

An Evaluation of the QTI E-Learning Standard in Resource-Limited Environments

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Abstract

Early Learning Management Systems (LMSes) were often criticised for their lack of interoperability. This situation is now being addressed by a cohesive standardisation effort in the form of IEEE-LOM, IMS-QTI and related specifications. While these standards are now supported by numerous LMSes, it is not known if they can be broadly applied to different types of LMSes developed for different communities, with widely varying facilities and requirements.

This question was the focus of this study, where the IMS Question and Test Interoperability (QTI) standard was investigated for its applicability in a learning environment where not all learners have access to computers. It was proposed that alternative electronic learning management systems could focus on the teacher, with a shift in learning medium (to paper) at the interface between educators and students.

To test this new philosophy for building LMSes, the QTI standard was used as the basis for a Web-based application to design questions and compose tests. Individual questions, collections of questions and entire tests were stored as linked and threaded collections of IMS-encoded records. The system then provided the ability to render a collection of questions for printing to paper. Analysis of the system building process revealed that the QTI standard is ambiguous and not easily applied in non-traditional situations where the focus is not on online testing. In spite of this shortcoming, a formal evaluation using a sample of educators

confirmed that the system's use of the QTI standard was virtually transparent and that the system was indeed usable.

Keywords:

Learning management systems, e-learning, metadata, assessment

1. Introduction

As Learning Management Systems (LMSes) became commonplace in the 1990s, there was a desperate need for interoperability so that educators and learners could move material from one system to another with relative ease. This led to many standardisation efforts related to the encoding of e-learning content - some of these efforts are discussed in the next section. This standardisation process has had varying degrees of success with commercial and even open source LMSes, but the emphasis is almost exclusively on online access to learning material. In contrast, there are many countries in the world where budding students do not have constant or regular access to connected computers, so do not benefit from the technological advances in LMSes.

Recognising that e-learning standards need to cater for the alternative needs of students in developing countries, this project has attempted to look at how a minimalist architecture could be designed for technology-enhanced learning as opposed to strictly e-learning. In doing so, the question as to whether e-learning standards can be used in an offline environment will be answered, as well as how extensible these standards are.

As a proof-of-concept, a prototype system was developed. It was then evaluated by a group of teachers as they would be the primary benefactors of this type of software. The Web-based system was designed to store test and examination question papers (and optionally their solutions) in a question bank, based on current standards and best practices from the e-learning community. This system can then be made available to teachers, who will need access to computers to create, edit and store assessments. Once a complete assessment has been designed the teacher would be able to generate a paper version for distribution and use in class. Thus, there is limited need for a computer system, while maximum benefit is derived from the adoption of standards as used in the international e-learning community.

2. Background**2.1 Learning Management Systems (LMSes)**

LMSes provide a mechanism for teaching and learning that exploits the capabilities of the Internet. They have numerous advantages and disadvantages, which have been well documented. The main disadvantage of an LMS is the initial startup and maintenance costs. The benefits include automated marking, online testing and learning at your own pace, to mention a few (ONGC, 2004).

Many LMS software packages exist (Moodle, WebCT, BlackBoard, etc.) and each of them has its own specific method for encoding, retrieval, storage and presentation of the digital learning material. This means that institutions using different learning management systems cannot exchange information and those who want to change LMSes would need to encode all the data again using the new encoding. Thus a need to standardise the format of digital

learning material arose. The IMS Consortium's Question and Test Interoperability (QTI) specification, IEEE's Learning Object Metadata (LOM) standard and the Sharable Content Object Reference Model (SCORM) are all attempts to standardise the formats of digital learning material.

Moodle is the only freely available LMS of those mentioned above (Moodle.org). It has been built to be used online and provides the user with discussion forums, online tests, online tutorials, file exchanges, etc. It is also capable of importing learning material from other LMSes (Answers.com). Moodle consists of modules that can be plugged into one another so that users can enable the desired functionality. Moodle is always evolving to suit the needs of the community.

WebCT started as a project at the University of British Columbia (EduTools, 2003). WebCT made the transition to a commercial product in 1997. Now, an annual license fee is required and this is based on the number of fulltime students. This system allows discussion forums, file exchange, online journals/notes, etc. Questions that include images and video files can be created. WebCT can import and export questions in the IMS QTI format.

