An Ontology-Based Learning Resources Management Framework for Exploratory E-learning

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Abstract

This paper presents an ontology-based conceptual framework for effectively managing exploratory e-learning resources. The proposed framework has five significant novel features including authentication of retrieved resources, automatic ontology-based query refinement, reuse-oriented management of retrieved resources, adaptive retrieval of learning resources based on the style and preference of individual learners, and synthesis of retrieval and management activities for creating reusable learning repositories. The applicability of the framework is demonstrated using a sample fragment of an ontology developed in the database domain.

Keywords: E-learning, Ontology, Exploratory E-learning, Learning Object Repository

1. Introduction

An ontology is a “formal and explicit specification of a shared conceptualization” (Gruber, 1995). In a simple term, an ontology is a representation of an existing knowledge in a taxonomical structure with semantic relationships between the concepts. Ontologies have been recognised to be effective in learning by exploring in an explorative e-learning context. Learning by exploring is “an approach to instruction through which students interacts with their environment by exploring and manipulating objects, wrestling with questions and controversies, or performing experiments” (Ormrod, 1995). This discovery-based approach to learning is popular due to its potential benefits to both teachers and learners (Piaget, 1980; Papert, 1990). To quote Papert (1990), “you can't teach people everything they need to know. The best you can do is position them where they can find what they need to know when they need to know it”.

Exploratory learning is where learners construct their own knowledge through exploring and discovering learning resources through their own initiatives. Learning resources, often referred to as learning objects, are information represented and stored in a variety of media and formats for facilitating the knowledge acquisition process of individual learners. Exploratory learning resources refer to digital learning objects that can be found and reused through information retrieval mechanisms. In this exploratory learning scenario, learners take control of their learning for acquiring knowledge through multiple channels. In such an interactive explorative learning process, searching for relevant and multidimensional learning resources becomes most critical (Sridharan et al., 2008).

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This search process forms an intrinsic aspect of exploratory learning for enhancing the meta-cognitive skill of individual learners. For instance, learners through exploration can reflect their learning, assess their state of knowledge, accumulate and refine their knowledge. Such a process enables learners to strengthen their foundation while becoming more knowledgeable. The inconsistencies in understanding fundamental theories and concepts can be corrected. To effectively adopt exploratory e-learning, applying effective information retrieval mechanisms and subsequently adequately managing the retrieved learning resources are vital (Wang et al., 2007; Dicheva, 2008).

Two challenges are present for sustainable e-learning through information search and retrieval in exploring alternative learning resources. The first is the availability of the sheer volume of resources without considering their relevancy, quality and context-specificity (Al-Khalifa and Davis, 2006; Berri et al., 2006; Bhogal et al., 2007). The second is the effective management of identified resources for their reuse (Dicheva and Dichev, 2006).

The volume of resources available for e-learning has been being a critical issue for sustainable e-learning. Learners often spend considerable time and effort in an unproductive manner to search for quality and relevant information. In this situation, disseminating context specific, quality and relevant learning resources to learners is even much greater a challenge in exploratory e-learning (Biletskiy et al., 2004). To effectively address this challenge, applying the knowledge management principle for organizing the learning resources is essential as e-learning is knowledge intensive.

To effectively manage the sheer volume of resources, there have been notable developments in information retrieval for supporting learners and teachers (Farrell et al., 2004; Dichev and Dicheva, 2006). These developments range from conventional general-purpose search engines (Li et al., 2002) to multi-engine search systems (Sugiura and Etzioni, 2000). These developments can enhance the coverage of searching and improve the precision of retrieval. These developments, however, do not completely solve the problem of information overload with respect to the relevancy, quality and context specificity of the retrieved results. For example, existing mechanisms such as Google return results in the form of links. To effectively explore the usability and relevancy of the content through these links, learners still need to open the link, which may in turn contain nested links. This process takes patience, time and much effort for identifying the required resources.

