Jovanović, J., Gašević, D., Knight, C., & Richards, G. (2007). Ontologies for Effective Use of Context in e-Learning Settings. *Educational Technology & Society*, 10 (3), 47-59.

Ontologies for Effective Use of Context in e-Learning Settings

Jelena Jovanović[1], Dragan Gašević[2, 3], Colin Knight[3], and Griff Richards[3]
[1]FON, School of Business Administration, University of Belgrade, Belgrade, Serbia // jeljov@gmail.com
[2]School of Computing and Information System, Athabasca University, Athabasca, Canada // dgasevic@acm.org
[3]School of Interactive arts and Technology, Simon Fraser University, Surrey, BC, Canada // {cjk2, griff}@sfu.ca

ABSTRACT
This paper presents an ontology-based framework aimed at explicit representation of context-specific metadata derived from the actual usage of learning objects and learning designs. The core part of the proposed framework is a learning object context ontology, that leverages a range of other kinds of learning ontologies (e.g., user modeling ontology, domain ontology, and learning design ontology) to capture the information about the real usage of a learning object inside a learning design. We also present some learner-centered and teacher-centered scenarios enabled by the proposed framework in order to illustrate the benefits the framework offers to these key participants of any learning process. Finally, we demonstrate how two present educational tools (i.e. TANGRAM and LOCO-Analyst) correspond to the proposed architecture.

Keywords
Learning objects, Learning context, Learning design, Ontologies, Personalization

Introduction

The recognition of the increased need for reusing learning content led to the adoption of a standard format for describing learning content with metadata, the widely known IEEE Learning Object Metadata Standard - IEEE LOM (WG12: Learning Object Metadata, 2002). The use of its predefined set of metadata fields promotes exchange of learning objects (LOs) among different e-learning systems and content providers, and offers higher potentials for finding existing learning content (i.e. LOs). Even though the IEEE LOM standard was undertaken by the e-learning community to facilitate and foster interoperability and reuse of learning artifacts among different e-learning platforms, decisions about reuse involve a broad set of issues about content, context and pedagogy that cannot be fully expressed in the LOM's metadata fields.

In order to be effective and bring expected learning results, LOs need to be organized in a pedagogically sound manner, according to an instructional plan, or a learning design. A learning design is about identifying necessary learning activities and assigning LOs to those activities in order to achieve the specified learning objective (Koper & Olivier, 2004). The idea of having a uniform method for expressing the design of the learning process began with the Educational Modeling Languages proposed by Koper (2001). This work evolved into the IMS Learning Design (IMS-LD) specification (IMS-LD-IM, 2003) that provides a common set of concepts for representing learning designs, hence enabling the share and reuse of learning designs across learning systems. These two specifications were supposed to enable specification of learning designs (and learning objects) targeted for different learning situations, based on different pedagogical theories, comprising different learning activities where students and teachers can play many roles, and that can be carried out in diverse learning environments.

However, the abovementioned specifications/standards (i.e., IEEE LOM and IMS-LD) do not enable capturing all the information required for advanced learning services, such as personalization or adaptation of content in accordance with the students' objectives, preferences, learning styles, and knowledge levels. The requirements for effective personalization include (but are not limited to) (Cristea, 2005):

1. Direct access to low-granularity content units comprising the structure of a LO;
2. Recognition of the pedagogical role played by each content unit in a specific situation (e.g., in a learning activity);
3. Awareness of the learners' evaluations about usefulness of a specific content unit within a specific learning design;
4. Characteristics of learners that best fit a specific learning design.

Further, if adaptation or personalization is supposed to happen automatically, all of these requirements must be codified in some unambiguous manner. Finally, the learning specifications/standards do not provide space for any kind of teacher-directed feedback about the usefulness and appropriateness of a LO or a learning design for certain learning settings. However, such a feedback is quintessential in online learning environments where the teachers' awareness of the learning process is significantly lower than in traditional classroom settings.

One strategy to address some of these shortcomings is suggested in the Ecological approach (McCalla, 2004). According to this approach, each time a user interacts with a LO, his/her user model is attached to the LO; as the time passes, user models accumulate around each LO stored in a repository. Annotation of a LO (i.e. assignment of metadata) is based on applying various data mining techniques on the data stored in the accumulated user models. However, metadata is generated only when needed and only for the needed purpose. In other words, the purpose determines which metadata will be generated and how – hence McCalla argues for the Pragmatic Web. This approach promises to provide LOs with metadata that are much more valuable for the personalization process than those prescribed by IEEE LOM.

Another strategy has been to encourage the use of concepts from controlled vocabularies, taxonomies, and ontologies as metadata values (Brase & Nejdl, 2004). Ontologies help increase the consistency and interoperability of metadata, however, they face strong barriers to adoption because users prefer using local terminology over familiarizing with ontologies and their structure (which can be rather complex) (Li et al., 2005; Li, 2006).The number of ontologies being developed is growing – domain ontologies covering diverse subject domains, competency ontologies and user model ontologies have already gained a widespread use in technology-enhanced learning. These different kinds of ontologies can be integrated in an ontological framework in order to enable adaptive use of LOs. This paper presents our proposal for such a framework, taking into account the need for contextualized metadata as suggested by McCalla (McCalla, 2004).

The paper first motivates the collection of metadata other than those prescribed by present learning specifications and standards. Next, the paper introduces the notion of the *Learning Object Context* as a kind of LO metadata that captures all the information that characterizes the specific situations (contexts) in which certain LO has been used. This idea is presented both at the conceptual level and at the level of formal representation, i.e., as an ontological framework (called LOCO). Some usage scenarios are also presented in order to illustrate the benefits of the proposed context-based approach. Finally, the paper illustrates two educational tools (TANGRAM (Jovanović et al, 2006a) and LOCO-Analyst (Jovanović et al, 2007)) that we have been developing, and positions them with respect to the proposed ontological framework. The last section concludes the paper and points out directions for future work.

