DOI
https://doi.org/10.3233/AO-170176

Handle
http://hdl.handle.net/10609/149598

An Ontology-driven Framework for Specifying, Adapting and Implementing Educational Settings

Àngels Rius[1], Jordi Conesa[1], Elena García-Barriocanal[2], Miguel Ángel Sicilia[2]

[1]Estudis d'Informàtica i Multimèdia, Universitat Oberta de Catalunya,
Rambla del Poblenou, 156, E-08018, Barcelona, Spain
Fax number: +34 933 568 822, Phone number: +34 933 263 740
mriusg@uoc.edu, jconesac@uoc.edu
[2] Computer Science Department, University of Alcalá
Ctra. Barcelona Km 33,600.28871. Alcalá de Henares (Madrid), Spain
elena.garciab@uah.es, msicilia@uah.es

Abstract: Learning institutions can work in very different manners, but they all share many common and regularly repeated processes. The unambiguous specification of both the processes involved in educational activities and how to adapt such processes to different contexts have not been covered by standards and specifications up to now. Therefore, processes are usually defined from scratch, even when they share and can reuse a great deal of other processes. Taking into account all learning institutions share many common and regularly repeated processes and the high number of information systems involved in educational activities, this lack of specification, reutilization and integration may be very limiting; making the deployment of educational processes repetitive and costly, while they could be easily automated. The goal of the presented research is to address this problem, by providing a system to facilitate the specification of educational processes, to promote their reusability and adaptability and to automate their implementation. To do so, the paper presents an integrated ontological framework that allows creating (or reusing) generic educational processes, adapting them to the particularities of each organization and generating part of their implementations. The framework has been constructed integrating different existing ontologies by providing an intermediate ontological level that connects them. The paper describes the details of the framework, evaluates its feasibility, shows some of its limitations and provides its improvement opportunities. The evaluation was carried out in the context of the Universitat Oberta de Catalunya (UOC), a real, complex and representative educational setting.

Keywords: Educational settings, Ontologies, Mapping, Reuse, Data sharing, Workflow management

1.Introduction

Virtual Learning Environments (VLE) are increasingly being used by educational institutions to support their daily activities. Nowadays, there are many information systems that habitually deal with educational information such as Learning Management Systems (LMS) and Content Management Systems (CMS). These systems have been designed to support educational processes that occur in learning institutions. Even though learning institutions can work in very different manners, they all share many common and regularly repeated processes, which have not been covered by standards and specifications up to now. One example would be the preparation of a subject before the course. LMS and CMS usually support these processes, but only partially and from a proprietary point of view, hindering the automation of processes and the sharing of information with other learning environments. For example, when a face-to-face university uses blended learning, it will probably have to repeat some processes (such as class preparation) for both environments: face-to-face and VLE.

Research related to LMS implementation has evolved very quickly. Many learning platforms (e.g. Claroline[1]; LAMS[2] or SharePointLMS[3]) or course management systems (e.g. Dokeos[4], ILIAS[5], Moodle[6] or SAKAI[7]) have been developed and there are many specifications of LMS architecture like IEEE Computer Society, (2003); IMS Global Learning Consortium, (2003a, 2006). There are also several standards and specifications about learning objects and their standardization like the ones developed by Advanced Distributed Learning, (2006); IEEE Computer Society, (2002); IMS Global Learning Consortium, (2007, 2012). However, research about how to specify and reuse the usual activities carried out in learning environments that are not part of the learning process, its design or the implementation of both of them is scarce (Burgos, 2010). In consequence, nowadays there are neither standards/specifications regarding educational processes nor sophisticated systems to deal with them. The necessity of these kinds of systems has been recognised long ago in other environments, e.g. in business, resulting in both the creation of enterprise systems such as Enterprise Resource Planning (ERP) and the creation of standard specification languages to specify business processes, such as the Business Process Management Notation (BPMN) (BPMN 2006). Even though there are some tools that allow to specify processes in the educational context using languages similar to BPMN, such as Dodero et al. (2010, 2012), they tend to focus to learning processes only.

[1] http://www.claroline.net/
[2] http://www.lamsinternational.com/
[3] http://www.sharepointlms.com/
[4] http://www.dokeos.com/es
[5] http://www.ilias.de/docu/
[6] http://moodle.org/
[7] http://sakaiproject.org/

Having systems with purposes similar to ERP would be useful in order to progress to more advanced LMS. The first task to create such systems will be to provide ways of specifying processes in educational institutions, similar to the BPMN, and to adapt them to different contexts, i.e., customization in ERP systems. To do this, it is necessary to define process patterns in learning environments. These patterns should specify implicit knowledge about the different actions performed in learning environments and the effect of each of these actions. If the patterns are specified formally, they can be shared across different organizations and understood by their systems, greatly facilitating the integration of generic processes in several environments and/or institutions. Furthermore, the use of patterns will be advantageous for the redefinition of learning processes, innovation and implementation and future LMS standardization.

Rius et al. (2013) provided a framework to improve the reusability of formal specifications of generic processes that usually occur in educational institutions, regardless of the organization and the learning platform that supports them. This framework allows to specify and share generic processes that occur in educational contexts. Rius et al. (2014) also presented an OKI-OSID metamodel to specify how the processes should be implemented, as well as a system to generate automatically partial implementations of these processes from the OKI-OSID metamodel in Open Knowledge Initiative (2003). These two works are not connected, so generic processes can be specified, but neither reused nor adapted to a given institution. Therefore, from the specification of a generic process there is not a systematic way to generate automatically its implementation. The current paper solves this problem providing a framework that allows creating general processes, reusing and adapting them in the context of educational institutions and generating their implementations semi-automatically. The presented work expands the previous works by providing the framework with the element it lacks; an element that allows generic processes to be adapted to given educational institutions and their link to an implementation profile, that simplify and automate part of its implementation and integration to different learning platforms.

A prototype based on this framework was created to test its feasibility and usability, which gives support to the formal processes representation, its adaptation to specific educational organizations and its definition in terms of an implementation profile.

This paper shows the first framework that has been created to specify processes that usually occur in specific educational institutions taking advantage of generic processes, adapting them to different organizations and according to a given implementation profile. The work also provides an integrated framework to deal with educational processes at different levels (conceptualization, design and implementation) increasing the applicability of the previous work in real environments. Regarding to ontologies research field, the paper also contributes showing how several ontologies can be integrated in a system in order to facilitate the specification and sharing of educational processes and to automate their implementation.

The paper is organised as follows: After an introduction, section 2 presents the difference between learning and educational processes as well as the importance of the educational scenarios to define them. In section 3, the ontological framework proposed is outlined and detailed, concretely It is shown the level of generic educational processes (subsection 3.1), the level of the organizations (subsection 3.2) and the level of implementations (section 3.3) are shown as well as their integration as a single framework. Section 4 deals with the framework evaluation and testing, so the implementation of the proposal is detailed and an overview of the case study is presented before evaluating the framework's feasibility and usability. Finally, conclusions and future work are presented in section 5.

2. Learning and educational processes: What they are and how to deal with them

Learning and educational process terminology is commonly used in several contexts with different meanings. To avoid ambiguities, this section deals with the meaning of educational processes and how to adapt them to different contexts.

2.1 What an educational process is and the importance of its context

According to the Oxford dictionary[8] the term "process" is defined as *a series of actions or steps taken in order to achieve a particular end*. The term "learning" is defined as *lifelong process of transforming information and experience into knowledge, skills, behaviours* and *attitude* and the term "educational" is defined as *relating to the provision of education*. Regarding previous definitions, we can define: 1) "learning process" as *a series of actions or steps taken in order to transform information and experience into knowledge, skills, behaviours and attitude and 2*) "educational process" as *series of actions or steps required to carry out a main mission in a learning environment.* This means that educational processes cover a wider context, not only constrained to learning. Therefore, educational processes include not only learning processes but also processes not directly related to learning but absolutely necessary to carry out daily activities in educational institutions, such as planning of new courses or selecting learning resources. These kinds of processes have not been addressed by highlighted specifications or standards such as the IMS LD in IMS Global Learning Consortium (2003b) that have only considered learning experiences from the point of view of learning design, but not from other management aspects required to carry them out.

In this paper, we will consider educational process as a collection of activities that aid the daily work of an educational institution. Such activities usually involve members of the educational institution and resources, both of which are required to achieve a goal related to learning. From the previous definition, we can observe that educational processes may happen before, during or after a learning experience. For example, assignment of students to classrooms is performed before the learning experience, publication of the activities in a course is done during the learning experience and evaluation of the student's final exams is done after the learning experience. From now on, we will use the term process (and processes) to refer to educational process (and educational processes).

[8]http://oxforddictionaries.com/

There are general processes that are carried out in many different institutions and environments. These generic processes can be adapted to different educational organizations according to their context and regulations. Conceptually, the definition of these general processes can be seen as a process pattern that can be adapted to different contexts, so from now on we will use the terms generic educational processes, generic processes and patterns of educational settings indistinctly. The generic processes will need to be adapted according to the environmental factors of the destination. For instance, classroom arrangement process will be materialised in a different manner in a face-to-face learning environment than in a VLE, but even different realizations may share the same general process: classroom arrangement. Then, the real context of a learning process must be taken into account to be able to implement the learning process formally. Then, for each process we must describe, on the one hand, the sequences of activities to be carried out and, on the other hand, the context where they take place. This context includes the people who interact with the process and the resources the process uses. To represent the educational process semantically as a single element, we created the educational settings.

