Volume 2 No. 4, April 2012 ISSN 2223-4985

International Journal of Information and Communication Technology Research

http://www.esjournals.org

Adaptive e- Learning using the Semantic Web: A Comparative Survey

[1]Salah Hammami, [2]Safwan Qassem, [3]Sarab Al Muhaideb

[1,2] Department of Computer Science, King Saud University, Riyadh, Saudi Arabia

[3]Department of Computer and Information Sciences, Prince Sultan University, Riyadh, Saudi Arabia

ABSTRACT

Semantic Web is emerging and maturing as a powerful extension of today's Web. In this environment, both humans and machines (like agents) can exchange data more efficiently. The shared understanding of this environment is based on an ontology backbone, used to model semantics and relations between various concepts. The e-learning domain is one of many domains that can benefit from the Semantic Web advantages. In this document, we survey a number of adaptive e-learning systems and analyze the components and needs of adaptive e-learning systems using the Semantic Web environment.

Keywords: *Adaptive e-learning, Semantic Web, Ontologies.*

1. INTRODUCTION

The reusability problem of learning resources has gained a lot of attention in the last decade. From one side, the cost of adaptive and intelligent e-learning systems and resources is quite high. An increased demands of a low-cost, just-in-time, just-enough and in-work-place e-learning arises in the corporate world, were organizations thrive to increase the competency of their employees in a highly dynamic and volatile market [21]. From the other side, there exist a large amount of quality learning resources that is scattered among heterogeneous distributed e-learning systems and repositories. This amount is in continual growth. However, these resources are not machine understandable and therefore a manual search would most likely result in an overloading amount of inaccurate information.[11] [21]. To increase benefits of these resources, the problem of their organization, indexing and search needs to be solved [26].

The semantic web appears as a promising technology for laying the proper foundations to address the learning resources reusability problem. The vision of Tim Berners-Lee, the father of the Semantic Web, is to create an environment where people and machines can seamlessly communicate and understand each other [1]. Unlike the current version of the Web, that can be considered as a dump text and image repository [16], everything from documents to Web pages, devices and even people in the Semantic Web has a well-defined meaning based on an ontology backbone and a set of inference rules [1]. This structured understandable environment will enable software agents to perform sophisticated tasks for their users. [1] described five layer structure of the Semantic Web: The first layer is a syntax layer. XML (http://www.w3c.org/standards/XML/) stands for eXtensible Markup Language (XML) allows people to structure their documents by defining and adding their own tags. However, nothing in this layer defines the meaning of those tags. Document constraints are defined through the use of XML Schema language (http://www.w3c.org/standards/XML/schema). The data layer partially express the meaning (semantics) using structured metadata files. Information on the Web including terms and concepts is defined by means of a standard for metadata called Resource Description Framework: RDF [27]. RDF statements come in a form of triples: entity-relation-value. For example, we can use RDF to explain that "QuickSort" "isTypeOf" "Sort Algorithms". RDF is machine understandable. XML is used for RDF syntax while Universal Resource Identifiers: URI (http://www.w3.org/Addressing/) is used for identifying each of its three components. The semantics of data can now be defined in a standardized and interoperable form. Yet, these semantics are still underspecified. For instance, they do not allow the description of properties on properties, which are necessary and sufficient conditions to express class membership, or equivalence and disjointness of classes [16]. Thus a more structured mechanism is needed.

The ontology layer complements the data layer knowledge representation. Ontologies model a conceptualization of a certain domain. Distributed and heterogeneous information resources can be formally described by means of ontologies [11]. There are many forms of ontologies; they share a taxonomy of domain-specific concepts (classes) featuring a set of properties and relations to other concepts [1] [11]. An ontology language for the Semantic Web is the Web Ontology Language (OWL) (http://www.w3.org/standards/techs/owl#w3c_all). OWL allows subclasses of the taxonomy to inherit properties and relations of their ancestor classes. Next is the Logic Layer that consists of a set of inference rules that act on the ontology. These rules are used to deduce actions or answer questions. For example, these rules are used to introduce learning material with a definition role before that of an exercise role [1] [26]. Some authors consider rules as part of the ontology [1]. Finally, the Proof Layer is used to provide "proofs", for example in the form of digital signatures, to show that the attached information is obtained from a trusted source.

For e-learning resources to be reusable in a personalized manner there is a need of a structured way of organizing, storing and indexing of these resources. Models need to be constructed not only for the domain knowledge, but also to describe the learner and possibly other entities like the pedagogical strategy. In addition, the search and retrieval must be customized automatically to learner's context and preferences. There must be a methodology to dynamically create custom-tailored learning paths covering just what the learner needs and in his/her preferred style. Finally, there is a need for a fast and convenient way of annotating the learning resources and building the ontologies.

