LUISA

Learning Content Management System Using Innovative Semantic Web Services Architecture

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Deliverable D7.2.2

Design and modelling of the specific (domain related) metadata and models

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EXECUTIVE SUMMARY

The LUISA project is exploiting the advantages of a Semantic Web Service Architecture to make richer and more flexible the processes of query and specification of learning needs in the context of Learning Management Systems and Learning Object Repositories.

The academic world's needs are exemplified by the UHP use case. A first version of the UHP academic scenario description has been provided in D7.1.2. It is expected to allow testing and validating the applicability of the LUISA concepts and prototype in an academic context.

This document describes metadata and ontologies used for indexing and retrieving Learning Objects (LO), in the academic use case of LUISA. In a first part, we compare different models of ontologies (like OpenCyc or Sumo) and highlight the difficulty to reuse existing ones. In a second part, we detail the ontology we used:

- s-lom which is a semantic version of IEEE-LOM,
- GCS which is a competency ontology,
- a basic ontology of disciplines extended from OpenCyc
- a Software ontology we have created to apply rules in technical environments.

Finally, a third part describes how ontologies can be used or extended for further cases. For example, we detail the mapping between instances of two competencies ontologies that will be experimented in ELUISA.

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Abstract (for dissemination)	This document describes metadata and ontologies used for indexing Learning Objects, in the academic use case of the LUISA project. The ontologies are about Learning Object, competencies, disciplines in a university and technical environment in computers (like Software).			
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1 INTRODUCTION

University Henri Poincaré (UHP) is the academic use-case partner of the LUISA project. Its role is to define an academic context to experiment Semantic Web Services (SWS) applied to Learning Objects (LO).

This deliverable lists the metadata required for indexing the LO and the ontologies used for experimenting semantic reasoning. It is the second and final version of D7.2. Since the precedent version, the metadata schema and ontologies have been tested into the implementation of a first LUISA prototype and the annotation of 80 documents. Hence the document provides updated versions of the ontologies and many local improvements in order to clarify the descriptions and to make easier the task of working with this document.

In a first part, we compare different models of ontologies and highlight the difficulty to reuse existing ones. In a second part, we detail the ontology we used:

- s-lom which is a semantic version of IEEE-LOM,
- GCS which is a competency ontology,
- a basic ontology of disciplines extended from OpenCyc
- a Software ontology we have created to apply rules in technical environments.

Finally, a third part describes how ontologies can be used or extended for further cases. For example, we detail the mapping between instances of two competencies ontologies that will be experimented in ELUISA.

The main clarifications (added to the first version) are the adding of the instances used into the competency ontology (section 3.3.4), the software one (section 3.5.4) and used for the mapping (section 5.3).

The main changes into the ontologies are modifications of the “details” and “requires” relation into the competency ontology, the adding of a PDF reader into the software ontology, and some renaming of namespaces visible into the WSML code in appendices.

Finally, we complete the document with lessons learnt from the annotation task.

2 ONTOLOGIES AND SEMANTIC INTEROPERABILITY

Universities are currently deploying Learning Management Systems in order to provide their students and staff with many kinds of guidance and services including retrieving learning resources from repositories (called Learning Object Repositories, LORs). However each LOR is built according to local requirements and usages and there is no way for different e-learning systems to exchange and share e-learning resources as different formats, languages, vocabularies, strategies and learner's information have been used. In short, there is no semantic interoperability among such LORs.

The LUISA project aims at demonstrating the benefits of semantic interoperability for sharing learning resources through the Web. Semantic interoperability requires ontological engineering and ontology based descriptions. Interoperability also means watching at what is already available, what could be reused and how new models and new developments can be properly linked to existing proposals.

In the area of education, we have to look at general ontologies such as upper ontologies in order to start from widely agreed definitions and hierarchies and then to consider more specific ontologies if available for resource, learner and context description and finally fields of study. We present some general concepts from these upper ontologies in section 2.1.

On the particular topic of Learning Object Repositories, there are currently several other international recent or ongoing initiatives aiming at allowing stakeholders to more easily exchange and/or sell Learning Objects across institutional and national borders. In section 2.2, we briefly list those projects and we consider reusing the Learning object type categories as proposed in the CELEBRATE European project.

