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A general model of learning design objects

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Repository;
Design support;
Instructor

Abstract Previous research on the development of learning objects has targeted either learners, as consumers of these objects, or instructors, as designers who reuse these objects in building new online courses. There is currently an urgent need for the sharing and reuse of both theoretical knowledge (literature reviews) and practical knowledge (best practice) in learning design. The primary aim of this paper is to develop a strategy for constructing a more powerful set of learning objects targeted at supporting instructors in designing their curricula. A key challenge in this work is the definition of a new class of learning design objects that combine two types of knowledge: (1) reusable knowledge, consisting of theoretical and practical information on education design, and (2) knowledge of reuse, which is necessary to describe the reusable knowledge using an extended learning object metadata language. In addition, we introduce a general model of learning design object repositories based on the Unified Modeling Language, and a learning design support framework is proposed based on the repository model. Finally, a first prototype is developed to provide a subjective evaluation of the new framework.

1. Introduction

Over the last few decades, information technologies have come to play an increasingly central role in classroom learning. The ability of instructors to design intensive technology courses that enhance the learning process is therefore the key to success in educating the youth of today. Several studies have focused on the pedagogical aspects of technologically intensive courses, but insufficient support has been provided in the area of curriculum design. The release of the Instructional Management Systems Learning Design (IMS-LD) specification is indicative of a directional shift in e-learning. The IMS-LD has many pedagogical benefits compared to earlier open specifications for e-learning. However, it is not straightforward for instructors to understand and work with (Griffiths and Blat, 2005), and the usability issue poses a major challenge for instructors who are not highly qualified as instructional designers. Instructors must master the IMS-LD specification and authoring tools before they can begin to design high quality courses. In addition, they require the means to express their effective teaching practices as learning designs in a uniform way and share them through web-based repositories (Sampson et al., 2011).

There is a current trend toward using learning design (LD) as a means of sharing best teaching practices. For a literature review on the subject, we refer the reader to (Beetham and Sharpe, 2007). However, LDs can only be shared if the

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representation provides all the information necessary for instructors to understand them, for example, the details of each learning activity, the associated learning and support tasks and the required resources (Conole, 2008). In other words, the sharing of LDs requires tools and strategies to facilitate their transparent communication between humans and machines (Sampson et al., 2011).

In this work, we propose a new approach to the representation and qualification of LDs to facilitate their reuse within LD repositories. Our approach is based on the concept of a learning design object (LDO) that includes two types of knowledge: reusable knowledge and knowledge of reuse.

The remainder of the paper is organized as follows. Sections 2 and 3 review the concepts of LOs and LDs, and Section 4 introduces the problem statement. Section 5 provides an overview of related work. In Section 6, we present our main contribution, the definition of an LDO, and a class diagram of the model is also proposed. A learning design support framework based on the LDO model is presented in Section 7, along with a subjective evaluation of a first prototype. The final Section concludes the paper and suggests directions for future work.

2. Learning objects

Various researchers have attempted to define an LO as an entity or particular type of artifact and have inevitably failed in the attempt to provide a definition that is both broad enough to include all that an LO might be and specific enough to reject what it is not (Parrish, 2004). In (Hodgins and Duval, 2002), an LO is defined as any digital or non-digital entity that may be used for learning, education or training. In (Grace et al., 2008), LOs are defined as building blocks that can be combined in a virtually infinite number of ways to construct collections that may be referred to as lessons, modules, courses, or curricula. LOs can be as small as an explanatory paragraph or as large as a complete tutorial and can be presented through a variety of media, including text, graphics, animations, audio and video.

The utility of LOs to instructors as designers can be illustrated through the following three examples: (1) an instructor discovers a concept with which his students frequently struggle and seeks a better way to explain the concept; (2) an instructor requires a reusable assignment covering a new topic in his course; or (3) in a course on software requirements, the instructor may wish to provide real-world examples to make the course more attractive and practical. Let us assume that an extensive collection of illustrative software requirement categories (data requirements, functional requirements, etc.) and styles (data dictionaries, entity-relationship diagrams, dataflow diagrams, etc.) is available. The instructor can save substantial effort and expense by reusing the same examples of software requirements from this collection.

(Parrish, 2004) takes a critical look at the proposed benefits of LOs in the published literature, particularly in terms of their scalability and adaptability. He also discusses the difficulty of defining the term LO and the limitations of metaphors used to describe the concept. He concludes that rather than attempting to define LOs as entities or particular artifacts, the following approaches may be more useful:

- viewing LOs as processes or strategies, such as object-oriented instructional design (OOID). OOID is a strategy for designing digital learning content and activities as discrete, addressable, and adaptable units to achieve fine-grained accessibility and improved reusability.
- using LOs to support active learning strategies (case-based learning, problem-based learning, generative learning, collaborative learning, etc.) rather than treating them as collections of static lessons. In this way, LOs can provide stimuli and support for students as they practice complex tasks rather than simply presenting a deterministic outcome.

LOs were developed to address the need for high-quality and reusable educational fragments that are organized in an accessible manner. These objects help to solve the problem of costly reproduction of instructional materials for e-learning courses. The decision on which LOs to include in a given course can be made in advance by the instructor or spontaneously by the student (adaptive learning). There are now abundant LOs available on the web. However, standard web search queries for LOs often return a prohibitively large number of results. It is more convenient to obtain instructional materials such as exams, exercises, and quizzes from repositories.