In the next section, we present an overview of the research work relevant to using the Semantic Web technology for solving the learning resource reusability problem from various perspectives. Next, we discuss these solutions and conclude the document.

2. LITRATURE REVIEW

Very early [44] [45] [46], Semantic Web technology has appeared as an important tool to solve many problems faced by the e-learning community, starting from the representation of the learner's knowledge areas, the assessment of knowledge levels to the knowledge domain representation in order to develop an efficient association between the learner's needs and the adequate learning resources [4].

Representation of the global corpus of domain knowledge has been performed using different types of Domain Ontologies. A powerful and comprehensive Domain Ontology has been presented in [10]. [15] presents a similar Domain Ontology with specific characteristics tailored to fit the openness, modularity and adaptability required by enterprise applications. [21] proposes a method to select and combine several learning resources to fit a specific learner's needs. The structure ontology is combined with the Domain ontology to represent the learning objects relationships like inclusion, pre-requisites and references. [14] demonstrates the use the semantic difference notion to determine if two learning objects can be targeted in parallel.

Learning resources have been represented as part of the domain ontology as in [18]. IEEE Private and Public Information for learners (PAPI learner) has been used by several authors [4] [10] [7] to represent the learner's profile including his portfolio and preferences. Recent works [4] [17] [25] model the learner's profile as a sub-graph of the domain ontology. This enables an easier relationship establishment between the learners acquired competencies and the competences to be targeted.

The availability of a large number of learning resources, raise the issue of association of learning material to specific learners needs and profiles. Personalized search service has been introduced to help the learner find adapted learning materials.

[7] presents a service-based architecture for a distributed learning environments based on Semantic Web technologies to add the personalization capability to open, dynamic, learning networks. Several web-services use the learners profile to customize the learner's queries, or to generate recommendations in accordance with his request and needs or generate links to other related resources.

[11] describes an architecture for educational knowledge service system using semantic web technologies to help the learner search and find the learning resources, courses, or complete learning paths that suit his needs. The user interface allows the learner to refine his queries using ontology annotation service. The search results are also classifies using the learner's profile.

IEEE-Learning Object Model [28] has been adopted by several authors [8], [12], [29], [30] to facilitate the search, evaluation, acquisition, and use of learning objects, for instance by learners or instructors or automated software processes [31]. [30] proposes ontology-based metadata to describe the learning materials and thus provide flexible and personalized search and access to these materials. A user can search for a learning material using a semantic query based on a three dimensional search space (content, context, structure) that is defined by the ontology.

[22] uses ontology-based strategy to focus web crawlers search for learning objects. The user selection of the desired learning material is facilitated by ontology visualization and various ontology views achieved by clustering.

[25] describes an e-learning search system for retrieving personalized semantically enriched learning resources. It ranks the search results according to their mapping with user profiles represented as ontologies and the user context particularly by re-ranking them based on the learner's past activities.

Preparing learning material to be searchable by the different search methods requires introduction of sufficient annotations to allow for a semantic classification.

In [6] proposes a methodology to reuse learning material in adaptive learning systems. Authors and/or instructors annotate the content of the learning material using editing tools. Annotations are based on a pedagogical ontology and a domain vocabulary. Once annotated, the learning resources are exploited by Semantic Web technologies.

The huge number of potentially available learning objects requires the automation of the annotation process. [31] proposes a methodology to automatically annotates learning material by identifying terms in a pre-defined set of domain vocabulary in every learning object. These methods are mainly based on text keywords and their application is limited to textual learning material.

[26] presents an approach for automatically building Learning Knowledge Objects through a reverse engineering process of existing textual learning resources, using text mining, natural language processing, and semantic annotation leading to an ontology-based organizational memory who serves to store, maintain, and reuse various types of learning objects. The presented tools had the inconvenient of producing a very important number of association rules, with very few conceptual relationships.

To avoid this inconvenient, [32] developed a tool for Semi-automated Ontology building that uses automatic concepts acquiring from large-scale document collections and uses traditional knowledge acquisition approaches to refine and organize the machine-generated concepts through human interventions. [5] present a general strategy based on establishing the pre-requisite relation through student tests and then applying fuzzy clustering.

To remove the manual intervention in the ontology building process, many researches work is geared towards developing techniques for fully automatic ontology generation covering all ontology building steps. [33] presents a survey

Volume 2 No. 4, April 2012 ISSN 2223-4985

International Journal of Information and Communication Technology Research

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with a comparative analysis of experiences for automatic ontology generation, investigating in detail which aspects of ontology development have been done automatically.
The domain of automatic ontology generation is still evolving and requires further research.