BlackBoard was founded in 1997 and is privately-held (EduTools, 2004). It supports the same facilities mentioned above (discussion forums, etc). Instructors can create questions with images, time constraints, passwords and selective release criteria. BlackBoard 6 has implemented the IMS QTI 1.2 Specification but no mention of import and export functionality has been made.

The following subsections highlight some of the major and most successful attempts to standardise digital learning material.

2.2 IMS Global Consortium

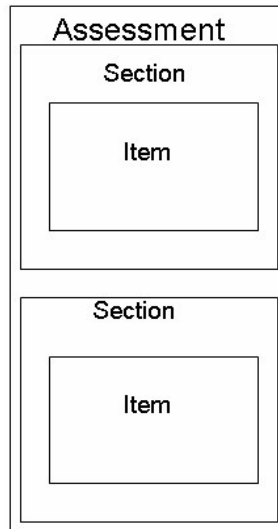
The IMS, formed in 1997, was meant to focus on higher education and has to date published a variety of specifications that address a wide range of learning contexts as well as corporate and government training (IMS Global Consortium, Inc., 2004). IMS has played a major role in the development of LOM, SCORM, Dublin Core, etc.

IMS develops specifications and these are usually standardised by approved certification authorities (ISO, IEEE, etc). IMS uses the current technology developments and user needs to develop specifications. These specifications go through phases in which they are reviewed publicly and privately. Once a final specification is released it is put into practice and the feedback is used by IMS in future developments.

2.3 IMS Question and Test Interoperability (QTI)

The QTI Specification aims to create Learning Objects (LOs) in a standardised manner so that they can be transferred and reused easily. Version 1.2 of this specification uses an Assessment, Section and Item (ASI) model as illustrated in Figure 1 and discussed below.

Figure 1: QTI model illustrating an Assessment, Section and Item



- **Item**
This is the smallest unit that can be exchanged using IMS QTI. This structure stores the question, its presentation instructions, the processing to be applied to the users response, feedback to the user and metadata describing the item.
- **Section**
A section contains one or more sections or items as well as any mixture thereof. It supports the grouping of constructs (e.g., a subject topic in an assessment) and controls the ways in which different sequences may be created.
- **Assessment**
Only one assessment can be contained within a QTI instance. An assessment must contain a minimum of one section and cannot house items directly. It contains all information regarding sequencing and scoring of questions to produce the final score.
- **Object Bank (Not shown in Diagram)**
Used for grouping together of items and sections.

The questions that may be encoded in this ASI Model span a wide variety of types, as listed in Table 1.

Table 1: IMS QTI Basic Question Types 0

Question Type	Description
True or False	A multiple choice question with 'true' or 'false' as possible answers.
Multiple Response	A multiple choice question with more than one of the choices identified as the answer or response identities (All answers are required for question to be answered correctly).

Fill-in-the-Blank	A formatted place for the input (viz., blank line or textbox) of text or integer/decimal/scientific number. The missing information needs to be supplied by the user.
Slider	Selection of a number from a predefined range with a set increment. The user is required to move the slider to the correct position.
Drag Target	Objects are required to be dropped into the target object.
Match Objects	Objects from one list have to be grouped with objects from another.
Multiple Choice	Multiple Choice question with one of the available choices identified as the answer or response identity.
Image Hot Spot	The response is a location on a graphic identified by the 'x-y' coordinates of the selected point.
Select Text	Identification of a piece of text from the paragraph or list presented. The user is required to identify the text.
Drag Object	Requires the user to move objects to predefined object locations. The response is determined by whether or not the user has paired the source object with the target one.
Order Objects	This type requires the user to unscramble the text, lines of text or objects and place them in the correct order in the correct locations provided on the page.
Connect the Points	The user has to connect the points in the correct order.

2.4 Learning Object Metadata (LOM)

LOM is used to describe learning objects and was approved as a standard in 2002 by the ISO (Duval, 2002)**Error! Reference source not found..** It defines metadata in 9 broad categories to store information and characteristics of the learning objects. These categories are described in the table below.

Table 2: Description of LOM categories

Category	Description
General	Stores information about the learning object as a whole.
Lifecycle	Stores information related to state and history of learning objects. It includes versions and contributors to the learning object.
Meta-Metadata	Stores the metadata lifecycle information.
Technical	Groups requirements to use the learning object, e.g., format, location.
Educational	Groups the teaching and educational characteristics of the learning object. This category includes information such as the use of the learning object, age range for usage, interactivity level and difficulty level.
Rights	Groups the intellectual property rights and conditions of use of the learning object.
Relation	Stores relationships between the learning object and other related learning objects.
Annotation	Stores comments on use of the learning object as well as by whom the comments were made and when.