2.2 Educational settings: A way of adding context to educational processes

The educational setting is a composite structure that contains information about the activity performed by the process and the context where the process occurs, as can be seen in Figure 1. In some cases, such activity may be complex, meaning that it may be created by a sequence of more simple activities. For example, the activity of deploying a new subject will be a sequence of different processes, such as the conceptualization of a new subject, the creation of the curricula and resources of the subject, etcetera. The context part corresponds to the scenario where the process occurs. It is defined by the agents that interact with the activity (e.g. teacher, teacher-coordinator or technical academic manager) and the resources used in the activity (e.g. teaching plan, learning activity or a student record file). Therefore, the activity part is used to define “what to do” and the context part “where it will be done and what resources it will consume and create”.

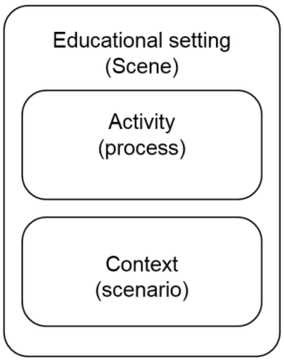

Figure 1- Educational processes as part of educational settings

Some educational settings potentially take place in all educational institutions, with minor changes motivated by the specific environment and the different policies and particularities of the institutions. In order to promote reusability, we can consider a generic educational setting that describes the general elements of the context of any educational institution, i.e. the kind of resources and actors that can be taken into account and participate in any educational institution. Then, the process can be defined generically and, thereafter, adapted to any institution. This adaptation should consider the particularities of the environment that will support education, and the constraints, regulations and particularizations of it. The overall idea is exemplified in Figure 2.

It can be seen in the figure 2 that a general process (Getting the classroom ready) is adapted differently in two universities considering their particularities. Later, the process can be implemented using different technologies. Note that conceptually, the process performed in the five different technological environments is the same. The implementations can be obtained following a refinement of the process at different levels: from conceptual to concrete level (that is from the definition of the generic process to its adaptation to a given educational institution), and for concrete level to implementation level (that is from the definition of a process in a given institution to its adaptation to a given information system). These levels are fully explained in next section.

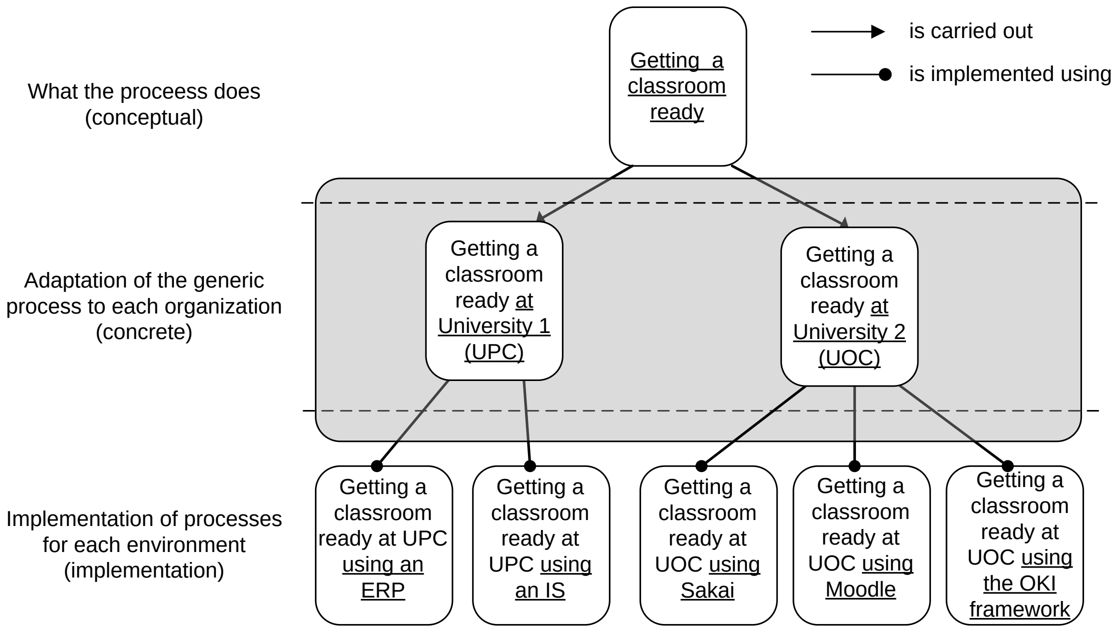

Figure 2- Dealing with educational processes in learning environments. An example of how a process (Getting a classroom ready) can be defined at conceptual, concrete and implementation level.

3. The ontological framework to promote reutilization and implementation of generic Educational Settings

To provide reusability of knowledge in the definition of educational processes through institutions and environments, an ontological framework to represent the knowledge related to educational processes has been created using three different levels of abstraction. Figure 2 provides an example of how the framework would be used conceptually in order to deal with the preparation of a course in two different institutions (UOC and UPC) and implemented in 5 different systems: an ERP and an Information System (IS) for UPC and in Sakai, Moodle and OKI-OSID for UOC. From the most generic one to the most specific, the purpose of each level is:

- What the process does (first - conceptual - level): its goal is to represent generic educational settings. Then, the sequence of activities that compound the educational process and their context are considered. The example of generic process shown in the figure is the course set up, which takes place in all educational institutions and may be composed of the following generic processes: selecting the course teachers, defining the resources to be used, assigning teachers to classrooms, scheduling the course calendar and defining evaluation criteria.

- How to adapt a generic process to an organization (second - concrete - level): it describes how the generic educational settings of the previous level can be adapted to different educational organizations. It should permit specification of the constraints and the policy rules of any institution and how these rules and constrains affect generic educational settings. It is also important to consider the possible participants and resources of each institution. An example could be the adaptation of the course set up from a generic educational setting to the UOC[9] University. To perform such adaptation the possible agents of the UOC should be established: the coordinators of a subject (named as PRA), which is how the coordinators are called in the UOC, and the teachers (named as consultants in the UOC), which are the figures who teach in this institution. Then, some constraints and policy rules particular to the UOC should be defined, such as virtual classrooms being the only ones available at the UOC, the definition of the UOC resources, constraining the schedule according to the academic calendar of the university, the evaluation models used by the UOC, etcetera. Note that, even though the process is concreted in the context of an institution, it is still defined in a generic way. The goal is to define processes that are general and are performed several times, otherwise their specification may be useless. In the case of course preparation at the UOC, the process will be adapted to the particularities of the UOC, but will be general regarding of the subject to be created, the teachers that will participate in the subject, the students enrolled, the place where the course will have place and the semester where the course will be performed. Therefore, we will have several instantiations for each

[9]UOC stands for the Universitat Oberta de Catalunya. A pioneering virtual university in Spain, created in 1994. During the 2013-2014 academic year, it had more than 52,500 students enrolled, 35,000 of them in degree studies. The technological platform where the learning takes place makes it different from traditional face-to-face universities in its pedagogical model as well as the learning organization system.

specified process (Course preparation), once for each application of the process in the real world (e.g. Course preparation for Databases I subject in first term of 2016, Course preparation for Databases I subject in second term of 2016, Course preparation for Maths I subject in the second term of 2016, etc.). In some cases, it may be interesting to create a more concrete process (course preparation of subject Advanced Databases) if it has significant differences with other courses. However, even in such case, the process will be defined generically and have several instances.

- How to implement a process according to the software environment (third level): it is aimed at specifying the knowledge needed to translate the information of the educational settings to a partial implementation in a given software environment. It describes formal specifications of educational settings in terms of their implementation. The transformation of educational settings from formal descriptions to implementation specifications should be carried out according to a given profile, which can be a programming language such as C, an LMS such as Moodle[10], a library or an implementation profile such as OSID-OKI in Open Knowledge Initiative (2003), etcetera. The effective use of this level would facilitate implementation of the specified educational processes in different software environments, enhancing the interoperability of such specifications and reducing implementation costs.

The first (what the process do) and third level (implementing the process in each technological environment) of the framework have been dealt, as isolated approaches, in previous works (Rius et al., 2013) and (Rius et al., 2014). These pieces alone allow to specify and share generic processes in the educational context (level 1) and to specify the implementation of processes in education (level 3). The work described in this paper is focused to integrate the ontologies provided in the levels 1 and 3 to create an unified ontological environment, which act as a bridge to link the abstract information from level 1 (what the process do) to the concrete information of level 3 (how the process is implemented). In order to do so, the current proposal

[10] http://moodle.org/

allows concreting the behaviour of an educational process in a given organization, by adapting the information of the generic process defined in level 1 ontologies. The proposed bridge also specifies how the concretion of such process should be implemented in a given implementation profile (level 3). Therefore, the proposed work allows to define educational processes at different abstraction levels, from the specification of their common parts, their adaptation to any educational organization and their final implementation in different technological environments.

The part of the framework related to the paper is grey-coloured in Figure 2. It includes the design of the framework, the creation of the second level and the necessary mappings to integrate the three levels together. Such mappings should be done consistently to guarantee transformation of formal generic descriptions into specific ones for a given organization and, secondly, adapting them in terms of their implementation. Mappings have been carried out by means of inference rules (using SWRL) and by the definition of constraints (mainly in form of equivalence and generalization/specialization relationships) between concepts and relations across the different levels.

Next subsection introduces the ontological architecture proposed. A detailed description of the different ontology levels and the mappings between them are shown in the following subsections. In addition, each level of the ontology will be exemplified using a real educational process that has been implemented in the presented framework. The example created deals with the preparation of a course at the Universitat Oberta de Catalunya (UOC).

3.1. Ontological architecture of the proposed framework

The framework proposed for specifying, adapting and implementing educational processes is an ontological infrastructure provided with rules and a support tool. The purpose of the rules is to join the different levels of the framework and to create the instances of a given level of the framework according to the knowledge defined in the superior level. The purpose of the tool is to support the user in the process of instantiating the ontological framework. A domain specific language (Brambilla et al. 2012) has been created to facilitate the instantiation process to users without technological knowledge, as can be seen in Rius, Conesa, & Gañan, (2010).