2.1 Reusing existing ontologies

The ontology beginner's guide[1] which is provided by the Protégé website suggests the following first steps:

- Determine the domain and scope, identify the concepts.
- Consider reusing existing ontologies

As presented in D7.1, the domain we intend to cover is the delivery of personalized learning resources to students acquiring general competencies in Informatics and Internet (applying for being awarded the C2I certification in French universities, details in section 3.1). For that purpose, we propose to build

- A C2I competency ontology
- A UHP field_of_study (called "preferred domain" in D7.1) ontology
- An Operating System (OS) and application software context ontology

[1] http://protege.stanford.edu/publications/ontology_development/ontology101.html

- An educational type ontology (preferably extracted from already existing ones).

Then we should consider reusing ontologies. As far as general concepts are concerned, we try either to reuse definitions/conceptualisations (from WordNet[2], SUMO[3] or Cyc[4]) or to explain why we need a different concept. Through this process we hope to increase the "semantic understanding" of our ontologies.

Hereafter are short presentations of the three studied ontologies.

"WordNet is a large lexical database of English. Nouns, verbs, adjectives and adverbs are grouped into sets of cognitive synonyms (synsets), each expressing a distinct concept. Synsets are interlinked by means of conceptual-semantic and lexical relations."

SUMO is an upper ontology being created as part of the IEEE Standard Upper Ontology Working Group. SUMO "is limited to concepts that are meta, generic, abstract or philosophical, and hence are general enough to address (at a high level) a broad range of domain areas. Concepts specific to particular domains are not included in an upper ontology, but such an ontology does provide a structure upon which ontologies for specific domains (e.g. medicine, finance, engineering, etc.) can be constructed."

Cyc, developed by Cycorp inc., is "a formalized representation of a vast quantity of fundamental human knowledge: facts, rules of thumb, and heuristics for reasoning about the objects and events of everyday life". The last version contains hundreds of thousands of terms and millions of assertions.

We provide more details hereafter about the field_of_study concept, which is a major issue for LOs description interoperability.

2.1.1 Terminological viewpoint for discipline (field_of_study)

In our use-case description, we referred to the discipline learnt by the student as "preferred domain". As the term "domain" could lead to misunderstandings, especially in the ontological world, we have queried WordNet with the term "discipline".

According to WordNet, the noun "discipline" has 5 sense(s).

We are interested by the first one when dealing with academic disciplines, the following definition and examples are provided:

> *a branch of knowledge; "in what discipline is his doctorate?"; "teachers should be well trained in their subject";*

By looking in SUMO for the WordNet concept of Discipline we find:

> *SUMO Mappings: FieldOfStudy (equivalent mapping)*

[2] http://wordnet.princeton.edu/

[3] http://sigma.ontologyportal.org:4010/sigma/KBs.jsp

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

This means that the concept represented by discipline (sense 1) is modelled in SUMO, it is a class and it is named FieldOfStudy.

2.1.2 SUMO viewpoint on field of study

In the SUMO ontology, we have:

- A parent class: (subclass FieldOfStudy Proposition)
- Instances, e.g.: Mathematics is an instance of field of study
- Subclasses, e.g.: Science is a subclass of field of study

Let us investigate further the Science subclass to see whether it fits to what we name “Sciences” in UHP.

Science is defined as "Any FieldOfStudy which tests theories on the basis of careful observations and/or experiments and which has a cumulative body of results." Biology, Chemistry, Engineering, MedicalScience, Physics, Physiology are instances of Science.

Exploring the concept of MedicalScience leads to a reference to a Mid-level-ontology. This statement brings one of the limits of the SUMO upper ontology and points to a more specialised Mid-level ontology.

Moreover, going deeper on Physiology brings the following:

- (subField Physiology Biology)

where subfield is a transitive relation defined as follows:

- (documentation subField "(subField ?FIELD1 ?FIELD2) means that ?FIELD1 is a proper part of the FieldOfStudy ?FIELD2. For example, Physiology is a subField of Biology.")

From the above examples, we see that the concept FieldOfStudy is described using a hierarchical link “is a” and also using a “subfield” relation. Let us look now at the same concept in the Cyc ontology.

