A Semantic Web Framework for Generating Collaborative E-learning Environments

M.Cubric[1], V.Tripathi[2]

[1] University of Hertfordshire, Hatfield, UK
[2] Infomatics Corp., Clifton, NJ, USA

Abstract—**In this paper we present a semantic web framework that can be used to generate web-based, e-learning and e-assessment environments for any given knowledge domain. We accomplish this by generating "learning ontologies" for a given knowledge domain. The generated learning ontologies are built upon our previous work on domain "Glossary" ontology and augmented with additional conceptual relations from the WordNet 3.0 lexical database, using Text2Onto, an open source ontology extraction tool. The main novelty of this work is in "on the fly" generation of e-assessments based on the underlying ontology and pre-defined question templates that are founded on the Bloom's taxonomy of educational objectives. The main deployment scenario for the framework is a web-service providing collaborative e-learning and knowledge management capabilities to various learning communities.**

Index Terms—**collaborative e-learning, e-assessment, learning ontologies, web services**

I. INTRODUCTION

One of the main priorities in the UK Government e-learning strategy [1] is to provide students with personalized on-line learning space and content that includes e-assessment. The creation and maintenance of the e-learning content can be helped by the use of Web 2.0 tools [2] that leverage on "collective intelligence" as a means of knowledge construction and management. Those tools are not only promoting the collaborative model of learning [3, 4] but also enabling "rapid e-learning design and development", which is, according to the E-learning Guild Survey [5] the most important future activity in the e-learning domain.

While the research in e-learning has been mainly focused on description [6] and standardization [7] of reusable e-learning resources very little research has been done in the area of "rapid e-learning design and development" and in particular, automated e-assessment generation.

E-assessment in a form of "objective tests", such as MCQs, has been extensively studied and evaluated [8]. While it is generally recognized that the "objective tests" need to be complemented by other assessment strategies in order to assess higher cognitive domains, they nonetheless can provide a "seed" for further assessment enhancements as well as a trigger for continuous learning conversation [4]. Furthermore, they can assist in directly addressing the most important students' needs such as, prompt and frequent feedback, as expressed in the UK National Students Survey [9].

However, creating a useful objective test is not only difficult but also very time-consuming, which prevents its more wide-spread adoption and use [10].

The purpose of this paper is to present a framework for dynamic and rapid creation of e-learning content including assessment, that will provide personalized/or collaborative e-learning and knowledge management capabilities to a learner/or learning community respectively.

The framework is based on Semantic Web ideas [11] and centred on a concept of a "learning ontology", which we define to be any domain ontology augmented with the domain assessment corpus. Furthermore, the framework includes e-learning services that support continuous process of knowledge construction (Figure 1) as for example defined in Kolb's "learning cycle" [12]:

- Creation of a learning ontology (including e-assessment) based on a given text corpus ("active conceptualization");
- Visual and textual exploration of the generated knowledge domain ("active experimentation") ;
- Self-assessment ("concrete experience") ;
- Analysis of assessment results and further extensions of the domain ontology ("reflective observation").

In addition to the above, a user's learning behavior can be quantified and fed back into the system for further enhancement of the knowledge domain model and personalization of learning tasks [13].

Related work in the area of ontologies and semantic web tools for learning and teaching has mainly been focused on development of domain ontologies [14], development of ontologies of learning resources [6,15], personalization techniques [13], and adaptation of reusable e-learning activities in the context of "educational semantic web" [13].
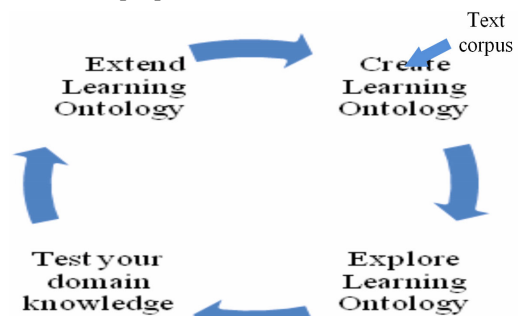

Figure 1.   E-learning cycle

Our work differs from each of the above mentioned in that it is based on dynamic generation of reusable learning ontology (including e-assessment) for a given knowledge domain. In addition to that, we provide an application built on top of the ontology that can be used as a cognitive support tool.