The framework proposed (see Figure 3) follows a three-layer ontological architecture used to formally describe patterns of educational settings (first level), to adapt them to different institutions (second level) and to rewrite them from an implementation point of view according to different implementation profiles (third level). The two main criteria used for designing and building the ontological framework were modularity and the reusability of knowledge. In addition, the multilevel design of the ontology facilitates mappings across different ontology levels, helping to reuse formal knowledge from one level to another.

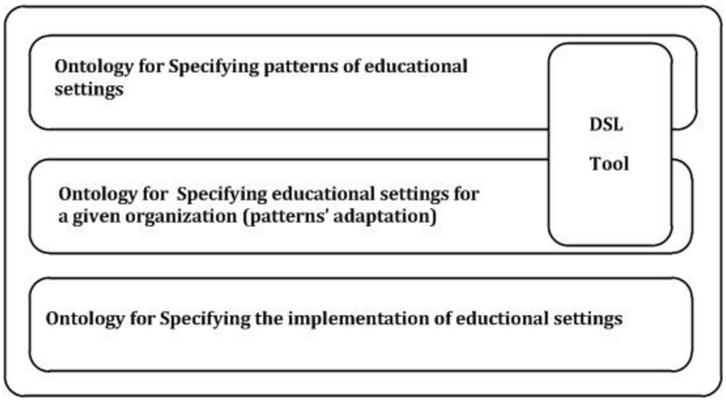

Figure 3- Main framework components

As mentioned above, the descriptions of the educational setting and its patterns require an implementation profile in order to be expressed in terms of its implementation. Even though the implementation profile may depend on the context (Java, Moodle, OKI-OSID, etc.), one profile has been integrated into the framework in order to prove its usefulness and to show the readers how integration of profiles can be done. The chosen profile was the Open Service Interface Design (OSID) specification proposed by Open Knowledge Initiative in Open Knowledge Initiative (2003).

3.2. Specifying generic educational settings

First ontology level[11] allows the specification of generic educational settings that is the general part of the educational setting that can be shared by all institutions. As aforesaid, a generic educational setting is composed by information of both its function and its context.

In order to describe both parts formally, two ontologies have been created (more details can be seen in (Rius et al., 2013):

a) The ontology of educational scenarios *ontoED*[12]. It has been created to define the type of context where processes take place. At this point, we are not able to identify which staff will be involved in a given process, but we can identify whether the process requires the intervention of teachers, students, or if lectures are involved, for example. Therefore, it defines the kind of resources and the kind of participants involved in educational processes, as well as other generic characteristics such as the grading. In our particular example, the participants involved in the process are *teacher coordinators*, the *teachers* and the *technical management staff* that gives support in the creation/management of classrooms. The resources that will participate in that process will be of the following types: *teaching plan*, *lessons*, *exercises*, *learning resources*, *institutional repository* (if any), *course calendar*, etc. Most of these types are predefined, so in most of cases no modification of the ontology will be necessary.

b) The ontology of generic educational processes *ontoProc*[13]. It provides a formal description of the generic processes in terms of other reusable processes and generic participants and resources. Special attention is given to the specification of how the processes are composed, how the processes are sequenced and the possible data flows between processes. The concepts of this ontology are generic and can be understood as

[11] The definition of the framework for specifying, reusing and implementing Educational Settings can be retrieved from http://hdl.handle.net/10609/17621
[12] The definition of Educational Scenarios ontoED can be retrieved from http://hdl.handle.net/10609/17661
[13] The definition of the ontology of generic educational processes ontoProc can be retrieved from http://hdl.handle.net/10609/17521

generic or parameterized concepts. They have been implemented using metaclasses. The ontology will provide also two metaclasses (*ParticipantType* and *ResourceType*) as interface with the ontology that defines the context where the processes occur (to define the kind of participants of a given process or the kind of resource sent in a data flow). Processes will be specified by using a metaclass called *Process_Type*, which will be instantiated once per specification of the process in different institutions. This metaclass can be defined as a syntactic metaclass specification (see Harel & Rumpe, (2004)). In the current example, the processes needed to prepare a course include: (1) the teaching plan, (2) the distribution of teachers in classrooms, (3) the course schedule and evaluation criteria, (4) the design of learning activities to be carried out by students, (5) the definition of calendar, (6) the creation of the classrooms, and other. In addition, a minimum context of the process should be defined, by indicating the expected kind of agents that participate in the process. These agents are defined as instances of the metaclass *ParticipantType* in order to restrict the range of agents that can access the classroom. An example of such instances would be the classes that denote teachers (*Teacher* class from the OntoED ontology), coordinators of the subject (*CoordinatorTeacher* class from the OntoED ontology) and students (class *Student* from the OntoED ontology).

The *Participant* and *Resource* classes were created to integrate both ontologies (see Figure 4). *Participant* denotes any agent that may participate in educational settings. Therefore, it is the supertype of all types of participants defined in *OntoED*. *Resource* contains all the resources that can be used by educational processes and, therefore, it is the supertype of all the types of resources defined in *OntoED.* These classes are related to the metaclasses *ResourceType* and *ParticipantType*, whose semantic are the kinds participants and resources related to educational processes. For example, in the generic process of preparing a subject, one resource type to take into account is the calendar. Then, when preparing a subject in the first term of 2017, the calendar of the 2017 term will be an instance of the class *Calendar*, which defines all the possible calendars that can be used in educational institutions and is an instance of the *ResourceType* metaclass.

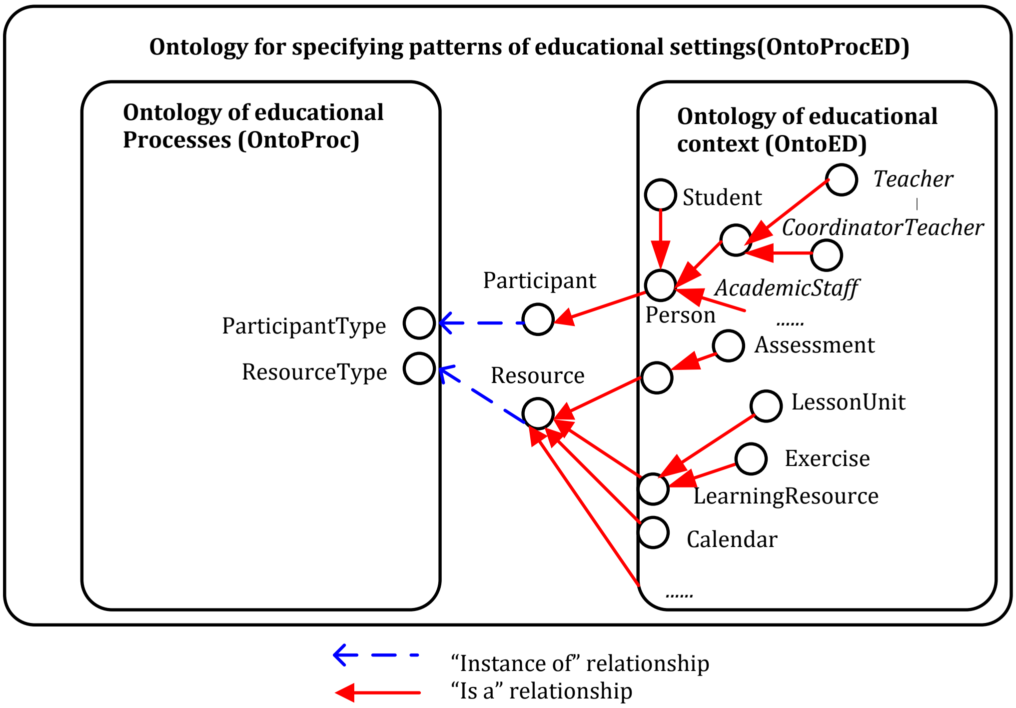

Figure 4- Ontology for specifying patterns of educational settings as integration of two ontologies.

In short, a new ontology, called OntoProcED, has been created from the integration of OntoProc and OntoED ontologies to represent generic Educational settings[14]. The integration has been done generating a few new concepts and relations to specialize, instantiate and create new links between ontology concepts. According to the example, the generic classes that have been instantiated in the framework are shown in Table 1. First column shows the name of the instantiated metaclasses, second column shows the number of instances of each metaclass and third column gives some of these instances.

[14] The definition of the framework for specifying, reusing and implementing Educational Settings can be retrieved from http://hdl.handle.net/10609/17621

Table 1- OntoProcED instantiation: the first level ontology population. Parenthesis denote that the instance is a class belonging to OntoED ontology.

Class	#Instances	Instances
ProcessType	17	SearchForSubject GetSubjectType SearchForClassroomTypes SearchForClassroomRatios SearchForEnrollments CountEnrollments AssignNoOpenCourseCode GenerateOpenCourseErrorCode …
ComplexProcessType	2	PrepareCourse PlanifyCourse
ParticipantType	3	CoordinatorTeacher (from OntoED) Teacher(from OntoED) …
ResourceType	43	Subject (from OntoED) Classroom (from OntoED) Enrolment (from OntoED) Repository (from OntoED) Calendar (from OntoED) …
MessageType	61	AskingForPreparationCourse ResponseToPreparationCourse AskingForSubjectType ResponseToSubjectType …
SequenceType	2	SequenceType_PlanificationCourse SequenceType_PreaprationCourse …
ConnectorType	10	AggregationTypePreparationCourse_C1 AggregationTypePreparationCourse_C1 DeagregationTypePlanificatioCourse_C0 SequenceTypePreparationCourse_C6 …
RoleType	4	R_Teaching R_Student R_Management R_System …

3.3. Adapting educational settings to a given institution

Specifying educational settings in the context of an organization requires adapting their patterns to the organization context, which is defined by its community members, particular resources policies and regulations. This specification is done by extending the first level ontology of the framework with a second ontology level[15].