Classification	Describes the learning object with regard to the particular classification system being used.
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This information is typically stored in an XML file because of its numerous benefits and ease of use (Software AG). There are implementations and variations of LOM currently in use in various LMSes, including the ones discussed above.

The LOM submission to IEEE was made jointly by IMS and the Alliance of Remote Instructional Authoring and Distribution Networks for Europe (ARIADNE). Since then IMS has been working on their Learning Resource Metadata Specification which is aimed to enhance the LOM standard (Kraan, 2004).

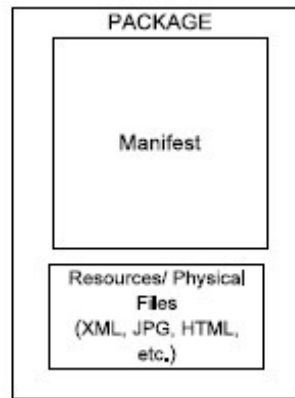
2.5 Sharable Content Object Reference Model (SCORM)

SCORM (ADL, 2004) is aimed at the creation of interactive, self-contained and interoperable learning objects. It targets the Web as the medium for delivering instructions and learning material. It is defined in a collection of specifications and standards that are bundled into a collection of (technical) books. There are 3 main books, namely Content Aggregation Model (CAM), Run-Time Environment (RTE) and Sequencing and Navigation. Each book documents different parts of SCORM.

2.6 IMS Content Packaging (CP)

The IMS CP Specification was created to describe and package learning material into interoperable and redistributable packages. This model defines a standardised set of structures that facilitate the exchange of content and provide the basis for standardised data bindings. These bindings allow software developers and implementers to create learning materials that interoperate across various platforms and environments that have been developed independently by different software developers.

The CP consists of a manifest file and the physical files being transferred (as illustrated below). The manifest file contains all information required to make use of the physical files being transferred. All these files are zipped and must conform to RFC1951 (IMS Global Consortium, Inc., 2003). This zipped file is the actual CP.

Figure 2: IMS Content Package

3. The Paper Based Assessment Creator

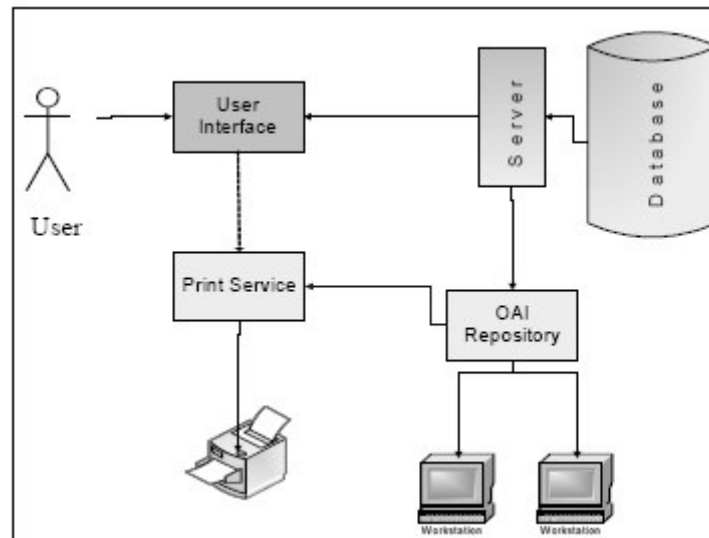
While a number of standards and specifications have been developed in recent years, most, if not all, are targeted at online LMSes. As has been discussed, popular LMSes have already embraced these standards and are to some degree interoperable with one another. This, however, does not meet the needs of communities with limited access to computers, where online and offline systems may be available to teaching staff but it cannot be assumed that all students can access teaching material through the Internet, let alone take tests and examinations online.

In order to address this somewhat challenging situation, it is suggested that teachers can use online systems based on current standards for the management of learning material, but then that material must be rendered on paper for subsequent dissemination among learners. To test this theory a system was built to submit, edit, store, manage and render assessments to paper, based on the IMS QTI, LOM and IMS CP standards. The following section describes the design of this appropriately-named Paper-Based Assessment Creator.

