Dynamic Assessment and Customizable E-Learning Content Generator

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Abstract - *This paper proposes a framework to create customizable on-demand educational contents with automated assessment. This framework can sequence educational contents logically based on content dependency, both implicit dependency in domain ontology and/or explicit dependency in external specifications. Based on the dependency information, the framework can propose several alternative and ranked learning paths so that educators or learners can make intelligent decisions. A metric called "Learning Path Relevance" can be used to evaluate alternative learning paths. The framework also has a formal model to generate questions automatically from domain ontology for assessment. Using the proposed framework, it is possible to customize various learning modules for individuals with different backgrounds with automated assessment.*

Keywords: Customizable content, on-demand learning content, dynamic sequencing, dynamic assessment, content reusability.

1 Introduction

An important objective of a good e-Learning system is to deliver individualized, comprehensive and dynamic learning contents to wide range of users. Two popular resources for finding learning contents are Learning Object Repositories (LOR) and Websites such as www.wikipedia,com. However, as today, not sufficient learning objects (LO) are available. Most of the available LO systems support teachers or instructional designers to incorporate knowledge into a course, but students have no control over the selection of materials. In other words, students cannot select an arbitrary set of topics that they wish to learn, the system can generate a set of LOs properly sequenced for them to learn with appropriate prerequisite knowledge placed in the right sequence, and automated assessment. This paper addresses these issues by proposing a framework that 1) allows educators and content developers to develop education contents collaboratively using ontology systems; 2) allows students to select a set of topics to learn and the system can create course modules properly sequenced based on knowledge dependency and student profile, i.e., personalized learning; 3) automatically generate questions for assessment to evaluate student understanding of the materials; 4) the framework can be deployed on the Web for easy access; and 5) the contents generated can be plugged-in to a Learning Management System (LMS).

2 Related Work

Personalization in e-learning is an important research area that focuses on customizable learning systems. Intelligent tutoring systems, adaptive hypermedia systems are being used to build educational models. Concepts of adaptation, personalization, techniques like data mining, user profiling are often used in these systems. They behave differently depending on user interactions with the system, available data, and user profiles. Chen and Peng [3] presented a personalized e-learning system based on ontology, correlations, and fuzzy clustering. It allows teachers to apply a concept map to arrange curriculum sequencing and to assist students in learning diagnosis. Stiubiener, Ruggiero and Rosatellli [5] discussed an approach to personalization by having designers define didactic activities as well as Personalization Learning Policies (PLP) which define interactions, status, conditions and actions.

Dividing the learning content into atomic units and organizing them using an intelligent recommendation system was discussed by Shen and Shen [6]. This system depends on sequencing rules, rollup rules and using concept trees that makes individualized content recommendation possible. Dynamic sequencing of learning activities is an alternate approach of adaptable learning systems. Sergio, et al., described a solution of selecting and sequencing Web resources to coherent material to address users needs [12]. It is a practical method used by IBM portals to allow users to learn Websphere-related topics. They used topic maps to obtain the instructional sequence. Chilali, Eberrichi and Malki discussed a dynamic composition of courses based on adaptable/customizable templates which can hold the fragments of learning resources [13]. Their approach is restricted to the customization of the PASCAL language.

OntAWare [4] is a semi-automatic question generation system based on a relational database management system. It takes an ontology system specified in OWL, and generates questions related to two relations: class-subclass and class-instance. In [14], when a user makes a new problem by changing the basic problem, the differences between them is tracked. However, it needs users to manually input all the questions.

In [1], the learning styles and test are categorized using ontology to support learning in an adaptive manner. With adaptive rules, the learning style is switched accordingly. An open and collaborative e-Learning system is suitable to address a variety of user requirements. Currently collaborative tools are used to support e-learning and different activities involved in the learning process. They include discussion forums, chat, file sharing, video conferencing, shared whiteboards, e-portfolios, weblogs and wikis. These tools are usually integrated to stand-alone system or LMS like Blackboard, WebCT or Moodle. LORs are now available to allow finding and reusing quality contents (such as LOs) provided by experts [9][10][11]. Also research is being done to provide wrappers that allow different e-Learning systems to talk to each other [7]. However the application of "social software" or "social networks" has not been done for e-Learning.