In the current example, the institution considered is the *Universitat Oberta de Catalunya (UOC)* and the specific course to prepare is a generic course in the context of the *Computer Science Degree*. According to the type of agents in to the example, there are two types: the coordinator teacher of the course, called *PRA*[16], and the teachers, called *Consultants* in the UOC. The type of resources considered in this case are the *UOC repository*, the *virtual classrooms* (this course requires two different kinds of classroom: theory and laboratory), the *academic calendar*, the *PAC* (assessment activities at the UOC) to be defined according to a predefined course pattern, a *schedule* of given course activities and so on.

Specific educational settings for a given organization are described adapting generic educational scenarios, as well as the generic educational processes that occur in such scenarios. Such extensions have been carried out by means of ontologies and define the second level of the framework, which is integrated with the first level ontology by matching the particular processes and scenarios to the generic ones. The ontologies that adapt general processes and educational scenarios to a given institution are called *OntoProc_X* and *OntoED_X* respectively, where the suffix *X* is the name of the institution. Then, the second level of the framework will contain one *OntoProc_X* and one *OntoED_X* ontologies for each organization to be dealt with, called *OntoOrg_X*[17]. In the current example, these ontologies would be called *OntoPROC_UOC* and *OntoED_UOC*. A graphic conceptual representation of the second level of the framework as extension of the first can be seen in Figure 5.

[15] The second level of the proposed framework can be retrieved from http://hdl.handle.net/10609/17661
[16] PRA stands for the initial letters of "teacher responsible for a subject" in Catalan.
[17] The ontoOrg_X ontology can be retrieved from http://hdl.handle.net/10609/17621

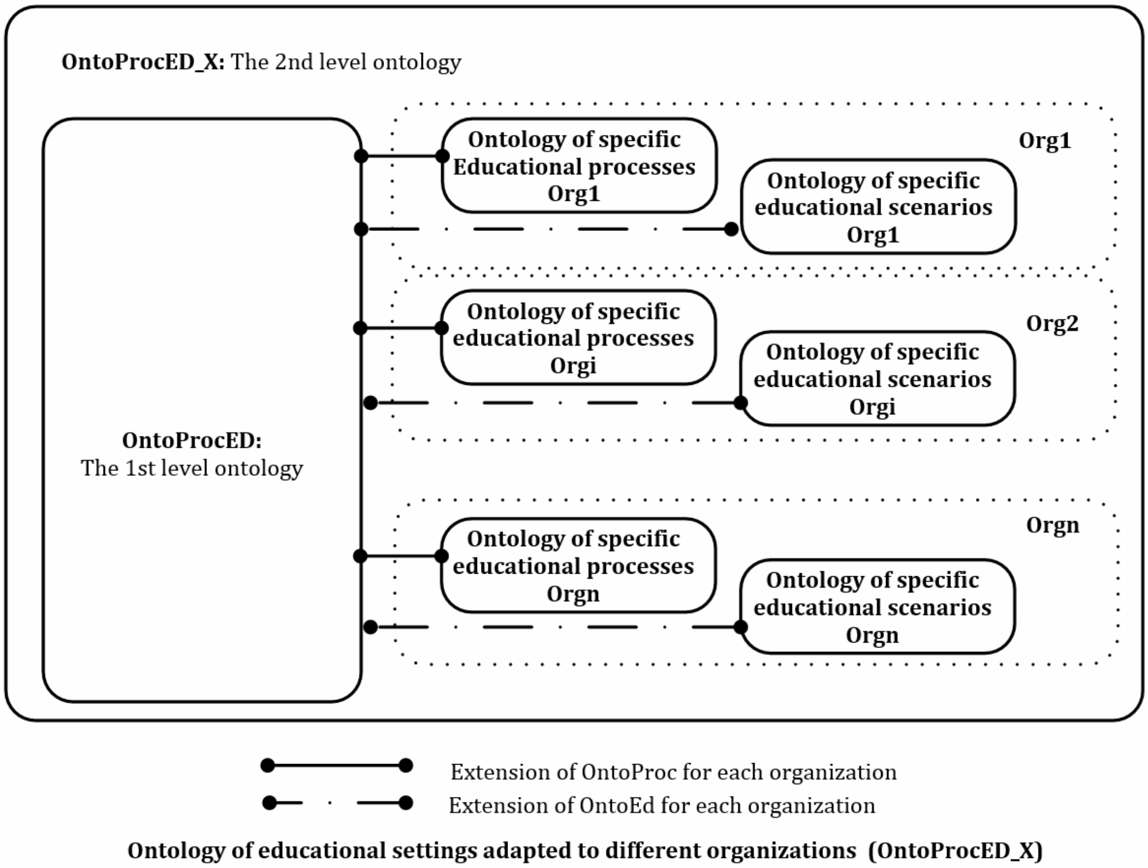

Figure 5- Ontology of patterns of educational settings adapted to different organizations

In the following subsections, the ontologies used to describe specific educational scenarios and specific educational processes for a given organization will be presented independently and their integration will be shown later.

3.3.1. Specifying the educational scenarios of an organization

The ontology *OntoED_X* enables a description of the context of educational settings for a given organization *X*. This context is described by adapting the educational scenario of the previous level. Adapting the educational scenario means: 1) To define possible participant types of the organization, 2) To define possible resource types the organization processes deal with, and 3) To specify a set of constraints and rules that represent the policies and regulations of the organization. This specification is carried out in the ontology called *OntoED_X* by means of specialization of the classes and the relationships of the first level *OntoED* ontology, as well as creation of new classes, relationships and constraints from scratch when necessary.

As mentioned before, participants, resources and ranges of values for defining a specific learning environment are in fact a specialization of generic kinds of participants, resources and enumerations of all learning environments. For instance, although every educational organization has academic staff, technical management staff and students, they do not usually play exactly the same role in all organizations and they sometimes have different names. Therefore, it is necessary to redefine participant types (*academic staff*, *technical management staff* and *students*) for each organization. This redefinition should take into account their particularities and the names used for each of them in each organization. The same can be said with regard to resources, which are defined according the particular organization's needs and sometimes have different names, are defined differently or may contain different data. Likewise, the ontology uses enumerated types (i.e. *types of marks*, *types of evaluation models*, *different enrolment-status*) to take into account different values for each institution.

Therefore, the ontology refines and adapt different generic concepts described in the ontology of educational scenarios to customize the educational scenarios for the particularities of each organization.

3.3.2. Specifying educational processes of an organization

The goal of *OntoProc_X* is to describe how educational processes are performed in a given organization, which means taking into account the idiosyncrasy and rules of the institution in question. Note that this ontology only deals with processes, not with their context. In particular, the context of processes: the agents that interact with them and the resources they use in are not defined in this ontology but in the *OntoED_X*.

If there is a generic educational process to be adapted, it will be used as starting point; otherwise the process may be created from scratch.

In the current example, we refined the two generic educational processes created in the previous level in twelve new processes that indicate how the preparation of a course should be performed at the UOC. Figure 6 shows the map of adaptations. The generic educational processes refined are presented in blue, while the specific educational processes defined according to the UOC institution are in red.

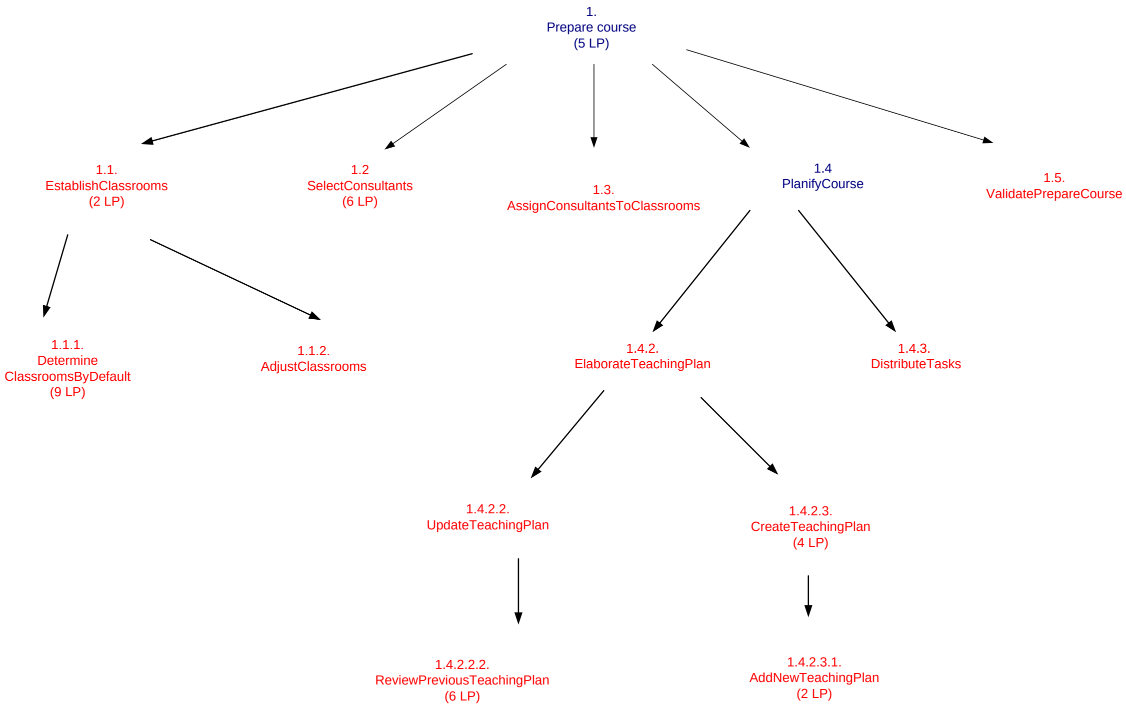

Figure 6- Adaptations of the generic educational process of Preparation of DBI Course to the particular case of the UOC.

