A semantic framework for cloud learning environments

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Cloud Computing for Teaching and Learning:

Strategies for Design and Implementation

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Chapter 2

A Semantic Framework for Cloud Learning Environments

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ABSTRACT

Cloud Learning Environments (CLEs) are gradually gaining ground over traditional Learning Management Systems (LMS) by facilitating the lone or collaborative study of user-chosen blends of content and courses from heterogeneous sources, including Open Educational Resources (OER). This chapter describes the use of ontologies for modelling various aspects of the learning process within such an environment. In particular, the author considers a semantic knowledge base as the core of the learning environment, facilitating learners in finding educational services on the cloud. He describes how different stakeholder clusters are involved in the creation and maintenance of this knowledge base, through collaborative ontology management techniques. Finally, the chapter defines the mechanisms for the evolution of this knowledge base and the constant updating of the associated cloud learning services.

INTRODUCTION

Web 2.0 offers new opportunities for e-learning, through the provision of open and reusable tools and services. Learners are enabled to assemble their Personal Learning Environment (PLE) by aggregating Web 2.0 resources in order to reach their learning goals. In addition, the cloud offers an abundant amount of services for building adaptive and customisable Cloud Learning Environments (CLEs).

Nevertheless, the wide range of the offered cloud learning services makes finding the suitable ones for achieving a particular learning goal, quite challenging. Learners are in dire need for support in constructing their learning environment according to their needs and preferences. The absence of semantic descriptions of the available learning services on the cloud hinders this task, thus preventing access to potentially useful Web 2.0 resources.

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Our work is targeting the adaptivity and personalization of PLEs and CLEs, in terms of content and navigation, as well as the entire learning environment and its functionalities (Mikroyannidis, Lefrere, & Scott, 2010a, 2010b). In particular, we propose the use of ontologies to model the key elements of the CLE and its learning services. Our semantic knowledge base aims at facilitating learners in finding and aggregating educational services on the cloud.

The proposed knowledge base allows us to match similar learner profiles with each other through ontology mappings, as well as discover connections between learner profiles and learning resources. In this way, recommendations can be offered to a learner about potential 'study-buddies', with whom the learner shares common competencies and learning goals. The learner can also receive recommendations about learning resources for targeting a particular learning goal.

We perceive a semantically enhanced CLE as the evolution of the present LMS-based approaches. This evolution aims at providing learners with personalised services on the cloud that will support them in reaching their learning goals and will allow them to assume complete control over their learning (Mikroyannidis, 2011).

BACKGROUND

Learning Management Systems have dominated e-learning for several years. They have been widely used by academic institutions for delivering their distance learning programmes, as well as for supporting their students outside the classroom. They have also been established in the business sector as the mainstream platform for delivering training services to employees. A Learning Management System (LMS) is an online software application offering facilities for student registration, enrolment into courses, delivery of learning materials to students, student assessment and progress monitoring. Popular examples of LMS used by the academic as well as the business world include Blackboard[1], Moodle[2], and CLIX[3].

However, the advent of Web 2.0 has altered the landscape in e-learning. Learners nowadays have access to a variety of learning tools and services on the web. These tools and services are usually provided by different vendors and in many cases are open and free. Repositories like Wikipedia[4], YouTube[5], SlideShare[6] and iTunes U[7] offer access to a wide range of learning materials for free. Augmenting and configuring the diverse and distributed Web 2.0 tools and services in order to address the needs and preferences of individual learners is a significant challenge for modern online learning environments.

The transition from the traditional e-learning approach of LMS to Web 2.0 e-learning solutions bears significant benefits for learners. It puts emphasis to their needs and preferences, providing them with a wider choice of learning resources to choose from. The European project ROLE (Responsive Open Learning Environments)[8] is exploring this transition within a variety of learning contexts and test-beds. One of the these test-beds is provided by the Open University[9] and concerns the transition from formal learning, where courses are exclusively prepared and delivered by educators, towards informal learning, where the learner is in control of the whole learning process. This transition is being implemented within the Open University test-bed as a transition from the LMS towards the Personal Learning Environment (Mikroyannidis, 2011).

The Personal Learning Environment (PLE) is a facility for an individual to access, aggregate, configure and manipulate digital artefacts of their ongoing learning experiences. The PLE follows a learner-centric approach, allowing the use of lightweight services and tools that belong to and are controlled by individual learners. Rather than integrating different services into a centralised system, the PLE provides the learner with a variety of services and hands over control to her to select and use these services the way she deems fit (Chatti, Jarke, & Frosch-Wilke, 2007).

The Cloud Learning Environment (CLE) extends the PLE by considering the cloud as a large autonomous system not owned by any educational organisation. In this system, the users of cloud-based services are academics or learners, who share the same privileges, including control, choice, and sharing of content on these services. This approach has the potential to enable and facilitate both formal and informal learning for the learner. It also promotes the openness, sharing and reusability of learning resources on the web (Malik, 2009).

The CLE is enabled by the technological infrastructure of Web 2.0, employing popular and established technologies such as HTTP, XML, and SOAP. This makes it an ideal platform for the easy sharing of online recourses, thus benefiting not only learners, but also those who design, produce, and publish creative digital works for educational purposes. This is a critical requirement for achieving a sustainable knowledge community, as not only consumers but also active producers are essential (Hu & Chen, 2010).

The web services employed by the CLE have made a significant impact on the design and delivery of e-learning resources (Vossen & Westerkemp, 2003). Unlike the traditional approach to courseware delivery followed by the LMS, where the focus is on the aggregation of learning objects, the CLE supports composition. Courseware units can be represented by cloud services and invoked within a workflow model (Anane, Bordbar, Fanyu, & Hendley, 2005). The composition and invocation of these services offers greater flexibility in designing and delivering learning paths.