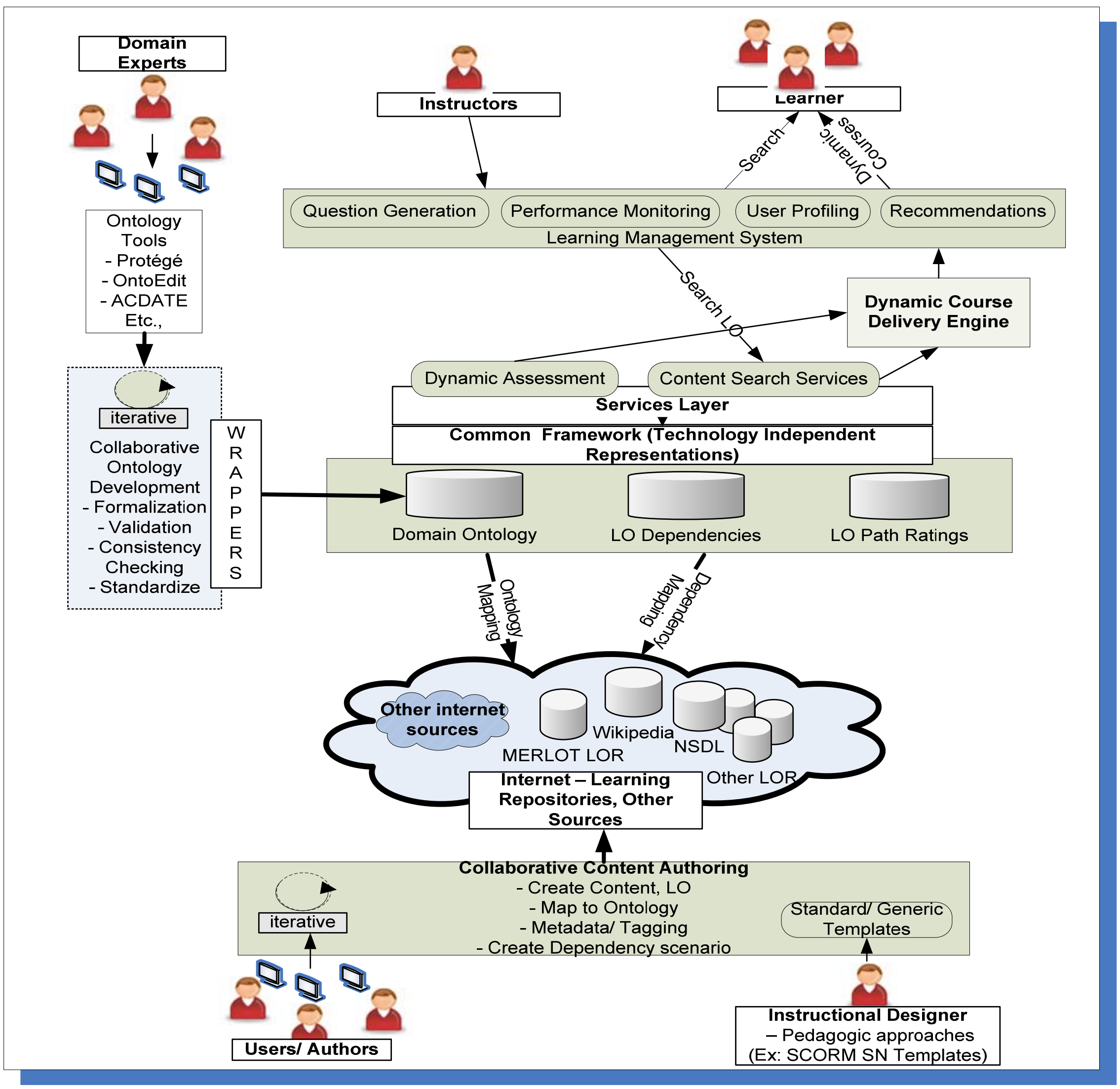

Figure 1: Architecture for Dynamic Web-based Content Delivery System.

