Deliverable 2.1

Semantic model design

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**Abstract:**

This report will make a state of the art analysis on existing Learning Semantic approaches in order to identify models, ontologies, vocabularies that can be re-used, as well as any gaps that could be filled by the proposed model.

The report will also define and document the Semantically Annotated Learning Object (SALO) model that will enable the semantic annotation of learning objects.

**Keyword List:**

Model, ontology, learning activity, learning content
## Consortium

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List of Abbreviations

The following table presents the acronyms used in the deliverable in alphabetical order.

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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>CAM</td>
<td>Contextualized Attention Metadata.</td>
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<tr>
<td>ESCO</td>
<td>European Skills, Competences and Occupations</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<td>JSON</td>
<td>JavaScript Object Notation</td>
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<td>LA</td>
<td>Learning Analytics</td>
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<td>LD</td>
<td>Learning Design</td>
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<td>LOM</td>
<td>Learning Object Metadata</td>
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<td>LR</td>
<td>Learning registry</td>
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<tr>
<td>LRS</td>
<td>Learning Record Store</td>
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<td>LS</td>
<td>Learning Semantics</td>
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<td>MLR</td>
<td>Metadata for learning resources</td>
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<tr>
<td>NSDL</td>
<td>National Science Digital Library</td>
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<tr>
<td>PBL</td>
<td>Problem-Based Learning</td>
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<tr>
<td>RDF</td>
<td>Resource Description Framework</td>
</tr>
<tr>
<td>SALO</td>
<td>Semantic Annotated Learning Object</td>
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<tr>
<td>SOLO</td>
<td>Structure of observed learning outcomes</td>
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<tr>
<td>XML</td>
<td>Extensible Markup Language</td>
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Executive Summary

The overall aim of the PBL3.0 project is to enhance Problem Based Learning (PBL) with Learning Analytics (LA) and Learning Semantics (LS). Therefore PBL3.0 will produce a new educational paradigm and pilot it to produce relevant policy recommendations. WP2 is responsible for defining and implementing a semantic model for PBL_LA, which will enable the annotation and description of learning resources in order to easily integrate them to the PBL approach and enable their discoverability when setting personalized learning pathways. Furthermore, within this WP an annotation tool for the SALO model will be developed to facilitate the annotation of learning objects and concepts by all learning content providers.

The present deliverable is the first report of the WP and aims to present a thorough State of the Art analysis on existing Learning Semantic (LS) approaches for identifying models, ontologies, vocabularies that can be re-used, as well as any gaps that could be filled by a new learning semantic model. The deliverable also aims to define and document the Semantically Annotated Learning Object (SALO) model that will enable the semantic annotation of learning objects.

The provision of a learning analytics framework for PBL 3.0 requires modelling the methods and activities used that convey the semantics required for the processing of information. This deliverable describes these semantics in the form of a conceptual model based on the identified requirements for learning analytics gathered from deliverable D1.2 “Learning Analytics (LA) Analysis”. The model is based on state of the art standards and specifications for learning resources and activities, thus guaranteeing a high degree of compatibility with current learning technology.

The case study used for the evaluation of the model is presented, also serving as a guide for the implementation of the model. That case study is based on the information provided in deliverable D1.1 “Problem Based Learning (PBL) Analysis”.

In addition to describing the model, the deliverable sketches how the model can be used to record learner data using the framework of the xAPI, that assumes an underlying Learning Record Store as a common repository for the variety of tools and systems the learner interacts with.
1 Introduction

1.1 Scope
This deliverable covers the modelling phase of the PBL 3.0 solution. It is intended to provide the fundamental semantics on top of which the rest of the semantic components of the project can be derived. The expression of the model is that of a conceptual model to allow for a diversity of potential implementations. However, the model covers all the data required to build learning analytics solutions and is comprehensive in that regards.

1.2 Audience
This deliverable is primarily intended to inform the implementation of the rest of the PBL 3.0 project. However, the model reported is not restricted to the specificities of the project and can be used as a blueprint to deploy data gathering and analytic frameworks for diverse PBL implementations outside the scope of the project itself. It can also be useful to a broader audience interested in understanding PBL as an instructional method and its practical implications in assessing its effects and benefits.

1.3 Structure
The structure of the document is as follows:
- Section 2 includes definitions and terminology needed to general understanding of the rest of the document.
- Section 3 shows data models currently used in learning.
- Section 4 describes the most widely accepted formal models and ontologies for learning modelling.
- In Section 5 a model to annotate learning activity in a project-based learning context (SALO model) is defined.
- Section 6 provides document conclusions.
2 Definitions and basic terminology

The following terms will be used within the document:

- Metadata: Data describing the context, content and structure of records and their management through time\(^1\). They are usually provided in schemas.

- Model: A schematic description or representation of something, especially a system or phenomenon, that accounts for its properties and is used to study its characteristics\(^2\).

- Conceptual model: A model made of the composition of concepts, which are used to help people know, understand, or simulate a subject the model represents\(^3\).

- Ontology: formal specification of a shared conceptualization (Gruber, 1993).

- Unified Modeling Language (UML): General-purpose, developmental, modeling language in the field of software engineering, that is intended to provide a standard way to visualize the design of a system (Booch, Rumbough and Jacobson, 2005).


\(^2\) http://www.thefreedictionary.com

\(^3\) https://en.wikipedia.org/wiki/Conceptual_model
3 Data models in learning

Learning is a very complex activity. As such, it can be seen from many different perspectives. There are diverse learning types and approaches to learning, thus when we aim at modelling learning-related activities, entities or processes, the formal representations can widely vary. Quite frequently, these models are later evolved and “ontologised” to end up with e.g. an ontology of learning objects, or an ontology on usage metadata, but we will discuss this in depth in the forthcoming section 4.