It is already viable to reuse, share, and freely interchange LOs via the World Wide Web. The leading Open Educational Resources (OER) movement and other international initiatives have highlighted the importance of sharing and reusing LOs among teaching communities (Caswell et al., 2009). LOs and their metadata are therefore organized, classified and stored in learning object repositories (LORs) (McGreal, 2004). In recent years, a number of interactive and user-friendly web-based LORs, such as Ariadne[1], Merlot[2], Maricopa[3], and Careo[4], have been developed worldwide in various disciplines. However, despite the extensive development of LORs, their impact on teaching practices in the classroom has been rather limited. According to (Sampson et al., 2011), this limited impact may be due to a lack of systematic mechanisms for connecting LOs with their educational contexts.

3. Learning design

The IMS-LD (Koper et al., 2003) is an open standard that is used to code a wide variety of digital courses, known as units of learning (UoLs), in a formal, semantic, interoperable and machine-readable fashion. The IMS-LD supports a wide range of modern pedagogical approaches such as active learning, collaborative learning, adaptive learning, and competency-based learning (Koper and Manderveld, 2004; Koper and Olivier, 2004).

In (Koper and Olivier, 2004), LD is defined as the description of the teaching process following a specific pedagogical approach that addresses specific learning objectives for a particular audience in a particular discipline. Fig. 1 illustrates the relations among the UoL, learning model, domain model, and theories of learning and instruction. The UoL is the result of LD. The learning model describes how students learn based on various learning theories. The domain model describes

[1] www.ariadne-eu.org
[2] www.merlot.org
[3] http://www.mcli.dist.maricopa.edu/
[4] http://www.careo.org

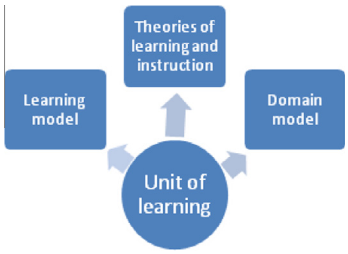

Figure 1 The context of learning design (Koper and Miao, 2008).

the content and its organization, for example, software engineering, data on the web, or business process engineering. The theories of learning and instruction describe the instruction principles and models based on the literature or the experience of practitioners (Koper and Miao, 2008).

In the conceptual model provided by the IMS-LD specification, the LD process can be represented using the following core concepts. Each person (typically a learner or staff member) plays a specified role in the learning process. Each role is designed to satisfy certain learning objectives through learning and/or support activities within an environment. The environment consists of the appropriate LOs and services to be used during the performance of the activities. The process description is provided in the method section. The method is designed to provide a coordination of roles, activities and associated environments that enables learners to meet specified learning objectives, given certain prerequisites. The learning process is modeled based on the metaphor of theater. A method consists of one or more concurrent play(s); a play consists of one or more sequential act(s); an act consists of one or more concurrent role-part(s); and each role-part associates exactly one role with one activity or activity structure (Koper and Miao, 2008).

Previous research in the field of e-learning has focused on LOs and LORs. It has been found that instructors can benefit from participation in communities centered around best teaching practices by sharing LDs that reflect their teaching experience in addition to LOs (Conole, 2008; Griffiths and Blat, 2005). Similar to LOs, LDs and their associated metadata can be organized, classified and stored in learning design repositories (LDRs). LDRs are designed to support storage, discovery, retrieval, use, reuse and sharing of LDs (Wilson, 2005). In recent years, a number of web-based LDRs have been developed (Sampson et al., 2011), including the Canadian LD Repository[5], which was developed in the framework of the project referred to as «Implementation and Deployment of the Learning Design specification» (IDLD); the LDR[6], which was developed by the Australian Universities Teaching Committee (AUTC) project on ICT-based LDs; and the LAMS repository[7], an open source software package that enables instructors to design and run LDs, which was developed by the LAMS Foundation.

[5] http://www.idld.org
[6] http://www.learningdesigns.uow.edu.au/
[7] http://www.lamscommunity.org/lamscentral/

4. Problem statement

Two aspects of the IMS-LD are identified as relevant in (Griffiths and Blat, 2005): (1) the learning designer is served with a wide range of possibilities and receives no guidance regarding the types of pedagogical structures that are targeted; and (2) the underlying concepts of the IMS-LD are not complex. These concepts are, however, unfamiliar to many instructors who are not experts in LD. The IMS-LD Best Practice Guide (Koper et al., 2003) describes the stages of developing a UoL as follows:

1. Analysis phase: a concrete educational requirement is analyzed by the various stakeholders, resulting in a narrative didactic scenario.
2. Design phase:
   (a) The narrative scenario is translated into an activity diagram to make it more formal.
   (b) The activity diagram is used to generate an XML document instance that conforms to the LD specifications.
3. Implementation phase: the document instance forms the basis for the development of the actual resources. The content package, including both the resources and the LD, is subsequently evaluated.

(Griffiths and Blat, 2005) identify two distinct challenges in this process: (1) a structure must be provided for the preparatory stage of the design process. A methodology is required for the first stage of the analysis and the creation of the didactic scenario; and (2) a representation and an interface must be developed to enable instructors to understand and edit the UoL in a straightforward fashion. The modification of UoLs remains difficult due to the lack of high-level authoring tools for IMS-LD. New tools and representations are therefore needed to enable instructors to edit and create UoLs.