Concerning the learning activity sequencing has been discussed by standardization bodies such as IMS Global Consortium [36] and ADL [37]. IMS proposed IMS Simple Sequencing specification (IMS-SS) [38] in which the structure of learning activities is defined using a concept called an Activity Tree. The activity tree represents the branching or flow of instruction through content according to the outcomes of a learner's interactions with content. The SCORM SN specification [39] was derived from the IMS-SS specification with the objective of simplifying the model and allowing for more sophisticated sequencing possibilities.

[8] developed an approach to define learning paths by dynamic assembling learning objects based on the learner’s preferences and context. In this approach the learning content is pre-processed to create small learning objects, with sufficient meta-data, that can be recomposed into a coherent and logically sequenced learning path customized for the individual. The resulting assembled paths can be archived and shared with other learners.

[34] proposed a technique to define sequences of learning activities using hierarchical graphs. Sequences of learning units are built according to the tutor’s knowledge and the user’s previous activities using the system.

[35] used the concept of ontology and activity to build an approach of learning activity sequencing. He implemented an algorithm to realize activity sequencing and dynamically updating learner ontology.

3. COMPATIVE SURVEY

Works presented above are only a part of all studied experiences; nevertheless they represent a significant sample covering the different concepts used to define an adaptive e-learning systems based on web semantics and essential steps in the automatic ontology generation process. We now provide a comparative analysis of the different research works previously presented according to the following aspects: Resource Representation, Personalized Search, Automatic Ontology Building and Resource Annotation, Curriculum Sequencing.

Various types of learning resources are currently available on the web with the increasing of e-learning usage. There are various names of pedagogical resource. e.g. learning object, learning material, teaching material, and instructional object. Therefore, learning resources representation appears to be fundamental to good quality of adaptive e-learning system. Different research work shared the same standard model, but with different way to represent the different resources of the e-learning system.
Table 1 summarizes the resource modeling in the different presented research works:

Table 1: Resource Modeling: A Comparison

	Domain Ontology		Learner Ontology					
	Representation	**Standard**	**Sub graph of Domain Ontology**	**Evidence-based Competency**	**Standard**	**Instructional Role Ontology**	**Structural Ontology**	**Instructional Goal / Level**
[4]	Documents, objects, classes, attachments and their relations	IEEE LOM	Yes	Yes	IEEE PAPI	Part of domain ontology	Part of domain ontology	Beginner/ intermediate and advanced
[7]	Domain concepts and their relations + learning resources	Dublin Core and Dublin Core Metadata	No	Yes	IEEE PAPI and IMS LIP	Part of domain ontology	Part of domain ontology	—
[8]	IBM products and their relationships	IEEE LOM, IMS CP and W3C RDF	—	—	—	Part of domain ontology	Inferred	Overview/ in-depth
[10]	Various (hierarchical) classes and their relations	IMS or IEEE LOM	No	Yes	IEEE PAPI	Yes	Part of domain ontology	—

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	Domain Ontology		Learner Ontology			Instructional Role Ontology	Structural Ontology	Instructional Goal / Level
	Representation	Standard	Sub graph of Domain Ontology	Evidence-based Competency	Standard			
[18]	Learning concepts, course, chapter, chapter, learning resource and goal	IEEE LOM or Dublin Core	No	Tests	Extension of AEH User Model [3]	None	Part of domain ontology	—
[14]	Not specified	Not specified	Yes	Tests	Extension of AEH User Model [3]	Not specified	Not specified	—
[17]	Math domain concepts and relations	IEEE LOM and Dublin Core	Yes	Not specified	No	Yes	Yes	Blooms Taxonomy
[25]	Colleges, courses, lectures and associated relations	Not specified	Yes	Not specified	Not specified	No	No	—
[21]	Domain concepts and corresponding relations	RDF	—	—	—	Yes	Yes	—
[15]	Domain concepts and their relations. Graph leafs are learning resources.	Not specified	—	—	FOAF extension	None	Part of domain ontology	—

Accurately identifying the material that fits learners needs is one of the most challenging problems in the e-learning as this requires intelligent methods for representing the learning material, the learner's profile and the learning context.

Many research works adopted coupling semantic domain ontology with learning resources and the variety of learning contexts to enhance the retrieval results on a real e-learning platform. Some other authors implemented the personalized search as web-services on top of the domain and learner ontologies. Table 2 gives an overview of the different techniques used to implement the personalized search.