Motivation

In our opinion, the learning specifications, such as IEEE LOM, IMS-LD and SCORM (SCORM, 2006), are of limited use and we are not alone in that belief. For example, Recker and Wiley (2001) have noted that prescriptive metadata in the form of IEEE LOM does not provide enough information to adequately support the learning process (e.g. to enable recommendation of learning content). We share this view and as well as their opinion on the main drawbacks of such metadata:

- Metadata of limited complexity and semantics. Metadata is often stored as simple text, sometimes as terms from a controlled vocabulary and sometimes not. As authors are typically reluctant to provide metadata, the amount of metadata is usually negligent, and either too broad (e.g. determining the target audience using the age range) or too narrow (excessively specific descriptions that are unlikely to anticipate all possible situations of use). Besides, restricting metadata to the values from controlled vocabularies is both a help and a hindrance – help as it enables automatic processing and hindrance since specification of an adequate vocabulary for a metadata element is an extremely complex and never fulfilled task. For example, the IEEE LOM standard defines 'School', 'Higher education', 'Training' and 'Other' as possible values of the Context metadata field. However, this set of values is neither comprehensive enough to cover all possible learning contexts, nor descriptive enough to depict their peculiarities. Or consider the acceptable set of values of the Learning Resource Type metadata element – it is a mix of presentation related (e.g. table, slide) and instruction related (e.g. exam, experiment) terms.
- With prescriptive metadata, it is neither possible to receive feedback from the users to determine the accuracy of the made assumptions about metadata values, nor to suggest new possible contexts of use. Likewise, some metadata values are difficult or even impossible to predict during content authoring, i.e. before the actual use of the learning content. Accordingly, in such situations content users (i.e. learners) are in a far better position to determine the suitability of the learning content for the learning situation at hand.

Even when learning content is substantially annotated (which is often not the case), the user needs to absorb this information, consider the value of the metadata given the context of the publisher of the metadata, and finally make a decision as to which object fits the present circumstances best. In other words, metadata is always influenced by the particularities of the authoring context and the intended use of the learning content – this is something that has to be taken into account when metadata-based query is issued to search for learning content with the ultimate aim of content reuse.

Finally, all of the information in a conventional learning system flows in one direction – towards the learner. We instead argue that the information needs to circulate, i.e. that a communication flow between all tools and actors in a learning environment needs to be established. The key to such a dynamic workflow is being able to represent the context of use of a LO. By associating a LO with a user model, and the observed interactions the user has with the LO, the process of inspecting metadata can be changed from a database lookup into a process of reasoning. This changes both the concept and the target of metadata – instead of being aimed directly at end users, metadata is now aimed at computer programs that can make sense of this data for end users (Jovanović et al, 2006c).

Learning Object Context – Conceptual Model

In the previous section, we have explained why the present learning specifications and standards are not sufficient for providing advanced levels of learning process support (e.g. recommending the content to learn from). If those advanced services are to be provided, then besides prescriptive metadata (e.g., IEEE LOM metadata) one also needs to be aware of the particularities of all the situations in which a LO was used. In other words, one needs to be informed of the *learning object context* – the specific context of use of the LO.

Likewise, context-related data are essential for instructors. When learning content is assembled into larger objects or designs to be presented to learners many assumptions are made about the learners and the learning situation: assumptions about the learners' experiences, skills, and competencies; about their personal preferences, learning styles, goals, and motivations; about the available time, etc. These assumptions are what we refer to as the *context* – the unique situation-related rules that implicitly govern how content should be structured into a flow of interaction for a particular learner.

To overcome the abovementioned shortcomings of learning specifications and enable capturing of context-related data, in our previous work, we developed an ontology-based framework, called LOCO (Learning Object Context Ontologies) (Knight et al, 2006), which consists of:

- *Learning object content structure* ontology – Formally identifies the information objects within a LO with the goal of making each component of the LO directly accessible.
- *Learning design* ontology – We have developed an ontology aimed at formal representation of the basic building blocks of an instructional design. The design of the ontology was inspired by the IMS-LD Information Model (IMS-LD-IM, 2003). However, the ontology is general enough to support any other model of instructional design.
- *Learning object context ontology* – The LOCO-Cite is an ontology originally developed to promote the integration and reuse of LOs and learning designs (Knight et al, 2006). The original conceptual model focused on using a Learning Object Context as a bridge between a LO (or one of its components) and the learning design in which the LO (or its component) was used.

Our subsequent efforts to utilize the elements of context for personalization of the learning process revealed that the LOCO framework needs to be further extended. Hence, we extended it to integrate connections to user modeling and subject domain ontologies as well as user evaluation information and other relevant data. These extensions are described in the next section.

LOCO-Cite Ontology

Aiming to further enhance the proposed formalization of the learning object context, we extended the LOCO framework to make use of a number of other types of ontologies relevant in the e-learning domain (Figure 1a). Specifically, connections with those other relevant ontologies are established via an additional set of properties introduced in the LOCO-Cite ontology. The *LearningObjectContext* class, representing a specific context of use, is maintained as the central item of the ontology. A number of properties were introduced to enable formal description of a LO's context-related (meta)data (Figure 1b).

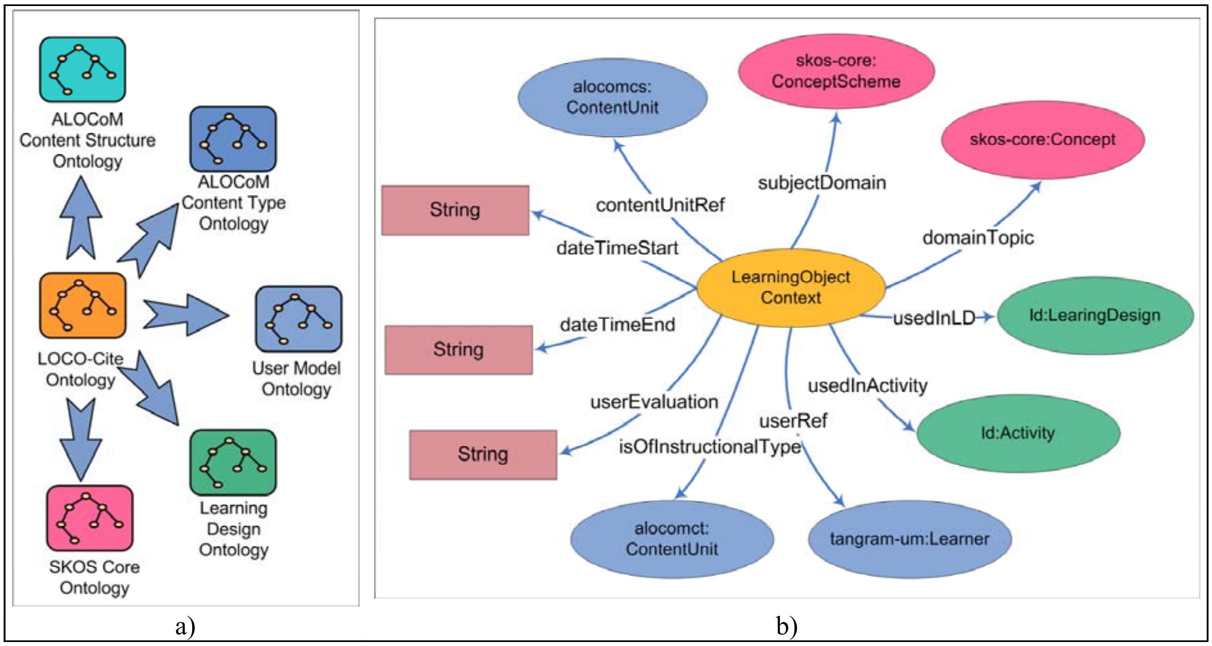

Figure 1. The LOCO-Cite ontology and its relations with other e-Learning ontologies