Tremendous efforts are taken for improving coverage and precision (Sugiura and Etzioni, 2000), context specificity (Al-Khalifa and Davis, 2006; Berri et al., 2006; Bhogal et al., 2007) quality (Miller et al., 2001; Stojanovic, 2005), and management (Dicheva, 2008; Keleberda et al., 2006; Tane et al., 2004; Wang et al., 2007) of retrieved resources. Representative developments include multi-engine search (Sugiura and Etzioni, 2000), metadata tagging (Nejdl, 2002; Brase and Nejdl, 2003), ontologies and semantic web technologies (Maedche et al., 2002; Staab, 2004; Richards and Hatala, 2005), query refinement (Berri et al., 2006; Lee et al., 2008), personalization (Keleberda et al., 2006) and management (Studer et al., 2001; Horrocks and Hendler, 2002) of retrieved results. These mechanisms, however, do not adequately address the adaptability, reusability and more importantly the validity of the retrieved resources in explorative e-learning. Developing an integrated framework for supporting all these features is therefore essential.

This paper presents an ontology-based conceptual framework for effectively managing exploratory learning resources. The proposed framework through semantically enriched quality resources not only provides learners with context-specific and validated resources but also caters to the differences in learning styles and preferences of individual learners through automatic query refinement and management of retrieved resources using ontologies. Furthermore, this framework synthesises retrieval and management activities for creating a quality learning object repository along with associated ontologies.
In what follows, Section 2 presents a review of relevant literature, followed by the research questions in Section 3. Section 4 presents an analysis of the requirements for the proposed framework. Finally Section 5 presents an ontology-based framework for effectively authenticating, adapting and reusing retrieved resources in explorative e-learning.

2. Related research

A learner-centred environment in e-learning “integrates technologies for enabling opportunities for activities and interaction in both asynchronous and real-time modes in campus-based delivery and distance education” (Volery and Lord, 2000). Developing such an environment for sustainable e-learning is supported by the pedagogical theory, in particular Papert’s constructionist theories (Papert, 1990). In the constructivist model of learning, the knowledge building process becomes a “cycle of internalization of what is outside, then externalization of what is inside” (Papert, 1990). In contrast to the traditional teacher-centred learning, the constructivist model revolves around the learner’s initiative in the knowledge construction process. Accordingly, adopting such a model is pertinent as this conforms to the e-learning philosophy of self-centred and self-guided learning.

Following the philosophy of student-centred learning, actively exploring learning resources for uncovering inconsistencies in understanding is essential in knowledge acquisition (Dalgarno, 2001). This leads to the use of reflective learning for helping learners refine their understanding and reinterpret the previously accumulated knowledge (Or-Bach, 2005). As a result, explorative learning becomes one of the most popular strategies for enhancing knowledge discovery and acquisition in e-learning (Sridharan et al., 2008).

Effective search and retrieval mechanisms are the key drivers for successfully exploring alternative learning resources. Usually there are numerous retrieved results with little or no value to learners due to the superfluity and lack of relevancy of the resources. To overcome this problem, effective filtering mechanisms are required for ensuring the relevancy, context specificity and authenticity of the learning resources. Furthermore, these filtered results should be effectively organised for their reuse. Such an effective representation of resources is critical for keeping the learners’ interest alive in knowledge exploration. In this regard, appropriately applying the principles and technologies of knowledge management can enhance the access to the quality learning resources (Holsapple and Joshi, 2002).

Knowledge management is a systematic process of acquiring, eliciting, organizing, representing and retrieving information and knowledge (Duffy, 2001). Effectively managing learning resources requires a well understanding of the relationship between data, knowledge and information because learning is a progression from data to information and then to knowledge (Dawson, 2000). The relationship between data, information and knowledge is a continuum with grey areas overlapping between them (Song et al., 2003; Teo and Gay, 2006). In e-learning, the difference between knowledge and information is relative. Mental models are transferred to learners through dialogue, discussions and lectures as information. Knowledge is context specific, dynamic and relational (Nonaka, et al., 2000). Information becomes knowledge in a given context when cognition takes place.