In this section, we will focus on the different learning data models, which can be classified into (a) models of usage (such as e.g. Contextualized Attention Metadata (CAM), Activity Streams, Learning Registry Paradata or NSDL Paradata), (b) learning object models (such as IEEE LOM or MLR) and (c) activity models such as IMS Learning Design. The following sections will examine these models focusing on their usefulness and implications from our project perspective.

3.1 Usage metadata

User activities and their usage of data objects in different applications is called “Usage Metadata” or more commonly “paradata”. According to Wikipedia, paradata are defined as “usage data about learning resources that include not just quantitative metrics (e.g., how many times a piece of content was accessed), but also pedagogical context, as inferred through the actions of educators and learners”.

Usage data can come from many sources, e.g. centralized educational systems, distributed learning environments, open data sets, personal learning environments, adaptive systems/ITS, web-based courses, social media, student information systems, and mobile devices (Lukarov et al., 2014). These data sources in the background have centralized educational systems. At the same time, if we want to characterize usage data to enable the representation of user actions across learning management systems, we find that several data representation formats exist for usage data.

In the following subsections we will detail the four most commonly used data representations, namely Contextualized Attention Metadata (CAM), Activity Streams, Learning Registry Paradata and NSDL. Most of the contents in what follows has been extracted from the excellent summary by Lukarov et al. (2014) about the same topic.

3.1.1 CAM

Contextualized Attention Metadata (CAM) allows monitoring user interactions with learning environments, thus allowing modelling a user’s handling of digital content across system boundaries. Once recorded, CAM metadata can be analysed to provide an overview about where (i.e. with which application) and when an action takes place and what happens in the environment.
CAM focuses on usage information (CAM Core), not on information about the resources. Therefore, the most central concept here is the event and neither the user nor the data object as in other models. In CAM, the events have a flexible set of attributes according to a simple abstract scheme that allows storing basic information about an event (see Figure 1. CAM CORE Schema (taken from https://sites.google.com/site/camschema/home)). Other information for each event is stored as entities.

The Event represents the central entry point and is the most granular element. An Event is defined by name, date-time, a reference to a context and connections to other entities (one or more) that represent the participants of this event. An Entity represents persons, documents, applications, devices and further stakeholders. Entities can be part of an Event or a Context. For each Event one or more Entities can be directly connected to the Event. The Session concept includes further information about where the event took place such as domain, IP address and session ID.

The role that an Entity plays in a given setting must be specified and can be e.g. sender, receiver, context, writer, forum or thread. CAM requires some rules to be enforced on the instances of role attribute, and for instance if the role attribute is “forum”, there needs to be exactly one related entity with the role attribute “writer” and at least one with the value "message".

Overall, the information can be serialized in different formats such as JSON, XML, RDF and later stored in those formats or, alternatively, in relational databases.
3.1.2 Activity streams

An Activity Stream (Snell and Prodromou, 2016) is a collection of individual activities carried out by users. In its simplest form, an activity consists of an actor, a verb, an object, and a target. It tells the story of a person performing an action on or with an object -- "Lucas posted a photo to his album" or "Paula shared a video". In most cases these components will be explicit, but they may also be implied. The verb attribute plays the same role as event type in the CAM scheme. It describes an action which is done in the learning activity. Additionally, every object that is within an Activity Streams object can be extended with properties not defined by the core definition and specification and this way a lot of flexibility is provided. Figure 1 shows the knowledge schema of Activity Streams.

Activities are serialized using the JSON format. Alternative serializations may be used but are outside the scope of this specification.

![Figure 1. Activity streams schema](https://www.w3.org/TR/activitystreams-core/)

3.1.3 Learning Registry paradata

Learning Registry Paradata is an extended version of Activity Streams purposefully designed for storing aggregated usage information about resources. The three main elements of Learning Registry Paradata are actor, verb, and object. The actor refers to the person or group that does something, the verb refers to a learning action and detailed information can be stored, and the object refers to the thing being acted upon using a string or a LR Paradata object.

3.1.4 NSDL paradata

The NSDL Paradata format was defined to capture aggregated usage data about a resource (e.g. “downloaded”, “favoured”, “rated”) which is designated by audience, subject or education level (NSDL, 2016). In contrast to the other usage data formats presented so far, this format is not event, but object-centric. Each data object has exactly one NSDL Paradata record, which is identified by a recordId and must contain the URL of the resource to which the paradata record applies (usageDataResourceURL). The most important element is the usageDataSummary, which comprises all available usage statistics/information about a resource using five different types of values.
3.2 Learning Objects metadata

For many reasons such as e.g. efficient retrieval of learning resources from repositories, the learning materials are usually tagged with a set of metadata which describes educational aspects such as the topic of the resource, its author, or the typical learning time, just to name a few. In order to facilitate interoperability and reuse of learning resources across platforms (repositories or learning management systems), learning objects are annotated using metadata standards.

Several metadata standards have emerged for the annotation of learning objects. The following sections will describe the most commonly used.