4. System design

The diagram below shows the different parts of the Paper-Based Assessment Creator (PBAC) and how they interact with one another.

Figure 3: Overview of entire system



The implementation and functionality of the main parts of the PBAC are discussed in the following sections.

4.1 User Interface

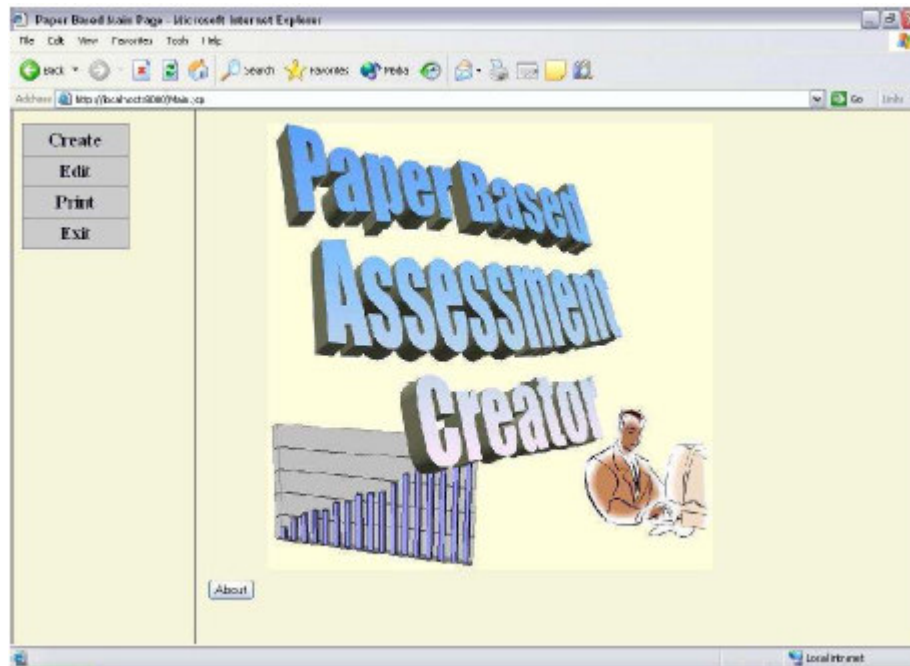
The user interface was created using Java Server Pages (JSP). JSP was chosen as it is open source, secure, lightweight and makes use of open standards (Hall, 1999).

The functions provided by the interface, as shown in Figure 4, are:

- Creation of learning objects (LOs): items, sections and assessments.
- Editing of LOs stored in the repository.
- Previewing of created and stored learning material.
- Printing of assessments

Additional information about each learning object is stored e.g., level of difficulty, which academic field it falls into and the intended audience of the question.

Figure 4: Paper-Based Assessment Creator Main Interface



4.2 Data encoding and transfer

The encoding method implemented reduced redundancy that exists within the IMS QTI specification. Our approach uses references for Items within Sections and Sections within Assessments. The references would be to external XML documents stored separately. This is discussed in more detail in the section on the repository.

An XML template was created for each question, section and assessment type available. The user is required to supply information to fill this template. The appropriate template with the information supplied is then used to create the XML document, as a representation of the LO.

Once the LO has been created, it is transferred to the repository in a Content Package (CP) (IMS Global Consortium, Inc., 2003) using SOAP (W3C, 2000) with attachments.

4.3 Repository

The repository was designed to easily store and extract information about LOs that are submitted to the system. The repository allows for the dissemination of learning objects through both an HTTP gateway and a SOAP interface.

All LOs stored in the repository are encoded and stored as XML. A unique identifier (UID) is associated with each LO that is submitted to the system. This allows the system to efficiently store and extract information pertaining to it. Other information, such as the question type, maximum score and version number, are all stored in the repository and serve to describe the LO.

Our implementation attempted to reduce the amount of redundant data that is stored. This is achieved by modifying the encoded LO to contain references to Sections and Items. This is in

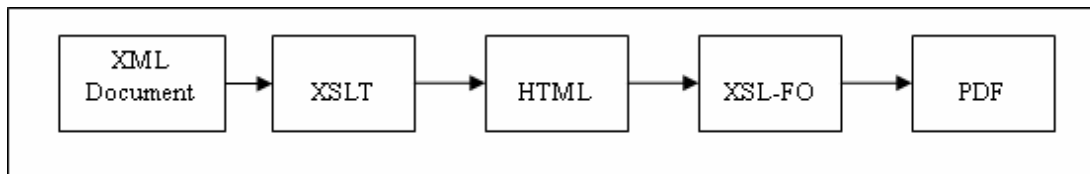
contrast to the IMS QTI specification where each encoded Section and Item is repeated when referenced by an Assessment or Section respectively. All resources that are associated with each LO are stored in a unique location, a local directory named after the UID assigned to each LO.