Semantic web technologies have great potential for tackling the problem of information overload through effectively managing explorative learning resources. The semantic web is an extension of the World Wide Web with advanced features enabling not only the presentation of information on the web but also the manipulation and understanding of the content by humans and computers (Berners-Lee et al., 2006). Adopting this technology in e-learning is essential because online learning resources are increasing at an astronomical rate. The use of the semantic technology allows the computer to process and filter resources for their intelligent discovery, extraction, integration, and reuse (McIlraith et al., 2001), while learners
devote their time in productive knowledge accumulation. To make this technology a reality, structuring and standardizing learning resources are essential.

Two key components for structuring and standardizing learning resources are metadata and ontologies (Brase and Nejdl, 2003; Haase, 2004). Metadata is “any data which conveys knowledge about an item without requiring examination of the item itself” (Haase, 2004). It is popular due to its capacity in facilitating efficient management, discovery and retrieval of information. Metadata contains structured information about information. The creation of metadata with the formal description of the content, context and structure of learning resources (Marshall, et al., 2003) is fundamental to the semantic web technology.

In e-learning, learning object metadata (LOM) (Brase and Nejdl, 2003) is used to facilitate the standardisation of learning resources. A learning object is a chunk of learning materials regardless of whether it is a small piece or whole content. LOM provides a set of standard elements for describing learning objects in order to enable sharing and reusing of learning resources and to facilitate fast access to relevant learning resources. A semantic description of learning objects through metadata descriptions supports the interoperability and reusability of learning resources (Malcolm, 2005).

An ontology is a “formal and explicit specification of a shared conceptualization” (Gruber, 1995). It is a conceptualization of a domain into a human-understandable and a machine-readable format consisting of entities, attributes, relationships and constraints (Fensel, 2002). Ontologies enable reusing and sharing critical knowledge through creating semantic relationships between various learning objects. They facilitate the provision of consistent vocabulary representation within a specific knowledge domain (Berners-Lee et al., 2006).

Effective retrieval of learning resources is imperative for successful explorative e-learning. There are several information retrieval frameworks with multiple viewpoints ranging from simple to multi-search engines, use of metadata, ontologies and semantic metadata for improving and personalising the search results, and ontology-based retrieval techniques for effectively retrieving learning resources. Since the inception of the Internet in the early 1990s, information retrieval systems have evolved from simple keyword matching, such as world wide worm (Li et al., 2002) to techniques such as personalization of search engines (Fan et al., 2000) and user’s query mining to improve the precision of search. Numerous retrieval tools have been developed for filtering the exponentially growing information online. The traditional search engine is improved to become multi-engine search services (Sugiura and Etzioni, 2000). These multi-engine search services combine the search results from various search engines so that the search results can be organised with respect to designed objectives in a consistent format.

A major limitation of existing searching engines is the loss of true context of the search, leading to low precision of the searching result due to the ignorance of the relevance, specificity and context of the query. To overcome this limitation, Al-Khalifa et al. (2006) and Haase (2004) propose using metadata to enable efficient retrieval. With the use of metadata, learning resources are represented in terms of content, format, and related elements for facilitating their retrieval, leading to their standardised representations. To ensure a universal acceptance of standardisation for learning objects, various metadata standards have been developed including the Dublin Core, IEEE LOM, the IMS learning resource meta-data, the shareable content object reference model, and Cancore.

Dublin Core (Nejdl, 2002; Brase and Nejdl, 2003) is one of the most well-known standards containing 13 elements such as title, creator, data, publisher, subject etc, for supporting information retrieval. Dublin Core, however, does not help much when one looks for a context specific learning environment due to availability of little information about the subject. Furthermore, Dublin Core does not include the relevance ranking of the retrieved sources. In e-learning, IEEE-LOM standard (Duval, 2006) is widely accepted due to the
flexibility of the standard in terms of extending and adding new data elements. The IEEE-LOM standard has 80 fields arranged in a taxonomical structure with categories such as educational, general, annotation and so on (Duval, 2006).