3.2.1 Dublin Core

The Dublin Core metadata initiative (Weibel and Koch, 2000) is an open forum engaged in the development of interoperable online metadata standards that supports a broad range of purposes and business models. Dublin Core is extensively used because of its flexibility and limited set of mandatory elements. However, although Dublin Core attributes contain metadata such as author, title or granularity –which are useful for describing learning content– this specification does not include attributes describing the pedagogical perspective of a document. This is a shortcoming when describing learning resources aimed at being stored and retrieved from repositories where some kind of pedagogically-aided search must be present. Figure 3 shows the knowledge schema of Dublin Core.
3.2.2 IEEE LOM

Departing and somewhat extending the Dublin Core terms, IEEE Learning Objects Metadata standard (IEEE LOM) is the most widely and extensively used metadata schema for tagging learning resources. It includes metadata classified into 9 hierarchical categories including all kinds of metadata about the object, from general information (e.g. author, title or coverage) to very specific educational metadata such as the typical learning time or the intended end user role (see Figure 4). In this manner, IEEE LOM covers the need expressed in the previous section about a specific metadata schema for tagging learning resources and complements the simpler, more loosely defined set of elements of Dublin Core.

IEEE LOM is an open specification, usually encoded in XML, that can be extended or adapted to any given domain or community of users through a so-called an application profile, a set of metadata elements that make sense for the given domain and are classified as mandatory, recommended or optional elements for such domain.
3.2.3 ISO/IEC 19788 MLR

The ISO/IEC 19788 standard (Figure 4) is a multipart standard prepared by the ISO/IEC JTC1 Information Technology for Learning, Education and Training. It is intended to provide optimal compatibility with both DC and IEEE LOM schemas and supports multilingual and cultural adaptability requirements from a global perspective.

Although both Dublin Core and IEEE LOM are widely used to describe learning resources, there is a number of shortcomings related to interoperability that MLR addresses. For instance, interoperability among data sets is challenging in Dublin Core and IEEE LOM, given that those are described as recommended best practices.

ISO/IEC 19788-1:2011 provides data elements for the description of learning resources and resources directly related to learning resources. ISO/IEC 19788-2:2011 provides a base-level data element set for the description of learning resources, from the ISO 15836:2009 Dublin Core metadata element set, using the framework provided in ISO/IEC 19788-1:2011. Those data elements being cast into the metadata learning resources framework can be used with data elements defined in other parts, in order to address specific user communities’ needs for extensions, modularization or refinement. ISO/IEC 19788-3:2011 is designed to help implementers with a starting point for
adopting ISO/IEC 19788, defining an application profile that specifies, through adding constraints to the use of some data elements, how the ISO/IEC 19788-2 element set can be used. ISO/IEC 19788-4:2014 specifies, using ISO/IEC 19788-1, technical aspects of learning resources, i.e. requirements for use, location, size, etc. Finally ISO/IEC 19788-5:2012 specifies, using the framework specified in ISO/IEC 19788-1, educational aspects of learning resources across various educational, cultural and linguistic settings.

### 3.3 Learning Activities: IMS Learning Design

The IMS Learning Design specification is not strictly-speaking a data model, but instead a global model that allows to model learning experiences from different perspectives. It supports the use of a wide range of pedagogies in online learning by providing a generic and flexible modelling language. This language is designed to enable many different pedagogies to be expressed. The approach has the advantage over alternatives in that only one set of learning design and runtime tools need to be implemented in order to support the desired wide range of pedagogies. The language was originally developed at the Open University of the Netherlands (OUNL), after extensive examination and comparison of a wide range of pedagogical approaches and their associated learning activities, and
several iterations of the developing language to obtain a good balance between generality and pedagogic expressiveness.

The IMS learning design allows describing teaching strategies (pedagogical models) and educational goals. The language is represented in XML which makes it machine-readable: An IMS LD-aware tool is able to "play" a unit of learning. IMS LD is a language for modelling units of study—“the smallest unit providing learning events for learners, satisfying one or more interrelated learning objectives”. A learning design, modelled using the language described in the IMS LD specification, captures who does what, when, and using which materials and services in order to achieve particular learning objectives. Using a XML binding, an XML document instance can be created to describe a learning process. The main idea is that this XML document instance is ‘loaded into’ an IMS LD-aware application and ‘played’. Playing an IMS LD instance implies that once people are assigned into the various roles in the learning process (for example, learners, tutors and mentors), the various activities prescribed in the document instance can be performed.

Figure 6. IMS Learning Design information model (taken from: https://www.imsglobal.org/learningdesign/ldv1p0/imsld_infov1p0.html)

The first version called Final Specification v1 was approved in February 2003 and is composed of 3 parts: IMS Learning Design Best Practice Guide, IMS Learning Design Information Binding and IMS
Learning Design Information Model. As it can be seen, IMS LD represents the most comprehensive view among all the different perspectives of learning, as it models resources, actors, environments and activities.
4 Formal models and Ontologies

We already stated in section 3 that learning is a very complex activity. An ontology, an “explicit specification of a conceptualization” (Gruber, 1993) is a recurrent way to make a formal model of learning as a domain.

According to Genesereth and Nilsson (1987), “a body of formally represented knowledge is based on a conceptualization: the objects, concepts, and other entities that are assumed to exist in some area of interest and the relationships that hold among them”. Thus learning can be modelled by making use of ontologies, but given that it is such a complex domain, there is a good number of efforts each one covering different aspects of learning. This has been studied in the previous section. Here we will see how some of the models described in section 3 are frequently evolved and “ontologized” to end up with e.g. an ontology of learning objects, or an ontology on usage metadata, just to name a couple of examples.