In this paper, we address the first challenge after extending it to the entire development life cycle. We aim to provide a structure for the analysis, design and implementation phases. (Griffiths and Blat, 2005) discuss various structures that could

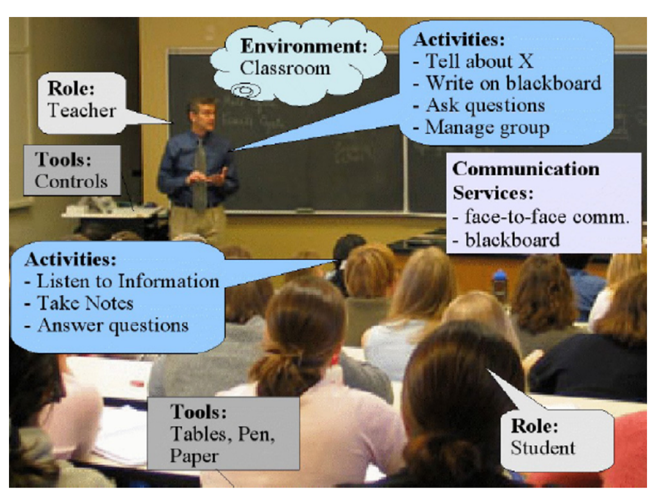

Figure 2 Labeling a classroom setting with IMS-LD concepts (Koper and Miao, 2008).

Figure 3 ≪Explore, Describe, Apply≫ template extracted from the Australian Flexible Learning Framework (http://www.flexiblelearning.net.au).

provide support to instructors in the initial analysis stage and creation of the didactic scenario, including design patterns, primitives, and taxonomies. In this work, we propose to encapsulate these structures within LDOs that have a more complex structure; we view these LDOs as a subcategory of the LOs (Section 2). Moreover, we propose to enrich the LDOs with additional theoretical and practical structures, such as standards, theories and templates, which can provide support to instructors over the entire development life cycle. Furthermore, the semantics (contextual knowledge) can be modeled using an extended learning object metadata (LOM) scheme, that we call LOM +, to help designers retrieve them and enhance their reuse. The hypothesis underlying the use of LDOs is that if successful LDs can be documented (designed for reuse) in an efficient way, then instructors will be able to understand them easily and reuse them in the construction of new LDs (design by reuse).

5. Related work

(Koper, 2005 and Paquette et al., 2005) have stated that to sustain the reusability of high-quality LDs, it is essential that the designs be made accessible as LOs in repositories.

(Paquette et al., 2006a) explain that LD is a knowledge engineering process in which knowledge, competencies and delivery models are constructed within an integrated framework. They show that the process of constructing LDs can itself be viewed as a UoL; designers learn from the construction of LDs, both individually and in groups. The problem of representing knowledge, cognitive skills and competencies is also addressed. The authors propose that LORs should distinguish between ≪content objects≫, ≪tool objects≫ and ≪process objects≫, where the third category includes both generic and specific LDs or scenarios. New LD templates can be constructed by abstracting generic processes from a large body of existing scenarios and situating the resulting abstraction in the framework of the generic skills' taxonomy. In the MISA (a French acronym for ≪method for engineering learning systems≫ see Paquette et al., 1999) documentation and in subsequent field applications, a large set of designs have been collected, which require systematic organization into a learning scenario repository. These LD templates can be organized as a hierarchy indexed by the main cognitive skill that they exercise, and other metadata can be added to further identify the type of knowledge (e.g., concept, procedure, principle or fact).

(Lejeune and Pernin, 2004) have established a taxonomy of scenarios based on the following criteria: the goal, granularity, degree of constraint, degree of customization, degree of formalization and degree of reification. This taxonomy leads to the formulation of questions regarding the modes of organizing, reusing and indexing LOs within interoperable repositories. The formal separation between activities and resources led the authors to redefine an LO as a digital or non-digital entity that can be used, reused or referenced during instruction through a technological medium. An LO may be a concrete component of the environment (knowledge resource, service or tool) or a scenario describing the a priori or a posteriori execution of a learning situation.

The same authors conclude that the use of indexing standards in the documentation does not foster the development of an activity-centered approach. An explicit dissociation between the activities and the resources causes the educational information to be linked to the associated activities rather than the resources. This dissociation poses a major challenge in the design of LORs, which currently permit queries of the following form: Retrieve the knowledge resources in a given domain with certain pedagogical features (e.g., the target audience or duration of use). By integrating the appropriately indexed scenarios and referencing the associated resources indirectly, queries of the following form would be permitted: Retrieve those scenarios that illustrate concepts in mechanics to new students and the associated knowledge resources.

Two approaches can be distinguished among previous studies aimed at devising sharing mechanisms for LDs (Emin et al., 2007). The first approach, which was adopted in the IDLD project (Lundgren-Cayrol et al., 2006; Paquette et al., 2006b), offers repositories of scenarios modeled in a notation language such as IMS-LD and indexed using a specific set of LOM metadata. The main objective of this approach is to enable the scenarios to be adapted for reuse in technical contexts that are different from the former context. If this strategy is essential for reuse in e-learning, then the related system should be modified for improved usability. The second approach is to set up repositories of best practices for instructors, such as the databases offered by the education portal Educnet[8] of the French Ministry of Education. The scenarios are indexed according to their attributes and disciplines. The descriptions of the scenarios can take a variety of forms, ranging from simple narrations to formalizations following the notation languages (Macedo and Perron, 2007).

The objective of (Marcelo et al., 2011) was to identify, represent and document a wide variety of LDs designed by experienced and innovative instructors. The participants in this study were 58 university instructors. Based on interviews, they created representations of a wide variety of learning sequences and made them available in the repository of sequences known as ≪Alacena≫[9]. The LDs provide all the information needed by instructors to understand and reproduce the learning sequences, including details such as the following:

8 http://www.educnet.education.fr

9 http://prometeo.us.es/idea

1. Identification information that can help to contextualize the sequence, such as the instructor qualifications, subject and student-to-instructor ratio.
2. A graphic that summarizes the most important events in the sequence or the main tasks performed by the students.
3. An in-depth description of the sequence, presenting each of its phases in detail. For each learning activity, the resources used, the role played by the instructors and the types of interactions are highlighted.
4. A table focusing on three essential aspects of each sequence: the required resources, concrete tasks and roles of the actors.
5. An image representing the learning activity management system (LAMS) sequence. LDs are represented visually by a sequence of activities in the form of a diagram that is easy to interpret (Agostinho, 2008).

