Abstract:
The development of learning objects which are smaller chunks of learning content is often time consuming and expensive. Recent efforts in producing learning objects that are reusable and sharable were not very successful due to the lack of interoperability between different learning systems and applications. On the other hand, Semantic Web technologies together with ontologies provide rich medium for facilitating e-learning via the semantic annotated learning objects and shared repositories. However, Semantic Web technologies have not yet been applied widely to deliver learning objects and support e-learning. In this paper, we demonstrate how the ontologies and Semantic Web technologies provide a solution to overcome the problems with interoperability among e-learning environments. This paper provides a conceptual framework that provided the basics for the development of ontology-driven learning objects repository on the Semantic Web. The paper also outlines the development of repository using the ontology-driven Semantic Web approach. The developed learning object repository has been evaluated with users for usability, functionality and acceptability. The repository scored high in usability and functionality testing; however acceptability of the system is low in the academic setting.

Keywords:
E-Learning, Learning Objects, Learning Objects Repository, Ontology, Semantic Web

1 Introduction

In the last decade, learning objects, which are smaller chunks of learning contents, have gained a lot of interest as the basis of a new type of computer-based instruction in which the instructional content is created from individual components. The concept of learning object has evolved from the need to reuse digital learning materials. Learning objects offer economic as well as pedagogical advantages over the traditional learning materials. The learning objects are created just once, but used several times in different contexts, compensating the high cost of production. Also, high quality, thoughtfully designed, multimedia learning objects could be easily accessed by any instructor or learner. This object-based principle is based upon the idea that a course or lesson can be built from reusable instructional components which can be built separately but modified
to the user's needs. A learning object is a self-contained component with associated metadata that allow to reuse the object in different contexts. Additionally, learning objects are generally understood to be digital entities deliverable over the internet, making them accessible and usable by multiple users in parallel (Wiley, 2001). Learning object metadata are a schema used for describing learning objects. IEEE LOM is one of the standards exists for describing learning objects (LOM, 2003). Although the IEEE LOM standard has led to a wide adoption of learning objects metadata, learning objects still suffer from the difficulty to create metadata. As a result, some issues are identified which are given below:

- Most reuse initiatives still struggle to achieve a critical mass of learning objects to really establish reuse,
- Many learning objects only have a very limited set of metadata associated to them (Najjar et al., 2003; Najjar et al., 2004),
- Metadata are added only once and remain unchanged afterwards, during the further life of the learning object.

This research applies Semantic Web technologies and ontologies to address the issues mentioned above. Therefore, aim of the research is to develop an environment for learning objects that are interoperable, transparent and sharable by the community of educators and learners within the construction discipline. This paper first describes conceptual framework, followed by research methodology, design and development and evaluation of the developed system. Next section describes the conceptual framework that addresses the challenges faced by the development of learning objects and the enablers that facilitates the development of online environment.

2 Conceptual Framework

The three main challenges that are faced by the development of learning objects are:

- Intelligent by developing semantic metadata,
- Sharable through content packaging and
- Dynamic using ontologies and Semantic Web.

Figure 1 shows the conceptual framework that is produced as part of the research to develop an online environment of learning objects.
To meet these challenges the following methodological steps are followed to design and develop the online environment:

- **Stage 1:** To develop a metadata framework which integrates pedagogical and construction metadata that can be applied to a variety of learning objects.
- **Stage 2:** To apply a content packaging standard that packages learning objects together in order to export to and retrieve from various learning management systems.
- **Stage 3:** To identify the ontology (i.e. a common vocabulary of terms and concepts) for construction education and to develop a Semantic Web environment that will increase sharability of objects within construction domain.

This research adapted UKLOM metadata standard for developing learning objects for construction (UKLOM, 2004). Next section outlines the research methodology adapted to follow the methodological steps mentioned above.

## 3 Methodology

The research reported in the paper has a design science intent, one that acknowledges IT as a component of improving and developing artefacts for the development of better solutions and tools. The research approach leverages design science research and follows the general design cycle described by Vaishnavi and Kuechler (2004). In this model, all design begins with Awareness of a Problem. Design science research is sometimes called “improvement research,” and this designation emphasises the problem-solving or performance-improving nature of the activity. An attempt at implementing an artifact according to the suggested solution is Development. Partially or fully successful implementations are then evaluated according to the functional specification implicit or explicit in the suggestion. Development, Evaluation, and
further Suggestions are often iteratively performed in the course of the design research. The basis of the iteration, the flow from partial completion of the cycle back to Awareness of Problem, is indicated by the Circumscription arrow. Conclusion indicates termination of a specific design project. The Design Science Cycle is shown in Figure 2.

3.1 Awareness of Problem

The first step of the Design Science Cycle is an awareness of a problem through problem identification and definition. The problem identified in the current research is the difficulty in reusing and sharing learning content among educators, learners and curriculum developers. The research developed a framework as shown in Figure 1 that addresses the challenging of developing sharable learning objects.