The concepts of this ontology are similar to the concepts of the *OntoProc* ontology from the first level, but differ in the abstraction level. There are two main differences between them: the concepts of this ontology are classes while the concepts of the first level are metaclasses and the participant and resource concepts in this level are described as part of the specific educational scenario in another ontology. These differences makes necessary to instantiate the generic processes defined in the *OntoProc* ontology in terms of the the *OntoProc_X* ontology. The further adaptations will be done by using these instantiations as a basis. As aforesaid, such instantiation is related with notation more than with semantics.

3.3.3. Integration of specific educational processes and educational scenarios for a given organization according to generic educational settings

The methodology that a designer should follow to adapt the patterns of educational settings to a given organization is made up of the following phases:

1) Creation of a taxonomy of participants involved in the specific educational context under definition. These participants can be community members or software programs. Community members are defined as specializations of the *Person* class from the educational scenario ontology (*OntoED*). In the case of the UOC they are called *Member_uoc* as it can be seen in Table 2. Software programs should be defined as specializations of the *System* class, which is a specialization of *Participant* and disjoint with the *Person* class. In the current example, this adaptation means, for instance, to specify that the academic staffs of the UOC are the *PRA* plus the consultants. The full adaptation of the generic processes in the case of the UOC institution is shown in Table 2.

Table 2-Participant taxonomy extended for the UOC in the case example

Generic Classes	Specific Classes
Student	Student_uoc
Teacher	Consultant
CoordinatorTeacher	PRA
TechnicalManagementStaff	TeachingSupport_uoc

Person	Member_uoc
	    ClassroomMember_uoc
	      TeachingMember_uoc
	        PRA
	        Consultant

In Table 2, a new class specializing the class *Person* has been created: the *Member_uoc*. This class has been specialized in *ClassroomMember_uoc*, which are all the persons that may have access to a classroom. These persons include teachers and coordinators, denoted by *TeachingMember_uoc* class.

2) Creation of a taxonomy of the specific resources that will be used in the specific educational settings. These resources will include the courses of the organization, which will be created as subclasses of the class *Course*, the different learning activities, which will specialize the *LearningActivity* class, the different teaching plans of the

organization, which will specialize the *TeachingPlan* class, and so on. If a resource does not match any of the predefined types, it should be defined as a new specialization of the *Resource* class. Regarding the current example, Table 3 shows the main changes that have been carried out to adapt the resources of the generic process to the case of the UOC organization.

Table 3- Resource taxonomy extended for the UOC in the case example

Generic Classes	Specific Classes
LearningActivity	EC_activity PEC Practice EvalFinal_activity Exam PV
TeachingTaskAssignation	TeachingOrderAssignation
Course	Course_uoc
Classroom	Classroom_uoc
Material	InformationSources SupportTools Software LearningModules
Resource	CoursePart ClassroomPart DeliveryMailbox Forum BoardClass QualificationRecord

As can be seen in the table, learning activities at the UOC institution may be of different kinds: final evaluation activity by exam (*Exam* class) and a validation test (*PV* class) to validate that the student really did the activities related to his/her formative assessment[18] and continued evaluation activity, which can be theoretical (*PEC*) or practical (*Practice*). There are other specific resource classes that have been created more for

[18]At the UOC, there are subjects where formative assessment is conducted. Then, the student carries out several activities during the course, which are reviewed and marked and are used to give feedback to students, allowing students to improve their knowledge/competencies. In these cases, at the end of the semester, a test, called “Validation Test”, is performed in order to guarantee that the student really did the activities. Such test contains questions related to the activities done by the student.

managerial reasons, such as the class *CoursePart*. This class refers to the elements of a course that are managed for the technical support at the UOC, although they are accessible by all course members. When these elements refer to a classroom, class *ClassroomPart* is instantiated to represents all the classroom elements updatable by the classroom members. Some examples of this kind of element are the classes *DeliveryMailbox*, *Forum*, *QualificationRecord* and *BoardClass*.

3) Creation of a taxonomy that defines the relevant kinds of resources and agents and the policy names followed by the organization. For instance, different kinds of subjects, learning resources and marks must be defined by each educational organization although they may have different values depending on the institution. Regarding subjects, different kinds of subjects for a given organization X should be instances of the *Subject_Type_X* enumeration class, which is a specialization of the *Subject_Type* enumeration class. This class is abstract and should be defined for each educational institution to define the possible different types of subjects. Furthermore, *Subject_Type_X* class, *LearningActivity_Type_X* and *Marks_Type_X* should be also specializations of the *Enumerated* class through its generic classes respectively. In the current example, this step will imply to specify that the possible marks of a Learning activity is the set *{A,B,C+,C-,D}*, or defining the different kind of classrooms that the UOC has *{virtual classroom, virtual laboratory}*. Table 4 shows different adaptations of the enumeration classes done in the running example.

Table 4- Enumeration taxonomy extended for the UOC

Generic Classes	Specific Classes	Generic Classes	Specific Classes
ParticipantType	MemberType_uoc ConsultantType_uoc	TaskType	TaskOrder_uoc
MaterialType	MaterialType_uoc	CalificationType	CalificationType_uoc CalificationTypePV_uoc

4) Instantiation of the *Process* class defined in level 1 of the ontology of processes (*OntoProc*) with all the specific processes that take part in the educational setting for the given organization. See figure 6 for an example the implementation of this phase in the current example. Each defined process has its corresponding class. Therefore, even though processes are narrowed to an institution context, they continue being generic. By generic we mean that they specify how what a given process should do but not the way a process has been performed in a given context. So each time the process is executed, it can be specified as an instance of the process class. Examples would be instantiations denoting the preparation of the subject Databases I in January 2017 and of Maths I at June 2017. However, it could be interesting to create a more concrete process (the creation of a database subject) when the process differs significantly from other processes.

5) Creation of the relationships between processes and their related participants and resources within their particular context. The kinds of relationships to be created are the same as those used in the first level of the ontology framework: processes with participants who interact with them and resources used within processes. In the current example, this can be done by indicating that the teacher assigned to a classroom may be different according to the kind of classroom we are dealing with (see table 5). For example, for a theoretical classroom (*TheoClassroom* class), we need a theory teacher (*TheoConsulant* class), and for a laboratory classroom (*LabClassroom* class), the required teacher is a practice teacher (*LabConsultant* class). Note that specialization between relationship types (or a relationship type refinement (Costal & Gomez 2006)) can be done to define the adaptation more completely. In the presented example, a relationship type that specializes the aforementioned relationships is created, defining that the UOC teachers (*Consultant* class) are the only ones that can be assigned to the classrooms of the UOC (*Classroom_uoc* class). The new relationship constraints the possible individuals of one of its participants (the teacher) according to the value of the

other participant (when the classroom is from the UOC, then the teacher should be an instance of the *Consultant* class).

Table 5-Specialization of relationships at the UOC

Generic Relationship	**Specific Relationship**
ClassroomAssignedToTeacher: Classroom -> Teacher	ClassroomAssigned_uoc: Classroom_uoc -> Consultant TheoClassroomAssigned_uoc: TheoClassroom_uoc->TheoConsultant LabClassroomAssigned_uoc: LabClassroom_uoc->LabConsultant FinalClassroomAssigned_uoc: FinalClassroom_uoc->FinalConsultant

In Table 5, each relationship has a name and its participant types. In the second column, a taxonomy of relationships has been created in order to deal with the original relationship in more detail.

6) Association of the concepts created in the context of organizations with their metaclasses. As aforesaid, it is necessary to check that specific elements of educational settings are created taking into account the constraints defined in their patterns. That is done by defining the elements of a specific educational process as instances of the metaclasses defined in the first level of the ontology.

At the end of the process, we will have a generic process adapted to a given organization. Figure 7 shows the graphical representation of the adaptation process *Determining classrooms by default* (see process 1.1.1 in Figure 6). The process defines in detail how to determine the amount of classrooms necessary to satisfy the needs for a given semester.

The graphical representation shown in figure 7 is based on the BPMN and designed to take profit of its advantages and to get over the obstacles it presents Sicilia et al. (2004). It has been created as a refinement, based in a reduction and adaptation, of the BPMN from a semantic point of view, following a philosophy similar to (Karastoyanova, D. et al 2009). The proposed language and the CASE tool created to manage it are described in detail in (Rius A. et al. 2010).

In the Figure 7 the sequence of processes linked by connectors determine the execution flow of the process to be carried out. As it can be seen several UOC repositories are used in, repositories containing data about subjects, classrooms, enrolments as well as some institution rules to take into account to know the ratio per classroom. There are no agents because at the UOC this task is done automatically. However, if this scenario were carried out in another university like the UPC, a face-to-face university, then repositories should change because the catalogue of subjects and types of subjects are different. Also as in the UPC classrooms are physical rooms probably there will be other considerations to take into account at determining the number of classrooms for a similar subject than at the UOC. Furthermore, a technical manager will probably take part in the task of assigning room to classrooms, at least at the ending stage when calculation or supervision is done.

