The digitilisation of paper-based assessment using e-standards

Afzal Dalwai
University of Cape Town
+27 21 82 839 3220

adalwai@cs.uct.ac.za

CS04-23-00

Muammar Omar
University of Cape Town
+27 21 82 391 2333

momar@cs.uct.ac.za

ABSTRACT

The use of computers to automate the process of learning and assessment is used in most educational and commercial institutions today. This is done by creating and storing online or digital learning materials and using them in required tasks. In order to use this principal in the automation of paper-based assessment, a standardised encoding scheme has to be employed.

We have attempted an explorative study using the Instructional Management System's (IMS) Question and Test Interoperability (QTI) specification and IMS Learning Resource Metadata Model (LRMM) to create learning objects (LOs). These LOs were based on traditional paper-based assessments and stored additional information that allowed for their effective sharing.

The sharing was achieved by creating an OAI-compliant repository and the unqualified Dublin Core metadata (DC) set to describe them.

A group of teachers evaluated the quality of paper-based assessments generated from these LOs and were very optimistic about the automation of this process.

Categories and Subject Descriptors

H.3.7 [**Digital Libraries**]: User Issues and Systems Issues.

General Terms

Management, Design, Human Factors, Languages, Theory.

Keywords

Question and Test Interoperability, paper-based assessments, learning object repositories.

1. INTRODUCTION

The use of computers to automate the process of learning and assessment is used in most educational and commercial institutions today. This provides an easier means to assess and enhance the abilities of individuals of these institutions. This is done by creating and storing online or digital learning materials and using them in the required tasks. Despite these advantages there are problems that need to be overcome before it can be used to its full potential. The major problem is that there are various ways of formatting or encoding these LOs and no standard way to transfer or interchange them. In addition, there are problems of searching, locating, and management of LOs.

Our research's principal objective was to test the quality of generated paper-based assessments using LOs created with QTI and LRMM. It also involved the creation of an OAI-compliant

repository that would allow for the effective sharing of information about these LOs [1]. In order to pursue this objective we modeled the creation process using a simple user-interface and stored the created LOs in a relational database. The system that was developed is called Paper-Based Assessment Centre (PBAC). Using PBAC, users were able to create and transform LOs. The transformations allowed these encodings to be converted into a format that can be used in paper-based assessment.

The list of question types supported by the system is given in the table below:

Table 1: Question Types supported by the System

Question Types
True or False
Mutliple Choice
Fill-in-the-Blanks
Order the List of Items
Match the Columns
Multiple Response Questions

2. BACKGROUND AND MOTIVATION

2.1 The IMS QTI specification

The first public draft of the specification was released in February 2004 and the IMS QTI version 1.0 was released in May 2000. Version 1.1, released in March 2001, contained the first QTILite specification [2]. This specification describes the basic components needed to construct the simplest QTI-compliant system. QTI version 1.2, released February 2002, contained restructuring of the specification and a substantial number of amendments. Version 2.0 will contain significant restructuring of the item component and is due in July 2004 [3].

The encodings were done using version 1.2 of the specification and the Assessment, Section, Item (ASI) model it is based on is shown below.
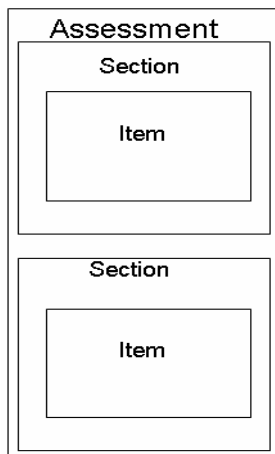
Figure 1: QTI model illustrating an Assessment, Section and Item

- 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.

2.2 The Open Archives Initiative (OAI)

The OAI is an organisation that attempts to simplify the collection of electronic pre-prints. It allows repositories to share information, known as records, about their resources using the OAI-Protocol for Metadata Harvesting (OAI-PMH) [1]. The OAI-PMH is based on HyperText Transfer Protocol and uses the GET and POST mechanisms.

In this framework, a repository is an aggregate storage mechanism that contains metadata that can be retrieved using the OAI-PMH. The metadata is encoded in XML using the DC. There are two classes of participants in the OAI framework:

Data Provider:

> Data Providers, or repositories, make metadata available in DC and other formats.