Self-regulated learning (SRL) comprises an essential aspect of the CLE, as it enables learners to become "metacognitively, motivationally, and behaviourally active participants in their own learning process" (Zimmerman, 1989). Although the psycho-pedagogical theories around SRL predate very much the advent of the CLE, SRL is a core characteristic of the latter. SLR is enabled within the CLE through the assembly of independent resources in a way that fulfils a specific learning goal. By following this paradigm, the CLE allows learners to regulate their own learning, thus greatly enhancing their learning outcomes (Steffens, 2006).

The emergence of the PLE and the CLE has facilitated significantly the use and sharing of open and reusable learning resources online. Learners can access, download, remix, and republish a wide variety of learning materials through open services provided on the cloud. Open Educational Resources (OER) can be described as "teaching, learning and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or repurposing by others depending on which Creative Commons license is used" (Atkins, Brown, & Hammond, 2007).

The OER movement aims in developing a comprehensive set of resources and content that is freely accessible and can be modified by anyone, whilst giving the original author credit. OER can comprise of any kind of learning resource material, textbook, papers, pictures, or websites that is published in a format that can be copied or modified by anyone under a common licence. This very broad concept includes curriculum materials, educational software, computer-based learning systems, educational games, and more (OEDB, 2007).

The OER movement has appealed to a broad range of institutions, universities, researchers, teachers and scientists, who aim in opening up access to the world's knowledge resources. Their mission is to freely distribute teaching materials of high quality into the public domain. Such OER can then be customized, improved and shared with local communities (Wiley, 2007). Furthermore, they can be adapted for local and cultural contexts, such as language, level of study, pre-requirements, and learning outcomes.

SEMANTICS ON THE CLOUD

In order to efficiently manage the semantics associated with the CLE and its learning services, we propose the organisation of these semantics into a number of ontology layers. Modelling the semantic knowledge base of the CLE in a layered form provides the advantage of clearly defining the boundaries between the ontologies comprising the knowledge base, as well as the interfaces through which they are connected.

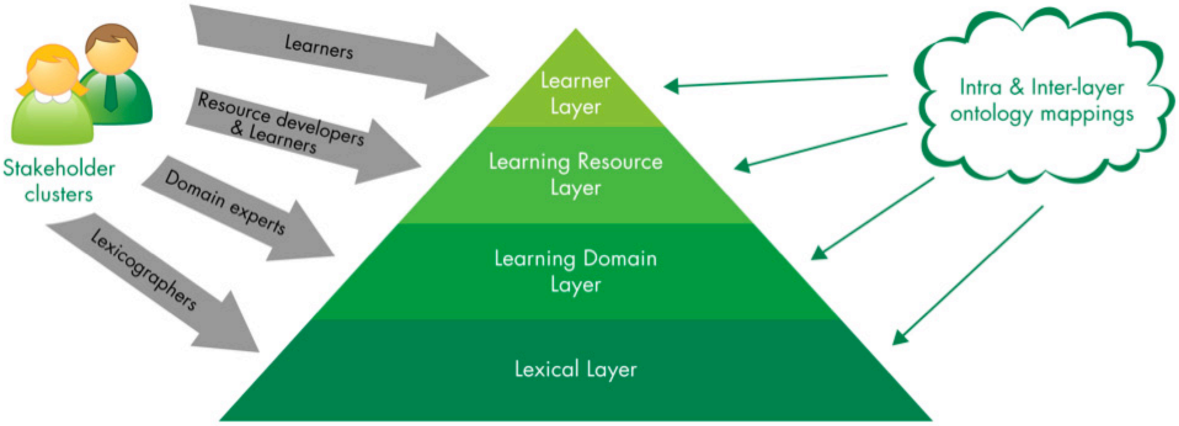
Semantic Knowledge Base Architecture

Figure 1 shows the multi-layered semantic knowledge base adapted from the Heraclitus II framework (Mikroyannidis, 2007; Mikroyannidis & Theodoulidis, 2006, 2010). In this pyramid, the lower layers represent more generic and all-purpose ontologies, while the ontologies of the upper layers are customized for modelling specific cloud learning services. When traversing the pyramid from bottom to top, each layer reuses and extends the previous ones. In addition, whenever a layer extends the ones below it (e.g. with the insertion of new concepts), these extensions are propagated to the lower layers. Different stakeholder clusters curate each layer, depending on the expertise that each layer requires. The integration of the ontology pyramid layers is achieved with the use of ontology mappings between ontologies belonging to the same or different layers.

Starting from the top of the pyramid, the *Learner layer* contains ontologies that model the profiles of the learners involved in the learning process. In particular, the ontologies of this layer model the learners' profiles according to their interests, goals, preferences, and skills. Some ontology standards corresponding to this layer are the IEEE Personal and Private Information for Learner (IEEE PAPI) developed by the IEEE Learning Technology Standards Committee (LTSC), the IMS Learner Information Package (LIP), and the IMS Reusable Definition of Competency and Educational Objective (RDCEO).

The *Learning Resource layer* models the learning resources that are used by learners within the CLE. These resources are either learning tools, e.g. widgets, or learning content, e.g. OER. The ontologies of this layer are built out of metadata associated with learning content, user-generated tags of content and tools, as well as knowledge maps associated with learning content. The IEEE Learning Objects Metadata Standard (LOM) corresponds to this layer, as it defines models for

Figure 1. The CLE semantic knowledge base



learning objects, including multimedia content, instructional content, as well as instructional software and software tools.

The *Learning Domain layer* models the learning domain of interest. These are more generic ontologies describing a certain domain of interest to the learner, e.g. bioinformatics. The ontologies of the Gene Ontology (GO) project (The Gene Ontology Consortium, 2000) and the Foundational Model of Anatomy (FMA) (Cornelius Rosse, 2003) are some widely used domain ontologies in bioinformatics.