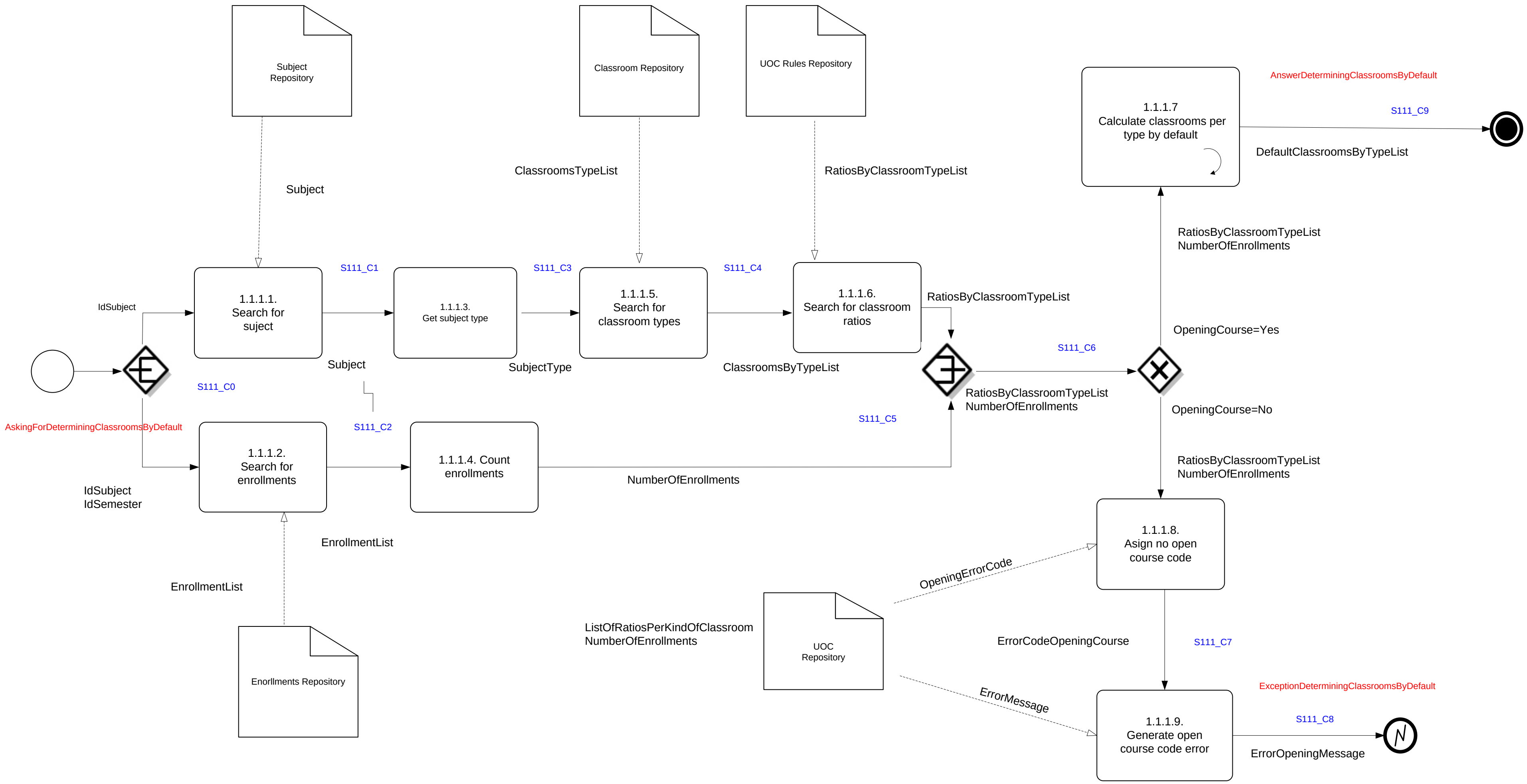

Figure 7- Sequence of educational processes at the UOC scenario describing the educational setting: Determine classrooms by default at the UOC.

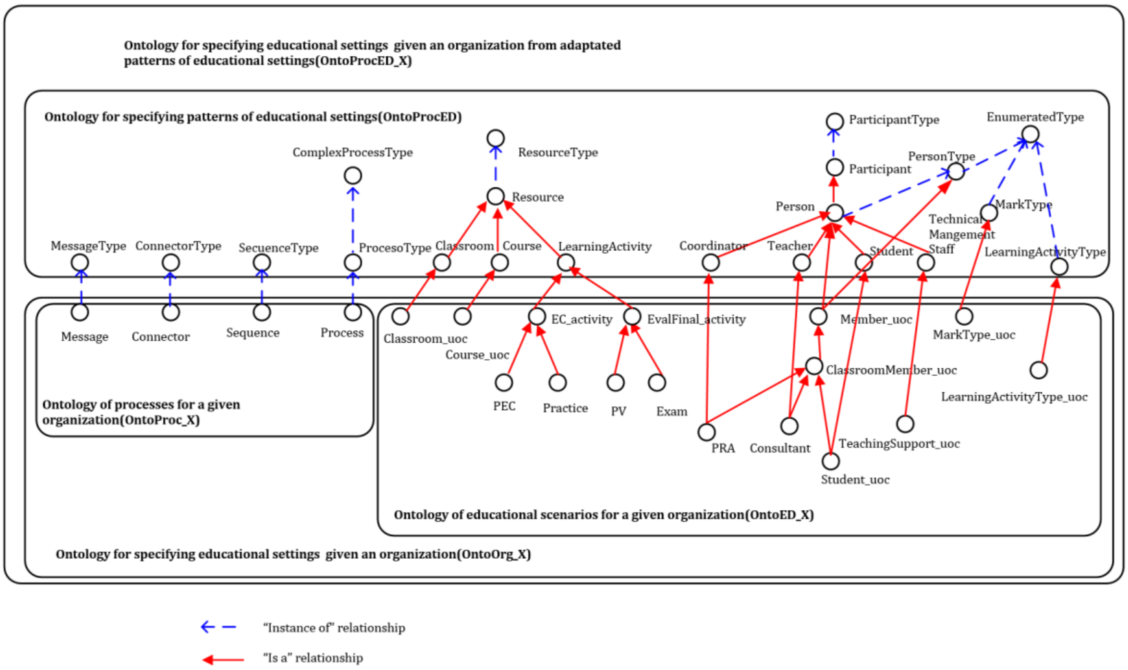

Figure 8- Ontology for specifying educational settings given an organization X as an adaptation of patterns of educational settings.

In short, the integration of the second level of the ontological framework *OntoOrg_X* with its first level *OntoProcED* for a given organization *X* (see Figure 8) is carried out in four parts: 1) adaptation of educational scenarios to the organization (steps 1, 2 an 3), 2) adaptation of the educational processes to the organization (step 4), 3) identification of the participants and resources of the specific process in the organization (step 5) and finally, 3) instantiation of specific concepts from generic ones, in order to guarantee that specific processes satisfy the constraints defined by their patterns (step 6). Figure 8 shows an excerpt of the adaptation process in the case of the UOC. In order to facilitate legibility we avoided to draw the relactionships between the elements of ontoProc_X and ontoED_X. The resultant ontology is called OntoProcED_UOC[19].

As aforesaid, the process defined in Figure 7 will be instantiated for each occurrence of the process. In the creation of the classroom of Database I at first semester of 2017, each element

[19] OntoProcED ontology can be downloaded from http://hdl.handle.net/10609/17661.

shown in the figure diagram will be instantiated. The flows will have specific values according to the executed process, for example the two flows of the left part of the figure will be instantiated defining the code of the subject (05.522) and the identification of the semester 20171, the *enrolmentList* related to the process 1.1.1.2 and the output of the process 1.1.1.2 will be the list of the enrolled students in the subject, and the output of process 1.1.1.4 will be the number of enrolled students. According to the context, some processes of the specification may not be necessary instantiated in the execution. For example, process 1.1.1.7 will not be executed, and therefore instantiated, when the number of enroled students is insufficient to open the subject.

3.4. Specifying implementation of educational settings

The first two levels of the framework give precise, concise and unambiguous descriptions of educational settings according to given patterns. However, such specifications are not related to implementation and, therefore, their implementation cannot be generated automatically. In order to give support to implementation, a third level should be added to the framework[20]: the implementation level.

This new level should describe educational settings from the implementation point of view, defining in detail how the processes will be implemented and how they will access the resources or the agents required to perform their tasks. As the implementation should be suitable for any learning platform, the educational processes may be defined according to different implementation profiles, thus facilitating interoperability.

Developing the implementation level of an educational process for a given implementation profile requires a metamodel of the profile. The metamodel will be used to unambiguously define how the process will be implemented. To do so, the educational settings should be described by means of the implementation profile. That means defining the educational settings as instances of the metamodel of the implementation profile. Such instantiation will be partially automated by defining a set of rules that match the formal specifications from the first two

[20] The third level of the framework can be retrieved from http://hdl.handle.net/10609/17641

levels of the framework to the descriptions of the implementation profile. Therefore, implementation of the educational settings and their educational processes can be partially automated from their specifications. For instance, if there is a need to create classrooms in two different institutions, both can share the same pattern of educational setting although the ratio of students allowed may be different according to the institution rules. Suppose that Moodle is the learning platform used in both, in that case, the creation of classrooms will be carried out according to Moodle procedures, which are defining the implementation metamodel.

Even though different implementation profiles could be used, a third level using the OKI-OSID specification provided by Open Knowledge Initiative (2003) was created in this research. The main contribution of this specification is a set of web services for defining communication between components in learning management environments. Such services and operations are organized in Java and C# packages called OSID. The definition of such web services interfaces can be used inside the system platform or between different learning platforms, because it facilitates the integration of LMS in other technological infrastructures as well as its adaptation to new technologies.

Since the specification of OKI-OSID is mainly technical and it neither provides a conceptual description nor a metamodel, we have used the metamodel of the OKI-OSID implementation profile presented in Rius et al. (2014). We use the term OKI ontology for referring to the OKI-OSID metamodel.

The integration of the OKI ontology with the presented framework consists in defining a set of rules to establish mappings between the ontologies of the framework and the OKI ontology. The goal of these rules is to automatically populate the OKI ontology, by identifying the processes defined in the two previous ontology levels that should have a piece of implementation associated. This kind of integration will facilitate the implementation of educational settings, automatically providing a partial and preliminary implementation that fits with the defined specifications.