The use of the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) (Lagoze & Van de Sompel, 2001) allows the repository to exchange information, known as records, about its resources. The metadata is encoded in XML using the Dublin Core (DC) metadata set. In comparison to other retrieval protocols, such as Z39.50 and WAIS protocols, the OAI-PMH provides a low-barrier and simple approach to interoperability.

4.4 Paper generation

A core function of the system is to generate paper-based assessments from the LOs in the repository. This meant transforming an XML-encoded document into a human readable form. The use of Extensible Stylesheet Language – Formatting Objects (XSL-FO) (Harold, 2002) was used to create a PDF files from the LOs. Thus users of the system can share and print assessments of their choice. The following workflow was used:

Figure 5: Implementation of creation of paper-based assessment



The procedure that was adopted allows for additional information (mentioned in the User Interface section above) to be added to the LO at generation time and allows users to preview the material before printing. The system does not accommodate all the various encodings that can be created using IMS QTI but use of the Extensible Stylesheet Language Transformation (XSLT) to convert the XML files will allow for easy extension if required.

5. Evaluation and Analysis

5.1 User Testing

The aims of the user testing were to assess:

- the ease of creating items or questions, sections and assessments or question papers,
- the functionality of the system and
- the quality of the question papers created.

5.1.1 Test subjects

The test group consisted of 6 participants. Each participant was required to have teaching and question paper creation experience. This ensured they had knowledge on the types of questions and contents of a typical question paper. The participants were not required to be teaching currently to participate in the testing.

5.1.2 Test procedure

The system was installed on an Intel Pentium IV Laptop. This enabled us to do user testing at any location thereby accommodating the users' time constraints. Each user was required to complete a predefined list of tasks, which included:

- choosing the most relevant and irrelevant question types from those provided,
- creating these two questions using the system,
- rating the preview or representation of the questions created,
- checking if the system supported all the question types required,
- creating a section and adding the items, created previously, to it, and
- creating an assessment and adding sections to it.

Users were also asked to provide comments about the system, what improvements they would like and whether or not the system is useful to instructors, teachers and assessors. Users were allowed to ask questions, make comments and ask for assistance if required. The assistance was kept to an absolute minimum to prevent bias.

5.1.3 User testing results

The most relevant question types of questions were Multiple Choice and Multiple Response questions. Almost all of the participants mentioned the need to add graphs, tables and images, features not supported by the system. The need for complex mathematical and scientific equations was also noted. It was noted that the users cannot create in-depth questions with the system. Most participants found it easy to create questions while Sections and Assessments were considered more complex. The most notable comments were that the system can create question papers faster than traditional methods. The previews for each learning object was good and similar to those found in normal question papers. All users said that they would administer the output as part of a normal examination although half of them thought that additional information regarding the numbering of questions within the assessment was required.

5.2 Testing the repository

The repository was tested for OAI-Compliance as this would allow LOs and information about them to be exchanged easily. This was done using the Repository Explorer (Suleman, 2001), which issues a stream of tests with varying parameters to the repository being tested.

5.3 Testing Content Packages and XML validation

The CPs created by the system were also separately evaluated. This was done using the Reload editor (RELOAD, 2005). LOs were acquired, from the system, and these CPs were then imported into Reload. All CPs were imported successfully and no errors occurred. Since no errors were detected by Reload, the CPs were deemed to conform to the IMS CP specification.

Each fragment of XML generated by the system was validated with its associated schema. This was done using an online validator (DecisionSoft, 2005). This tool was tested by using an incorrect XML document and its schema. The validator detected the error successfully.

The schema provided was also tested using the schema validator available on the same site and this was successful. All the XML files created validated without any problems. The Items were the easiest to validate since the system created the entire XML file that was to be transferred. Validation of the Sections and Assessments took a bit longer. The Sections and Assessments had to be recomposed by the repository and stored on the machine. These XML files were then validated and this was also successful.