Finally, the *Lexical layer* provides lexical and multilingual modelling with the use of domain-independent ontologies of a purely lexicographical nature. An example of such an ontology is the widely adopted WordNet (Fellbaum, 1998).

Although lexical ontologies constitute a strong basis for the construction of any domain-specific ontology, their relations tend quite often to be imprecise and thus not suitable for logical reasoning. This can be addressed with the use of more strictly constructed, general-purpose ontologies, such as the Suggested Upper Merged Ontology (SUMO). Such models can act as structuring mechanisms for lexical ontologies or intermediates between lexical and domain ontologies (Sevcenko, 2003).

Knowledge Base Integration

The integration of the ontology pyramid layers into a single manageable scheme is achieved with the use of ontology mappings. In terms the layers of the ontology pyramid being mapped, ontology mappings are either *intra-layer*, mapping ontologies of the same ontology layer, or *inter-layer*, mapping ontologies belonging to different layers.

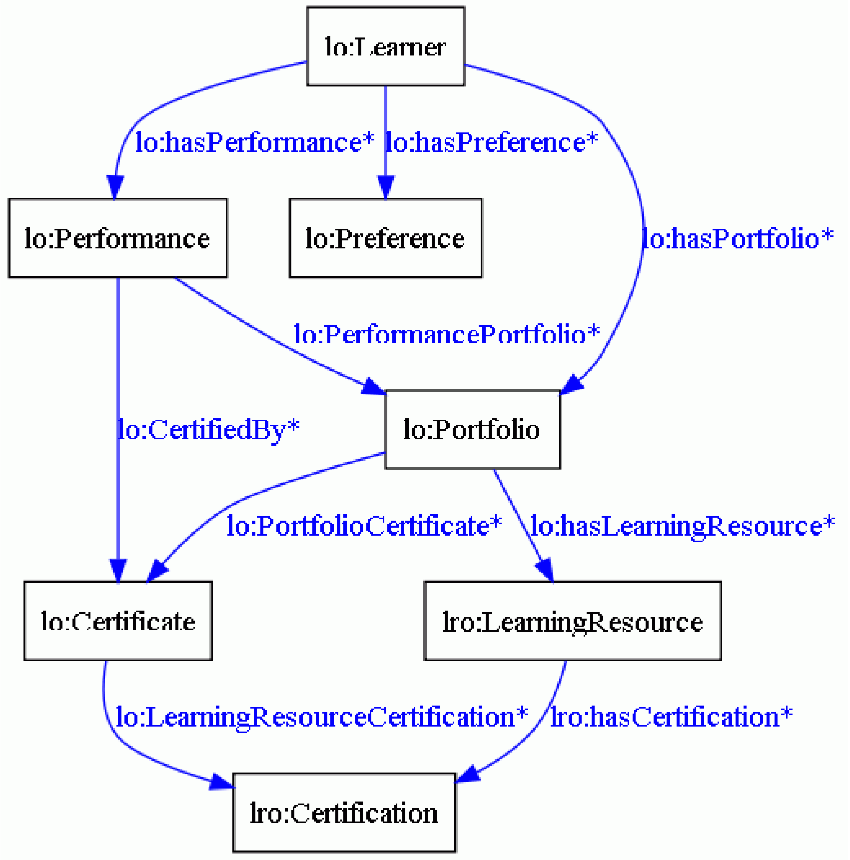
From an architectural point of view, ontology mappings can be either *structural*, namely referring to the structure of the mapped ontologies, e.g. via is-a relations, or *semantic* when mapping two ontology objects via a semantic relation, such as an employer-employee relation. OWL Full (Bechhofer et al., 2004) offers a variety of constructs for representing structural ontology mappings, including owl:subclassOf, owl:sameAs, owl:inverseOf, owl:equivalentClass, and owl:equivalentProperty.

Ontology mappings are particularly useful for the extraction of recommendations to the learner, as they link her profile to learning resources, as well as to profiles of other learners. They can therefore be used to recommend learning resources of potential interest to the learner. They can also be used to recommend a ‘study-buddy’, with whom the learner shares common abilities and interests.

Ontology mappings can be *intra-layer*, mapping ontologies of the same ontology layer, or *inter-layer*, mapping ontologies belonging to different layers. Inter-layer mapping between the Learner layer and the Learning Resource layer is particularly important for linking a learner’s profile with learning resources, building in this way her portfolio. Figure 2 shows an example of inter-layer mappings between the Learner layer and the Learning Resource layer. The classes belonging to the Learner layer have been assigned the lo namespace, while the classes of the Learning Resource layer have the lro namespace. According to the inter-layer mappings of this example, the lo:Portfolio and lo:Certificate classes are connected to the lro:LearningResource and lro:Certification classes, through the lo:hasLearningResource and lo:LearningResourceCertification relations respectively.

Intra-layer mapping has also several positive effects. In the layer of learner profiles, links between learners are identified, formulating a network of potentially peer-assisted learners. In the learning resource layer, integration of heterogeneous learning resources is realized. Last but not least, the integration performed in the domain ontologies layer can accomplish metadata fusion towards the creation of a wide-ranging, in terms of covered domains, web of semantics (Klein, Ding, Fensel, & Omelayenko, 2002).

Figure 2. Example of inter-layer mappings between the learner and learning resource layers



Stakeholder Clusters

Since each ontology layer represents a different degree of specialization, different stakeholder clusters are required to contribute to the curation of each layer. In the context of this chapter, a stakeholder cluster is defined as a group of people associated with a certain aspect of a CLE. For example, learners comprise a stakeholder cluster that uses a CLE to achieve their learning goals.