3.2 Suggestion

To examine the research question of how to reuse and share the learning objects among educators and learners, it is important to gain an understanding of the current usage of the learning content and the technologies that enable reusability and sharability. According to the conceptual framework, Semantic Web technologies together with the ontologies provide a solution to enable the development of dynamic environment. A literature review is conducted to see how intelligent and dynamic learning objects can be developed. Metadata standards provide the label for learning objects that enhance the discovery of learning objects. Content packages provide the ability to package the relevant learning objects together in order to export to the learning management systems like Blackboard.
3.3 Development
The literature review of learning objects, educational standards and web technologies provides a suggestion to address the research problem of reusability and sharability of learning objects. With the knowledge gained in the first two steps, the next step is to utilise it for implementing the suggestion as discussed in the Suggestion phase. This phase is where most of the actual design takes place, which is the creative effort required in synthesising existing knowledge and a well-defined problem definition into an artifact for solving the problem. A resulting artifact of design science research may be rather abstract in nature, such as in the form of constructs, models, or methods (March and Smith, 1995). However, the research reported in the paper has developed a full-working prototype of repository.

3.4 Evaluation
After the development of an artifact, it is necessary to evaluate the artifact using empirical methods “to determine how well an artifact works” (Hevner et al., 2004). There are multiple evaluation options, including action research, controlled experiments, simulation, or scenarios (Vaishnavi, 2004). According to Whitley (1996), experimentation has the high internal validity and control and therefore it has been chosen as a research methodology for the Evaluation phase. Experiments in terms of testing the functionality, usability and user acceptability are used to evaluate the learning objects repository. Functional (black-box) and structural (white-box) tests are carried out to check the systems for any failures in execution of any commands during the software testing.

3.5 Conclusion
Conclusion is drawn from the findings from the evaluation stage. Future research is also identified and discussed in this final stage. Next section describes the design and development of the learning objects repository.

4 Design and Development
4.1 Ontology Concepts and Classes
According to Gruber (1993), ontology is an explicit specification of a conceptualisation. According to Noy and McGuinness (2001), ontologies are developed in order to:

- share common understanding of the structure of information among people or software agents
- enable reuse of domain knowledge
- make domain assumptions explicit
- separate domain knowledge from the operational knowledge and
- analyse domain knowledge

This research has developed ontology for sharing learning objects in construction. Figure 3 outlines the concepts and classes in the ontology including, structure, disciplines, learning objects types and pedagogy. The programme structure including modules, topics have been modelling in the construction education ontology.
4.2 Design of Learning Objects Repository

The learning objects repository is developed as an iterative development process. A use case diagram is a type of behavioural diagram defined by the Unified Modelling Language (UML) (UML Wikipedia, 2008). Its purpose is to present a graphical overview of the functionality provided by a system in terms of actors, their goals (represented as use cases), and any dependencies between those use cases (Use Case Wikipedia, 2008). Use case diagram is used to design the functionalities of the learning objects repository. Figure 4 shows the use case diagram designed as part of this research to develop the learning objects repository. Unregistered users will have limited access to the learning objects repository compared to registered users.
4.3 Development of the Learning Objects Repository

The repository is built using open source software and tools. The core of the system is the Semantic Web toolkit called Jena. Jena is a Java framework for building Semantic Web applications. It provides a programmatic environment for RDF, RDFS and OWL, SPARQL and includes a rule-based inference engine. The repository has two separate systems that work together to function as a repository. The learning objects system is built using Semantic Web technologies and ontologies. The system is to manage content packages is built using SCORM content packaging standard and PHP. Figure 5 presents the architecture framework of the Semantic Web based Learning Objects Repository.

![Architecture Framework](image)

Figure 5: Architecture Framework of the Repository

Learning objects can be uploaded, browsed and searched within the repository. Similarly, within the repository content packages can be created using learning objects, uploaded to the repository in a zip format and exported to the learning management systems such as Blackboard. Figure 6 shows how the learning objects and its metadata are stored in the semantic database. Information are stored as RDF (Resource Description Framework) with three elements i.e. subjects, properties and objects.
5 Evaluation

Usability tests are carried out in order to test the systems for the fitness to their purpose (effective, efficient and satisfying) in the context of use (user, tasks, socio-technical environment). In order to carry out a usability test, a small sample of users is selected from user group. A set of tasks based on the scenarios is carried out by the user being watched by the evaluator (Rubin, 1994). Role of the evaluator is to brief the user and to annotate time, number of errors and completion percentage for each task. At the end of the test the users are handed a psychometric questionnaire – in order to cross check the perceived usability and satisfaction with the performance data. Brooke’s (1996) System Usability Scale (SUS) questionnaire is used to evaluate the usability of the learning object repository as it is relatively short, however it is proved to be more effective than their longer counterparts such as Questionnaire for User Interface Satisfaction (QUIS) and Computer System Usability Questionnaire (CSUQ) (Tullis and Stetson, 2004).