Table 2: Personalized Search Solutions: A Comparison

	Implemented as Web services	Material	Reference learner ontology/profile	Visualization	Accesses distributed learning repositories
[4]	No	Not specified	Yes	No	No
[7]	Yes	Not specified	Yes	Yes	Yes
[11]	Yes	Not specified	Yes	Yes	No
[12]	No	Not specified	Yes	No	No
[17]	Yes	Math	Yes	No	No
[22]	Yes	Text only	No	Yes	Yes
[25]	No	Text only	Yes	No	No

With the continuously increasing number of available learning material and learning domains, building domain and learner ontologies and manually annotating the available learning material to allow for their automatic selection and reuse, appear to be a heavy time consuming activity.

Researchers have focusing on semi-automatic and full-automatic automatic ontology building and learning material annotation. Five steps have defined by the literature as the major steps in the ontology building: Extraction, Analysis, Generation, Validation and Evolution. [40] presents a complete framework that classifies software and techniques for building ontologies. Table 3 below presents some techniques used in building e-learning system.

Table 3: Automatic Ontology Building Techniques: A Comparison

	Technique	Focus	Text Based	Manual Intervention
[5]	Student tests, concept correlation and fuzzy clustering	Conceptual relations	No	No
[26]	Text mining and pattern matching	Conceptual and hierarchical relations	Yes	Yes

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[31]	Keywords and pattern matching	Conceptual and hierarchical relations	Yes	Yes

E-learning systems proved to be very efficient in allowing the reuse of learning material and the search for the suitable resource in big repositories of learning material. In the case of synchronous learning, at every step, the learners may be presented with different alternatives to achieve an intermediary learning objective. Course sequencing in compulsory, synchronous learning has been dealt with efficiently in traditional and e-learning environments. However, in the case of asynchronous learning, the learner faces the problem of selecting,` among the huge number of possibilities, the appropriate learning resource that can help him use his existing skills to acquire new knowledge inline with his general learning goal.

The learning sequencing is concerned with presenting the learner with the optimal learning resources that will help him gradually reach the pursued learning outcomes. Early research work [42], simply represented topics as dependency graph, with links representing the relationship between topics, which include prerequisite, co-requisite, related, and remedial.

Later Ontologies have been used to represent the learner profile, the knowledge domain to identify the path that the learner needs to follow reach his goal and the instructional role a learning resource can play in the learning process [43]. [41] combines the use of an ontology to represent abstract views of content sequencing and course materials with semantic web rules to represent semantic relationships between individual knowledge materials and build the content sequencing.

4. CONCLUSION

Time limitation, information overload, lack of accuracy and cost are the main obstacles facing the e-learning community. There is an urgent need for a mechanism to structure the huge amount of valuable e-learning resources and make it readily accessible and reusable in a personalized manner. This access should be assisted for the various types and levels of the e-learning community, whether they belong to academic programs, professional training, lifelong learners or others. The Semantic Web is a powerful promising technology with a potential to improve the e-learning quality, interoperability, flexibility and personalization all at a reduced cost. The Semantic Web will view the virtually endless amount of information and resources on the Web as a huge database. The ability of both people and machines to effectively communicate on a semantic basis relies on a structured ontology and a set of inference rules. The World Wide Web Consortium (http://www.w3c.org) has already laid down the foundations of the Syntax and Data layers of the Semantic Web through defining their standards. A lot of research has been done and is still ongoing to address the other layers.

The emphasis on e-learning standards is important for interoperability reasons. Ontologies form the link of resources to learners. The e-learning community needs to establish a standard (or a set of standards) for the domain, learner, instructional role and pedagogical ontologies. The various models presented in literature share a lot of similarities. There has to be a common vocabulary used as well. For example, the three terms *isPrerequisiteFor*, *prerequisiteFor* and *IsRequiredBy* all refer to the same conceptual relation. Services like searching and curriculum sequencing are based on the ontology layer and should be implemented in the Rule and Application Layers of the Semantic Web. Competencies need to be certified by evidence (for example by an exam), issued by a trusted authority. This may be linked to the Proof Layer.

Based on these standard ontologies, search services may be implemented as independent Web services. Each institution may then use its own instructional task ontology and set of inference rules to personalize the learning experience according to its vision, context and needs.

Also, most of the research addresses text-based learning resources. Text-based learning resources constitute a large percentage of the learning resources in general. However, other intelligent and rich e-learning resources need to be considered as well.

Visual annotation tools play an important role in facilitating and standardizing the learning resource annotation process. More research needs to be done for facilitating the integration of existing e-learning resources into the Semantic Web environment.

Finally, optimization techniques maybe considered for e-learning in the semantic Web, particularly for curriculum sequencing and recommendation purposes.

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