Starting from the bottom of the pyramid, lexicographers have the knowledge on language structures that is required in this level. Domain experts need to be employed for the next layer. These are professionals on a certain domain, e.g. biologists are responsible for a biology-related ontology.

For the Learning Resource layer, a more diverse group is suitable: producers and consumers of learning resources. The producers are those that develop learning resources, either content or tools. They can be lecturers, learning designers, or team leaders who develop new courses, workshops or training sessions and author new learning materials. The consumers are learners who use and annotate the offered learning resources.

Finally, the Learner layer is curated by learners, who provide information about themselves in order to receive recommendations about learning resources and create personal networks with users from different learning environments, with whom they may share common learning interests.

Depending on the scope of intra and inter-layer ontology mappings, these are performed by one or more stakeholder clusters. For example, an inter-layer ontology mapping between the lexical and the domain layers will be created jointly by the stakeholder clusters of these two layers, namely lexicographers and domain experts. Intra-layer ontology mappings are performed by the stakeholder cluster of the corresponding layer. The assignment of stakeholder clusters as curators of the ontology pyramid layers is summarized in Table 1.

Collaborative Ontology Management

Collaboration between stakeholder clusters in curating the CLE semantic knowledge base is essential; however, it involves several challenges, including concurrency, consistency, and scalability issues. We will be targeting the following set of parameters for collaborative ontology management, as outlined in (Bao, Hu, Caragea, Reecy, & Honavar, 2006):

- **Knowledge integration:** A fundamental task in a collaborative environment is the integration of contributions from multiple participants. The proposed semantic knowledge base consists of a multi-layer architecture that is curated by diverse clusters of stakeholders. Reusability and integration are supported through ontology mappings.
- **Concurrency management**: Different ontology authors need to be able to work on different parts of the knowledge base simultaneously. In case the same part of the knowledge base is concurrently edited by more than one author, this can cause conflicts. Various technologies can be used to address this issue, such as Concurrent Versions System (CVS) (The Gene Ontology Consortium, 2000), Wiki (Auer, Dietzold, & Riechert, 2006; Schaffert, 2006), or peer-to-peer based solutions (Becker, Eklund, & Roberts, 2005; Xexeo et al., 2004).
- **Consistency maintenance:** Parts of the knowledge base curated by different authors may be inconsistent with each other, since an ontology usually reflects the point of view of each author. Mechanisms for structural and semantic consistency preservation as well as change propagation need to be provided to ensure that the knowledge base is free of inconsistencies at all times.
- **Privilege management:** In order to ensure the accuracy of the knowledge base, a collaborative environment needs to assign different levels of privileges to its users, based on their expertise, authority, and responsibility. Our architecture is based on a flat scheme regarding privilege management, by giving each stakeholder cluster equal privileges in their layer of responsibility.
- **History maintenance:** Collaborative environments should provide the means to recover from wrong or unintended changes to the knowledge base. All changes to the knowledge base should be thus recorded in order to be able to track the authorship of

Table 1. Assignment of stakeholder clusters as curators of the semantic knowledge base

Ontology layer	Stakeholder cluster
Lexical layer	Lexicographers
Learning domain layer	Domain experts
Learning resource layer	Learning resource developers / Learners
Learner layer	Learners
Inter-layer ontology mappings	Stakeholder clusters of corresponding layers
Intra-layer ontology mappings	Stakeholder cluster of corresponding layer

a change and to prevent loss of important information. The bitemporal ontology model of Heraclitus II (Mikroyannidis, 2007) retains the necessary information to achieve this goal.

- **Scalability:** Long-term collaboration of diverse parties usually increases the size of knowledge bases; therefore, a collaborative environment has to be scalable to large ontologies. This is particularly important in the abundant environment of the CLE, where a wide variety of cloud-based services is employed.

Bitemporal Ontology Modelling

In order to model the evolution of CLE ontologies, we use an ontology model based on the object model defined by the Object Data Management Group (ODMG) (Cattell & Atwood, 1996) and more specifically on TAU (Kakoudakis & Theodoulidis, 1999; Theodoulidis et al., 1998). The TAU model is an extended version of ODMG that supports modelling and reasoning about time and evolution. TAU adopts a discrete model of time. The model supports multiple granularities and only absolute times are considered. User defined times are supported through the temporal literal types: Date, Time, Timestamp, Interval, Timepoint, Period and Temporal_Element. Users can choose the precision of user-defined times by selecting an appropriate granularity supported in the types Timepoint, Period and Temporal_Element. In addition, the model specifies three special temporal values named now, beginning and forever that denote the present, the least and the greatest time values on the time line respectively.

We model CLE ontologies *bitemporally*, enabling the representation of semantics over two dimensions of time: *valid* and *transaction* time. The notions of valid and transaction time have been first used in temporal databases (Snodgrass & Ahn, 1985). The valid time of a fact is generally defined as the time when that fact is true in the modelled reality. The transaction time of a fact is defined as the time when that fact is current in the knowledge base of the CLE and may be retrieved. Valid times can belong in the past, present or future and are usually supplied by the ontology curator. Transaction times are provided by the CLE, cannot change and are bounded between the knowledge base creation time and the current transaction time.

Ontology objects are associated through their temporal type with transaction time (*tt*), valid time (*vt*), both (bitemporal - *bt*), or none of them (static - *s*). Temporal support is optional, since the model provides the users with the ability to choose the temporal support for a model construct according to their needs. Ontology objects with temporal type other than static are associated with *transaction time history*, *valid time history*, or both. The transaction time history (*TTH*) or valid time history (*VTH*) of ontology object obj_i^T is a set containing the unique identifier *id* of the ontology object, the transaction time *tt* or valid time *vt*, and the value *v* of the object at the given time:

$$TTH_{obj_i^T} = \{id_{obj_i^T}, tt, v_{obj_i^T}\}$$

$$VTH_{obj_i^T} = \{id_{obj_i^T}, vt, v_{obj_i^T}\}$$

The value of the object is present in its history only when the object is a relation/property; in both other cases, namely being a concept or an instance, its value is inferred from the values of its properties. The valid and transaction time history contains information about the valid and transaction time lifespan of an object. The *valid time lifespan* of an object represents the period when the object exists in the modelled reality, whereas the *transaction time lifespan* of an object represents the period when the object exists in the knowledge base.