The various LDs are organized so that they can be located easily by discipline (social sciences; mathematical and natural sciences; arts and humanities; health sciences and technology; or engineering and architecture); teaching method (sequences based on practical work; problems; projects; case studies; or group work); and learning format (face-to-face, online, or blended). This study concluded that many of the LDs promote student learning through innovative forms of inquiry and collaboration and are representative of good teaching practices in universities. According to Marcelo et al. (2011), the Alacena repository could become a useful tool in the planning of learning sequences as it makes the teaching practices of effective university instructors public and describes a variety of flexible educational activities in detail, including the required resources and support and the roles to be played by the various actors.

(Sampson et al., 2011) constructed the COSMOS[10] web-based LDR, which aims to support communities of science instructors by enabling them to develop and share their LDs in a standard and transparent format that is compatible with the IMS-LD specification. Two steps are required for the sharing of LDs: (1) typical pedagogical models are expressed in the form of LD templates using an existing LD authoring tool known as the ASK Learning Design Toolkit (ASK-LDT); and (2) the templates are incorporated into the system using a customized authoring tool (COSMOS ASK-LDT), enabling instructors to develop their LDs based on the templates and share them through the COSMOS LDR.

The main functionalities of the COSMOS LDR are as follows: (1) storing; (2) searching for; (3) downloading; (4) rating/commenting on; (5) viewing metadata on; and (6) browsing LDs and LD templates. Although many LDRs are available, there is a lack of empirical studies on how they are being used and which metadata are most essential in describing the LDs. (Agostinho et al., 2009) studied what constitutes an effective LD description based on an analysis of LDs in an existing repository. The study concluded that an effective LD description consists of a clear description of the pedagogy, a quality rating and advice on potential reuse. In a repository of 32 LD descriptions, six were identified as effective descriptions.

A preliminary analysis of the existing LDRs indicates that most of them do not provide systematic instructions for the reuse of design-centered LOs. Some of the LDRs (see, e.g., Paquette et al., 2006a; Lejeune and Pernin, 2004; Emin et al., 2007) limit the reusable knowledge to scenarios. The LDRs proposed in (Sampson et al., 2011) and (Marcelo et al., 2011) are limited to best practices and use a limited set of specific metadata. In the next two Sections, we propose a systematic approach to reuse based on the concept of LDO, which includes both reusable knowledge and knowledge of reuse.

6. A general model of learning design objects

We first consider instructors who are beginners in course design as learners in the LD field. Furthermore, we consider the entire life cycle of the design process as a problem-based learning (PBL) scenario. We aim to assist new instructors in solving the design problems that they face during the engineering or re-engineering of a course and provide them with a set of design-centered LOs known as LDOs. We define an LDO (which is a subclass of the LO) as any digital or non-digital entity that can be exploited or reused by instructors in building an LD. An LDO is composed of two complementary parts: (1) reusable knowledge, consisting of either theoretical or practical information related to the LD; and (2) knowledge of reuse, consisting of a set of LD metadata that are necessary for the description and qualification of the reusable knowledge while accessed and reused.

6.1. Reusable knowledge

LDOs include both theoretical knowledge and practical knowledge. The theoretical component is an extension of the theories of learning and instruction concept in LD (Fig. 1) and includes: taxonomy; concept; standard; theory; approach; method; and tools (Table 1). The practical component includes: design pattern; primitive elements; and template (Table 2) related to either the IMS-LD specification or the LD in general. The theoretical knowledge may be presented in various forms, depending on the role of the content in the LDO. Possible forms include definitions, illustrations, references, points of view, discussions, remarks and recommendations.

Practical knowledge, which is more powerful than theoretical knowledge in PBL, can be reused in the construction of scenarios. In this context, a scenario is a description of the task at hand from the perspective of the learner. A sequence of concrete problems is described, and choices are made, which enable the learner to reach a satisfactory outcome.

The reusable knowledge can be organized as a hierarchy indexed by the primary metadata in the knowledge of reuse.

6.2. Knowledge of reuse

To facilitate the semantic retrieval of LDOs, we choose to qualify them using an extended version of LOM, which we propose and refer to as LOM+. The original IEEE-LOM (Hodgins and Duval, 2002) record defines 80 fields arranged in a hierarchical structure and employs the following categories: (1) general; (2) life cycle; (3) metametadata; (4) technical; (5) educational; (6) rights; (7) relation; (8) annotation; and (9) classification. These nine categories are applied in the context of LOM+ to describe LDOs rather than LOs.

1. The **general** category includes the general information that describes the LDO as a whole.

[10] http://www.cosmosportal.eu/

Table 1 Theoretical knowledge in LDOs.