Service Provider:

> Service providers, or harvesters, issue the OAI-PMH requests to data providers and use the harvested metadata to create value added-services.

The OAI-PMH is based on six verbs (Table 2) that facilitate sharing of records amongst repositories.

Table 2: Verbs that Service Providers issue to obtain metadata records

Verbs	Description
GetRecord	Retrieve an individual metadata record from repository.
Identify	Retrieve information about a repository.
ListIdentifiers	Get a list of identifiers that can be retrieved from the repository. Various sets of records can be requested by specifying certain qualifiers.
ListMetadataFormats	Retrieve a list of metadata formats supported by the repository or available for a specific record.
ListRecords	Retrieve records from the repository. Various sets of records can be requested by specifying the set or date range.
ListSets	Retrieve a list of the metadata sets that the repository has available.

In comparison to other retrieval protocols, such as Z39.50 and Wais protocols [4], the OAI-PMH provides a low-barrier and simple approach to interoperability.

Although the OAI-PMH is not specifically designed for learning objects, the issue of copyright infringement is avoided as only metadata is exchanged between providers. In addition, providers can store metadata in any format.

3. METHOD
3.1 Aims
The aims of PBAC was to test the effectiveness of encoding paper-based questions and tests using the IMS QTI specification. These encodings were transformed into a PDF medium that allowed effective evaluation of the generated paper-based assessment. Users of the system can create a single question, collection of multiple questions or a whole test.

3.2 System Design
In essence, the system comprised of two core modules that interacted using a well-defined interface. This interface was controlled using the Simple Object Access Protocol (SOAP) with attachments. The user-interface serves to capture information regarding the created LO. This information is then encoded using extended markup language (XML) that follows the IMS QTI specification. These encodings are transferred over HTTP and

stored in the relational database. This architecture is illustrated in the diagram below:
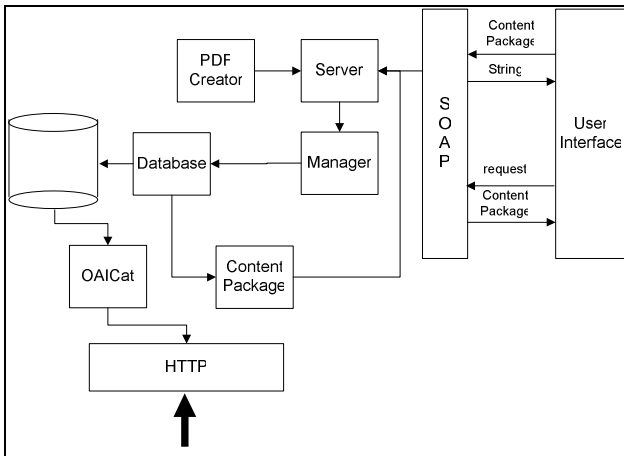

Figure 2: Overview of System

3.2.1 The User Interface

The interface was required to be web based and therefore the technology used had to be taken into account. The various options considered were Macromedia Flash MX, Java Applets and Java Server Pages (JSP). After doing further research, JSP was selected to create the interface. The Paper Based Assessment Creator (PBAC) Interface allows for creation and editing of learning materials. These options can be accessed through the main interface (see figure below).
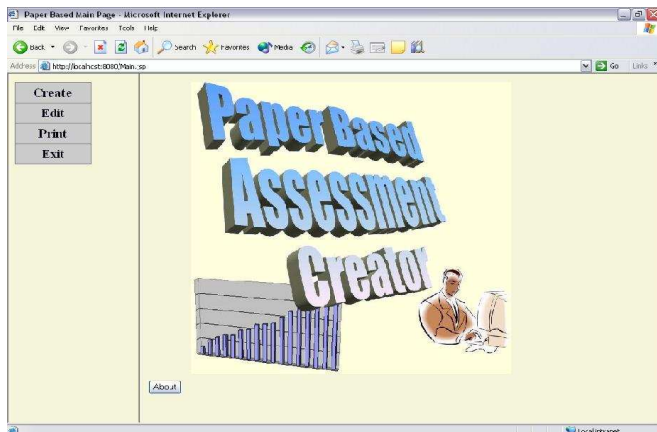

Figure 3: Paper Based Assessment Creator Main Interface

The functions that the PBAC provide relates to the material being created as well as their encodings and additional information. The functions provided are listed below:

- Creation of LOs from paper-based material.
- Editing of LOs stored in the repository.
- Ability to preview the learning material and print Assessments.

