internal error code variable to a value that represents the type of error. Data transfer functions are used to set and get values in the data model.

Figure 9 illustrates the SCORM data model, which makes sure that a defined set of information about SCOs can be tracked by different LMS environments. The elements identified with italic/red are the mandatory parts of the data model that have to be implemented for SCORM compliancy. These elements are used for tracking the basic information, such as lesson status, time and scores. For example, a SCO can call a function LMSSetValue ("cmi.core. score.raw", 57) to set the score for a particular user in this SCO as 57 per cent. Another SCO can use LMSGetValue ("cmi.student_preference._children") to identify what elements of cmi.student_ preference the LMS is supporting. If supported, the SCO can then call LMSGetValue ("cmi.student_ preference.speed") to get an indication of the student's preferred speed of content execution. This information can be used inside the SCO to either slow or speed up the flow of learning.

Figure 9 SCORM RTE data model elements



Summary

In this paper we briefly introduce the trends towards e-based learning, and amplify some examples of the state-of-the-art systems. However, all of these are to-date limited by adaptability and shareability of content. In order to overcome these problems it is essential for industry to develop and use an inter-operability standard. We have used the SCORM specifications, as a leading form of emulator in this field to specify the skeleton of an architecture that can be used to develop an advanced learning management system.

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IMS Global Consortium Inc (2002): www.imsproject.org
ISO/IEC JTC1/SC36 (2002) http://jtc1sc36.org/
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Campus-Wide Information Systems
Volume 21 · Number 1 · 2004 · 4-21

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Campus-Wide Information Systems
Volume 21 · Number 1 · 2004 · 4-21

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