1. Taxonomy: This component is designed to provide the instructor with a classification covering a complete range of options. The instructor can use the taxonomy as a guide when creating a UoL. One example is Bloom's taxonomy11,[a] which provides a classification of educational objectives
2. Concept: This component includes the core concepts of the IMS-LD specification (Section 3), such as roles; learners; staff members; learning objectives; learning activities; support activities; environment; learning objects; services; methods; play(s); act(s); role-part(s); and activity structure. More general concepts related to the analysis and the LD can also be considered, for example, the stakeholders and the interactivity. Fig. 2 (from Koper and Miao, 2008) illustrates the labeling of a classroom setting based on IMS-LD concepts
3. Standard: This component is used for many purposes in LD. The LD may be required to conform to certain standards defined in the domain. Standards are defined by various groups, including enterprise consortia such as the AICC (Aviation Industry CBT Committee); consortia of national and international collaborative projects such as IMS (Educause USA); SCORM (Advanced Distributed Learning USA); and ARIADNE (EU and Switzerland); and professional associations such as the IEEE (Institute of Electrical and Electronics Engineers). A few of the existing standards include EML (the Educational Modeling Language); RDCEO (Reusable Definition of Competency and Educational Objective); PPI (Participant Performance Information); LTSA (Learning Technology System Architecture); and LIP (the Learner Information Package)
4. Theory: This component includes various theories of learning and instruction, such as empiricism (behaviorism); rationalism (cognitivism and constructivism); and pragmatism/sociohistorism (situationalism)
5. Approach: This component includes various modern pedagogical approaches, such as active learning; collaborative learning; adaptive learning; competency-based learning; and problem-based learning
6. Method: This component determines the organization of the entire LD process. Among the existing LD methods, we cite MISA. MISA is an instructional engineering method that graphically illustrates the instructional design processes and their products, thereby defining the complete learning system
7. Tool: This component includes various tools provided by some LD methods. For example, MISA developed the MOT/MOT+ editor, which can be used as a standalone tool. MOT is a specialized concept map editor, and MOT+ includes support for IMS-LD. This notion of a tool is clearly different from the tool concept employed in IMS-LD, which refers to the tools used by a learner during a learning activity.

[a] <http://www.flexiblelearning.net.au/>.

Table 2 Practical knowledge in LDOs.

1. Design pattern: This component addresses an LD problem and provides a solution. For example, a pattern may be used to construct a scenario that can then be represented using the IMS-LD, EML, LAMS or some other specification. One of the main objectives of the e-LEN project[a] is to identify and collect best teaching practices, create a collection of design patterns and e-learning research roadmaps and promote the dissemination of these results (Goodyear and Yang, 2009)
2. Primitive elements: This component provides a set of basic elements that can be applied in any context. The approach based on primitive elements involves the capture and production of parts of designs. Each part is a simple and unambiguous structure that provides a single common interactive event in a classroom or e-classroom, such as «research this topic on the web». These structures, which represent the lowest level of reuse, provide instructors with recognizable items that can be reused in building new UoLs
3. Template: This component guides the construction of LDs. Templates offer direct assistance in the implementation of a particular type of LD in a familiar setting. Two examples of templates from the Australian Flexible Learning Framework[b] are as follows: (1) the «Explore, Describe, Apply» template in Fig. 3, which supports learners in their construction of knowledge; and (2) the «Review, Interpret, Construct, Justify» template, which is a situated problem-focused LD

[a] <http://www2.tisip.no/E-LEN/>.
[b] <http://www.learningdesigns.uow.edu.au/>.

2. The **life cycle** category includes features related to the history and current state of the LDO and those who have affected the LDO during its evolution.
3. The **meta–metadata** category includes information regarding the metadata instance itself (as opposed to the LDO described by the metadata instance).
4. The **technical** category includes the technical requirements and technical characteristics of the LDO.
5. The **educational** category includes the educational and pedagogical characteristics of the LDO. In this category, LDOs are treated as ordinary LOs, and instructors are considered as learners (of design).
6. The **rights** category includes the intellectual property rights and conditions of use for the LDO.
7. The **relation** category includes features that define the relationship between the LDO and other LDOs.
8. The **annotation** category provides comments on the educational use of the LDO and information on when and by whom the comments were created. This category can be considered as a feedback from the other instructors on the use of the LDO.
9. The **classification** category describes the LDO in relation to a particular classification system.

LOM+ is obtained by modifying each of these nine metadata categories to describe LDOs rather than LOs. Furthermore, a tenth «Learning design» category is added to account for the specific nature of LDOs. This new «Learning design» category is presented in Table 3, whose structure is extracted from the LOMv1.0 base schema table. We have adopted the criteria used to establish the taxonomy of a scenario (the scenario goal; granularity; degree of constraint;

Table 3 LOM + ≪Learning Design≫ category.

Nr	Name	Explanation	Value space	Data type	Example
10	Learning design	This category describes the key instructional characteristics of this LDO			
10.1	LDO nature	These metadata indicate whether the reusable knowledge comes from theory or practice	Theoretical, practical	Vocabulary (State)	- Theoretical: reusable knowledge such as a concept or theory in the relevant field of e-learning - Practical: reusable knowledge that represents a given best practice, such as a design pattern
10.2	LDO type	These metadata describe a specific type of reusable knowledge characteristic of each LDO class. The most dominant type comes first	For theoretical knowledge: standard, taxonomy, concept, theory, approach, method, tool For practical knowledge: design pattern, template, primitive element	Vocabulary (State)	An explanation of each metadata value is provided in Tables 1 and 2
10.3	LDO form	These metadata describe a specific form of the theoretical reusable knowledge. The most dominant form comes first	Definition, illustration, reference, point of view, discussion, remark, recommendation	Vocabulary (State)	This value is null for reusable knowledge whose nature = ≪Practical≫
10.4	LDO credibility	These metadata describe the credibility of the reusable knowledge	Very low, low, medium, high, very high	Vocabulary (Enumerated)	This value is very high for practical reusable knowledge whose content is certified, such as well-defined design patterns or theoretical reusable knowledge whose content is well established
10.5	LDO goal	These metadata describe the specific goal of the practical reusable knowledge.	Predictive, descriptive	Vocabulary (Enumerated)	This value is applicable only for reusable knowledge whose nature = ≪Practical≫; the value is therefore null for reusable knowledge whose nature = ≪Theoretical≫ - Predictive: when the LDO is established a priori to set up a learning situation - Descriptive: when the LDO is established a posteriori to setup a learning situation including more particularly the activities' traces of actors
10.6	LDO granularity	These metadata describe the specific granularity of the practical reusable knowledge	Elementary activities, sequence of activities, units of pedagogical structuration	Vocabulary (Enumerated)	This value is applicable only for reusable knowledge whose nature = ≪Practical≫; the value is null for reusable knowledge whose nature = ≪Theoretical≫ - An elementary activity corresponds to the lowest granularity in a learning situation, in which one or many actors (learners, tutors...) act or interact within a defined environment for a short and contiguous period - A sequence of activities corresponds to an intermediate granularity in a learning situation, in which many elementary activities are organized to reach a learning objective in terms of knowledge or competency - An activity structure corresponds to the highest granularity in a learning situation, in which a set of sequences of activities are assembled to build a logical unit around a given learning topic for a specific audience