4.1 Typologies, taxonomies and ontologies

Typologies and taxonomies are essentially categorizations, i.e. models developed to classify phenomena into discrete categories. Ontologies are more formal models, aimed at unambiguously modelling a domain for machine understandability and reasoning. As Guarino mentions, “the backbone of an ontology consists of a generalization/specialization hierarchy of concepts, i.e., a taxonomy” (Guarino, Oberle & Staab, 2009) but there are some computation-oriented properties added. Therefore, computational ontologies are a means to formally model the structure of a system, which basically means to model the relevant entities and relations of such system. When we say “formally” we mean that a formal language, often based on first order logics is used, but also that a set of strict rules are enforced and applied.

4.2 Upper ontologies

According to Wikipedia, an upper ontology is “an ontology which describes very general concepts that are the same across all knowledge domains”. Upper-level ontologies make sense because ontologies of multiple domains share a given set of categories that is the same in all these domains. For example, most domains will deal with objects, processes, properties, relations, space, time, roles, functions, categories, individuals or similar. Therefore, upper-level ontologies define and axiomatize these most general categories. The main application of upper level ontologies is to provide semantic interoperability of ontologies across multiple domains. Because upper-level ontologies provide general concepts which are common to all domains, they can provide a common ontological foundation for domain ontologies.
Very frequently, learning ontologies described in the forthcoming sections make use of upper ontologies to avoid reinventing the wheel—for instance when a formal definition of “actor” or “event” is needed. Thus, the annotations of learning entities, or the modelling of learning processes, objects and objectives, is often making use—directly or indirectly—of terms, properties or restrictions defined by an upper ontology.

4.3 Ontologies in e-learning

Al-Yahya et al. (2015) provides a comprehensive survey of key contributions related to the development and usage of ontologies in the e-Learning domain. According to these authors, 4 types of ontologies can be identified: domain ontologies (reusable within a specific domain), task ontologies (describing vocabulary relevant to a generic task or activity), domain-task ontologies (those which represent the vocabulary for a task within a specific domain but are not reusable across domains), and application ontologies (describing vocabulary relevant to a specific application). Sampson et al. (2004) also studied and discussed the role and use of ontologies in e-learning.

The above mentioned authors classify the different applications of ontologies in e-learning according to the following areas:

- Curriculum Modelling and management
- Describing learning domains
- Describing learner data
- Describing e-Learning services

4.3.1 Ontologies in CV modeling and management

Ontologies are used in e-learning for defining major curriculum elements, linking the learning units with objectives and outcomes and also for linking learning units with other learning units. From this perspective, the CURONTO ontology and the Crampon project are the most remarkable efforts:

- The CURONTO ontology (Alfaris et al., 2014) is designed for the general management of an entire curriculum, as well as to facilitate program review and assessment. The ontology model is used to map relationships between learning outcomes, learning units, and overall program objectives.
- The Crampon project (Dexter & Davies, 2009) creates a knowledge base application to manage and maintain the complex interrelationships between curriculum contents. The data elements and entities in the ontology are cases for inquiry–based learning and their learning outcomes.
4.3.2 Ontologies describing learning domains

Online assessment systems often make use of ontologies. For instance, the system described by Kumaran and Sankar (2013) presents a concept map based on assessment from students’ learning. The student creates a concept map, and this map is converted to an ontology, after which a teacher maps the reference ontology and observes how much the student’s ontology covers the teacher’s produced ontology.

The Ontology E-Learning –OeLe– (Litherland et al., 2013) is an ontology-based assessment system which automatically marks the students’ free-text answers to questions of a conceptual nature, which is done by mapping the students’ answer in the form of a concept map using a domain ontology. Although originally developed for assessment and marking, it has also been used for generating feedback from the domain ontology used in the annotation and marking processes.

As Sameh (2009) demonstrated, ontologies can also play an important role in the design of feedback systems. His work describes an ontology in the mobile computing domain, which is used to provide learners with feedback during assessment in the form of recommendations.

Regarding pedagogy design, the Recommendation System of Pedagogical Patterns (RSPP) by Cobos et al. (2013) uses ontologies to represent pedagogical patterns.

The CHOCOLATO tool (Isotani et al., 2013) leverages ontologies to represent knowledge related to different pedagogies and collaboration practices. It provides intelligent guidance that helps teachers by explicitly and formally representing the core characteristics of learning theories using ontologies.

Jovanovic, Gasevic and Devedzic (2006) presented an ontology-based approach for automatic annotation of learning objects based on IEEE LOM. In their work, the metadata elements’ title, description, unique identifier, subject and pedagogic role are automatically generated from the learning object.

European projects such as CUBER (Poyry and Puustjarvi, 2003) or Organic.Edunet (Ebner et al., 2009) made use of ontologies for annotating learning objects using IEEE LOM metadata enriched with ontology annotations. These projects presented ontology-based frameworks which supported learners in searching educational resources in a central repository. In Organic.Edunet, the Classification element (LOM metadata category number 9) was suggested as the most used link from metadata records to ontology elements.

Lee et al. (2008) presented an ontological approach for the enhancement of IEEE LOM metadata elements, with semantics to facilitate retrieval of learning objects. This model uses an ontology-based query expansion algorithm, utilizing constructs in the ontology such as relations and subclasses.
4.3.3 Ontologies describing learner data

There are a number of standards for representing learner data, such as PAPI (Public and Private Information), IMS LIP (Learner Information Package), or FOAF (Friend of a Friend) just to name the most widely used ones. All of these have been used as the basis for ontology modelling of learners’ data. For instance, Paneva (2006) presents an ontology-based student model for E-Learning systems with two main parts: general student information and information about the student’s behaviour in the learning domain.