Ontology Evolution

We define ontology evolution as a transformation with 3 sets of ontology objects as arguments, namely new ($obj_i^{T,N}$), removed ($obj_j^{T,R}$) and modified ($obj_k^{T,M}$) of temporal type *T*. The transformation operates on the previous snapshot of the ontology O_{t-1}^L belonging to layer *L* and has as output the current ontology snapshot O_t^L:

$$O_t^L = f_{O_{t-1}^L}(\{obj_i^{T,N}\},\{obj_j^{T,R}\},\{obj_k^{T,M}\}),$$

$i = 1, \ldots, n$, $j = 1, \ldots, m$ and $k = 1, \ldots, \ell$

We have modelled the process of ontology evolution as a cycle, which is initiated by the change capture phase, as shown in Figure 3. The operations that are executed in each iteration of the cycle may cause further inconsistencies in the ontology pyramid. Thus, the evolution cycle is iterated until all inconsistencies have been resolved.

The evolution process starts with the capture of changes in all layers. Changes are captured either automatically, e.g. with the use of web usage mining or clustering techniques, or manually by the corresponding ontology curator. The captured changes are mainly *usage-driven* or *data-driven*. Usage-driven changes are derived from changes in the ways an ontology is used. Data-driven changes are captured from changes in the data that an ontology has been derived from.

Data-driven changes occur in the Learner layer whenever the learners update their profiles with new information, such as competencies, learning goals, etc. Data-driven changes in the Learning Resource layer correspond to changes in the learning material or tools, e.g. creation of a new course or modification of the metadata of an existing one. In the Learning Domain layer, data-driven changes are captured from changes in the learning domain. For example, an ontology that models a market sector needs to be updated whenever a new company is introduced in the sector, or a merger takes place. Data-driven changes in the lexical layer concern lexicographical changes in a language.

Usage-driven changes mainly concern the Learning Resource layer and correspond to changes in the ways the learners use their learning resources. For example, a knowledge map that has been built by a teacher for a particular course reflects the ways the teacher intends the course to be studied. When learners provide feedback to this knowledge map by adding annotations or making modifications, this feedback reflects changes in the ways that the course is being studied.

The next two steps in the ontology evolution cycle regard the detection of inconsistencies and their resolution. This is performed in two levels: *structurally* and *semantically*, resolving inconsistencies that arise when the structure or semantics of an ontology become invalid because of a change. An example of a change that affects the structural consistency of an ontology is the removal of a concept that contains subconcepts. In this case, the subconcepts can become children of the deleted concept's parent concept. Alternatively, the subconcepts can be attached to the root concept, or completely removed from the ontology.

A change that affects the semantic consistency of an ontology is demonstrated in the following example. Let us consider a relation that represents the enrolment of students in current and past online courses, as shown in Figure 4. The Learner concept is related via an isEnrolledIn valid time relation with the Course concept. At a certain time, a change is captured that modifies the status property of a Course instance from active to completed. This invalidates the isEnrolledIn relations this instance participates in. In order for this inconsistency to be resolved, the range of isEnrolledIn must be set to null. Courses that the student has registered for in the past will be provided by the valid time history of the isEnrolledIn relation.

Structural and semantic inconsistencies require different detection and resolution techniques. Structural inconsistencies can be identified and

Figure 3. The evolution process of CLE ontologies

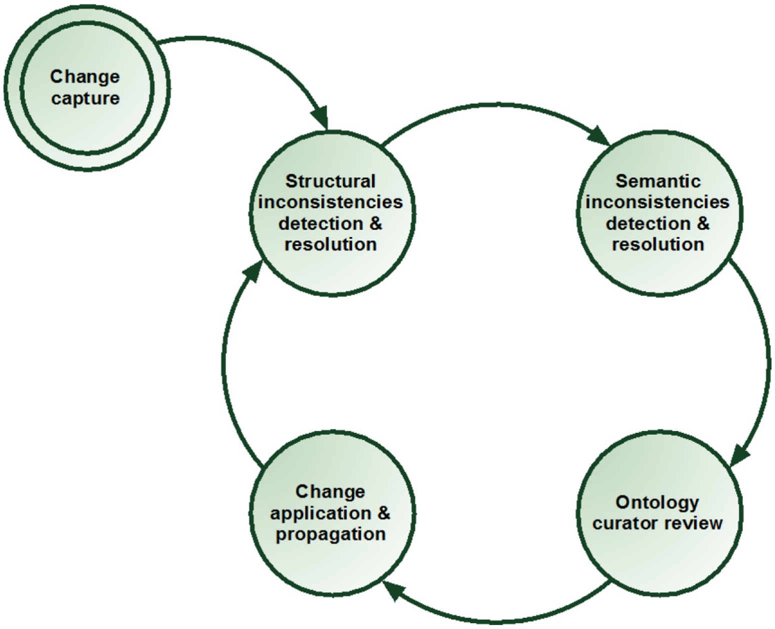
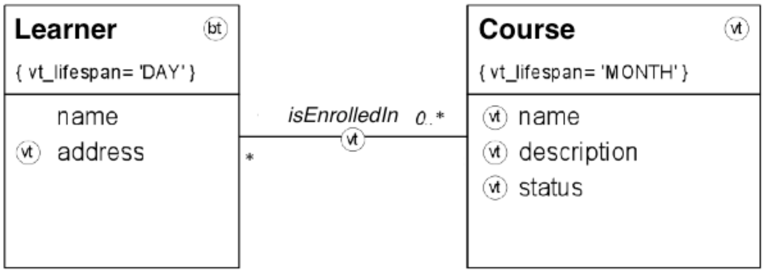


Figure 4. Example of a relation that can cause a semantic inconsistency



resolved based on a predefined set of rules and policies, since they are caused by a standard set of changes. On the other hand, a general set of changes that causes all semantic inconsistencies cannot be defined. Further research is needed on rules and policies defining the conditions about the state of the objects of an ontology that have to be satisfied in order for the ontology to be semantically consistent.