Existing standards have improved the precision of search through effective retrieval, share and reuse of learning resources (Al-Khalifa et al., 2006; Haase 2004). These standards based on existing retrieval techniques with term-based metadata search, however, are confined to a simple structure, often leading to unsatisfactory results (Richards and Hatala, 2005). Addressing this concern, a concerted effort is directed for improving the search precision through exploiting the potential of ontologies. Specific endeavours in this direction include refinement of user’s query (Muller et al., 2004; Stojanovic, 2005; Lee et al., 2008), provision of personalised results (Keleberda et al., 2006; Mittal et al., 2006), and management of retrieved resources (Studer et al., 2001; Horrocks and Hendler, 2002).

Recognising the power of query modification, Lee et al. (2008) suggest an automatic ontology-based query expansion algorithm for semantic-awareness learning object retrieval. With regard to domain specific research, Stojanovic (2005) and Muller et al. (2004, 2008) describe an ontology-based approach for query refinement and information extraction in a library scenario for improving the precision of retrieval. Identifying the importance of context-specific search, Bhogal et al. (2007) describe the use of context through relevancy feedbacks and knowledge models while Chiang et al. (2001) propose exploring domain semantics for query refinement. However, authentication and validation, which are critical from the perspective of novice learners, are not given due consideration in these studies. To address this issue, an authentication mechanism is included in the proposed framework. The proposed mechanism for query refinement to capture the semantic relationship between concepts is integrated in this framework through metadata and domain specific ontologies.

Appreciating the importance of providing personalized search results, Mittal et al. (2006) present a personalized delivery of learning materials using a domain ontology and pedagogical models based on the learner’s query. Keleberda et al. (2006) suggest an approach by building learners’ ontologies for facilitating personalized search. Makris (2007) proposes adapting the search results based on the requirement of users by categorizing search results. Lee et al. (2008) resort to user’s feedback through an ontology-based query expansion algorithm for achieving personalized retrieval. Extending these approaches, this paper proposes merging specific ontologies to represent type and style of resources for helping individual learners to choose the learning object to suit their individual learning styles and preferences.

Equally important in sustainable e-learning is the effective management of retrieved learning resources for reuse. In this direction, Tane et al. (2004) propose an ontology-based tool suite for effective organization and retrieval of learning resources. Farrel et al. (2004) describe a dynamic assembly of learning resources for fulfilling focused learning needs by sequencing and linking resources in an organized manner. Dicheva and Dichev (2006) recommend an ontology-driven repository based on topic map for managing all information, while Stojanovic et al. (2001) and Huang et al. (2006) suggest an ontology-based semantic web technology for enhancing the management of learning resources. Jovanovic et al. (2006) suggest including annotation apart from ontologies, LOM and semantic metadata. To facilitate access to heterogeneous learning sources, Keleberda et al. (2006) recommend using ontologies for describing learning resources, while Wang et al. (2007) propose using ontologies and topic map for effectively managing learning repositories. The proposed framework extends the developments in these studies above for facilitating effective management of retrieved learning resources and associated metadata ontologies.

The studies above reveal a significant improvement in information retrieval. The support for adaptability and reusability, however, has received only limited attention in exploratory
learning (Tane et al., 2004; Craven et al., 2000; Yang, 2008). Furthermore, the development in information retrieval embedding authentication features is far from satisfactory. Embracing all these features in one framework is critical for sustainable e-learning. To fill this void in the literature, this paper develops an ontology-based framework for effectively managing exploratory e-learning resources.

3. Research questions

The rapid advance in information and communication technologies has made exploratory e-learning a great success with easy and fast access to learning resources (Tane et al., 2004; Craven et al., 2000; Yang, 2008). These technological developments, however, have proven to be a double-edged sword. On one hand, the developments facilitate a swift access to knowledge and information at any time from anywhere. On the other hand, these developments have augmented the problem of information overload and stalled the timely access to relevant, authentic, context-specific information (Haase, 2004; Al-Khalifa and Davis, 2006).