Regarding the research in the e-assessment area, there are very few publication on automated MCQ generation and they are mainly based on parsing and natural language processing (NLP) techniques for generating questions directly from the text corpus [16] with the exception of [17] that in addition to NLP techniques uses ontology-based strategies for generating question "distractors".

The approach described in this paper differs from the latter one in that it uses not only the meta-ontology concepts (classes/concepts, relationships/properties and instances/individual), but also pre-defined question templates to generate e-assessment of the underlying domain ontology.

In the subsequent sections we describe the main usage scenarios of the framework as well as its application architecture.

II. USAGE SCENARIOS

The uses of this framework and the entailing e-learning environments can be divided in two categories, namely – personalized e-learning and e-learning communities.

A. Personalized e-learning

The framework is designed to provide individual learners (e.g. students) with personalized online learning space that includes e-assessment capabilities.

In particular, learners using the tool (Figure 2) can "select a domain" (e.g. business studies), "extract a domain" (e.g. generate business learning ontology from a given text corpus), "search a domain" (i.e. perform a textual search of concepts defined in the ontology), visually explore a domain (e.g. through "neighborhood" graphs [18]), and assess their knowledge of a domain at any point in time ("test yourself").

Personalized learning can further be supported by "computer adaptive testing" [19] where each new e-assessment is generated according to the increasing levels of educational competencies [20] and targets are set according to the individual learning patterns and discovery of areas of "troublesome knowledge" [21]. This is made possible by maintaining click graphs, repetitive sub-domain exploration patterns and assessment metrics.

B. Learning communities

The framework can be used for rapid generation of e-learning environment for a specific subject area, by allowing registered users ("learning community") to add to or modify the content of the underlying learning ontology. This is achieved by using the same capabilities provided for individual learners (Figure 2) augmented with the standard infrastructure for multiple user access (i.e. concurrency control, revision control, user management etc) and Web 2.0 features for collaboration and sharing e.g. discussion pages, content tagging, RSS etc.

The framework is equally applicable to educational context as it is to the context of organizational learning, where it can be used as a tool for capturing, maintaining and disseminating organizational knowledge.
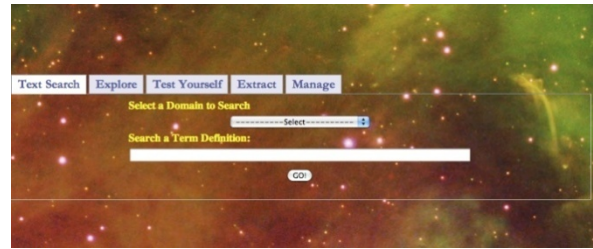

Figure 2. On-line learning environment

III. APPLICATION ARCHITECTURE

The core of the application architecture (Figure 3) is the domain ontology augmented with the IMS-based [22] repository of generated assessment. The overall application architecture consists of seven modules, five of which are new (modules "addGlossary", "genTest", "manage", "extend" and "test" in Figure 3), while the other two (modules "create" and "explore" in Figure 3) are currently using open source implementations [23, 28]. In the subsequent sections, we provide implementation details of the most important modules.

A. Ontology Extraction ("create" module)

The ontology extraction mechanism is a plug-in module, where in future, we could choose between different providers. Current prototype uses Text2Onto [23], an open source framework for ontology extraction.

The underlying semantic lexicon for aiding Text2Onto ontology extraction is WordeNet 3.0 [24]. WordNet provides short, general definitions of the terms, groups them into sets of synonyms called "synsets", and records various semantic relations between the synonym sets such as hypernyms, hyponyms, holonyms, meronyms, troponyms, entailment, coordinate terms, root adjectives, similar-to, related-nouns, participle of verb etc [24].