After the changes and their consequences have been established, the corresponding ontology curator is required to review the proposed changes. Finally, the reviewed changes are applied and propagated *internally* (inside the changed ontology), as well as *externally* (in depending ontologies via intra and inter-layer mappings), so that the consistency of all ontology layers is preserved.

A Learning Scenario on the Cloud

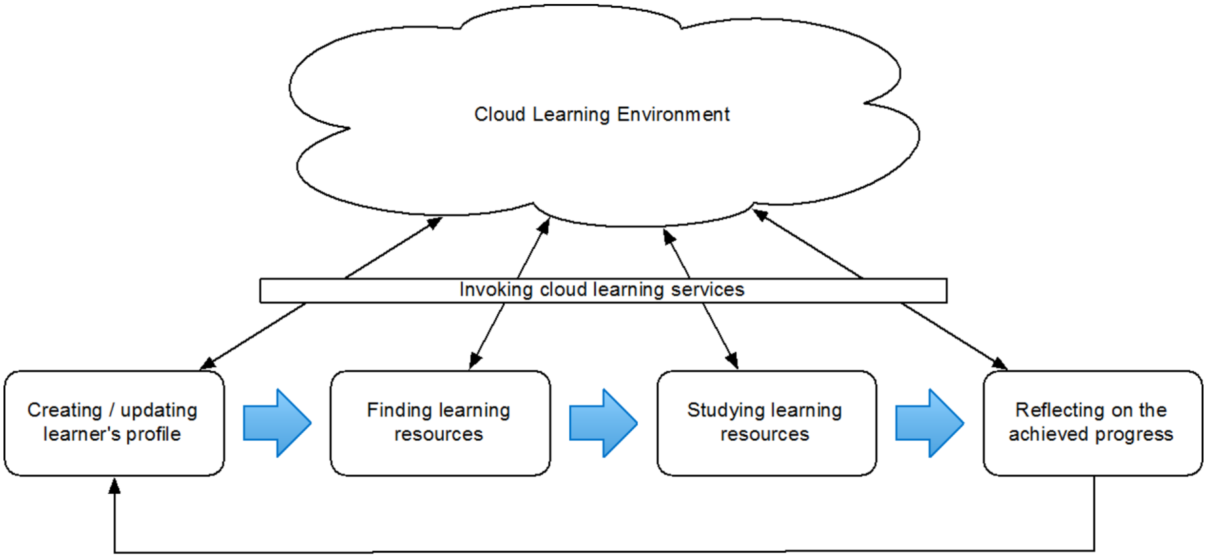
To illustrate the practical applications of the proposed semantic framework, let us consider a learning scenario based on the use of a CLE. This scenario will showcase the potential benefits for the learner from the existence of a semantic infrastructure on the cloud.

The overall goal of this scenario is enabling self-regulated learning by allowing the learner to take complete control over his learning process with support from the technology and his peers. For this reason, we model the interactions of the learner with the CLE services and his peers according to a psycho-pedagogical integration model (PPIM). The PPIM divides the learning process in 4 learner-centred phases: (i) the learner profile information is defined or revised, (ii) the learner finds and selects learning resources, (iii) the learner works on selected learning resources, and (iv) the learner reflects and reacts on strategies, achievements and usefulness. It is assumed that the learner will implicitly or explicitly perform these phases during learning, with support from distributed tools and services (Fruhmann, Nussbaumer, & Albert, 2010).

The sequence of phases executed during this learning scenario is illustrated in Figure 5. Our learner – we will call him Jim – is looking for OER on the particular subject that he is studying. In order to find the relevant resources on the cloud, he first provides some information about himself, including his competencies and learning goals. In this way, he is creating his learning profile, the metadata of which allow the CLE to match his learning goals to potentially useful learning resources and other learners through mappings in the corresponding ontologies. Jim then receives recommendations by the CLE about learning materials and cloud learning services that suit his profile. He also receives recommendations about connecting with other learners that have a profile similar to his. Jim starts building his personal network of fellow learners and receives additional recommendations from them about learning materials and cloud learning services.

Jim uses the recommended cloud learning services in order to study the learning material that he found. He studies this material in a collaborative fashion with other learners from his personal network. He interacts with them through social cloud services and shares with them the outcomes of his learning activities, such as the knowledge maps that he has created. Jim then reflects on what he has studied by receiving feedback both from the CLE and his peers about his progress. He also provides his feedback to the CLE and his peers. Finally, Jim updates his profile

Figure 5. A learning scenario based on the use of cloud learning services



according to his progress in accomplishing his learning goals. He can thus receive new recommendations about learning materials and services that match his updated profile.

CONCLUSION

This chapter presented a framework for the layering of ontologies that comprise the knowledge base of the CLE. In particular, we introduced the architecture of a semantic knowledge base, which models the key elements of the CLE. We then described how different stakeholder clusters are involved in the creation and maintenance of this knowledge base, through collaborative ontology management techniques. The evolution of the semantic knowledge base was subsequently analysed, with a focus on keeping the semantic knowledge base and the associated cloud learning services up-to-date. Finally, we illustrated the potential benefits of the proposed semantic framework through a learning scenario. The proposed framework employs ontology evolution in order to keep the metadata of the CLE's knowledge base constantly updated and free of inconsistencies. Learners will thus be able to receive valid and updated recommendations about fellow learners and resources, derived from the updated knowledge base.