3 ACDATER e-Learning System Architecture

E-learning is often a collective effort of instructors creating quality contents and instructional designers delivering the contents as an integrated package according to appropriate pedagogical models. The current systems that support these activities are composed of standard/ proprietary functions/API including content management service, learner profiling services, assessment services, tracking services, and content delivery services. It is difficult to build a conventional e-Learning system, which can be deployed on a large open environment like the Web. This paper proposes a framework to design customizable contents based on ontology and external dependency information for different individuals with different backgrounds and needs. The framework will reduce the effort needed to create customized courses as shown in Figure 1 with the following features:

1. It is open, i.e., it allows people to participate and contribute following the Web 2.0 principle where users can be active contributors.
2. The overall framework can be implemented in a service-oriented manner following Service-Oriented Architecture (SOA).
3. Users can collaborate in generating contents as they are open to public.
4. It allows users to evaluate and rank contributed resources, and such ranking provides valuable guidance to other users. User ranking has been proven to be useful for well-known websites such as Amazon where users provide book reviews and rank re-sellers.
5. Based on ontology systems, the framework can generate questions for automated assessment of user understanding, and such knowledge is useful for user profiling, customization and personalization.
6. The framework allows folksonomies by allowing people to provide metadata or data about data when they contribute contents collaboratively. This often follows a bottom-up organic taxonomy that organizes contents of Web, e.g., the approach taken by www.digg.com. This can be applied to metadata for LOs.

In summary, the framework allows people to contribute contents collaboratively using domain ontology, to upload content, to tag them, and to map them to appropriate concepts. It helps a user to self-analyze her understanding of the subject at any level, and start learning only the required materials dynamically composed by the system.

3.1. ACDATER Knowledge Specification

Ontology specification can be created by describing individuals (instances), classes (concepts), attributes and relationships. A tool is available to specify to contents as Actors, Conditions, Data, Actions, aTtributes, Events, and Relations (ACDATER). The tool has been applied to model system requirements for mission-critical applications, and it can also perform various static and dynamic analyses including simulation. The tool can show information in graphical representations as well as in textual formats. The tool can facilitate teachers to share their knowledge by collaborating on the ontology and students to understand the skeleton and to obtain an overview of knowledge. Even though the relationships among concepts may be different across different domains, several basic relationship patterns can be defined:

- "IS" – the concept definition.
- "Part of" – the theory definition.
- "Is not Part of" – the theory definition.
- C1 is "Subclass of" C2 – for key concepts and categories.
- C1 is "Superclass of" C2 – for key concepts and categories.
- C1 "Compose" C2 – represent that two terms has "whole-part" relation.
- C1 is "ComposedBy" C2 – represent that two terms have "whole-part" relation.
- C1 and C2 are "Synonym" – represent two terms have the same semantics.
- C1 and C2 are "Antonym" – represent two terms have the opposite semantics.
- C1 and C2 are "Disjoint" – occur when no intersection exists between the abstractions represented by two terms.
- C1, C2, …, and C_n "Covering" C_m – occur when the abstraction represented by the union of other given abstractions that are subsumed individually by the term is the same as the abstraction represented by a term.
- C_m is "Covered" by C1, C2, …, and C_n – occur when the abstraction represented by a term is the same as the abstraction represented by the union of other given abstractions that are subsumed individually by the term.
- C1 and C2 are "Overlapping" – occur when an intersection exists between the abstractions represented by two given terms.
- C1 is "Step before" C2 – when one term must occur before another one.
- C1 is "Step After" C2 – when one term must occur after another one.
- C1 is "Result In" C2 – the occurrence of C1 will lead to the occurrence of C2.
- C1 is "ResultOf" C2 –The occurrence of C1 is the result of occurrence of C2.