Regarding personalization, systems like ONTODAPS (Nganji et al., 2012) or PASER (Kontopoulos et al., 2008) allow ontology-based tailoring of learner content based on the learners’ different needs and preferences. As an example of the many similar systems published over the years, Wen et al. (2012) presented a system for providing personalized contents to learners, but many others exist. Referencing all of them is out of the scope of this deliverable, although interested readers are encouraged to check the comprehensive work of Al-Yahya et al. (2015).

4.3.4 Ontologies describing e-learning services

As previously said, ontologies are often used for describing e-learning services and components. Using ontologies to describe services and resources results in learning resources that are searchable, accessible and sharable.

The work by Raju & Ahmed (2012) describes a model for representing a learning object repository using ontologies. The ontology also enables learning objects annotation, resulting in more discoverable and reusable learning objects from the repository perspective.

Ontology mapping is another pivotal area in e-learning. Some e-learning systems are not interoperable because of the diversity in learning resource metadata. Ontology mapping facilitates the interoperability and sharing of learning resources. A good example is the work by Arch-int & Arch-int (2013) where an ontology mapping technique helps to detect conflicts between local ontologies and provides guidance for resolving them.

4.4 Learning Object Context Ontologies - The LOCO Framework

LOCO (Learning Object Context Ontologies) ontological framework (Siadati et al., 2008) was initially aimed at facilitating reusability of learning objects and learning designs, and later extended to also provide support for personalized learning. It defines formal representation of learning object context and its principle building blocks: various kinds of learning-related activities, participants in the learning process (i.e. learners, teachers, teaching assistants, and the like), and the learning content. Accordingly, it integrates a number of learning-related ontologies.

LOCO-Analyst makes use of the following LOCO ontologies:
- Learning Context ontology - an ontology of learning context; the central component of the framework and the integration point of the other ontologies integrated into the framework.

- User Model ontology - an ontology for modeling the participants of a learning process (students, teachers, content authors).

- Learning Object Content Structure ontology - formally identifies the information objects within a learning object with the goal of making each component directly accessible and thus reusable.

- Quiz ontology - a tiny ontology for formal representation of assessment instruments having the form of a questionnaire (i.e., a quiz)

- Domain ontology - an ontology formally modeling the subject matter of the learning content; LOCO-Analyst requires that domain ontologies are implemented by instantiating appropriate concepts and relations of the PROTON upper-level ontology (Terziev, Kiryakov & Manov, 2003). Here we provide an example of such an ontology for the Programming Process learning module.

As a part of the LOCO framework, a Learning Design Ontology has been designed. This ontology, inspired by the IMS LD Information Model, is aimed at formal representation of the basic building blocks of an instructional design. It is a part of our future research to determine the best way to integrate and make use of this ontology in the educational software solutions under development.

4.5 Ontologies for competencies

Quite often, as we have seen in the previous sections, learning objects, activities and objectives are described in the form of competencies or directly linked to them. In this regard, ontologies have been widely used to formalize competency models as a means to annotate learning resources and other entities with them.

One example of this is the ESCO ontology\(^4\). ESCO is the multilingual classification of European Skills, Competences, Qualifications and Occupations which identifies and categorizes skills, competences, qualifications and occupations relevant for the EU labor market and education and training. The ontology of the taxonomy "European Skills, Competences and Occupations", i.e. the ESCO ontology, actually forms the Data Model on which the ESCO project relies upon. The ontology considers three ESCO pillars modelled as separate taxonomies, and 2 registers also modelled as taxonomies.

The work by Garcia-Barriocanal et al. (2012) addresses how computing with competencies can be approached from a general perspective, using a flexible and extensible ontological model that can be adapted to the particularities of concrete organizations. Then, the consideration of competencies as

\(^4\) Available at http://data.europa.eu/esco/model
an organizational asset is approached from the perspective of particular issues as competency gap analysis, the definition of job positions and how learning technology can be linked with competency models. The framework presented provides a technology-based baseline for organizations dealing with competency models, enabling the management of the knowledge acquisition dynamics of employees as driven by concrete and measurable accounts of organizational needs.
5 SALO model definition

In this section, a definition for an annotation model to describe PBL-related learning activities called SALO (*Semantic Annotated Learning Objects*) is described. The model is focused on facilitating the description of the activity that takes place in a learning environment based on PBL approaches. The description will be used for further learning analytics, which are aimed to improve the overall learning process.

To the extent possible, existing models and schemas should be reused and they will be extended to deeply fulfil the most typical PBL activities.

5.1 Model requirements

The utilization of learning analytics to improve the learning process when using problem-based learning approach requires the registration of many facts and interactions from both students and learning content.

In the context of PBL3.0, although the Aalborg PBL model has been adopted as reference framework for PBL practice (see deliverable D1.1: PBL Analysis), the model must be useful to describe learning activities in a broad sense and it can be used for anybody independently of the institution or subject. On the other hand, the work needed to analyse the learning analytics domain and all the learning analytics components that are required to be employed in order to effectively raise the quality of education and training have been described in D1.2. LA Analysis. From both of these documents several requirements have been raised, in order to define a model to annotate learning activities in a PBL context to enable further analytics.