This phenomenon is attributed to the vast information available online. As a result, individual learners often find themselves overloaded with redundant information. Continuous updating of web pages and the freedom to upload “anything by anyone” add to this problem. As a result, the creation and distribution of knowledge online on such a phenomenal basis have effectively trapped the learner's ability to digest the superabundance of information and knowledge (May, 2003). This is particularly true in explorative e-learning. As a consequence, both researchers and practitioners have been working tirelessly in investigating ways for retrieving relevant and quality information on a timely basis.

One important problem from the technological revolution in e-learning is the optimal use of advanced technology for developing an efficient learning environment. In this regard, several issues warrant further investigation including (a) replication and redundancies of knowledge due to information superfluity, (b) lack of transparency and authenticity in online knowledge, (c) lack of consideration to learning styles and preferences of learners, and (d) lack of reuse of valuable knowledge obtained through experience and learning. It is obvious that developing an ontology-based conceptual framework for facilitating the effective knowledge capture, reuse and distribution within learning communities is highly desirable.

Against this background, the main research question in this study is: How does one develop a comprehensive ontology-based framework for effectively authenticating, adapting and reusing exploratory learning resources? Specifically, several subsidiary questions can be formulated: (a) What are the existing ontology-based factors for facilitating effective knowledge acquisition in exploratory e-learning? (b) What are the associated ontology-based tools and techniques in managing knowledge, in particular its acquisition, evaluation, and dissemination? And (c) what can be done to improve existing standards in providing validated quality resources to learners?

To answer these questions, this research presents a conceptual framework for supporting explorative e-learning through discovering context-specific and quality resources. The contributions of the framework towards sustainable e-learning are five folds. First, the framework proposes a mechanism for embedding authentication for preventing learners from developing misconceptions in enhancing explorative learning. Second, the framework includes automatic ontology-based refinement of query for improving the retrieval result. Third, the framework integrates all management activities for reusing retrieved results in explorative e-learning. Fourth, this framework incorporates an adaptive retrieval and storage system for catering to the differences in learning styles and preferences. Fifth, this framework
synthesises retrieval and management activities as a continuous cyclic process for creating a quality learning object repository along with associated ontologies.

4. An ontology requirement analysis with a motivating scenario

Existing approaches in information retrieval rely on metadata and selected ontologies for enhancing the quality and relevancy of the retrieval process. In this way the retrieved result often contains resources irrespective of its authenticity and adaptability in exploratory learning. In this situation, learners have to go into the identified link to explore the suitability of the content in a given context. As a result, learners may end up with broken or unsuitable or unauthentic learning objects. They are often required to go into each link to filter the results for validity, availability, adaptability and relevancy. Furthermore, locating the valuable resources through this filtering process is of limited use, unless a concerted effort is taken to manage these resources in a reusable repository for avoiding reinventing wheels by the next learner. The proposed framework extends the use of ontologies and metadata not only for retrieval, but also for authentication, adaptability and reusability, which are critical for effectively managing learning resources.

To fulfil this objective, the framework proposes to use three types of ontologies namely metadata ontology, domain ontology, and validation ontology. The metadata ontology includes details like creator, course, keyword, annotation and others following IEEE LOM standards. Following Stojanovic’s (2001) classification, the domain ontology is further classified into content, context and structure ontologies. The content ontology is specific to the given domain to include synonyms, abbreviations, similar concepts and others. It is general to any domain but specific to the learning object which can be type (e.g. pdf, ppt, word, audio, video, image), duration (for audio and video objects), level, other characteristics (such as FAQ, definition, problems and solutions, demo, etc). The structure ontology is specific to the domain including prerequisite, part-of, co-requisite, follow-up and others. The validation ontology includes details such as validated list of authors, validated list of sources, context of the resource, rating, validity status etc.