We are currently working on the implementation of prototype cloud learning services that will employ the set of ontologies defined in this chapter. We plan to pilot this prototype with Open University teachers and students, in order to study and analyse the evolution of CLE ontologies over time. The outcomes of these pilots will allow us to refine our methodology for ontology management and evolution. In addition, the feedback from these pilots is expected to provide us with an insight into the requirements for offering recommendation services to learners and supporting them throughout their learning journey.

REFERENCES

Anane, R., Bordbar, B., Fanyu, D., & Hendley, R. J. (2005). *A Web services approach to learning path composition.* Paper presented at the 5th IEEE International Conference on Advanced Learning Technologies (ICALT), Kaohsiung, Taiwan.

Atkins, D. E., Brown, J. S., & Hammond, A. L. (2007). *A review of the open educational resources (OER) movement: Achievements, challenges, and new opportunities*. The William and Flora Hewlett Foundation.

Auer, S., Dietzold, S., & Riechert, T. (2006, 5-9 November). *OntoWiki - A tool for social, semantic collaboration.* Paper presented at the 5th International Semantic Web Conference (ISWC 2006), Athens, GA, USA.

Bao, J., Hu, Z., Caragea, D., Reecy, J., & Honavar, V. G. (2006, 4-8 September). *A tool for collaborative construction of large biological ontologies.* Paper presented at the 17th International Conference on Database and Expert Systems Applications (DEXA'06), Krakow, Poland.

Bechhofer, S., Harmelen, F. v., Hendler, J., Horrocks, I., McGuinness, D. L., Patel-Schneider, P. F., & Stein, L. A. (2004). OWL Web ontology language reference. In Dean, M., & Schreiber, G. (Eds.), *W3C Recommendation*. World Wide Web Consortium.

Becker, P., Eklund, P., & Roberts, N. (2005, 22-26 August). *Peer-to-peer based ontology editing.* Paper presented at the International Conference on Next Generation Web Services Practices (NWeSP 2005), Seoul, Korea.

Cattell, R. G. G., & Atwood, T. (Eds.). (1996). *The object database standard: Odmg-93: Release 1.2*. San Francisco, CA: Morgan Kaufmann Pub.

Chatti, M. A., Jarke, M., & Frosch-Wilke, D. (2007). The future of e-learning: a shift to knowledge networking and social software. *International Journal of Knowledge and Learning*, *3*(4/5), 404–420. doi:10.1504/IJKL.2007.016702

Cornelius Rosse, J. L. V. M. J. (2003). A reference ontology for biomedical informatics: the Foundational Model of Anatomy. *Biomedical Informatics*, *36*, 478–500. doi:10.1016/j.jbi.2003.11.007

Fellbaum, C. (1998). *WordNet: An electronic lexical database*. The MIT Press.

Fruhmann, K., Nussbaumer, A., & Albert, D. (2010). *A psycho-pedagogical framework for self-regulated learning in a responsive open learning environment.* Paper presented at the International Conference eLearning Baltics Science (eLBa Science 2010), Rostock, Germany.

Hu, S.-C., & Chen, I.-C. (2010). *A mechanism for accessing and mashing-up pedagogical Web services in cloud learning environments.* Paper presented at the 3rd IEEE International Conference on Computer Science and Information Technology (ICCSIT), Chengdu, China.

Kakoudakis, I., & Theodoulidis, B. (1999, July). *TAU: Towards a temporal object-oriented DBMS.* Paper presented at the 9th International Database Conference (IDC), Hong Kong.

Klein, M., Ding, Y., Fensel, D., & Omelayenko, B. (2002). Ontology management: Storing, aligning and maintaining ontologies. In Davis, J., Fensel, D., & Harmelen, F. v. (Eds.), *Towards the Semantic Web: Ontology-driven knowledge management*. John Wiley and Sons Ltd. doi:10.1002/0470858060.ch4

Malik, M. (2009, 22-01-2010). *Cloud learning environment - What it is?* Retrieved from http://edublend.blogspot.com/2009/12/cloud-learning-environment-what-it-is.html

Mikroyannidis, A. (2007). *Heraclitus II: A framework for ontology management and evolution.* Unpublished PhD Thesis, University of Manchester, Manchester.

Mikroyannidis, A. (2011, July 7). *Supporting self-regulated learning within a personal learning environment: The OpenLearn case study.* Paper presented at the International Workshop on Self-Regulated Learning in Responsive Open Learning Environments (SRL-ROLE 2011), 11th IEEE International Conference on Advanced Learning Technologies (ICALT 2011), Athens, Georgia, USA.

Mikroyannidis, A., Lefrere, P., & Scott, P. (2010a, July 5-7). *An architecture for layering and integration of learning ontologies, applied to personal learning environments and cloud learning environments.* Paper presented at the The 10th IEEE International Conference on Advanced Learning Technologies (ICALT), Sousse, Tunisia.

Mikroyannidis, A., Lefrere, P., & Scott, P. (2010b, May 22). *A semantic knowledge base for personal learning and cloud learning environments.* Paper presented at the Workshop on Supporting e-learning with language resources and semantic data, Language Resources and Evaluation Conference (LREC), Valletta, Malta.

Mikroyannidis, A., & Theodoulidis, B. (2006, December 18-22). *Heraclitus II: A framework for ontology management and evolution.* Paper presented at the 2006 IEEE /WIC/ACM International Conference on Web Intelligence (WI 2006), Hong Kong, China.