Existing models and schemas described in the third and fourth section of this document can fulfil most of the SALO model requirements, which are the following:

- Concerning modelling requirements, SALO must have the capability to describe:
  - Programs and course structures. This part of the model can be adopted from ISO/IEC 19788 MLR, concretely the part related with *curricula*, and IMS Learning Design, concretely those terms related with *methods*. This adoption must be extended with descriptions of the *cohort* that course the program and the semester structure in terms of courses and the corresponding project works.
  - Activity design. Terms to describe the activity design can be fully adopted from IMS Learning Design, concretely from *activity & activity structure* terms.
  - Group works and group assessments. As a pillar in PBL, group work and group assessment must be described in SALO. The IMS Learning Design *role* concept can be reused in the model although they should be extended to fit completely the main features of group work.
o **Learning objectives** is another important issue that should be covered in SALO. ESCO classification of European skills, competences, qualifications and occupations can be reused to model learning objectives in the specific PBL3.0 context but SALO should extend it to fit SOLO taxonomy (Biggs & Tang, 2007), the one adopted to concretely formulate course and project learning objectives.

o **Activity structure** type and activity types. In order to provide as much information as possible for further analytics, generic activities and structure of activities should be provided. Currently there is not any model or schema widely used that describes those kind of meta-descriptions, so this should be included in SALO from scratch.

- About data and recording requirements, it should be noted that SALO model must be supplemented with:
  
  o Description of heterogeneous resources and tools, which could be provided using existing models like IEEE LOM or ISO/IEC 19788 MLR.
  
  o Detailed recording of interactions for learning analytics. This recording will be provided by the xAPI model statement, which has been adopted as a unified persistence model for this project.

To conclude, the IMS Learning Design specification is the most complete and closest to our project needs. It is well-known and widely used by practitioner and it helps to model a complete learning experience, including actors, environments, resources and activities.

Other models referenced in previous sections, such as metadata for learning resources or usage data standards (like IEEE LOM or CAM), are interesting and mature, but show only a partial view of the overall process of learning. Certainly, those standards are useful and necessary to describe learning contents that are included in SALO model, as described in next section.

Therefore, from the perspective and needs of the PBL3.0 project, IMS LD seems the main source of inspiration for our semantic annotation model SALO.

### 5.2 Conceptual model

According to the requirements described above, in this section the SALO model is presented to represent and annotate the whole activity carried out by actors who take part in learning context using PBL. SALO is intended to enable further learning analytics to adapt and improve student learning process.

SALO is presented here as a conceptual model that presents the vocabulary, the functional relationships between the concepts, and the relationship with other well-known models. The conceptual model is expressed as a set of UML class models and a definition of the vocabulary.
Figures 7 and 8 show the general overview of SALO model. The two diagrams are complementary and both of them are needed to obtain the whole vision of the model. For the sake of readability, those terms that can be reused from existing models and schemas have been coloured in grey. The name of the external model and specific terms are written in brackets.

![Diagram](image)

**Figure 7. SALO model (description for activities and structures)**

The model is built on the concept of project, as basis of the PBL approach. Semesters of a program can be made up of traditional face-to-face courses and a mandatory group work laid out as a PBL project.

The resolving methodology of problems laid out in projects is structured in three main phases which are decomposed in more concrete sub-phases that should be understood as a high-level learning activity structure-type. A set of prototypical learning activities (activity type) are suggested to board each activity structure.

The learning objectives are characterized by terms such as knowledge, analysis, synthesis, application etc. The formulation of such intended learning outcomes fit to the SOLO (Structure of the Observed Learning Outcome) Taxonomy (Biggs & Tang, 2007).\(^5\)

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\(^5\) Detailed information is provided in D1.1 “PBL Analysis”.
Both activity structure types and activity types have a link to the corresponding concrete activity structure and learning activity, respectively. The activity structure and the learning activity take place in the specific context of a concrete project work, which is developed by students cooperating in a group and is supervised by a project supervisor. Students must adopt a role during the project resolution and this role can change depending on the activity and the group decisions. During the resolution of the problem, several meetings between the project supervisor and the group of students are planned. At any time, students can use provided learning content to board courses and project work.

Student acquisition of project learning objectives is assessed in an extended examination. This involves all group members and censors from teaching staff. A grade is assigned to each member of the group.

5.3 Case study

In this section, a case study to prove the completeness of SALO model is provided. The case study is based on the one described in D1.1 “PBL Analysis” about Medialogy Bachelor in Aalborg University.

Aalborg University provides a Medialogy Bachelor structured in six semesters. Each semester comprises a project work and one or more several courses. The first semester comprises 3 active-

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learning courses: Problem based learning in Science, Technology and Society, Audio-Visual Sketching and Introduction to Programming, 5 ECTS each one. A mandatory PBL project work (15 ECTS) that encompasses topics of all the semester courses is also required.

Although in Aalborg University learning objectives are usually associated with each semester\(^7\), SALO model provides functionality to associate learning objectives to courses and projects to enlarge other context adaptation. Nonetheless, Table 1 in D1.1 can be used to give examples of the statement of learning objectives. Those learning objectives are divided in skills, competencies and knowledge and each of them are characterized according to SOLO vocabulary\(^8\).

The process of project work can be divided in three main phases: problem analysis, problem solving, and project report\(^9\). The three main phases of project work according to the Aalborg PBL approach can be also described in terms of activity structures that take place during these phases\(^10\). A set of typical learning activities for each activity structure is provided, together with some example of tools to support them\(^11\).

Table 1 shows the SALO terms corresponding to each fact in the case study describe until now, according to those described in Figure 6.