Table 3 *(continued)*

Nr	Name	Explanation	Value space	Data type	Example
10.7	LDO constraint degree	These metadata describe the degree of constraint of the practical reusable knowledge	Constrained, open, adaptable	Vocabulary (Enumerated)	This value is applicable only for reusable knowledge whose nature = ≪Practical≫; the value is null for reusable knowledge whose nature = ≪Theoretical≫ - Constrained: an LDO describing the precise activities to be performed - Open: an LDO describing the outline of the activities to be performed, leaving the actors with substantial freedom to organize the activities or adapt their sequence - Adaptable: an open LDO whose characteristics are modifiable by the actors
10.8	LDO Customization degree	These metadata describe the degree of customization of the practical reusable knowledge.	Generic, Adaptive	Vocabulary (Enumerated)	This value is applicable only for reusable knowledge whose nature = ≪Practical≫; the value is null for reusable knowledge whose nature = ≪Theoretical≫ - Generic: predictive LDO whose execution is always identical - Adaptive: predictive LDO considering stereotypes and enabling conditional execution of many personalized LDOs to be distinguished by the nature of the proposed interactions or the available knowledge resources
10.9	LDO formalization degree	These metadata describe the degree of formalization of the practical reusable knowledge	Informal, formalized, automatable	Vocabulary (Enumerated)	This value is applicable only for reusable knowledge whose nature = ≪Practical≫; the value is null for reusable knowledge whose nature = ≪Theoretical≫ - Informal: LDO designed by instructors according to empirical rules - Formalized: LDO using an instructional modeling language to foster the reuse of practices between communities - Automatable: formalized LDO using a ≪computational≫ instructional modeling language to ensure partial or total automation during its life cycle
10.10	LDO reification degree	These metadata describe the degree of reification of the practical reusable knowledge	Abstract, contextualized	Vocabulary (Enumerated)	This value is applicable only for reusable knowledge whose nature = ≪Practical≫; the value is null for reusable knowledge whose nature = Theoretical≫ - Abstract: an LDO describing the components of the learning situation in abstract terms - Contextualized: an LDO describing the real components associated with the abstract LDO in specific terms, including the roles of physical persons and availability of knowledge resources, services or tools

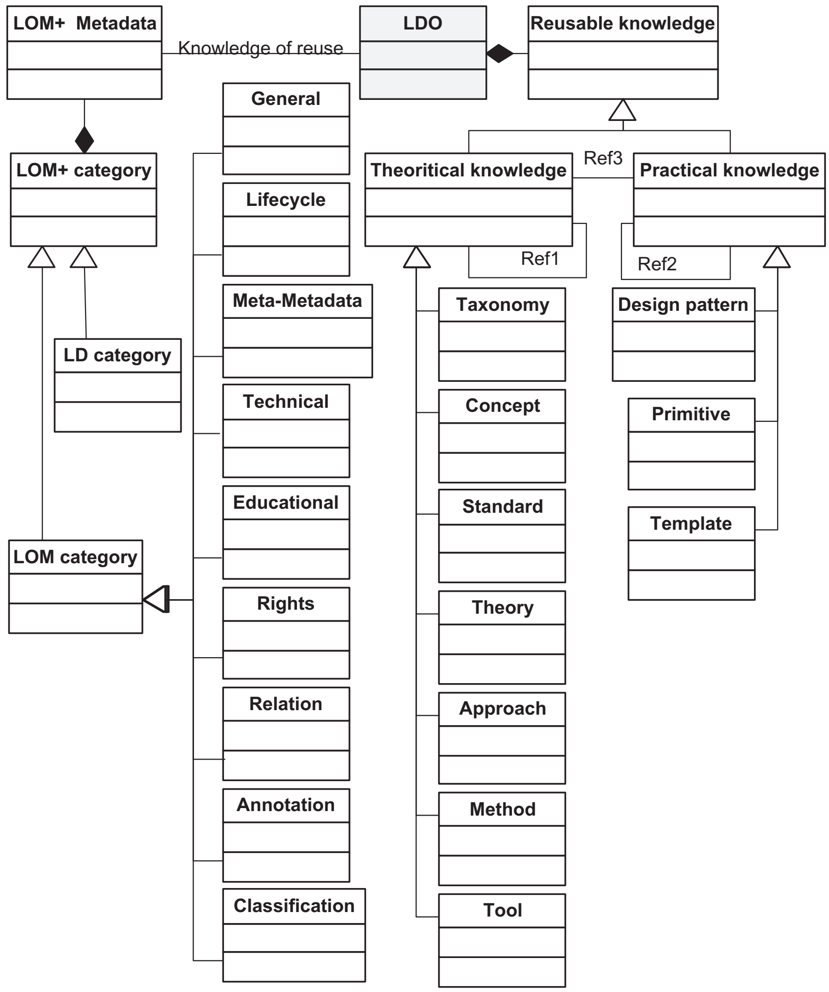

Figure 4 UML class diagram of the general LDO model.

degree of customization; degree of formalization; and degree of reification) from (Lejeune and Pernin, 2004) in LOM+ to describe the practical knowledge in the LDOs (design patterns; primitive elements; and templates).