The key point in integration consisted in discovering equivalent concepts and equivalent relations between the specification ontology level and the implementation ontology level, and matching them by means of rules. For instance, regarding the first level, the *LearningActivity* concept has a correspondence with two classes in the OKI-OSID specification: *AsssessmentPublished* and *GradableObject*. The *name*, *code*, *description* and *content* of the *LearningActivity* concept in the first level ontology match the *DisplayName*, *Id*, *Description* and *Data* properties of *AssessmentPublished*. In addition, the *evaluationCriteria* property matches the *Description* property of the *GradableObject*. In addition, the *learningGoal* and *evaluationProperties* of *LearningActivity* do not have correspondence with the *AssessmentPublished*, but they can be dealt with properties of the *AssessmentPublished* OSID. Regarding relations, *studentWhoDelivers* has correspondence with the *AgentId* relation whose domain is the *AssessmentTaken* class and the *LearningActivityDelivered* relation does not have any correspondence with the third level ontology. Note that once these relationships are identified and the corresponding rules created, part of the implementation of the learning activities will be automatically done. Therefore, designers will have no further need to deal with such implementation manually.

In the current example, we created several rules to translate the information represented in the first two levels of the ontology to the OKI metamodel. These rules were created using SWRL transformation rules[21] as part of the three-level ontology integration[22]. The next two examples of rules are presented: the first (*Rule-Transf-AcademicCourseToTerm* rule) maps the academic courses (academic semesters in the case of the UOC) to the OKI *Term* class. The second example (*Rule-Transf-AcademicCourseTiedToClassroom*) infers the term in which a course is taught in a given classroom. To do this, the classroom and the term are related to the course according the course classrooms (*CourseSections*) and the course term (*Term*).

---

[21] The transformation rules created to transform data from OntoProcED to OntoOKI can be retrieved from http://hdl.handle.net/10609/25261

[22] The three level Integration can be retrieved from http://hdl.handle.net/10609/25281

Rule-Transf-AcademicCourseToTerm:
AcademicCourse (?x) →Term (?x)

Rule-AcademicCourseTiedToClassroom:

term(?co, ?t) ∧courseSections(?co, ?cs) ∧ course(?co) → term(?cs, ?t)

4. Framework evaluation and testing

This section deals with the evaluation and test of the proposed ontological framework. Firstly, some details about the implementation are provided. Secondly, although different parts of the case study have been presented throughout the paper, an overview is shown to study it as a whole. Finally, evaluation criteria to validate the framework are commented.

4.1. Prototype implementation

Prototype implementation will be presented in terms of the implementation and alignment of the different ontologies developed to create the ontological framework.

Ontologies have been created using OWL (Ontology Web Language) DL, extended with SWRL (Semantic Web Rule Language).

First of all, each ontology has been created taking the UML class diagram that represents its knowledge domain as starting point. Most elements from the UML diagrams have been translated to OWL while others have been represented using SWRL rules.

SWRL has been used mainly to represent: 1) constraints and 2) mappings between different ontology levels. Examples of rules to describe constraints are those that calculate the value of properties from other ontology elements, i.e. which is defined by the following rule, where the *?t* is the term, *?cs* is a classroom, and *?co* is the course where the classroom belongs to:

Rule-AcademicCourseTiedToClassroom:

term(?co, ?t) ∧ courseSections(?co, ?cs) ∧ course(?co)→ term(?cs, ?t)

Other examples of rules used to represent mappings between levels of the ontology framework are:

Rule-Transf-CourseToCourseOffering

Course(?x) → p1:CourseOffering(?x)

Rule-Transf-NameCourseToTitleCourseOffering

Course(?x) ∧ name(?x, ?nc)∧p1:CourseOffering(?x) → p1:title(?x, ?nc)

The first one, *Rule-Transf-CourseToCourseOffering, is used to define* the equivalence between the classes *Course* from *OntoED_X* (second level of the framework) and *CourseOffering* from OntoOKI (third level of the framework). Meanwhile, the second one, *Rule-Transf-NameCourseToTitleCourseOffering*, establishes the equivalence between the property *name* (?nc) of a *course* (?co) in *OntoED_X* with the property *title* (?nc) of a *courseOffering* (?cs) in *OntoOKI*[23].

Furthermore, another part of the proposed ontological framework to have in consideration is a Domain Specific Language (van Deursen et al., 2000) tool created to assist users in the ontology instantiation. It's aimed to identify the graphical elements that represent educational settings to translate them automatically in instances for the ontological framework. The details of the language representation created to represent educational settings and the tool implementation can be found in Rius, Conesa, & Gañan (2010).

4.2. Case study

The ontological framework developed has been tested by using the DSL tool in a real case study. This case study dealt with the preparation of the introductory Database Systems course at the Universtitat Oberta de Catalunya (UOC) for a specific semester. The case study has been implemented in detail, creating the generic processes for the creation of a subject, adapting these processes to the particular case of the creation a subject at the UOC University and finally specifying how to translate such information to an OKI Metamodel. As a result, it was possible

[23] The full ontology integration, OntoProcEDUOC_OKI, provided by Rius, (2016a) can be downloaded from http://hdl.handle.net/10609/25281.

to create partial implementations of the specific educational processes from the process specifications. Figure 6 shows the generic processes created (in blue) and their adaptation in the case of the UOC (in red). Details about what information they contain and how they are adapted are provided throughout the paper.

Each of the learning processes mentioned in Figure 6 has been specified. However, due to space constraints, only a small part of the educational setting given as example has been shown; exactly the process highlighted in Figure 7, called *Determining Classrooms by default.*

4.3. Testing

According to Gomez-Pérez (2001) and Gomez-Pérez, Fernández-López, Corcho (2004), a reference model has to be validated according to correctness, completion and usefulness. The reference model to validate is a framework based on a multi-level ontology defined for an open environment (the learning environment). Since it is not possible to use it for representing all possible educational settings, the completion criterion has been substituted by the feasibility one. The following lines justify that the presented ontological framework satisfy these criteria:

1) Correctness: it must be ensured that the framework does not contain any contradictory constraints and, therefore, it can be satisfied. The Pellet reasoner[24], which is integrated to the Protégé editor, has been used to test the correctness of framework ontologies, their integration and the SWRL rules. From the output of the reasoning, we conclude that the framework proposed is formally correct.

2) Feasibility: it must be ensured that the ontological framework permits specifying the relevant knowledge of the domain of interest: the educational settings. A real, complex and representative educational setting has been chosen as the case study and the framework created has been enough to fully represent it using all the different ontological levels without problems. This case study deals with the preparation of subjects at the UOC and some details have been shown in the paper[25]. As a result of this case study formal specifications of the educational

[24] http://www.mindswap.org/2003/pellet/

[25] The full case study can be seen and checked by downloading the ontology framework from http://hdl.handle.net/10609/25281.

settings have been obtained as an outcome; therefore, we can conclude that the proposed framework is feasible.

3) Usefulness: it must be ensured that specifications obtained from the ontological framework can be useful in educational organizations where educational settings take place. A questionnaire has been prepared to check whether expert domain users consider the framework outcomes useful to them. The questionnaire was answered by a group of coordinator teachers at the UOC.

The parts of the questionnaire relevant for this work are two: 1) a generic part to discover the experience of coordinator teachers at the UOC, 2) an educational setting described by using a textual description by using the DSL notation of our tool. Each part contained several questions to find out the profile of the interviewed, and the perceived usefulness of educational settings definition and whether our proposed representation is better for specifying educational settings.

According to the questionnaire results, users did not miss any element in the provided description of tasks on both representation mechanisms (textual and graphical). Therefore, it seems that the general educational settings considered in the case study fit perfectly into the everyday practice of users. In fact, most of the people interviewed said that the generic educational settings could be adapted to their own experience. Only one of them said that it could only partially be adapted. One of the most remarkable advantages mentioned was the reduction of ambiguity in the definition of educational processes using educational settings.

According on the different representations of educational processes, most interviewees agreed with the fact that textual description is not an agile mechanism and that the graphical notation is more useful and intuitive. However, some of them highlighted the necessity of having more knowledge of the proposed graphical notation in order to take advantage of the educational settings specifications and that an excessive level of detail in the diagrams may play against their comprehension. Quantitatively, we can say that respondents required equivalent time to understand the educational settings in both formats: 6 minutes 42 seconds on average for the textual format and 7 minutes 5 seconds on graphical format. Level of comprehension was also similar in both formats (7.9 over 10 for textual format and 8.2 for graphical format).

From quantitative results it may seem that both formats are equivalent, but it must be noticed that reading a text is a learned ability and interpreting a new graphical notation requires knowledge of the meaning of all the symbols used in descriptions of educational settings. Some users took time consulting information about the semantics of the symbols while they were reading the diagrams. Therefore we believe that using a graphical representation for populating the ontologies of the framework would facilitate its use and the sharing of educational settings.

From all these results, it can be concluded that the use of educational settings was found useful for teachers. Also, the notation proposed to describe educational settings showed to be useful for representing and sharing generic educational settings although its effectiveness have not been tested yet. In addition, some implementation code was automatically generated from parts of the educational setting from the case study. Therefore, the ontological framework proposed also satisfies the usefulness criteria mentioned in the ontology evaluation.

5. Conclusions and future work

This paper shows the application of ontologies to create a framework that permits definition and adaptation of the knowledge of educational processes and finally automate their implementation. The framework facilitates adaptation of specified knowledge to different organizations and environments, promoting reusability of process specifications, at the same time, such specifications help in the implementation of educational processes on any learning platform.

A multi-level ontology that permits representation of educational settings, adaptation and implementation was created. The system created used OWL ontologies plus SWRL rules to represent the knowledge of educational settings and how they are adapted to different institutions and learning management systems. The system was used to test the proposed framework and to validate the feasibility of its implementation.