In these relations, the last four are dynamic, i.e, they are extracted from the theory definition in the ACDATER model and can be used in the question generation phase.

A set of axioms is available to define relationships. Based on them, the completeness and consistency checking on ontology can be performed. After the knowledge is specified, the ontology can be verified to see if there are any inconsistencies. The following are the axioms:

1. The axiom for relationship definition
   a. $\exists x$: inst-of(x, A) $\wedge$ inst-of(x, B) $\leftrightarrow \neg$ Disjoint (A, B)
   b. $\exists x$: inst-of(x, A) $\wedge \neg$inst-of(x, B) $\leftrightarrow \neg$ Subclass-of (A, B)
   c. $\forall x$: inst-of(x, A) $\wedge$ $\neg$inst-of(x, B) $\leftrightarrow \neg$ Overlapping(A, B)
   d. $\exists x$: inst-of(x, A) $\wedge$ inst-of(x, B) $\leftrightarrow$ Overlapping(A, B)
   e. $\forall x$: inst-of(x, A) $\wedge$ inst-of(x, B) $\leftrightarrow \neg$ Synonym(A, B)

2. The axiom for relationships among relationships
   a. SubclassOf (A, B) ➔ ¬ Disjoint (A, B)
   b. Disjoint(A, B) ➔ ¬ SubclassOf (A, B)
   c. Disjoint (A, B) ➔ ¬ Overlapping(A, B)
   d. Antonym (A, B) ➔ ¬ Disjoint (A, B)
   e. SubclassOf (A, B) ⇔ SuperclassOf (B, A)
   f. Synonym (A, B) ⇔ SubclassOf (A, B) ∩ SuperclassOf(A, B)
   g. StepBefore (A, B) ⇔ StepAfter (B, A)

3.2. Learning Objects and Metadata Creation

Locating and composing LOs depend on the standard metadata proposed by standards organizations such as IEEE LOM and Dublin Core. The author or content creator can upload the content as well as assign metadata for a particular LO through an interface, this allows mapping of LOs with concepts in ACDATER ontology.

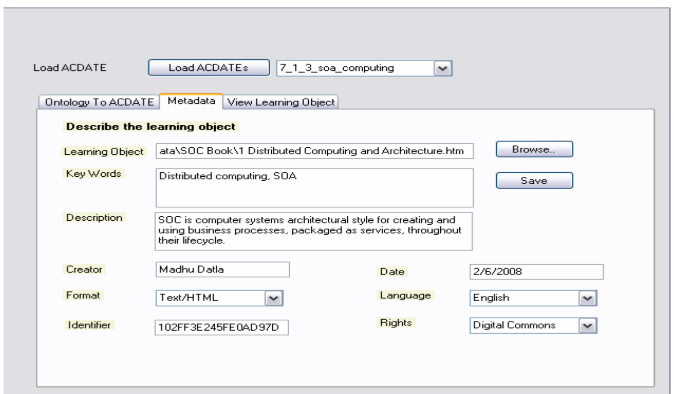

Figure 2: Mapping LO, ACDATER Actors, Metadata

3.3. LO ACDATER Dependency Specification

To understand a given concept, often it is necessary to understand prerequisite concepts, and thus concepts have dependency relationship. In most subjects such as computer science and biology, multiple dependencies across several concepts, and it is important for instructors to specify the dependency relationships so that they can be tracked among LOs. The dependency information is essential in creating personalized learning modules. The ACDATER tool provides an easy way to incorporate dependencies for LOs using the existing Actors, Conditions, and Data specified for creating domain ontology. The following conditions were specified to represent different requirements for understanding a particular concept:

[ACTOR]_LO_CRITICAL
[ACTOR]_LO_REQUIRED
[ACTOR]_LO_OPTIONAL

The following diagram shows how the LO representation in the system looks like after adding metadata layer and ACDATER specification.