The *contentUnitRef* property refers to the actual unit of content that the context is about. The range of this property is the *alocomcs:ContentUnit* class, an abstract class defined in the ALOCoM Content Structure Ontology to formally represent a content unit of any granularity level (Jovanović et al, 2006b). Therefore, even though we refer to the context of a LO, the ontology design enables for a more generic approach – it provides a common formalism for representing context-relevant metadata for content units of diverse levels of granularity.

The *subjectDomain* and *domainTopic* properties are aimed at representing the subject domain and the domain topic, respectively, that best describe the context of use of a specific LO. Specifically, the two properties link learning object context with an appropriate domain ontology and its concept(s) represented in accordance with the W3C's SKOS Core Specification (http://www.w3.org/2004/02/skos/core/). The SKOS Core ontology is aimed at formal representation of concept schemes (e.g. taxonomies, thesauri, controlled vocabularies) (Miles & Brickley, 2005) and contains an excellent variety of classes (e.g. *concept scheme, concept*) and properties (e.g. *broader, narrower, prefLabel*) that can be used to describe topics of a LO and their relationships.

The *usedInLD* property points to the instance of the *ld:LearningDesign* class as a formalization of the actual learning design the LO was used in. Here we assume that a repository of learning designs, represented in compliance with the ontology of learning design exists and is accessible. If such a repository does not exist, but an elementary set of data about the design of the unit of learning that the LO was used in is available (e.g. general pedagogical model it is based on, learning objective both general and domain-specific, targeted learners), an instance of the *ld:LearningDesign* class would be created and stored with the learning object context.

The *usedInActivity* property is actually a reference to the learning activity (*ld:Activity*) the LO was used within. The underlying assumption for this property (as for the previous one) is the existence of an ontology-based repository of learning designs that facilitates direct access to any activity of any learning design stored in it. Alternatively, an instance of the *ld:Activity* class needs to be created out of the available activity-related data and stored with the learning object context.

The *isOfInstructionalType* property relates the learning object context with the instructional/pedagogical role the LO assumed in the learning activity it was used in. The range of this property is *alocomct:ContentUnit*, the top level class of the ALOCoM Content Type ontology developed to formally represent different instructional types a content unit might have (Jovanović et al, 2006b).

The *userRef* property refers to the user model of the learner who actually used the learning object in that specific learning context. We suggest the usage of the user model ontology developed in the scope of the TANGRAM project (Jovanović et al, 2006a). Even though the ontology enables formal representation of relevant information about all participants in the learning process (content authors, teachers and learners), it is mostly focused on the representation of the learners' features. The ontology defines formalisms for representing the learners' basic personal data, their preferences regarding language, domain topics and content authors, their performance, as well as different dimensions of their learning styles. A detailed description of the ontology is given in (Jovanović et al, 2006a).

The *dateTimeStart* and *dateTimeEnd* properties store data about the date and the time when the learner started and finished working with the LO. Hence, the time period the learner spent dwelling on the LO can be deduced.

The *userEvaluation* property reports on the usefulness of the LO in the given context as perceived by its users. Even though, this kind of user feedback is often neglected, we consider it highly important to capture the users' opinion about a LO with respect to different evaluation categories, such as clearness, usefulness, and pro collaborative nature. Each category is modeled as a subclass of the *UserEvaluation* class, hence the inclusion of a new (different) evaluation category is made as easy as extending this class with a new subclass. Course players should provide support for this kind of feedback.

The Framework in Use

The proposed ontological framework is beneficial both for teacher-centric and learner-centric tools and systems. In this section we present some usage scenarios in order to illustrate the advantages of the suggested approach, whereas in the next section we give an overview of two applications based on the LOCO framework.

Learner-centric scenarios

Figure 2 illustrates the basic architecture of an adaptive educational system leveraging the capabilities of the presented ontologies for discovery, reuse and adaptation of LOs. The architecture comprises a repository of LOs and its accompanying repository of learning object context (LOC) data. The repository of LOCs stores learning objects' context-related data in accordance with the LOCO-Cite ontology. The idea is that each object from the LO repository has its context data in the repository of LOCs. Being aware of the fact that right after being uploaded to the repository, a LO can not have any context-related data (as it has not been used yet), we introduce the notion of 'artificial' LOCs in order to alleviate the 'cold-start' problem (well known in recommender systems (Recker et al, 2001)). Since LOs are often designed for a specific purpose (i.e., intended use), their (prescriptive) metadata can be collected to seed the "artificial" LOCs. As the time passes and the LO is used in different courses (i.e. learning designs), its context data become available in the repository of LOCs.