A typical scenario is described in the following. A learner is in the process of learning a complex topic on a higher order data model (HERM). To fulfil this objective the learner sends a query to a search engine with the keywords such as “HERM”, “ERD”. Using an existing retrieval mechanism, the learner would be rendered hundreds of links. In the proposed approach, the learner is rendered limited but much focussed relevant resources.

To arrive at such a result, employing four types of ontology are critical. First, the structure ontology, the content ontology and the metadata ontology look after the query refinement. The structure ontology includes all the keywords relating to prerequisite and co-requisite, part-of and necessary concepts into the query. The content ontology helps embrace multiple terms for the same concept with different names, abbreviations and other relevant elements. The metadata ontology incorporates additional details such as keyword, author, date etc. Second, a validation ontology checks for authenticity of learning resources using elements such as the author, source and other relevant validation elements. Third, the built-in context ontology is exploited to display the level, context, type of resources for accommodating the difference in learning styles and preferences. Finally, the annotation element from the metadata ontology is used to exhibit a short summary of learning resources, facilitating the learners to assess the suitability of the learning resource before exploring further. Figure 1 represents these ontologies as superclasses, subclasses and their relationships.

In the example above, a small subset of ontology is developed using Protégé OWL as shown in Figure 2. OWL constructs representing classes, relationships, properties and restrictions associated with HERM for the structural ontology are developed for
demonstration. Each class embodies subsumption hierarchies. For example, the super-class HERM subsumes all concepts associated with relationships. Multiple inheritances are represented with entities as a concept of ERD under HERM. The disjoint axiom is used to prohibit overlapping of members between these classes. Object properties representing relationships within and between classes are included for specifying the relationships. To enrich the semantics of these properties, property characteristics such as transitivity are included. For instance, “HERM” has-concept “attributes” which in turn has concepts “simple and nested attributes”. This ensures that the relationship is automatically inferred because “HERM” has concepts “simple and nested attributes”. Existential quantifier restrictions are used to ensure that every concept in the class HERM must have at least one LO and each LO must have at least one LOM. To infer more information, OWL reasoners are used for checking the consistency, subsumption, equivalence and instantiation of the constructs.

Figure 1. Representation of content, context, structure, validation and metadata ontology.

It can be observed in this scenario that (a) elements in content and metadata ontologies are useful in extending the query based on the ontological structure, (b) elements in the validation ontology help refine and authenticate resources, (c) elements in the context ontology facilitate representing resources for showing their suitability for individual learners, and (d) elements in the metadata ontology help learners choose appropriate learning objects for further
exploration based on the summary of content and other details. The existing approach fulfills some segments of (a) and (c) of the requirements above. The proposed framework accomplishes all the four requirements above as explained in the following section.

![Figure 2. A snapshot of ontologies using Protégé OWL.](image)

5. A conceptual framework

This section presents a conceptual framework capable of incorporating authenticity, adaptability and reusability features for effectively managing exploratory e-learning resources. The framework as shown in Figure 3 encompasses four crucial components. The knowledge management component includes various knowledge management activities required for providing e-learners with alternative learning resources. The ontology component includes a range of instrumental elements such as LOM, annotation and creation of semantic meta-data ontology structure for enhancing knowledge management activities. The authentication component validates the resources based on the inference rule and the authentication profile. The learning component includes facilities for accessing resources through navigational or query-by search and provision of resources with characteristics representing the resources.
In this framework, the search query in the learner component is gathered either through the keyword-based path or the navigational path. It is extended for the context specificity through ontologies based on semantic metadata. This refined query is processed through the information retrieval system. The learning objects returned from the search are further checked for authenticity before being provided to the learner. The returned result contains not only the link but also the annotation, relevancy rating to the query, level of the resource and type of resource and relationship. This additional information will enable learners to choose appropriate learning objects for further investigation without wasting time in exploring the learning resources.

The ontology component has domain specific ontologies and upper ontologies. Domain specific ontologies for a specific course are created based on the semantic relationship between the concepts such as part-of, pre-requisite, is-a, co-requisite and so on. This facilitates a refinement of the query, including all the subordinate concepts that a learner is required to learn for getting a strong foundation in a learning object. In combination with the upper ontology this would help in the query process as the elements of LOM such as annotation, keywords, subject area and others will enable access to better quality learning resources. Furthermore some of these elements will be rendered through a drop-down menu for choosing appropriate learning resources for dissemination.