6.3. UML representation of the general LDO model

Fig. 4 illustrates the general LDO model using a UML class diagram. It depicts the composition of the LDO and the relationships between its components, which consist primarily of the reusable knowledge described in Section 6.1 and the knowledge of reuse described in Section 6.2. At the top of the figure, the main class ≪LDO≫ is connected to the ≪Reusable knowledge≫ class on the left through a composition relationship and to the ≪LOM+ metadata≫ class on the right through the association ≪Knowledge of reuse≫. Furthermore, the ≪Reusable knowledge≫ class is specialized into two subclasses: ≪Theoretical knowledge≫ and ≪Practical knowledge≫. Each of these subclasses is specialized into further subclasses corresponding to the various items presented in Tables 1 and 2.

In Fig. 4, Ref1 illustrates how a piece of theoretical knowledge (TK) in LDO1 can be related to a TK in LDO2; for example, a theory may be based on a particular concept, or a method may be based on a particular approach. Ref2 illustrates how a piece of practical knowledge (PK) in LDO1 can be related to a PK in LDO2; for example, a design pattern may use a particular template or primitive element. Finally, Ref3 shows how a TK in LDO1 can be related to a PK in LDO2; for example, a design pattern may be based on a particular theory. The ≪LOM+ metadata≫ class contains various metadata describing the knowledge of reuse, as discussed in Section 6.2. The metadata categories are provided through a composition relationship with the ≪LOM+ category≫ class. This former class is specialized into ten subclasses corresponding to the nine LOM categories through the ≪LOM category≫ subclass and to the tenth ≪LD category≫ category through a direct specialization. Finally, the ≪LD category≫ class contains the ten metadata described in Table 3.

7. Learning design support framework

We now discuss the proposed learning design support framework (LDSF). This framework illustrates the use of the general LDO model presented in Section 6. The architecture in Fig. 5 is constructed around four main components, whose functional details are described as follows:

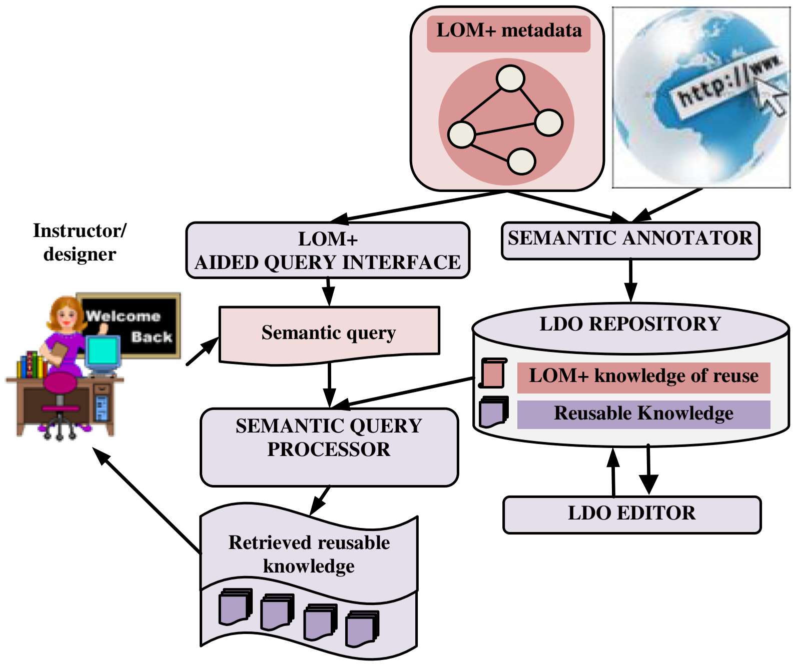

Figure 5 Learning design support framework.

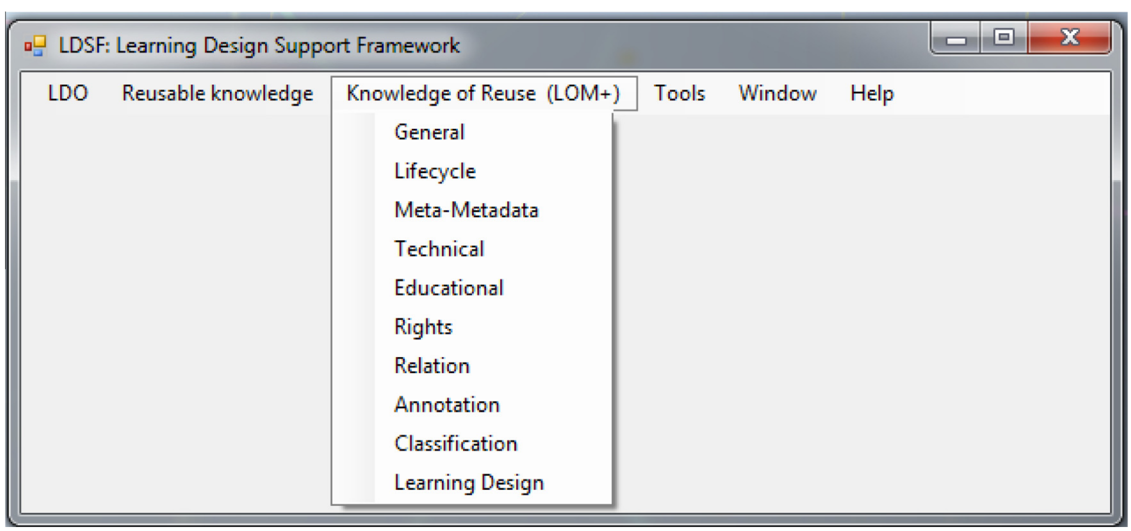

Figure 6 First prototype of the learning design support framework – main interface.