During the learning process, the repository of LOCs can be searched for LOC instances that 'match' the requirements of the current learning situation (e.g., prerequisites, learning objectives, and available amount of time). These requirements can be expressed as a query using an ontology query language (e.g. RDQL (Seaborne, 2004)). Such a query should use the concepts/instances from relevant ontologies and/or taxonomies whenever it is possible, since their usage enables an advanced matching process. For example, if no LOC instance can be found that 'has' the required learning activity, an instance with a 'similar' activity can be used instead. The notion of similarity here is rooted in the ontologies used and semantic relations among their concepts. In our example, the similarity can be inferred from a taxonomy (or an ontology) of learning activities (as the one suggested in (Conole et al, 2005)) and the search query can be extended to encompass other kinds of activities that are semantically close to the desired one. Accordingly, a course/lesson delivery system working on top of the aforementioned repositories is able to provide a learner with the best suited LOs for every learning activity specified in the learning design of the course/lesson (i.e. course/lesson plan) (s)he is taking. To put it differently, we suggest providing the learner with a custom 'view' (or a ‘virtual subsection’) of the LOs repository, generated in accordance with the requirements (e.g., prerequisites and learning objectives) of the current learning situation. The introduced notion of the custom ‘view’ is analogous to the well-known concept of view in databases that is used to protect the database users from the complexity of the underlying database schema. The learner is free to search and/or browse through that ‘virtual subsection’ of the LOs repository. This way the learners are given a substantial level of control over their learning process (i.e., we advocate in the active learning approach), whereas, at the same time, the usage of custom ‘views’ over the repository protects them from the cognitive overload. The learner’s searching/browsing behavior is tracked, as that data can be mined to infer the learner’s preferences, as well as some dimensions of his/her learning style. Based on the acquired insights into the learner’s preferences, the virtual subsection of the LOs repository for every subsequent activity the learner performs can be further customized. In other words, the customization would not be based only on the requirements of the learning activity, but also on the information inferred about the learner’s preferences/style. One should also note that each time a learner selects a LO from the repository of LOs, a learning object context instance is created in the repository of LOCs and all relevant context-related data for that usage are stored in it.

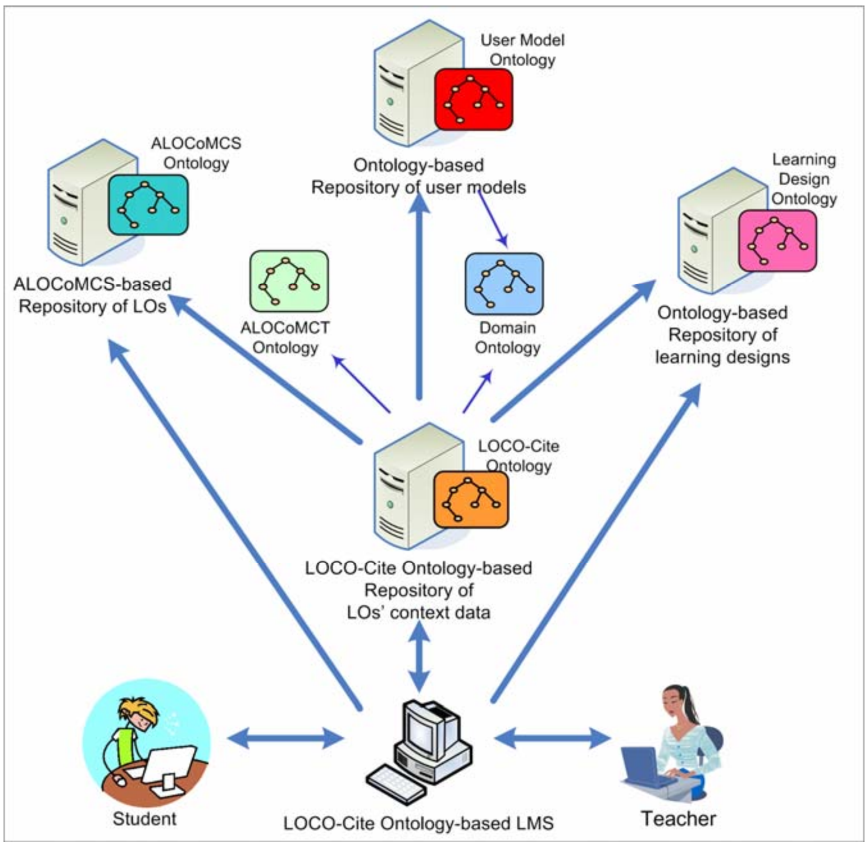

Figure 2. The architecture for the learning process adaptation

Furthermore, the information about the learners’ on-line communication and collaboration activities can also be used to improve the learners’ learning experience. In particular, by analyzing the context and the content of the messages exchanged in on-line discussion forums and chat rooms, a learning system can identify the problems some learners might have experienced and take appropriate actions. For example, having recognized that a learner is experiencing problems with a certain domain topic, the system can:

- recommend additional readings for the sake of clarifications (i.e., provides links to potentially relevant content that treats the unclear topics);
- suggest reading some postings from a specific discussion forum/chat room where the problematic issue was already discussed;
- suggest discussing the topic with some other learner(s) who knows the topic well, that is, with learner(s) who had high score on the quiz which tested the knowledge on that topic and/or related topics (where relatedness is inferred from the domain ontology).

Teacher-centric scenarios

Besides being beneficial for providing learners with personalized learning experience, the proposed framework and the reasoning that can be performed over it are also useful for generating feedback for other key participants in the learning process – content authors and instructors. Content authors are typically subject matter experts who create learning content, that is subsequently used by instructors (i.e., teachers) who wrap that content into a learning design (Jovanović et al, 2006c). The proposed framework can be used to inform learning content authors about the actual usage of their content during the learning process. Likewise, the framework can be used to provide feedback to instructors about the learners' activities, their performance, achieved collaboration level and the like. In both cases, the feedback helps improve the learning process. To support this statement, we give a few illustrative scenarios:

- If the majority of learners have spent a lot of time on some lesson and made frequent revisits to it, it is highly probable that the lesson is overly difficult for learners. This finding can be a signal for the content author to improve the expressivity of the content. It might also be a signal for the instructor to alter the applied instructional model (e.g., include more exercises or alter the lessons' sequence).
- If the majority of learners who performed poorly on an assessment followed the same or similar learning trajectory (i.e., sequence of lessons), it might signal to the instructor that either more tutoring (i.e., explicit directing of learners activities) is needed or the learning trajectory should be restricted (e.g., by means of link hiding techniques). Semantic annotation of lessons can further improve this feedback by helping identify semantically similar learning trajectories.
- If majority of learners answered incorrectly to the assessment question(s) about a particular domain topic and there were a lot of on-line exchanged messages discussing the topic in question as well as frequent revisits to the lesson(s) explaining the 'problematic' topic, then it is a clear signal that some alternations of the lessons' content or way of teaching the respective topic are needed.
- The feedback may be generated out of analyzes of the learners online communication and collaboration. Being informed about how active students were in social interactions, the instructor can more easily decide how to alter his/her teaching approach to activate them more, or make them more focused on the relevant parts of lessons.
- Finally, the ontological framework facilitates visualization of the learning process, hence providing instructors with visual clues of the learning progress. For example, from the visual representation of the learning object's context data, an instructor can easily perceive the suitability of that LO for different learning activities.