3.2.2 Encoding User Input

The encoding method implemented reduced redundancy that exists within the IMS QTI specification. Our approach references Items within Sections and Sections within Assessments. The references would be to external XML documents stored separately. Further details are discussed in section 3.2.4. Although IMS QTI has provided *<itemref>* and *<sectionref>* tags, these are to be used when referencing information within the same XML document.

To create the learning objects or XML files, Document Object Model (DOM) classes was used. These classes provide methods to create an XML document that is stored in a DOM tree. These classes provide methods to extract and modify information within the tree. Its also provides an XML validator to check each XML file against its schema.

For each question, section and assessment type available an XML template was created. The user would be required to input the information required through the user interface. The appropriate template with the information supplied was then used to create the XML document.

3.2.3 Transferring XML Documents To Repository

Once the learning material has been created, it is transferred to the repository in a Content Package (CP) using SOAP with attachments. CP allows digital objects to be packaged in a known format with additional information which describes the files, their format and also what can be used to view them [5]. This package is attached to the SOAP message and sent to the repository. The figure below describes the structure of a CP.
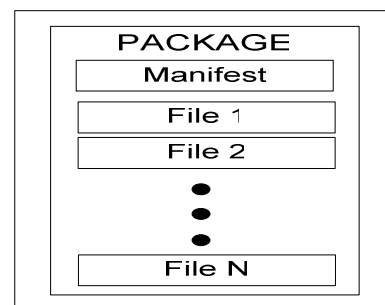

Figure 4: An IMS Content Package

The CP (Figure 5) consists of a manifest file and the physical files being transferred. 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 [6]. This zipped file is the CP that is transferred. Information about the LO was also placed inside the Content package. This information includes the author of the material, subject, level of difficulty and the intended audience for whom the material is created.

3.2.4 The Repository

The repository was designed to easily store and extract information about LOs that were submitted to the system. In addition, the repository allowed 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. For each LO that is submitted to the system a unique identifier

(UID) is associated to it. This allows the system to efficiently store and extract information pertaining to it. Other information, such as the question type, maximum score, 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 ASI unit 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. One of the requirements in implementing this method was to remove the root element namely, *<questioninterop>*, from the stored encoded content. An additional benefit of using this approach was the efficient recreation of composites such as Sections and Assessments since very little modification was required to transmit the stored learning object.

All resources that are associated to the LO had to be stored in an exclusive location. This is achieved with the creation of a local directory named after the UID assigned to each LO. Thus, each resource is stored in the locally created directory and a reference to it is stored in the database.

When transmitting LOs, any additional information that is stored in the repository is encoded using LRMM and is attached to the content package. This allows for an effective description of the transmitted LO. The metadata and content stored in the repository are exposed using the OAI-PMH.

The functional module that allows for the OAI-compliance of the repository was implemented with the use of the OAICat tool [7]. This tool generates XML-responses to the specified OAI-PMH requests. This allows information about LOs to be shared efficiently that facilitate the dissemination of the repository's contents.

Using the OAI-PMH record format for each LO the UID attributed to the object could be shared. This allowed them to be retrieved using the HTTP gateway.

3.2.5 The Paper-generation module
In order to effectively test the system that we have developed, an actual paper-based assessment was created. This meant transforming an XML-encoded document into a human readable form. The use of Extensible Stylesheet Language – Formatting Objects (XSL-FO) was used to create a Portable Document Format medium from these encodings. This allowed users of the system to both share and print assessments of their choice. This was achieved with the following procedure:

Figure 6: Our implementation of creating paper based assessment

The procedure that we have adopted allows for additional information to be added to the LO at generation time and allows users to preview the material before printing.

The procedure implemented does not accommodate all the various encodings that can be created using IMS QTI but we believe that the use of the Extensible Stylesheet Language Transformation

(XSLT) to convert the XML files will allow for easy extension if required.

3.3 Experiment
3.3.1 Test Subjects
The participants chosen for testing had to satisfy certain criteria. Each participant was required to have teaching and question paper creation experience. This gave them knowledge on the types of questions and contents in a question paper. Our sample included users that were either currently teaching and users that had taught in the past.