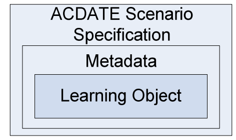

Figure 3: LO with scenario specification

Scenario specification for LOs in ACDATER has the following advantages:

1. The learning objective for each specific LO can be clearly defined.
2. List of environments, courses, learner scenarios for each LO can be easily specified.
3. Allows reusing and accessing by others easily.
4. This allows high precision recommendations for learners. Hence the material is not tied to usage specified by the learning/ instructional designer.
5. It allows determining any level of usage for different users.

This basically enables the individual LOs to interact in an environment with other LOs. The technique described in the next section will allow dynamic composition of the LOs and allows the learner to meet their educational objectives.

Scenario 1: Understanding "Garbage Collection" concept depends on concepts of class objects, constructors and destructors.

using ACTOR:3_3_Constructor_Destructor
using ACTOR:6_1_4_Class_and_object_csh
using ACTOR:6_1_6_base_classes_constructor
using ACTOR:6_1_7_constructor_desc_garbage_coll
if(CONDITION:3_3_Constructor_Destructor.3_3_Constructor_Destructor_required &&
CONDITION:6_1_4_Class_and_object_csh.6_1_4_Class_and_object_csh_critical &&
CONDITION:6_1_6_base_classes_constructor.6_1_6_base_classes_constructor_required)
then{}
else{}

Scenario 1 can be represented by the following figure:

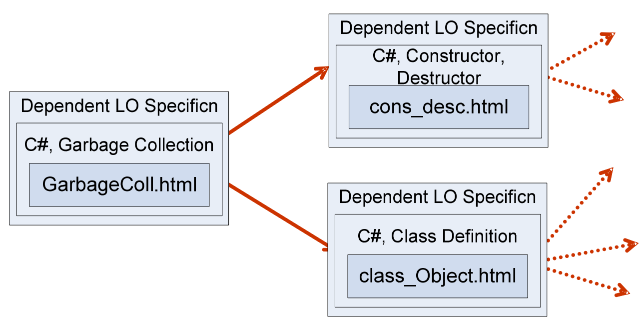

Figure 4: Dependencies between LO's

3.4. Incorporating Assessment and Dynamic courses

The system allows two ways of creating dynamic, customized courses.

1. Based on user provided search terms.
2. Based on dynamic assessment questions.

Method 1:
If the user needs to learn a certain concept, she can query the system based on her requirements. The relevant LOs are retrieved based on the keyword search of metadata or LO descriptions. Since each LO is associated with an ACDATER dependency specification, all the dependencies are analyzed. Once the LO dependencies are available, the algorithm specified in the next section shows a method to determine the learning path dynamically.

Method 2:
For each concept, the questions database is pre-populated with all the relevant and reviewed questions. Depending on the current user assessment requirements, and her expertise levels, the questions and answers can be gathered and analyzed by the system. From the relationship patterns, knowledge specifications the ACDATER concept names that the user failed to understand can be retrieved. The dependency graph can then be generated from the above set of Actors/Concepts.

3.5. Question Generation Process

From the above defined knowledge and relationship patterns, the assessments can be dynamically generated by defining the following question patterns:

With introducing of process logic specification, the sequential information embedded in theory is enhanced. It is manipulated for question generation. Linear Temporal Logic (LTL) is use to formalize the extracted sequential information. Two kinds of LTL expression are available: general LTL and conditional LTL. Since all LTL is used to express temporal relationships existing in a specific theory, only conditional LTL are used in theory specifications.

The questions generated base on sequential information can be categorized into two types:

1. Temporal order. According to process logic specification, a set of Linear Temporal Logic (LTL) rules will be generated. This kind of questions is focusing on the sequential order of the occurrence of steps/phenomenon.
2. Temporal disjoint. When there is an action A existing on the path when condition C is satisfied, while action B existing on the path when condition C is not satisfied, A and B cannot occur at the same time.

Figure 5 shows the sample generated question set. From the template-based question generation, one knowledge point will have multiple questions associates with it. The system will assign the exclusive relations between them during the question generation process.