Applications

This section describes two educational systems based on the suggested ontological framework. The first one is TANGRAM, an ontology-based environment for generating personalized assemblies of learning object components. The second one is LOCO-Analyst, a tool for generating feedback for online instructors.

TANGRAM

TANGRAM is an adaptive learning environment for the domain of Intelligent Information Systems (Jovanović et al, 2006a). It is implemented as a Web application built on top of a repository of LOs and intended to be useful to both content authors and learners interested in the domain of Intelligent information systems (see http://iis.fon.bg.ac.yu/TANGRAM/home.html for more information).

Being fully ontology-based, TANGRAM actually illustrates how Semantic Web technologies, particularly ontologies and ontology-based reasoning, enable on-the-fly assembly of personalized learning content out of existing content units (note that a content unit is an abstract concept aimed at representing content of any level of granularity). Its principle functionality is to enable reuse of existing content units to dynamically generate new learning content adapted to a learner's knowledge, preferences, and learning styles. Additionally, the use of ontologies for structuring and annotation of the learning content (i.e., LOs) enables advanced search of the LOs repository, empowered by the Semantic Web reasoners. This means that the system is able to search for a content unit of a certain type (as defined in the ontology of pedagogical roles, e.g. "definition"), dealing with a certain topic (from the domain ontology, e.g. "Semantic Web") and being at a certain level of granularity (as defined in the structure ontology, e.g. "slide").

Accordingly, TANGRAM provides students with quick access to a particular type of content about a topic of interest, e.g. access to *example*s of RDF documents or *definition*s of the Semantic Web (both topics belong to the domain of Intelligent Information Systems).

To enable formal representation of learning content TANGRAM makes use of the aforementioned ALOCoM CS ontology and ALOCoM CT ontology (see Section 3.1). Additionally, TANGRAM uses the domain ontology to semantically annotate content units with appropriate domain concepts. We used an OWL binding of the SKOS Core specification (Miles & Brickley, 2005) to formally represent a sub-domain of intelligent information systems. However, note that TANGRAM is actually domain independent – to support any other subject domain it suffices to provide TANGRAM with a SKOS-Core-compliant ontology of that domain. To perform its personalization task TANGRAM heavily relies on its user model ontology. The system contains a repository of user models represented in accordance with this ontology.

TANGRAM also makes use of a Learning Paths ontology that defines learning trajectories through the domain's topics. This ontology relates instances of the domain ontology through an additional set of relationships reflecting a specific instructional approach to teaching/learning intelligent information systems. Hence, it can be regarded as a simplistic form of a learning design ontology. Whenever a student requests a certain topic (i.e. domain concept) to learn about, TANGRAM performs a sort of comparative analysis of data stored in the student's model and in the learning paths ontology in order to determine the student's knowledge about the domain concepts required for successful comprehension of the chosen topic. Information resulting from this analysis is used to provide adaptive guidance and direct the student towards the most appropriate learning content for him/her at that moment (Figure 3).

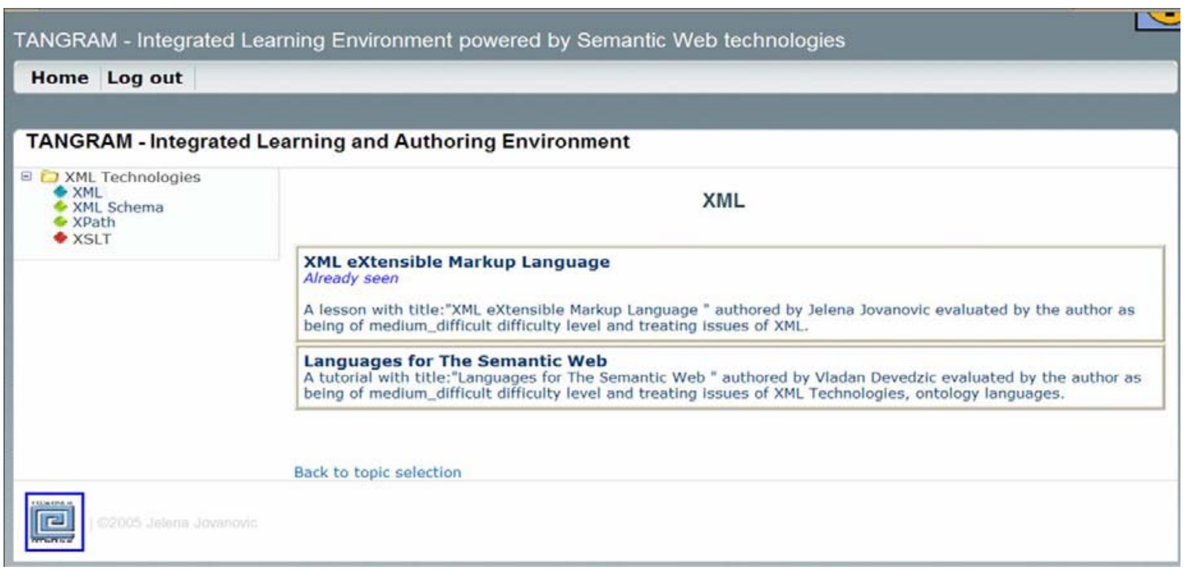

Figure 3. A screenshot of TANGRAM

TANGRAM also enables a content author to upload a new LO into the repository of LOs with the idea of later being able to reuse its components. The uploaded LO is decomposed into its components and its structure is explicitely represented according to the ALOCoM CS ontology. Additionally, the author can easily attach semantic markup to the uploaded LO, whereas TANGRAM automatically annotates the learning object's components using its own IEEE LOM profile (in RDF format).

As the previous discussion suggests, TANGRAM generally fits into the proposed framework: it decomposes LOs in accordance with a content structure ontology (ALOCOM CS) and enables direct access to (and hence reuse of) content units of diverse granularity levels; it annotates content units with concepts of an ontology of instructional roles (ALOCOM CT); it annotates content units with concepts of the domain ontology structured in accordance with the SKOS Core ontology; it keeps track of its users through the concepts and properties of its user model ontology. Besides, the architecture of TANGRAM (Jovanović et al, 2006b) closely resembles the one presented on Figure 2. The only part of the framework that TANGRAM currently does not support is the learning design. In particular, it does have an instructional model (formalized in the Learning Paths ontology), but it is really a rudimentary form of learning design. Essentially, TANGRAM's main deficiency is its lack of support for active learning, i.e. learning that is not restricted to reading, but also includes (even fosters) learning through communication and collaboration with others. Extending the system to include more advanced instructional planning is one of the main directions of our future work regarding TANGRAM.