The participant was not required to be teaching currently to participate in the testing. The participant's knowledge of setting question papers was seen as the main criteria.

The criteria mentioned above would ensure that the paper-based assessment created would encompass all the various question types required. It also ensured that the feedback received would be from of an individual who has previous experience in completing these procedures.

3.3.2 Questionnaires Used During Experiment
Two questionnaires were used to test the system. These questionnaires were composed of two sections. The first section contained Likert Scale questions and the second open ended ones. Analysis of the quantitative information was done.

3.3.3 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 user's time constraints. The user was required to complete a predefined list of tasks.

Each participant was contacted and asked for an appropriate time that they would be available. Testing was to be done at the participant's house rather than having them using the system in an unknown and possibly uncomfortable environment. The testing procedure commenced as follows:

1. The participant was given a brief introduction to the system, what it aims to accomplish and the model it is based on.
2. The participant was guaranteed that all testing would be confidential and that the results are a reflection of the system.
3. The user was then given the task list to complete.
4. After completing the tasks they were thanked for their time and the feedback provided.

During the testing users were allowed to ask questions, make comments and ask for assistance if required. The assistance was kept to a minimum as this could cause the results to be biased.

4. RESULTS
4.1 User Testing
The results of the testing were recorded and analysis follows.

Table 3: Quantitative Results extracted from Testing

Question	User 1	User 2	User 3	User 4	User 5	User 6
2	2	2	4	4	2	2
3	1	1	1	1	1	1
5	1	1	1	1	1	1
6	3	3	4	4	4	3
7	3	4	4	3	4	3
8	3	3	4	4	4	3
10	2	2	4	4	3	3

Questions 2, 3 and 5 covered the creation of Items and the preview of the material created. Questions 6 and 7 covered the creation of Sections while question 8 covered the Assessments. Other questions were on the system in general and these results are qualitative.

The analysis of the results obtained is summarised in the following paragraphs:

The most relevant question types were Multiple Choice and Multiple Response questions. Eighty three percent of the participants mentioned the need to add graphs, tables and images which is 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 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 fifty percent thought that additional information regarding the numbering of questions within the assessment was required.

4.2 XML Validation and Protocol Testing
All XML that is created by the system was validated using the associated schemas. This was achieved with the use of an Xerces XML validator and can be found online [8]. In addition, the repository was tested for OAI-compliance using the Repository Explorer. This tool issues all the verbs and parameters upon which the OAI-PMH is based [9] to the repository thereby validating OAI-compliance.

5. CONCLUSION
From the user testing conducted, it can be concluded that the system captures the information to be stored in paper-based material with minimum effort and it is not too complex to use, it is lightweight and can be used anywhere. It also enables users to create assessments faster than traditional methods.

The supplementing of IMS QTI with IMS LRMM creates a fully interoperable LO that is effectively described using the Dublin Core metadata set. This allows for the creation of an OAI-compliant repository that facilitates sharing of LOs.

Paper-based assessments are created reasonably successfully from LOs. The created paper-based assessments are a *close* representation to traditional question papers and tests.

Despite this there is still a lot of work required to fully capture the essence of paper-based assessments.

6. FUTURE WORK
6.1 More Questions and Features
The system provides for basic question types and thus still requires encoding for more advanced or complex types. It also falls short with not providing a method to add complex mathematical and scientific equations that are commonly found in question papers.

The following is a list of features to be implemented to enhance the questions and features:

- 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[1]
- Provide ability to preview and print Random Subtests.

6.2 Better Interface
The interface was built on the model provided by the IMS QTI specification and implemented an unnatural way of creating paper-based learning material. An interface that allows users to create question papers and assessments in a more natural way would enhance the users' experience. This would enable them to make use of the system more effectively and creatively.

This would be ideal in creating a system for use in educational and commercial institutions.

6.3 User Profiles
Currently the user of the system has to complete the assessment, section or question that is being created in a single attempt. 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.

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[1] MATHML is an xml encoding used to store mathematical equations.

6.4 Notification Of Updates

The system should notify the user if any questions he or she has used previously have been updated or edited. When creating an assessment the user would add certain questions and could save his progress until he or 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.

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