The ontology layer, on top of the metadata layer, will provide extension to the query vocabularies by the links between concepts, which would be unrelated in classical search systems. This facilitates retrieval of context specific relevant learning resources while
effectively addressing the problem of information overload. By adding an authentication layer within the ontology structure, learners can have access not only to relevant learning resources but also be able to authenticate learning resources for building mental models in their learning processes. The authentication layer is kept separately for providing flexibility for domain experts to validate and manage the learning resource.

The authentication component has an authentication profile within an authentication knowledge base. The authentication profile contains various parameters set by the teacher and the domain expert. It can either be generated manually through a simple interface by the domain expert or semi-automatically generated from the learning objects. The confirmation, however, has to come from the domain expert for authentication. The authentication knowledge base represents the authentication rule for validating the learning object and refining the results before rendering it to learners.

The knowledge management component includes activities such as knowledge acquisition, classification and dissemination before storing the resource in the local learning repository. With respect to knowledge acquisition, the authenticated and refined results are processed for creating an ontology structure through capturing LOM, content and terminology with some inputs from the domain expert. Each learning resource is classified based on both the LOM and the ontology structure. In knowledge classification, ontologies play a crucial role for maintaining LOR and the conversion of open resources for their reuse. With regards to knowledge dissemination, the retrieved results are stored locally within the course website for distribution both through “push” or “pull” technology. Learners have access to both a navigational view and an overall view based on the ontology structure. The reusability of learning objects is more effective through this approach in exploratory e-learning.

The elements with respect to the context, content and structure are identified for each learning object based on the relevancy to the course and the general metadata ontology. To improve the reliability of the learning resource, a combination of manual and automated processes is suggested. In addition each learning resource is pruned for storing the relevant section in a given learning context. The conversion of the authenticated material is incorporated wherever possible with original links for giving credit to the creator. The identified, authenticated, and classified resources are then populated to the local learning object repository collection along with all four types of ontologies.

Through the recurrent search-retrieve-authenticate-create process, the local LOR contains a comprehensive coverage of authenticated resources. As a result, the reuse of authenticated resources becomes possible. Learners can use the local search agent to search the local repository rather than wasting time in searching online for validated and relevant materials. Subsequent learners have the benefit of accessing quality resources with short synopsis of the content and the type to choose the learning objects suitable for individual learners. This framework has facilities to enable learners to populate learning resources in a particular context subject to the authorization from the domain expert.

6. Conclusions and future work

This paper develops an ontology-based conceptual framework for effectively managing exploratory e-learning resources. It uses a small section of an ontology-based domain example for demonstrating the applicability of the proposed framework in exploratory e-learning. A pragmatic approach to address the problem of information overload is proposed by limiting the provision of resources with respect to the context-specificity, adaptability, and authenticity of learning resources. Overall, the proposed framework shows its capacity in assisting with creating reusable learning repositories in explorative learning.
This study has several limitations including a lack of empirical evidence for accepting the proposed framework and for supporting the choice of ontology elements for its successful implementation. In addition, identifying a mechanism for automatic uploading of various ontologies is critical for developing sustainable e-learning object repository.

Future research in this area includes the identification of other factors as perceived by learners and teachers in developing ontology-based support for learners in exploratory e-learning. There is a need to incorporate other learning strategies and to enable other context specific relevant resources readily available for learners in knowledge acquisition. By embedding context ontologies and learners’ profile ontologies, the learner can choose the resources based on their individual styles and preferences. It is equally pertinent to identify mechanisms to incorporate automatic updating of learning object repositories in a given domain, checking for outdated links and automatic updating of LOM including annotation and authentication details. Finally, an empirical study identifying the critical ontology elements is important before developing a prototype for the proposed framework.

References