### Table 1. SALO model: case study (description for activities and structures)

<table>
<thead>
<tr>
<th>Case study statement</th>
<th>SALO term</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohort 2015-16</td>
<td>COHORT</td>
<td>Academic Year: 2015-16</td>
</tr>
<tr>
<td>Medialogy Bachelor</td>
<td>PROGRAM</td>
<td></td>
</tr>
</tbody>
</table>
| Semester 5           | SEMESTER | Theme: Audio-Visual Experiments  
|                      |          | Prerequisite: Semester 3  
|                      |          | Comprises: Computer Graphics Programming  
|                      |          | Comprises: Project Module S5 |
| Computer Graphics Programming | COURSE   | ECTS: 5  
|                      |          | Elective: No |
| Project Module S5    | PROJECT  | Aims for: Learning Objective 07 |
| Learning Objective 07| SKILL    | Description: “Carry out a basic evaluation of an |

\(^7\) See D1.1. “PBL Analysis”, pp. 30.  
\(^8\) See Figure 7, D1.1 “PBL Analysis”, pp. 33.  
\(^10\) See Figure 10, D1.1 “PBL Analysis”, pp. 37.  
\(^11\) See Figure 12, D1.1 “PBL Analysis”, pp. 41.
Both courses and projects are concreted when a teacher lectures a course or a group of students work in a specific project. A student participates in an activity with a role and obtains a grade independently of their group partners.

Description of the case study corresponding with terms shown in Figure 7 are detailed in Table 2.

Table 2. SALO model: case study (activity implementation)

<table>
<thead>
<tr>
<th>Case study statement</th>
<th>SALO term</th>
<th>Properties</th>
</tr>
</thead>
</table>
| Computer Graphics Programming | COURSE    | ECTS: 5
|                            |           | Elective: No
|                            |           | Results: Course Work 1516 CGP 01                |
| Project Module S5          | PROJECT   | Aims for: Learning Objective 07
<p>|                            |           | Results: Project Work 1516 03                   |
| Project Work 1516 03       | PROJECT   | Title: “Usability of Artifacts”                  |
|                            | WORK      | Composed: Analysis 1516 03                      |
|                            |           | Supervised: Prof. Smith                         |
|                            |           | Elaborated: Group 1516 05 01                    |</p>
<table>
<thead>
<tr>
<th>Course Work 1516 CGP 01</th>
<th>COURSE WORK</th>
<th>Lectured: Prof. Smith</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ann</td>
<td>STUDENT</td>
<td>Belongs to: Group 1516 05 01</td>
</tr>
<tr>
<td>John</td>
<td>STUDENT</td>
<td>Belongs to: Group 1516 05 01</td>
</tr>
<tr>
<td>Peter</td>
<td>STUDENT</td>
<td>Belongs to: Group 1516 05 01</td>
</tr>
<tr>
<td>Prof. Smith</td>
<td>PROJECT SUPERVISOR</td>
<td>Supervises: Project Work 1516 03</td>
</tr>
<tr>
<td>Prof. Poulos</td>
<td>CENSOR</td>
<td></td>
</tr>
<tr>
<td>Group 1516 05 01</td>
<td>STUDENT GROUP</td>
<td></td>
</tr>
<tr>
<td>Analysis</td>
<td>ACTIVITY STRUCTURE TYPE</td>
<td>Next: Implementation Matches: Analysis 1516 03</td>
</tr>
<tr>
<td>Diagramming</td>
<td>ACTIVITY TYPE</td>
<td>Matches: Prototyping U/I 1516 1</td>
</tr>
<tr>
<td>Analysis 1516 03</td>
<td>ACTIVITY STRUCTURE</td>
<td>Composed: Prototyping 1516 03</td>
</tr>
<tr>
<td>Prototyping U/I 1516 03</td>
<td>LEARNING ACTIVITY</td>
<td>Description: “Prototyping User Interfaces v1” Using: WebTool 07 Materials: LO 123</td>
</tr>
<tr>
<td>WebTool 07</td>
<td>TOOL</td>
<td>Name: Gliffy Common activity: Yes</td>
</tr>
<tr>
<td>LO 123</td>
<td>LEARNING CONTENT</td>
<td>Title: “How to make good User Interfaces”</td>
</tr>
<tr>
<td>Learning Objective 01</td>
<td>COMPETENCY</td>
<td>Description: “Take responsibility of one’s own learning during a 2-3 month project period and generalize the gained experiences (synthesis)”</td>
</tr>
<tr>
<td>Meeting 05</td>
<td>MEETING</td>
<td>Timestamp: 19/12/2015 Project: Project Work 1516 03 Attend: Peter, Ann, Prof. Smith</td>
</tr>
<tr>
<td>Test 1516 03</td>
<td>COURSE EVALUATION</td>
<td>Date: 8/01/2016 Evaluates: Course Work 1516 CGP 01</td>
</tr>
<tr>
<td>Extended Examination 220516 01</td>
<td>EXTENDED EXAMINATION</td>
<td>Date: 22/05/2016 Evaluates: Project Work 1516 03 Board: Prof. Poulos, Prof. Smith</td>
</tr>
</tbody>
</table>
It should be noted that learning contents must be annotated with learning object metadata using standards described in section 3.2.

### 5.4 Mapping to xAPI learning registries

Experience API (xAPI)\(^{12}\) is a 100% free, open source, lightweight, adaptable API that provides a way to share data on human performance, along with associated instructional content or performance context information (i.e., experience) and allows learning content and learning systems to speak to each other in a manner that records and tracks all types of learning experiences. It is currently promoted by the Advanced Distributed Learning (ADL) Initiative.

It captures data about a person or group of activities from any platform or software system in a consistent format —from traditional Learning Management Systems to mobile devices, simulations, wearables, physical beacons, and more.