The ontological architecture proposed was structured on three levels in order to reuse its parts in different contexts. The first level specifies generic patterns of educational settings, without taking into account the institution and the environment where they should be running. The second level refines the first level and specifies the educational settings according to a given educational institution; it is adapting the setting to the agents, roles, and policies of the institution. Finally, the third level refines the two previous levels to specify how the educational processes defined before will be implemented.

Even though from third level ontologies implementations of educational settings can be automatically created, we found that only few parts of educational settings were able to be automatically implemented from the framework. The reason seems to be the implementation framework used (the OKI-OSID), which resulted not complete enough to represent educational settings for specific organizations. This was clear due to the few rules that can be generated in the link between the second level of the framework and the OKI ontology. The reason is that OKI specification is generic and does not deal with organizations' particularities. For instance, it is difficult to find equivalences between the specific participants in a given institution and in the OKI-OSID ontology because the OKI ontology only considers generic members of the educational community.

Taken into account considerations above, the main contributions of the framework proposed are three: 1) A mechanism to create formal descriptions of educational settings adapted to particular educational institutions according to given patterns of educational settings, 2) a mechanism to obtain partial implementations of educational settings to support the automation of its formal specifications given a programming profile and 3) a multi-level ontology to facilitate and encourage the use of the proposed framework, helping users to design educational settings and ontological framework instantiation.

Furthermore, some of the advantages provided by this framework are: 1) it facilitates reusability of specification pattern, both in the same organization and though different organizations, 2) it enables validation of behaviour for new educational processes that are part of educational settings before its implementation, and 3) the analysis required to instantiate the ontological framework can also be used to improve and innovate educational settings as well as the processes associated to them, so it enables a shorter and cheaper development of new LMS functionalities.

Validation of the proposed framework has been tested from the correctness, feasibility and usefulness point of view.

The presented framework and notation can be easily adapted to other domains since the metamodel notation is totally independent of education, the notions of participant/agent, resource and context for processes are also widely applicable, and the application profile can be easily adapted to take into account the peculiarities of different domains. In addition, the three layer architecture facilitates the use of the proposed approach with other domains and the reuse of the elements defined in other ontologies, such as Schema.org[26] or OpenCyc for Semantic Web[27], in different abstraction levels. This integration can be done in different ways, but the easiest way would be to align the concepts of third-party ontologies with the concepts of the first level of the proposal and the individuals of third-party ontologies with the elements of second level of the approach using a linked data approach. Then, for example, the *Teacher* class of our ontology (first level) can be tied to the concept *Teacher*[28] from OpenCyc and the instance *University Oberta de Catalunya* (from the second level) can be aligned to the concept *Open_University_of_Catalonia*[29] from the DBPedia.

Finally, in order to give new uses to the developed framework, we propose: 1) to extend the DSL tool to give support to the instantiation of all ontologies in the framework, 2) adding new functionalities to the DSL tool to extract knowledge shared in the framework, 3) using the framework in a model-driven approach to obtain implementation of learning processes, and finally, 4) constructing a catalogue of educational settings that can be useful when comparing different LMS as the starting point for the standardization of educational processes in learning

[26] http://schema.org/
[27] http://sw.opencyc.org
[28] http://sw.opencyc.org/2012/05/10/concept/en/Teacher
[29] http://dbpedia.org/resource/Open_University_of_Catalonia

environments, 5) Enhancing the presented model with existent ontologies in order to specify other non-functional aspects of processes, such as service agreement (Garcia J.M. et al., 2015).

Acknowledgements

This work was partially supported by the project MAVSEL with code TIN2010-21715-C02-01, and the project TIN2013-45303-P ICT-FLAG, both founded by the Spanish Government.

References

Advanced Distributed Learning. (2006). Sharable Content Object Reference Model Version 1.3.1 SCORM® 2004 3rd Edition Conformance Requirements (CR) Version 1.0. Retrieved from http://www.adlnet.gov/wp-content/uploads/2011/07/scorm.2004.3ed.confreq.v1.0.pdf

Business Process Modeling Notation (BPMN) Specification. Final adopted specification (2006), retrieved 16/10/2009 from http://www.bpmn.org/Documents/OMG%20Final%20Adopted%20BPMN%201-0%20Spec%2006-02-01.pdf

Brambilla, M., Cabot, J., & Wimmer, M. (2012). Model-Driven Software Engineering in Practice (pp. 7–23 de 165). Morgan {&} Claypool Publishers. doi:10.2200/S00441ED1V01Y201208SWE001

Burgos, D. (2010). What is wrong with the IMS learning design specification? constraints and recommendations. In LWA 2010 - Lernen, Wissen und Adaptivitat - Learning, Knowledge, and Adaptivity, Workshop Proceedings.

Costal, D., & Gómez, C. (2006). On the use of association redefinition in UML class diagrams. In Conceptual Modeling-ER 2006 (pp. 513-527). Springer Berlin Heidelberg.

Dodero, J. M., Martínez del Val, Á., & Torres, J. (2010). An extensible approach to visually editing adaptive learning activities and designs based on services. Journal of Visual Languages & Computing, 21(6), 332–346. doi:10.1016/j.jvlc.2010.08.007

Dodero, J. M., Ruiz-Rube, I., Palomo-Duarte, M., & Cabot, J. (2012). Model-Driven Learning Design. Journal of Research and Practice in Information Technology, 44(3), 267–288. Retrieved from https://www.acs.org.au/__data/assets/pdf_file/0016/16702/JRPIT44.3.267.pdf

García, Jose María ; Pedrinaci, Carlos; Resinas, Manuel ; Cardoso, Jorge ; Fernández, Pablo and Ruiz-Cortés, Antonio (2015). Linked USDL agreement: effectively sharing semantic service level agreements on the Web. In: 2015 IEEE International Conference on Web Services, IEEE, pp. 137–144.

Gomez-Pérez, A. (2001). Evaluation of ontologies. International Journal of Intelligent Systemsgent Systems, 16(3), 391–409. doi:10.1002/1098-111X(200103)16:3<391::AID-INT1014>3.0.CO;2-2

Gómez-Pérez, Asunción, Fernández-López, Mariano, Corcho, O. (2004). Ontological Engineering (pp. 107–197). London: Springer-Verlag. doi:10.1007/b97353

Harel, D., & Rumpe, B. (2004). Meaningful modeling: what's the semantics of" semantics"?. Computer, 37(10), 64-72. Retrieved from http://www.wisdom.weizmann.ac.il/~harel/papers/ModSemantics.pdf

IEEE Computer Society. (2002). IEEE Standard for Learning Object Metadata. doi:10.1109/IEEESTD.2002.94128

IEEE Computer Society. (2003). IEEE Standard for Learning Technology-Learning Technology Systems Architecture (LTSA). doi:10.1109/IEEESTD.2003.94410

IMS Global Learning Consortium. (2003a). IMS Digital Repositories Interoperability - Core Functions Information Model Version 1.0 Final Specification. Retrieved from http://www.imsglobal.org/digitalrepositories/driv1p0/imsdri_infov1p0.html

IMS Global Learning Consortium. (2003b). IMS Learning Design Information Model. Version 1.0. Final Specification. Retrieved from http://www.imsglobal.org/learningdesign/ldv1p0/imsld_infov1p0.html

IMS Global Learning Consortium. (2007). IMS Content Packaging Specification Primer Version 1.2 Public Draft v2.0. Retrieved from http://www.imsglobal.org/content/packaging/cpv1p2pd2/imscp_primerv1p2pd2.html

IMS Global Learning Consortium. (2012). IMS Question Test & Interoperability Version: v2.1 Final. Retrieved from http://www.imsglobal.org/question/qtiv2p1/imsqti_oviewv2p1.html

Karastoyanova, D., van Lessen, T., Leymann, F., Ma, Z., Nitzsche, J., Wetzstein, B.: "Semantic Business Process Management: Applying Ontologies in BPM", in Handbook of Research on Business Process Modeling, J. Cardoso & W. van der Aalst, Eds. Information Science Publishing, 2009, 312–330.

Object Management Group. (2009). Business Process Model and Notation (BPMN) Version 1.2. Retrieved from http://www.omg.org/spec/BPMN/1.2

Open Knowledge Initiative. (2003). Open Service Interface Definitions. v 2. Retrieved from http://sourceforge.net/projects/okiproject/?source=typ_redirect

Rius, A., Conesa, J., & Gañan, D. (2010). A DSL Tool to assist specifications of educational settings. In Solo A.; Marsh A;Arabnia H (Ed.), The 2010 International Conference on Semantic Web and Web Services (SWWS 2010) (pp. 112–118). CSREA Press.

Rius, A., Conesa, J., García-Barriocanal, E., & Sicília, M.-A. (2013). Specifying patterns of educational settings by means of ontologies. Journal of Universal Computer Science, 19(3), 353 – 382. doi:10.3217/jucs-019-03-0353

Rius, A., Conesa, J., García-Barriocanal, E., & Sicilia, M.-A. (2014). Automating educational processes implementation by means of an ontological framework. Computer Standards & Interfaces, 36(2), 335–348. doi:10.1016/j.csi.2013.08.003

Sicilia, M.-A., Garcia, E., Sanchez, S., Rius, A., & Pages, C. (2004). Specifying semantic conformance profile's in reusable learning object metadata. In Information Technology Based Proceedings of the FIfth International Conference onHigher Education and Training, 2004. ITHET 2004. (pp. 93–97). IEEE. doi:10.1109/ITHET.2004.1358144

Van Deursen, A., Klint, P., & Visser, J. (2000). Domain-specific languages: An annotated bibliography. ACM SIGPLAN NOTICES, 35(6), 26 – 36.