B. Ontology Population ("addGlossary" module)

Utilizing the "Glossary" ontology introduced in [25] we model a knowledge domain by augmenting the extracted domain ontology with concept definitions provided by WordNet Java API [26] (or any other "Glossary" provider e.g. Wikipedia [27]). The necessary "disambiguation" process, i.e. selecting the context of a specific concept is assisted by user's (manual) interventions (similarly to Wikipedia's disambiguation). New meta-ontology is shown in Figure 4.
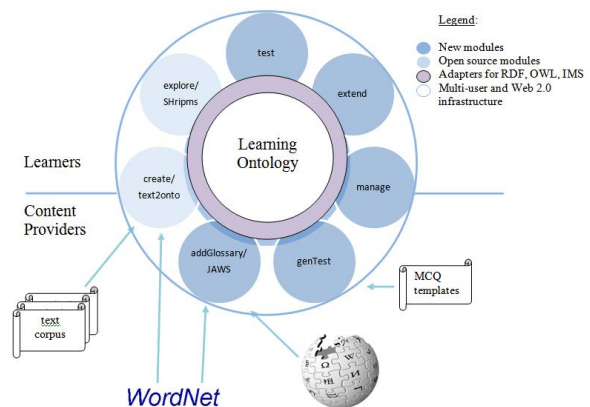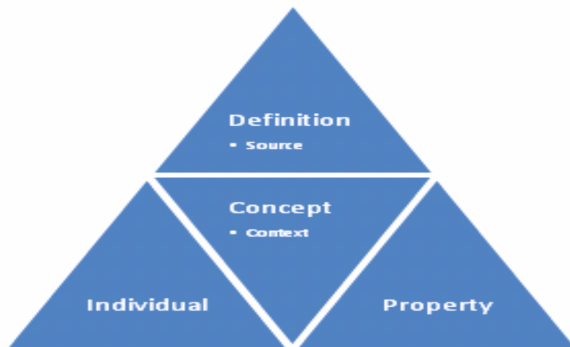

Figure 3. Application architecture

Figure 4.   Meta-ontology

C.   E-assessment Generation ("genTest" module)

The assessment is generated based on the user preferences and question templates provided by the framework that are populated randomly from the domain and saved in the assessment repository for further use.

The framework is using IMS XML-based standard for MCQ format specification [22] and it has been designed to include question templates built upon and corresponding to different levels in Bloom's Taxonomy [20]. Examples of templates testing knowledge, comprehension and application levels of the Bloom taxonomy are shown below, where t, t_1 and t_2 stand for any arbitrary term (concept) from the underlying domain ontology.

- Which one of the following definitions best describes $<t>$?
- Which one of the response pairs is the best match for the relationship between $<t_1>$ and $<t_2>$?
- Which one of the following relations best describes the relation between $< t_1 >$ and $< t_2 >$?
- Which one of the following is an example of $<t>$?
- Which one of the following terms is the best replacement for $<t>$ in the paragraph below?

Similarly to the approach described in [17], to generate "distractors" for the multiple choice questions we use heuristics based on the proximity and relationship between concepts in the underlying ontology graph.

Related to the "testGen" module is the "test" module, that provides standard e-assessment service. A user can interactively attempt any test saved in the repository and get the feedback on the results. The results of the assessment are saved for further analysis and can be used for setting the next level of assessment difficulty [19].

This feature has been designed to be flexible enough to allow future additions and enhancements of the question templates.

D.   Domain Visualization("explore" module)

While designing the framework we have kept in mind the importance of knowledge visualization in educational domain. Therefore, we also provide rendering of a knowledge domain in the form of a interactive and searchable graphical interface. Current prototype uses ShriMP [28] for rendering graphical views of the domain ontology and extends the search mechanism in the graphical interface to let the learner search for concepts and their relations along with definitions in the domain models.