When an activity needs to be recorded, the application sends secure statements to the Learning Record Store (LRS). The LRS is the application interface for storing, accessing, and often visualizing the data about learning experiences, activities, and performance.

Statements represent structured data about a tracked learning experience. In their simplest form, statements are represented as *Actor - Verb - Object (activity)*.

Nowadays, ADL provides a broad controlled vocabulary for xAPI statements but there are many communities of practice that have defined and shared thematically controlled vocabularies. The

The objective of a controlled vocabulary is to ensure consistency in the development and implementation of xAPI statements to avoid ambiguity and ensure the use of consistent language.

As a way to exemplify the registry of a project meeting with attendance of a group of students and the project supervisor (see Case Study: Table 2), the following statements are shown:

```json
{
   "id": "6690e6c9-3ef0-4ed3-8b37-7f3964730bee",
   "actor": {
      "name": "Group 1516 05 01",
      "mbox": "mailto:group01@example.com",
      "member": [
         {
            "name": "Peter",
            "account": {
               "homePage": "http://www.example.com",
               "name": "13936749"
            },
            "objectType": "Agent"
         },
         {
            "name": "Ann",
            "openid": "http://toby.openid.example.org/",
            "objectType": "Agent"
         },
         {
            "name": "John",
            "mbox_sha1sum": "ebd31e95054c018b10727ccffd2ef2ec3a016ee9",
            "objectType": "Agent"
         }
      ],
      "objectType": "Group"
   },
   "verb": {
      "id": "http://adlnet.gov/expapi/verbs/attended",
      "display": {
         "en-GB": "attended",
         "en-US": "attended"
      }
   },
   "result": {
      "extensions": {
         "http://example.com/profiles/meetings/resultextensions/minuteslocation": "X:\\meetings\\minutes\\examplemeeting.one",
         "success": true,
         "completion": true,
      }
   }
}
```
"response": "We agreed on some analysis decisions.",
"duration": "PT1H0M0S"
},
"context": {
"registration": "ec531277-b57b-4c15-8d91-d292c5b2b8f7",
"instructor": {
"name": "Prof. Smith",
"account": {
"homePage": "http://www.example.com",
"name": "13936749"
},
"objectType": "Agent"
},
"team": {
"name": "Group 1516 05 01",
"mbox": "mailto:group01@example.com",
"objectType": "Group"
},
"platform": "Example virtual meeting software",
"language": "tlh",
"statement": {
"objectType": "StatementRef",
"id": "6690e6c9-3ef0-4ed3-8b37-7f3964730bee"
}
},
"timestamp": "2015-12-19T05:32:34.804Z",
"stored": "2015-12-19T05:32:34.804Z",
"authority": {
"account": {
"homePage": "http://cloud.scorm.com/",
"name": "anonymous"
},
"objectType": "Agent"
},
"version": "1.0.0",
"object": {
"id": "http://www.example.com/meetings/occurances/34534",
"definition": {
"name": {
"en-GB": "example meeting",
"en-US": "example meeting"
},
"description": {
"en-GB": "An example meeting that happened on a specific project."
}
"en-US": "An example meeting that happened on a specific project.

},
  "type": "http://adlnet.gov/expapi/activities/meeting",
  "moreInfo": "http://virtualmeeting.example.com/345256"
},
  "objectType": "Activity"
}

This statement can be enriched providing other sub-statements and context activities\textsuperscript{13}, providing a way to put the experience in the context of a PBL course or project as defined in SALO model.

In the context of PBL3.0, xAPI has been adopted as a persistence model because it provides a flexible way to record any kind of events that involve the learning process participants. This kind of registrations, guided by SALO model, enhances further learning analytics to improve students’ learning. In addition, xAPI initiative provides a quick and easy way to generate graphs from your xAPI data\textsuperscript{14}, as well as a powerful query language to manipulate it, which can be considered a potentially useful tool for the project objectives.

\textsuperscript{13} See https://drive.google.com/file/d/0BxhK5TH2EphZFBXeVNaSG0zWEE/view
\textsuperscript{14} http://adlnet.github.io/xAPI-Dashboard/
6 Conclusions

The main objective of this deliverable is to cover the modelling phase of the PBL 3.0 solution. In order to reuse those existing models that could be useful for the project proposals, a review of the most important models and ontologies for modelling learning activities and processes has been provided.

In the light of needs for later learning analytics and the PBL approach, model requirements have been identified considering programs and course structures, learning objectives, group works and group assessments, activity design and activity structure as basic foundations of the model (called SALO).

Taking into account the requirements and the provided review, the IMS LD specification has been identified as the most complete and closer to our project needs. It is intended to model a complete learning experience, including actors, environments, resources and activities and it has been reused in the SALO model.

SALO model has been described as conceptual model to allow for a diversity of potential implementations. The model covers all the data required to build learning analytics solutions and is comprehensive in that regards.

As proof of concept, a case study has been discussed. The case study models a specific part of the project work example described in Deliverable 1.1 “PBL Analysis”.

In order to fulfil identified recording requirements, xAPI has been adopted as a persistence model as it provides a flexible way to record any kind of events that involve the learning process participants. Some examples of xAPI statements has been provided.

Resulting of those attempts to capture learner’s activity in the context of PBL, a community of practice focused on problem-based learning is needed here, as well as the definition/extension of a controlled vocabulary for this approach that can be integrated with other existing vocabularies like the one provided for MOOCS and learning analytics solutions (Berg, 2016).
References


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and Semantic Web for Intelligent Educational Systems at the 9th Int. Conf. on Intelligent Tutoring Systems, pp. 21-35.