LOCO-Analyst

LOCO-Analyst aims at helping instructors rethink the quality of the learning content and learning design of the courses they teach (Jovanović et al, 2007). To this end, it provides instructors with feedback about the relevant aspects of the learning process taking place in the online learning environment they use. The provided feedback is based on the analyses of the context data collected in the learning environment. In particular, LOCO-Analyst informs instructors about:

- the activities the learners performed and/or participated in during the learning process;
- the usage of the learning content they had prepared and deployed in the online learning environment;
- the peculiarities of the interactions among members of the online learning community.

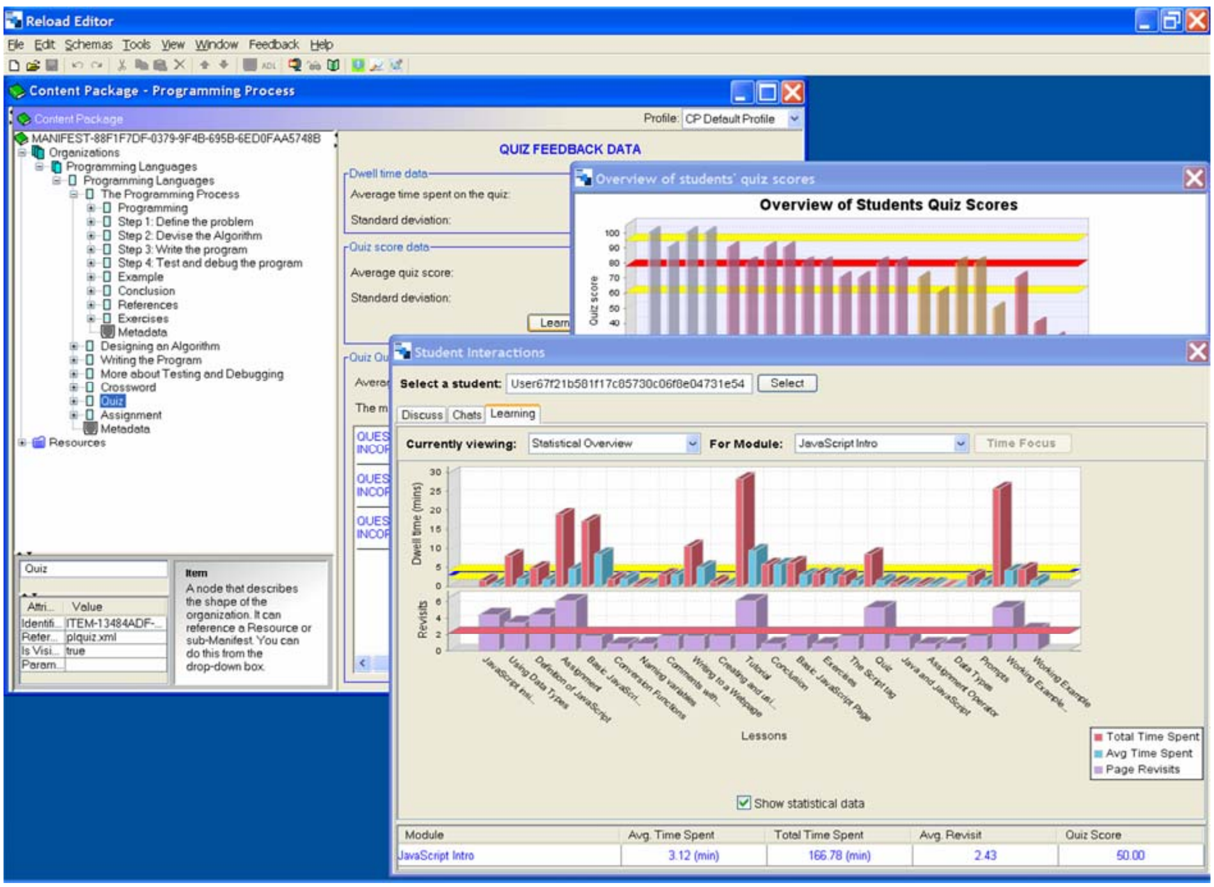

Figure 4. A screenshot of LOCO-Analyst

The current implementation of LOCO-Analyst uses tracking data from the iHelp Courses (Brooks et al, 2005) Learning Content Management System (LCMS). Nonetheless, LOCO-Analyst can be considered as a generic feedback generation tool since it is not tied to any specific distance learning environment. This independence is accomplished by developing the LOCO-Analyst's feedback provision functionalities on top of the LOCO ontological framework. Therefore, the only thing that needs to be done in order to apply LOCO-Analyst to any other online learning environment is to define the mapping between the tracking data format of that learning environment and the LOCO-Cite ontology.

LOCO-Analyst (Figure 4) is implemented as an extension of the well-known open-source Reload Content Packaging Editor (http://www.reload.ac.uk/editor.html). This way we have ensured that instructors effectively use the same tool for creating LOs, receiving and viewing automatically generated feedback about their use, and modifying the LOs accordingly. This further ensures easier and wider acceptance of LOCO-Analyst.

Like TANGRAM, LOCO-Analyst does not make use of the learning design ontology since the present state-of-the-art LCMSs do not support explicit definition and specification of learning design. We wanted to have a feedback generation tool that will meet the requirements of the presently available e-learning tools, so the ontology for learning design was redundant as in the present e-learning tools learning design is only implicitly present (typically as a sequence of lessons represented as a tree structure). However, as a part of our future work, we will investigate how implicit learning patterns can be extracted from the usage data and used to help course authors and instructors make better informed decisions when structuring the course. Successful patterns can be formalized as ontology-based learning designs according to the ontology of learning designs (build on top of IMS LD (Knight et al., 2006)), and thus made easily sharable and reusable.