E.   Domain and User Management ("manage" module)

This module lets the users of the framework to add, remove or update knowledge domains. For example, instead of extracting the ontology from the text corpus, user can directly import domain ontology in either RDF or OWL format. The module implements a simple ontology editor interface that allows a user to change the existing domain ontology (module "extend" in Figure 3).

The module also provides standard user management capabilities for the multiple-user environment (user registration, sign in, profile etc).

IV.   CONCLUSIONS

In this paper we have introduced a framework for rapid generation of e-learning environments based on semantically modeled [11] arbitrary knowledge domains. We have described the main usage scenarios of the framework as well as the application architecture.

The chief significance of this framework lies in its readiness in helping e- learners to conceptualize, explore, experiment with, and extend selected knowledge domains, individually or as a community of learners.

The main novelty of this work is in "on the fly" generation of e-assessments based on the underlying domain ontology and pre-defined question templates that are founded on the Bloom's taxonomy of educational objectives [20].

While it can be argued that a mental abstraction of a knowledge domain forms a significant part of the cognitive process, automatically generated knowledge domain models, such as ontologies, can aid the learning journey by providing a "seed" for "active conceptualization" [12] as well as a "trigger" for "learning conversations" [4]. This, together with the use of "collective intelligence" can further increase the quality and speed-up the formation of conceptual maps of the knowledge domain and the supporting e-learning resources, such as e-assessments.

In our future work we will concentrate on extending the prototype of the framework to a fully functional public web-service, as well as on its academic and organizational usage and evaluation. Future enhancements will include extensions of the assessment generator module ("genTest" in Figure 3) and ontology editing module ("extend" in Figure 3) to include more question templates, and collaborative "wiki"-based ontology editing features [29, 30] respectively.

Finally, according to the recent Google Squared Demo at Searchology 09 [31] one of the hardest computing problems today is "looking at the unstructured web and abstracting values and facts and information in a meaningful way in order to present it to users, building out some of these … in an automated way." The main contribution of this work is in bringing together different Semantic Web technologies as well as adding new ones (e.g. e-assessment generator) in an attempt to start addressing the problem of automated generation of e-learning content from the existing web corpus.

REFERENCES

[1]   HEFCE (2005) HEFCE strategy for e-learning, DfES Publications, Department for Education and Skills. Available on-line at: http://www.dfes.gov.uk/publications/e-strategy

[2] O'Reilly Media (2005) What is Web 2.0, Available on-line at: http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html

[3] Vygotsky, L.S. (1978) Mind in Society: The development of higher psychological processes. Cambridge, MA: Harvard University Press

[4] Laurillard D. Rethinking University Teaching: a framework for the effective use of educational technology - 2nd edition. London; RoutledgeFalmer

[5] E-learning Guild Survey (2006) Future Directions in e-Learning. Available on-line at: www.elearningguild.com/pdf/1/apr06-futuredirections.pdf

[6] Stojanovic, L. , Staab, S., and Studer, (2001) Elearning based on the Semantic Web. World Conference on the WWW and Internet (WebNet), Orlando, Florida, USA, 2001.

[7] Learning Technology Standards Committee (2002) Draft Standard for Learning Object Metadata. IEEE Standard 1484.12.1, New York: Institute of Electrical and Electronics Engineers, Available on-line at: http://ltsc.ieee.org/wg12/files/LOM_1484_12_1_v1_Final_Draft.pdf,

[8] CAA Centre Resources, Available on-line at: http://www.caacentre.ac.uk/resources/

[9] UK National Student Survey (2008) Available on-line at: http://www.hefce.ac.uk/learning/nss/data/2008/

[10] Bennett S., Nuthi V. (2008) Towards A Properly Web 2.0 Way Of Creating And Sharing Questions, Proceedings for 12th CAA Conference