- **The LDO repository** represents the knowledge, including both theoretical (literature reviews) and practical (best practices).
- **The LDO editor** enables indexing, use and reuse of LDOs contained in the repository.
- **The semantic annotator** exploits the LOM+ metadata to annotate the reusable knowledge. This module outputs those LDOs in which reusable knowledge is tagged with LOM+ metadata. Semantic annotation adds diversity and richness to the search process and helps to resolve the ambiguity of natural language when translating notions into a formal computational language. By communicating to a computer how data items are related and how these relations can be evaluated automatically, it becomes possible to process complex filter and search operations.
- **The LOM+ aided query interface** helps instructors to formulate semantic queries using LOM+ metadata at various levels of specificity in the LOM+ hierarchy.
- **The semantic query processor** renders the proposed framework capable of processing the LDO queries of instructors. The output of the query interface sub-module is a semantic query that is passed to the query processing engine to obtain relevant reusable knowledge from the LDO repository.

Education reform is one of the largest workshops in the e-Algeria program (2009–2013). Several Algerian universities already have a platform for distance education, such as ≪UABT-EAD≫, a Moodle platform, at the University of Tlemcen <http://www.univ-tlemcen.dz>. These universities aim to

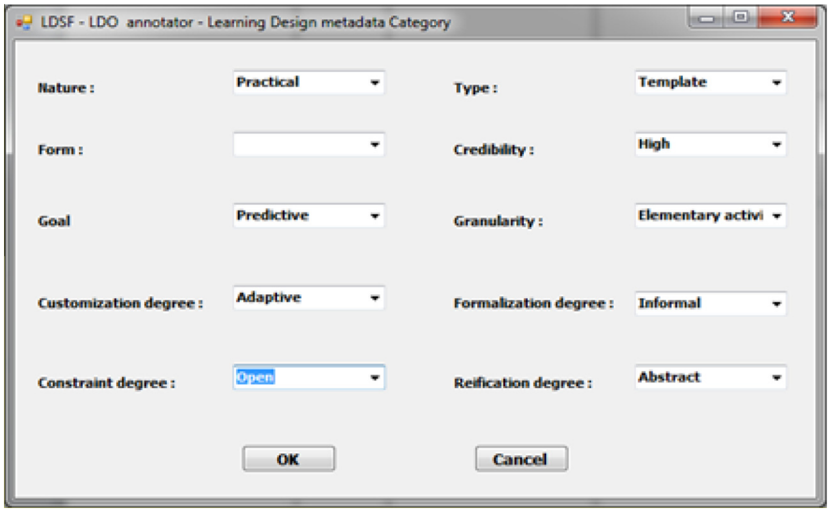

Figure 7 Learning design metadata editor screen.

improve the quality of learning of their students within the new educational system known as ≪LMD: License-Master-Doctorate≫. The LMD system requires substantial personal and cooperative effort through learning management system platforms and other e-learning tools.

A first LDSF prototype, presented at the beginning of this Section, has been developed to help instructors build an LDO repository at the University of Tlemcen. A brief survey was conducted on active instructors at the Department of Computer Sciences. Our aim was to determine how the instructors were using the LDSF. One of the participants, an experimented instructor in an object-oriented methodology course, stated that: ≪By using the tool, I was able to gain insight into the most popular design patterns related to IMS-LD specification. More than that, I was then able to create my own pattern related to problem-based activities≫. Another instructor of the database course found that the tool provides him with the appropriate theoretical resources to achieve his design objectives. These qualitative evaluations indicate that the LDSF will most likely receive an excellent reception by instructors at the university level. Note that as of now, the LDO repository includes more than 100 LDOs whose reusable knowledge is theoretical (selected from well certified web sources of knowledge) and less than 10 LDOs whose reusable knowledge contains IMS-LD based design patterns (developed locally).

Fig. 6 shows the main interface of the LDSF prototype.

Fig. 7 shows a screen shot of the metadata editor for the LD category of LOM+.

8. Conclusion

The high costs of design and development in e-learning and the challenge of restraining those costs cannot be denied. In this paper, we have presented a general LDO model to provide design support for instructors. LDOs are considered to be a subclass of LOs. The model is described using a new metadata category known as the ≪Learning design≫ category, which we have added to LOM to obtain the LOM+ metadata language. A novel aspect of this approach is the collection of various structures (based on either theory or practice) within the same reusable LDO entity to assist instructors in their design. However, although LDOs provide useful design support for instructors, they do not comprise a complete solution for their LD needs. A more efficient support system would include a complete set of CAD or authoring tools to aid instructors in building new scenarios. To the extent that LDOs can foster effective LD by introducing good LD theories, propagating LDs patterns, and promoting collaboration and sharing of best practices, they can play a major role in the improvement of educational design. We are currently improving the initial LDSF prototype to make it more user-friendly and intuitive. We hope to broaden the use of this prototype to other departments at Tlemcen University and other universities worldwide to further evaluate the effectiveness of LDOs in providing design support to instructors.

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