Related Work

Context has been the subject of research in different research areas, but it seams that it has been mostly explored in the fields of pervasive (ubiquitous) computing and ambient intelligence. In these fields, context is considered as any information that can be used to characterize the situation of an actor - a person, a computing device, or a software agent. A ubiquitous computing environment integrates different sensors that sense various contexts, reasoners that infer new context information from the sensed data, and applications that make use of context to adapt the way they behave (Ranganathan et al., 2003). In such an environment, ontologies are used to uniquely describe context, and hence ensure that different entities that use context have a common semantic understanding of the contextual information. In other words, ontologies define standard descriptions for locations, services, activities, user preferences, beliefs, intentions, and other information that may be used by context-aware applications. For example, in the GAIA ubiquitous computing environment, contexts are represented in the form of predicates - the name of the predicate is the type of context that is being described (e.g., location, temperature or time) (Ranganathan et al., 2003). Ontologies essentially define the vocabulary and types of arguments that may be used in the predicates. On the other hand, Preuveneers and his associates proposed a generic context ontology that can be considered as a metamodel for context modeling and not as a vocabulary. The ontology consists of four basic context entities: (i) user, as the central concept in context-aware computing, (ii) environment, as a description of relevant aspects of the user's surroundings, (iii) platform, the hardware and software of the device(s) in the user's disposal, (iv) service, the functionality offered in the user's environment (Preuveneers et al, 2004). Context is also the central concept of the CoBRa brokerage architecture aimed at supporting context-aware computing in intelligent spaces (Chen et al, 2004). The broker maintains and manages a shared context model on the behalf of a community of devices and agents and provides necessary common services. This shared model is actually a context ontology (dubbed CoBRa ontology), which defines some of the common relationships and attributes associated with people, places and activities in an intelligent space. The broker's reasoning engine uses the ontological knowledge together with the acquired situational information to reason about the context in an intelligent space. Our approach is closest to the one suggested by Preuveneers et al (Preuveneers et al, 2004), since our ontological framework can be considered as a metamodel for modeling context in e-learning settings.

Context has also been explored in relation to Web services. For example, Maamar et al. argue for and provide the rational for associating context with Web services (Maamar et al, 2006). They consider context as any information that characterizes the interactions between humans, applications, and the environment, and suggest using context in conjunction with Web services in three intertwined steps: 1) deploying context-aware Web services (i.e., Web services that assess their environment before accepting to participate in compositions), 2) using context to reduce the semantic heterogeneity of Web services that participate in a composition, 3) conciliating contexts of Web services using ontologies. Their idea of using context for tracing the execution of Web services and using the past context to predict and adapt the behavior of Web services is analogous to our idea of using LOCs to track the usage of LOs and enable personalization of the learning process. Another work on context that is oriented towards service frameworks in general, and Web services in particular is the work of Strang et al. (2003) on Context Ontology Language (CoOL). CoOL is an ontology-based context modeling approach, which uses the Aspect-Scale-Context (ASC) model where each aspect (e.g. spatial distance) can have several scales (e.g., kilometer scale or mile scale) to express some context information (e.g. 20). Whereas CoOL is very useful for requirements relying on concepts with an inherent metric ordering, it is less practical for requirements such as adaptation of the learning content to the user needs.

The notion of context has already been explored in the e-learning community as well, but primarily as a mean for improving the performance of content search and retrieval. For example, Dichev & Dicheva (2006) explore the idea of using contexts to enable more efficient information search in Topic Map-based digital library applications. They perceive context as an abstraction of grouping of domain concepts and resources based on the existing semantic relationships between them. Technically, in Topic Map (http://www.topicmaps.org) terms a context is a nested topic map drawn around the topic chosen to name the context. The proposed context model is integrated into TM4L, a Topic Maps-based environment for creation, maintenance, and use of ontology-aware courseware. Thus, TM4L enables personalized, context-based search by allowing users to define their own contextualized queries. The advantage of this context-based search is twofold: first, the retrieved resources better satisfy the user requirements; and second, they provide a starting point for further exploration of relevant resources.

Huang et al. (2006) propose a generic context model as a basis of an intelligent semantic e-learning framework. The proposed model is based on the notion of semantic context as a collection of semantic rich situational information about the entity's internal features and external relations in a specific situation. Their proposal can be considered as a metamodel for context-aware semantic description (annotation) of learning content, learning processes, and learners. Actually, it is a generalization of existing learning specifications/standards extended with some additional features aimed at better context modeling (e.g., assigning weights to define the impact of a statement in a specific context). The authors also propose a concept schema as a vocabulary to be used in conjunction with the proposed (meta)model. However, in the suggested e-learning framework the context (meta)model is used for representing explicit metadata, that is, descriptions of learning processes and their constituents (i.e., LOs, activities, actors) explicitly provided by content authors, course authors, instructional designers and/or learners. Contrary to that, our LOCO framework is aimed at capturing and representing implicit metadata (i.e. context data originating from the learning process itself) that is subsequently used for analyzing (i.e., reasoning about) the learning process, its participants, and LOs.

Conclusions

Aiming to enable advanced services for all key participants of the learning process (learners, content authors and instructors), we came up with the idea of learning object context (LOC) as a unique set of interrelated data that characterize a specific learning situation. We have also developed an ontology framework (dubbed LOCO) as a formalization of the concept of LOC. The framework integrates several kinds of learning-related ontologies (e.g., user modeling ontology and content structuring ontology) in order to capture the information about specific context of use of a LO inside a learning design. Information of this kind can be rather useful for personalization of learning process. For example, during a learning session a query specifying the main features of the current learning situation can be sent to the repository of LOCs in order to identify LOC instances representing similar learning situations and from them infer the most suitable LOs for the present circumstances (e.g., learning objectives, learner's preferences, and available time). Furthermore, the idea of personalized views over repository of LOs is presented as a benefit resulting from the proposed ontology-based framework. Some of these advantages we have already implemented in TANGRAM, a Web-based application for personalized learning in the area of Intelligent information systems. In addition, our work on the LOCO-Analyst tool proved that the LOCO framework is useful for generating feedback aimed at informing content authors and instructors about the relevant aspects of the learning process. In both of these systems, we have demonstrated that not all features of the LOCO framework ought to be used in a specific application. On the contrary, application developers should choose those features that are needed for their current needs. Yet, thanks to the generality of the LOCO framework and its ontological formalization, developers can easily interoperate with systems that support other features of LOCO.

In our future research we intend to relate TANGRAM and LOCO-Analyst. The idea is to make learners interactions with TANGRAM traceable by LOCO-Analyst and hence unify learner-centric and teacher-centric tools in order to accomplish the circular flow of information in the learning process.

Acknowledgment

This work is supported in part by Canada's NSERC-funded LORNET research network and Canadian International Development Agency (CIDA)'s grant No. 629.

References

ADL. (2005). *Advanced Distributed Learning SCORM Specification*, Retrieved June 6, 2007, from, http://www.adlnet.gov/scorm/.

Brase, J., & Nejdl, W. (2004). Ontologies and Metadata for eLearning, In Staab, S. & Studer R. (Eds.), *Handbook on Ontologies*, Berlin: Springer-Verlag, 555-574.