Table 1 Question Templates

Question Pattern	**Relationship**
Simple Answer Question Templates:	
What is XXX?	*"IS"*
Please give out the completed XXX.	*"Part of"*
Which of the following does not belong to XXX?	*"Part of"*
Single/Multiple Choice Question Templates: *Which of the following statement is(are) true?*	
xxx is a part of XXX	*"Part of"*
xxx is not a part of XXX	*"Not a Part of"*
xxx is a kind of XXX	*"Subclass of"*
xxx is not a kind of XXX	*"Disjoint", "Antonym"*
xxx has attribute of XXX	*"Subclass of", "Synonym"*
Every xxx is XXX	*"Subclass of", "Synonym"*
Not all instance of xxx belongs to XXX	*"Overlapping", "Disjoint", "Antonym"*
Every xxx is not XXX	*"Disjoint", "Antonym"*
There exists instance that belongs to both xxx and XXX.	*"Subclass of", "Superclass of", "Overlapping", "Synonym"*
True/False Question Templates	
Is xxx a part of XXX?	*"Part of"*
Does xxx have attribute of XXX?	*"Subclass of", "Synonym"*
Does there exist an instance that belongs to both xxx and XXX?.	*"Superclass of", "Overlapping", "Subclass of", "Synonym"*
Does statement xxx belong to XXX theory?	*"Part of"*

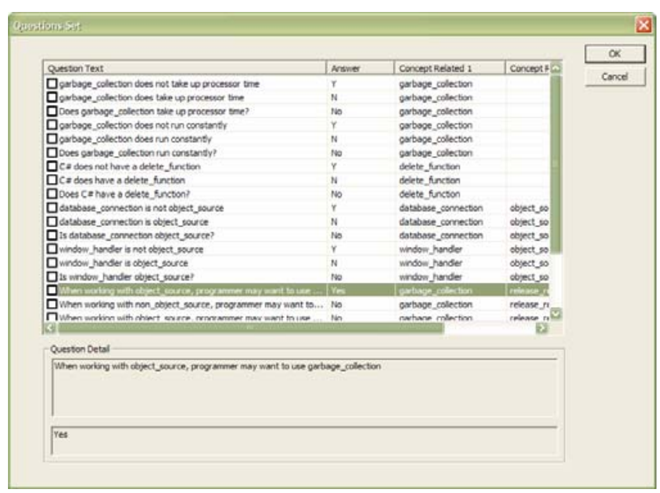

Figure 5: Automatically Generated Question Set

3.6. Customized Content Generation

The graph created from the ontology and dependency specifications is represented by multi-valued edges <e,d>. Graph traversal algorithms such as Floyd-Warshall can be used to obtain all the possible paths of traversal. A new metric called "Learning Path Relevance" can be used to determine the relevance of the dynamic content created.

$$\boldsymbol{LPR_i: Relevance = N/ D_i} \qquad (1)$$

Where:
W_c – Weight of critical dependency
W_r – Weight of required dependency
W_o – Weight of optional dependency
The total distance is calculated as follows:
D_i : Distance = $p(W_c)+q(W_r)+r(W_o)$
Number of edges N = p+q+r

Weights are assigned to each dependency edge. Figure 6 shows the dependency graph of several LOs:

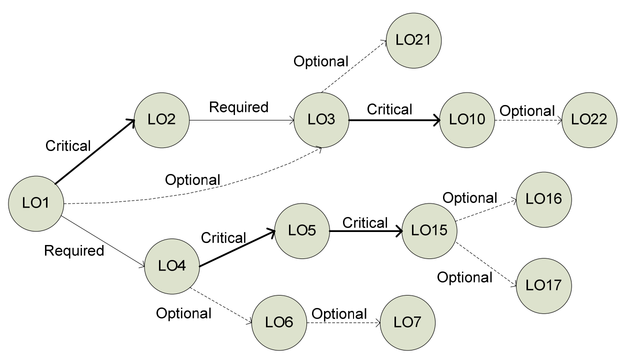

Figure 6: System generated dependency graph

Table 2 Multiple Learning Paths:

Path1	LO1-LO2-LO3-LO10	3/(10+2(5)) = 0.15
Path 2	LO1-LO2-LO3-LO21	3/(5+10+20) = 0.085

From Table 2, it is clear that Path 1 more relevant than Path 2

3.7. Generating Plug-n-Play Content

SCORM 2004 [2] defines the sequencing information that describes how learning contents may be sequenced. The SCORM standards does not allow a LO explicitly link to another. Hence sequencing and navigation plays an important role in controlling the environment for users. SCORM sequencing defines how a content package will be delivered, and defines the sequence of the content presented to the user. Each SCORM entity (SCO) cannot interact with other SCO. This is controlled by LMS API's. Hence SCORM defines this functionality through sequencing. SCORM conformant content can be sequenced in different ways according to the didactic approaches that the instructor thinks would be an beneficial way of sequencing. ADL has published Multiple Sequencing with API Content Example (MCSE) that pre-defines some of the strategy packages (none, LINEAR, ASSESSMENT, KNOWLEDGE_PACED etc).

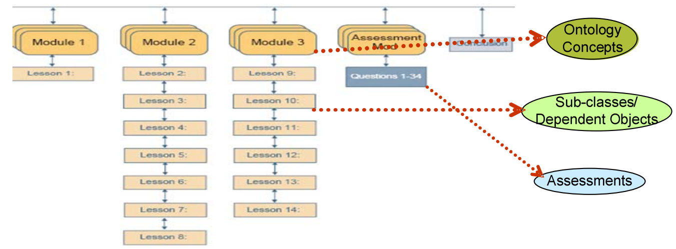

Figure 7: Standard SCORM SN Templates

The XML manifests and SCORM packages are dynamically system generated depending on the user requirements. The user can then download the package which can be imported to any compliant LO and can start learning.

Query:
Garbage Collection (search specific to computer science ontology)

Actual LO:
3.3 Memory management and garbage collection.htm

LO Dependent On(related LO)**:**
2.4.1arrays.htm
2.4.2pointers.htm
2.5.4linkedlist.htm
2.5.5stacks.htm

Table 3 Query Results Sample

Relevant Results	
Pointers➔ Garbage Collection	0.2
Linked List ➔ Dynamic Memory Allocation ➔ Garbage Collection	0.1
Linked List ➔ Dynamic Memory Allocation ➔ Garbage Collection	0.1
Other Results (optional)	
Arrays ➔ Garbage Collection	0.05
Basic Data types ➔ Garbage Collection	0.1

3.8. Comparison

MIT Open Course Ware (OCW) provides free course materials used at MIT, where the user can get lecture notes, problem sets, and labs on a wide variety of subjects. However the OCW follows information retrieval (IR) techniques for retrieving the results. Their approach is different from the proposed framework, and the differences are highlighted in Table 4.

Table 4 Comparing OCW Model with ACDATE Model

MIT-OCW model	ACDATE Model
Content retrieval based on IR techniques, metadata	Content retrieval and sequencing based on dependencies, metadata.
Pre-authored courses, materials used in the classes	Dynamically built courses from independent objects.
High-quality course materials	Community supported materials
Learners can use faculty support and feedback.	Users can pose open questions and are answered by peers and other experts.
Semi-open model for learning	Open-standards for e-learning.
Availability of a course depends on the offering or course material availability.	As soon as the LO is created by the user, and is peer review and the process is complete, it is available to any.

4 Conclusion

The Web has become an important medium for learning. This paper presents a framework that allows various users including content providers, instructors, and students to use and contribute education contents in a collaborative manner using ontology, dependency, and automated assessment. The framework follows the Web 2.0 principles where users can be active contributors. By using dependency information, even a student can configure a course module to learn specific concepts needed and all the prerequisite concepts will be automatically collected and packaged into the module. To ensure the student learns the material properly, the system can also generate questions based on collected concepts to evaluate the knowledge understanding. This approach has been experimented on computer science topics as well as biology topics.

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