The SUS scale is used after the respondent has had an opportunity to use the system, but before any discussion takes place. Respondents have been asked to record their immediate response to each item, rather than thinking about items for a long time. Respondents have also been asked to check all the items and if a respondent feels that they cannot respond to a particular item, they should mark the centre point of the scale. Evaluator is briefed the respondents with the purpose of the learning object repository and then a set of tasks are given to them to perform with the system. A set of tasks that have given to respondents is given below.

Task 1: Submit a learning object
Task 2: Search for a learning object, which consists of
- Simple search
- Advanced search
- Browse search
Task 3: Create a content package
The usability test is set to measure three aspects such as effectiveness, efficiency, and satisfaction.

- Effectiveness: a task is completed successfully
- Efficiency: the time taken to achieve a goal
- Satisfaction: the results of questionnaires

In order to measure the efficiency, the time taken to achieve a goal is measured from the time the user is asked to start, to the time the goal has been achieved. The expected time to complete the task has been estimated from pre-tests. According to Bevan (2007), the maximum time allowed to users before they are categorised as having failed should be at least three times the expected time. Table 1 outlines the allocated time in minutes for each task with the expected time.

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Expected time</th>
<th>Allocated time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submit a learning object</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Search for a learning object</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Create a content package</td>
<td>3</td>
<td>9</td>
</tr>
</tbody>
</table>

Each task is allocated a maximum amount of time to achieve its aim. Responses have been recorded and analysed. The next section reports the analysis of data obtained from the questionnaires using different methods.

5.1 Method 1 – Total Score

Usability testing using SUS is carried out with 14 users to test the satisfaction of the users in using the learning objects repository. The SUS score is calculated by summing up the score contributions from each item. Each item’s score contribution ranges from 0 to 4. For items 1, 3, 5, 7, and 9 in the SUS, the score contribution is the scale position minus 1. For items 2, 4, 6, 8 and 10, the contribution is 5 minus the scale position. Total SUS score is obtained by multiplying the sum of the scores by 2.5 to obtain the overall value of SUS. SUS score has a range of 0 to 100 which represents a composite measure of the overall usability of the system being studied, in this case learning objects repository. Figure 7 shows the results of the usability tests with total 14 users. All the questionnaires score above the 85% with 1 tests scored 100%. The figures show that high satisfaction of using the learning objects repository among the respondents.
5.2 Method 2 – Maximum Rating

Questionnaires were converted to percentages by dividing each score by the maximum score possible on that scale. So, for example, a rating of 3 on SUS was converted to a percentage by dividing that by 5 (the maximum score for SUS), giving a percentage of 60%. The frequency distributions of the ratings on each questionnaire is converted to percentages as described above, are shown in Figure 8. The higher frequencies of maximum rating in the SUS responses indicate that users satisfy with the learning objects repository, its interface and functionalities.
5.3 Method 3 – Goal Achievement

SUS questionnaire respondents are allocated a maximum amount of time for successful goal achievement for each task as set out in criteria in Table 1. Figure 9 shows the goal achievement of the respondents.

![Goal Achievement](image)

Figure 9: Goal Achievement by Time

All the users have completed Task 1 successfully within the allocated time. 93% of the users have completed Task 2 and 3 within the allocated time. Only 7% of the users have completed the Task 2 & 3 out of the allocated time. It shows that high efficiency of the learning object repository in terms of its usage and functionalities. In addition to that, all the users have completed the tasks in the usability tests. It demonstrates that 100% effectiveness of the learning object repository.

6 Conclusion

This research proposed a conceptual framework for developing dynamic, intelligent and sharable learning objects. The framework brought enabling standards and technologies together to develop a dynamic learning object repository. The framework is tested by developing a prototype learning object repository for construction. Metadata standard offered semantic annotation for learning objects and thus enhanced the discoverability and reusability of learning objects. UKLOM is adapted to develop the learning object repository as it provided the context of the UK education. There is no metadata for construction learning objects exist, and therefore this research proposed a metadata framework for construction by integrating construction domain as an element to UKLOM standard. The literature review revealed that no ontology for construction education exists. Therefore this research identified relevant pedagogical elements for learning objects which have been developed as classes for construction education ontology. The developed ontology demonstrated the application of ontology for sharable learning objects, however if the ontology is developed with more concepts, it can make huge contributions to develop lot more sharable and intelligent learning objects. An innovative approach has been adapted to develop the learning object repository using ontologies on the Semantic Web. Semantic Web is emerging as a next-
generation Web and has huge potential for developing intelligent learning objects and supporting e-learning at large. Semantic Web and ontologies offer great educational value to curriculum developers and users who are desperate for change in the way traditional e-learning tools and applications work. The developed learning object repository has been evaluated with users for usability, functionality and acceptability and to see if it satisfies the pedagogical needs of the users. The repository scored high in usability and functionality testing; however acceptability of such system is low in the academic setting due to several reasons. Academic institutions should encourage the use of various e-learning tools rather concentrating on a particular learning management system (e.g. Blackboard) and also recognise the successful implementation of such tools in the academic settings.

7 References