Brooks, C., Kettel, L., Hansen, C., & Greer, J. (2005). Building a Learning Object Content Management System. In Richards, G. (Ed.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2005*, Chesapeake, VA: AACE, 2836-2843.

Chen, H., Finin, T., & Joshi, A. (2004). An Ontology for Context-Aware Pervasive Computing Environments. *Knowledge Engineering Review, 18*(3), 197-207.

Conole, G., Littlejohn, A., Falconer, I., & Jeffrey, A. (2005). *Pedagogical review of learning activities and use cases, LADIE project report*, Retrieved June 6, 2007, from, http://www.jisc.ac.uk/uploaded_documents/PedVocab_VocabsReport_v0p11.doc.

Cristea, A. (2005). Authoring of Adaptive Hypermedia. *Educational Technology & Society, 8*(3), 6-8.

Dichev C., & Dicheva D. (2006). *Context-based Search in Topic-centered Digital Repositories*, Retrieved June 6, 2007, from, http://swui.semanticweb.org/swui06/papers/DichevDicheva/DichevDicheva.pdf.

Huang, W., Webster, D., Wood, D., & Ishaya, T. (2006). An intelligent semantic e-learning framework using context-aware Semantic Web technologies. *British Journal of Educational Technology, 37*(3), 351–373.

WG12: Learning Object Metadata (2002). *1484.12.1 IEEE Standard for learning Object Metadata*, IEEE Learning Technology Standards Committee, Retrieved June 6, 2007, from, http://ltsc.ieee.org/wg12/.

IMS Global Learning Consortium (2003). *IMS Learning Design Information Model, Version 1.0 Final Specification, revision 20*, Retrieved June 6, 2007, from, http://www.imsglobal.org/learningdesign/ldv1p0/imsld_infov1p0.html.

Jovanović, J., Gašević, D., & Devedžić, V. (2006). Dynamic Assembly of Personalized Learning Content on the Semantic Web. *Lecture Notes in Computer Science, 4011*, 545-559.

Jovanović, J., Gašević, D. & Devedžić, V. (2006). Ontology-Based Automatic Annotation of Learning Content. *International Journal on Semantic Web and Information Systems, 2*(2), 91-119.

Jovanović, J., Gašević, D., Brooks, C. A., Knight, C., Richards, G., & McCalla, G. I. (2006). Ontologies to Support Learning Design Context. *Lecture Notes in Computer Science, 4227*, 615-620.

Jovanović, J., Gašević, D., Brooks, C., Eap, T., Devedžić, V., Marek, H., & Richards, G. (2007). Leveraging the Semantic Web for Providing Educational Feedback. In Spector J. M., Sampson D. G., Okamoto T., Kinshuk, Cerri S.

A., Ueno M. & Kashihara A. (Eds.), *Proceedings of the 7th IEEE International Conference on Advanced learning Technologies*, Los Alamitos, CA: IEEE Computer Society, 551-555.

Knight, C., Gašević, D., & Richards, G. (2006). An Ontology-Based Framework for Bridging Learning Design and Learning Content. *Educational Technology & Society, 9*(1), 23-37.

Koper, R., & Olivier, B. (2004). Representing the Learning Design of Units of Learning. *Educational Technology & Society, 7*(3), 97-111.

Koper, R. (2001). *Modeling units of study from a pedagogical perspective - The pedagogical metamodel behind EML*, Retrieved June 7, 2007, from, http://dspace.ou.nl/bitstream/1820/36/1/Pedagogical+metamodel+behind+EMLv2.pdf.

Li, J. Z., Gašević, D., Nesbit, J. C., & Richards, G. (2005). *Ontology Mappings Enable Interoperation of Knowledge Domain Taxonomies*, Retrieved June 7, 2007, from, http://www.lornet.org/Portals/7/presentation_i2lor_05/papers/i2lor05-07.pdf.

Li, J. Z. (2006). Mapping Local Ontologies: Authentic Semantics for Learning Object Evaluation, *M.Sc. Thesis*, School of Interactive Arts and Technology, Simon Fraser University, Canada.

Maamar, Z., Benslimane, D., & Narendra, N. C. (2006). What can context do for web services? *Communications of the ACM, 49*(12), 98–103.

McCalla, G. (2004). The Ecological Approach to the Design of E-Learning Environments: Purpose-based Capture and Use of Information about Learners. *Journal of Interactive Media in Education, 2004*(7), Retrieved June 7, 2007, from, http://www-jime.open.ac.uk/2004/7.

Miles, A., & Brickley D. (2005). *SKOS Core Guide*, Retrieved June 7, 2007, from, http://www.w3.org/2004/02/skos/core/guide/2005-02-15.html.

Preuveneers, D., den Bergh, J. V., Wagelaar, D., Georges, A., Rigole, P., Clerckx, T., Berbers, Y., Coninx, K., Jonckers, V., & Bosschere, K. D. (2004). Towards an extensible context ontology for Ambient Intelligence. *Lecture Notes in Computer Science, 3295*, 148-159.

Ranganathan, A., McGrath, R. E., Campbell, R. H., & Mickunas, D. M. (2003). Ontologies in a Pervasive Computing Environment. In Giunchiglia, F., Gomez-Perez, A., Stuckenschmidt, H., Pease, A., Sure, Y. & Willmott, S. (Eds.), *Proceeding of the 1st International Workshop on Ontologies and Distributed Systems*, Retrieved June 7, 2007, from, http://sunsite.informatik.rwth-aachen.de/Publications/CEUR-WS//Vol-71/.

Seaborne, A. (2004). *RDQL - A Query Language for RDF, W3C Member Submission*, Retrieved June 7, 2007, from, http://www.w3.org/Submission/RDQL.

Recker, M. M., & Wiley, D. (2001). A Non-authoritative Educational Metadata Ontology for Filtering and Recommending Learning Objects. *Interactive Learning Environments, 9*(3), 255-271.

Recker, M., Walker, A., & Willey, D. (2001). Collaboratively filtering learning objects. In D. A. Wiley (Ed.), The Instructional Use of Learning Objects, Retrieved June 7, 2007, from, http://reusability.org/read/chapters/recker.doc.

Strang, T., Linnhoff-Popien, C., & Frank, K. (2003). CoOL: A Context Ontology Language to enable Contextual Interoperability. *Lecture Notes in Computer Science, 2893*, 236–247.