[11] Antoniu G. and van Harmelen F. (2004) A Semantic Web Primer. MIT Press

[12] Kolb (1984) Experiential Learning: Experience as the source of learning and development: Prentice Hall

[13] Aroyo L. and Dicheva D. (2004) The new challenges for e-learning : the educational semantic web. Educational Technology & Society, 7(4), 59-69

[14] Protégé ontology library, available on-line at: http://protegewiki.stanford.edu/index.php/Protege_Ontology_Library

[15] Gardner M. (2007) Using Ontologies to Support the Sharing of Learning Resources . Available on-line at: http://istr.wordpress.com/2007/01/18/jisc-paper-delta/

[16] Mitkov R. et al (2006) A computer-aided environment for generating multiple choice test items. Natural Language Engineering, Vol. 12, No. 2, pp. 177-194 (doi:10.1017/S1351324906004177)

[17] Papasalouros A., Kotis K., Kanaris K. (2008) Automatic generation of multiple-choice questions from domain ontologies. IADIS e-Learning 2008 (eL 2008) conference, Amsterdam.

[18] Protégé ontology editor http://protege.stanford.edu

[19] Cooper C. (1995) This Test Is for You. Wired Issue 3.01

[20] Bloom, B. S., and D. R. Krathwohl. (1956) Taxonomy of Educational Objectives: Handbook 1 and Lorin W. Anderson, David R. Krathwohl, Peter W. Airasian, Kathleen A. Cruikshank, Richard E. Mayer, Paul R. Pintrich, James Raths and Merlin C. Wittrock (Eds.) 2001 A Taxonomy for Learning, Teaching, and Assessing — A Revision of Bloom's Taxonomy of Educational Objectives; Addison Wesley Longman, Inc.

[21] Perkins, T.D. (1999) The many faces of constructivism, Educational Leadership, 57 (3).

[22] IMS Global Learning Consortium, "IMS Question & Test Interoperability Specification", http://www.imsglobal.org

[23] Montoyo A, Munoz R., Metais E. (2005) " Text2ONto – A Framework for Ontology Learning and Data-driven Change Discovery" in Proceedings of the 10th International Conference on Applications of Natural Language to Information Systems (NLDB), volume 3513 of Lecture Notes in Computer Science, pp. 227-238. Springer, Alicante, Spain, June 2005

[24] Fellbaum C. (2007) WordNet: An Electronic Lexical Database. MIT Press.

[25] Cubric M. And Tripathi V. (2007) Simple E-learning Semantic Tool, 10th International Protégé Conference, July 15-18, 2007, Budapest, Hungary. Available on-line at: http://protege.stanford.edu/conference/2007/poster-session.html

[26] Java API for WordNet Searching (JAWS) Available on-line at: wordnet.princeton.edu/links

[27] Wikipedia API: Available on-line at: http://wikipedia-lab.org/en/index.php/Wikipedia_API

[28] Storey, M.-A., C. Best, J. Michaud, D. Rayside, M. Litoiu, and M. Musen, (2002) "SHriMP views: an interactive environment for information visualization and navigation," in Proceedings of the International Conference on Human Factors in Computer Systems (CHI 2002), Minneapolis, Minnesota, USA, April 20-25, 2002, pp. 520-521.

[29] WebProtege ontology editor. Available at: http://protegewiki.stanford.edu/index.php/WebProtege

[30] Shuyska J.A, Davies C.(2008) ThinkSpace: the collaborative process of designing new technologies for the classroom, In Proceedings of The 2008 International Symposium on Wikis,

[31] Google Squared Demo at Searchology '09 Available on-line at: http://techpulse360.com/2009/05/13/a-360-view-on-google-squared/

AUTHORS

M. Cubric, is with the University of Hertfordshire, Hatfield, UK (e-mail: m.cubric@ herts.ac.uk).

V. Tripathi., is with the Infomatics Corp.,Clifton, NJ 07012 USA (e-mail: tripathi.vibha@gmail. com).