Mikroyannidis, A., & Theodoulidis, B. (2010). Ontology management and evolution for business intelligence. *International Journal of Information Management*, *30*(6), 559–566. doi:10.1016/j.ijinfomgt.2009.10.002

OEDB. (2007). *80 open education resource (OER) tools for publishing and development initiatives*. Retrieved from http://oedb.org/library/features/80-oer-tools

Schaffert, S. (2006, 26-28 June). *IkeWiki: A Semantic Wiki for collaborative knowledge management.* Paper presented at the 15th IEEE International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE'06), Manchester, UK.

Sevcenko, M. (2003, February 19-21). *Online presentation of an upper ontology.* Paper presented at the Znalosti 2003, Ostrava, Czech Republic.

Snodgrass, R., & Ahn, I. (1985). *A taxonomy of time in databases.* Paper presented at the ACM SIGMOD International Conf. on the Management of Data, Austin, Texas, USA.

Steffens, K. (2006). Self-regulated learning in technology-enhanced learning environments: Lessons of a European peer review. *European Journal of Education*, *41*(3/4), 353–379. doi:10.1111/j.1465-3435.2006.00271.x

Stojanovic, L., Maedche, A., Motik, B., & Stojanovic, N. (2002). *User-driven ontology evolution management.* Paper presented at the 13th European Conference on Knowledge Engineering and Knowledge Management (EKAW), Madrid, Spain.

The Gene Ontology Consortium. (2000). Gene ontology: Tool for the unification of biology. *Nature Genetics*, *25*, 25–29. doi:10.1038/75556

Theodoulidis, B., Kakoudakis, I., Hanias, K., Pilafitzis, G., Svinterikou, M., & Kazantzidis, E. (1998). *The TAU temporal object system.* Paper presented at the 6th Int'l Conf. on Extending Database Technology (EDBT), Demo Session.

Vossen, G., & Westerkemp, P. (2003). *E-learning as a Web service.* Paper presented at the IEEE 7th International Database Engineering and Applications Symposium (IDEAS), Hong Kong, China.

Wiley, D. (2007). *On the sustainability of open educational resource initiatives in higher education*. Retrieved from http://www.oecd.org/dataoecd/33/9/38645447.pdf

Xexeo, G., de Souza, J. M., Vivacqua, A., Miranda, B., Braga, B., Almentero, B. K., et al. (2004, 26-28 May). *Peer-to-peer collaborative editing of ontologies.* Paper presented at the 8th International Conference on Computer Supported Cooperative Work in Design (CSCWD 2004), Xiamen, China.

Zimmerman, B. J. (1989). A social cognitive view of self-regulated academic learning. *Journal of Educational Psychology*, *81*(3), 329–339. doi:10.1037/0022-0663.81.3.329

KEY TERMS AND DEFINITIONS

Bitemporal Ontology Modelling: Bitemporal ontology modelling allows for the ontology representation over two dimensions of time: valid and transaction time.

Cloud Learning Environment (CLE): A Cloud Learning Environment is a learning facility enabled by learning services on the cloud. The users of cloud learning services are academics or learners, who share the same privileges, including control, choice, and sharing of content on these services.

Learning Management System (LMS): A Learning Management System is an online software application offering facilities for student registration, enrolment into courses, delivery of learning materials to students, student assessment and progress monitoring.

Ontology: An ontology can be regarded as a representation of a certain domain, through the definition of ontology objects (or entities), namely concepts, relations between concepts, and instances of concepts. There is certainly not one correct way to model a domain and construct an ontology. The development of an ontology mainly depends on its possible uses, the level of necessary detail, personal preferences of the modeller, and requirements for compatibility with other models.

Ontology Evolution: Ontology evolution is the timely adaptation of an ontology to changed business requirements, to trends in ontology instances and patterns of usage of the ontology based application, as well as the consistent management/propagation of these changes to dependent elements (Stojanovic, Maedche, Motik, & Stojanovic, 2002). The main difference of ontology evolution from a mere ontology modification is that the latter does not retain the consistency of the modified ontology.

Ontology Management: Ontology management is a set of services for the efficient use of ontologies as the knowledge base of a system, in a scalable, accurate and secure manner. These services include creating, storing, modifying, versioning, querying and reasoning on ontologies.

Ontology Management Framework: An ontology management framework enables an application to utilize ontological data without explicit knowledge of how ontologies are internally maintained, in terms of representation languages, versioning issues, etc.

Personal Learning Environment (PLE): A Personal Learning Environment is a facility for an individual to access, aggregate, configure and manipulate digital artefacts of their ongoing learning experiences.

Self-Regulated Learning (SRL): Self-regulated learning enables learners to become metacognitively, motivationally, and behaviourally active participants in their own learning process.

Stakeholder Cluster: In the context of this chapter, a stakeholder cluster is defined as a group of people associated with a certain aspect of a CLE. For example, learners comprise a stakeholder cluster that uses a CLE to achieve their learning goals.

Transaction Time: The transaction time of a fact is defined as the time when the fact is current in the ontology model and may be retrieved. Transaction times are provided by the ontology management system, cannot change and are bounded between creation time of the ontology model and the current transaction time.

Valid Time: The valid time of a fact is defined as the time when the fact is true in the modelled reality. Valid times can belong in the past, present or future and are usually supplied by the domain expert.

ENDNOTES

[1] http://www.blackboard.com

[2] http://moodle.org

[3] http://www.im-c.de/germany/en/solutions/learning-management/clix-learning-suite

[4] http://www.wikipedia.org

[5] http://www.youtube.com

[6] http://www.slideshare.net

[7] http://www.apple.com/education/itunes-u

[8] http://www.role-project.eu

[9] http://www.open.ac.uk