5.4 Evaluation of the IMS QTI Specification

The IMS QTI Specification was analysed once in the design phase and again during the testing procedure. This was to determine how many of the tags provided in the specification were used and whether it stored the required information efficiently.

The tags in Table 3 played no role in the paper-based version of an assessment.

Table 3: List of IMS QTI tags not used

	Item	Section	Assessment
Tags not Used	itemprecondition	sectioncontrol	qtimetadata
	itempostcondition	sectionprecondition	assessmentcontrol
	itemcontrol	sectionpostcondition	selection_ordering
	response_slider	sectionfeedback	reference
	response_xy	reference	sectionref
	response_num	sectionref	assessfeedback
	response_na	itemref	
	render_hotspot		
	render_slider		
	itemfeedback		

Most of these tags provided functionality that is only applicable to an online assessment.

5.4.1 Lack of additional information

Encoding of additional information was done using the IMS Learning Resource Meta-data specification (IMS Global Consortium, Inc., 2003). No tags in the IMS QTI specification could be used for this information. This information is required to perform searching, determine the intended users to be assessed, the difficulty of the assessment as well as the author who has created the learning material. This information is vital and the IMS QTI Specification lacks direct support for this. This may be a major disadvantage in the specification, as encoding has to be done in conjunction with another specification to store this information.

5.4.2 Variations of learning material

Another issue that arises when using the IMS QTI specification is the use of composite types of questions. The variety of possibilities is so broad that the rendering engine used to display the information would need to be quite complex. The other problem is that systems importing or using of the learning object has to cater for that particular composite type. Many of the tags in the specification are optional, making the ability to rely on a specific tag very hard.

5.4.3 Ambiguity in the specification

There is quite a large amount of ambiguity in the specification. All the tags that have been deprecated are still listed inside the specification to maintain backwards compatibility. This makes the specification more complex as it refers to alternate structures that may be used. Most of the alternate structures mentioned are the deprecated ones making their use somewhat unacceptable. The specification requires a lot of time to work through and has to be done with the examples supplied with the specification. A lot is expected from version 2.0 of the specification and it is hoped that most of the ambiguity will be removed. This specification promises a redesign of the Item structure, which forms the basis of all learning material that can be created using QTI.

6. Future work

The system provides for basic question types and thus still requires encoding for the more advanced or complex types. It also does not provide a method to add complex mathematical and scientific equations, which are commonly found in question papers. The following is a list of features that can be implemented to enhance the question types and features provided by the system:

- Provide encodings for Essay-type and Short Answer Questions.
- Allow images to be added and form part of questions.
- Provide encoding of mathematical and scientific equations using MATHML
- Provide ability to preview and print randomised subtests.

6.1 User profiles

Currently, the user of the system must complete the assessment, section or question, which is being created, in a single session. With user profiles, users can work on their learning materials, save them and continue working on them later. This would also allow multiple users to contribute to one assessment and help to create better learning materials.

6.2 Notification of updates

LOs can be updated and edited anytime. When creating an assessment the user would add certain questions and could save his/her progress until he/she has time to complete it. If any of the questions used in the assessment were updated the user should be notified of the update and asked whether to modify the one currently in the assessment. This would ensure that the assessments made would use the most recent versions of LOs and that assessments do not become outdated.

6.3 Versioning

The current system does not employ an efficient versioning algorithm; a learning object that closely resembles some content in the repository should not be stored as a new learning object. The creation of a difference between these learning objects should rather be stored.

7. Conclusion

The paper-based assessment system has demonstrated that it is definitely possible to apply standards for online learning to more novel system development approaches in support of developing country infrastructures. The prototype could easily form the basis of production systems to support sharing of learning objects among educators, and possibly sharing of learning objects with repositories in other countries. Further, the lessons learnt from this project imply that standards bodies are not pushing the boundaries of experimentation far enough – more experimental and standardisation effort is required to make e-learning standards truly universal and applicable to more than a narrow set of use cases.

While these standards are evolving, some institutions and funding agencies are actively promoting open e-learning content. MIT's Open CourseWare is a prime example of a project where open access to learning material is being promoted at an institutional level. The US-NSF's NSDL project is much broader in scope and gathers e-learning material from many distributed partners for subsequent portal-based discovery and open redistribution. As such initiatives gather momentum, it is imperative that the needs of developing countries are taken into consideration and also that learning material produced in developing countries is contributed back to the global community so that they become not just consumers of knowledge but active participants and producers as well.

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