2.1.3 Cyc viewpoint on field of study

A request for FieldOfStudy in the Cyc browser provides the following description:

- “A specialization of AspatialInformationStore. Each instance of FieldOfStudy is a particular area of study, with its own distinctive set of theories, hypotheses, and problems. Instances of FieldOfStudy are typically the subject of teaching and/or research within instances of AcademicDepartment (q.v.), although one AcademicDepartment may cover several instances of FieldOfStudy.”
- SubClasses include AppliedDesignFieldOfStudy, EthnicStudies, FocusedTechnologyField, AreaStudies, LiberalArtsFieldOfStudy, ScientificFieldOfStudy,

Instances: Many instances are listed. The ones which fit with the UHP vision are:

- In FieldOfStudy (Medicine-FieldOfStudy, Dentistry)
- In ScientificFieldOfStudy (ComputerScience, Mathematics, Biology, Pharmacology, Physics, SportsScience)

2.1.4 Conclusion from upper ontologies

We can reuse the FieldOfStudy class as referred to in these ontologies. In both cases we notice a subclass named ScientificFieldOfStudy in Cyc and Science in SUMO. However those subclasses are not identical, neither are the hierarchical and relational links. We will take as much as possible from the Cyc ontology and complete it, if necessary, with instances adapted to our university.

2.2 Watching other projects and their ontological developments

Such projects (recent and ongoing) include:

- ARIADNE[5],
- Educanext[6],
- CELEBRATE[7],
- EDNA[8],
- Edutella[9],
- Elena Project[10],
- GLOBE[11],
- LORNET[12],
- ProLearn[13].

We can expect that these projects use mid level educational ontologies. Although the projects websites do not publish any ontologies, we can find some sources from other publications. We will take here the example of the “educational type” concept as developed in the CELEBRATE LOM application profile. Indeed, there is no entry for “educational type” in WordNet and consequently no mapping with upper ontologies like SUMO and Cyc. We are no more in the upper ontologies level.

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[5] http://www.ariadne-eu.org/

[6] http://www.educanext.org

[7] http://celebrate.eun.org/eun.org2/eun/en/index_celebrate.cfm

[8] http://www.edna.edu.au/edna/go

[9] http://www.edutella.org/edutella.shtml

[10] http://www.elena-project.org

[11] http://www.globe-info.net

[12] http://www.lornet.org/

[13] http://www.prolearn-project.org/

From the CELEBRATE LOM application profile we consider reusing Educational.Learning Resource Type as it is a LOM field for which the provided vocabulary does not completely fit our needs.

Educational.Learning Resource Type is a field in this profile, it is numbered 2.4.9. A comparison is provided with a similar field (5.2) from LOM

'5.2 Educational.Learning Resource Type' is intended to indicate the potential educational use(s) or type(s) of the LO.

The value space for '5.2 Educational.Learning Resource Type' element is a CELEBRATE Vocabulary.

Vocabulary values for Educational Learning Resource type in CELEBRATE:

Dictionaries and vocabularies.

Guide

Manuals and tutorials.

Manuals provide guidance on the particular topic (e.g. roadmap, hints, etc.) and are usually also intended to be kept at hand for reference. Tutorials are resources that provide guided, practical information about a specific subject.

Information resource

Pictures, texts, videos, presentations, collections and databases. Any presentation or informative content that is 'raw' material for learning.

Open activity

Artistic projects and creative exercises. Projects and exercises that are not very confined or limited. Many more complicated games that require more than simple logic belong to this category.

Tool

Editors and other kind of programs for producing something. Editors can process e.g. text or pictures and they can be used for creating and editing other LOs. Tools can also perform calculations or conversions.

Assessment

Assessment and evaluation items. Exams and tests. Any LO whose primary purpose is the evaluation of the user's actions or input or to support teacher design or development of such materials. Used e.g. for assess learner performance or self-assessment.

Drill and practice

Simple exercises and games. Exercises (drills) that perform skill training are very condition and action specific. They usually contain only simple IF-THEN logic rules. Many 'educational' games belong to this category if they concentrate on specific skills.

Exploration

Simulations and experiments.

Glossary

So our conclusion is that for describing C2I resources we could partly reuse this vocabulary for the LOM field 5.2.

2.3 General conclusion

As noticed in many papers, it is difficult to reuse existing ontologies. The above-mentioned examples show the limits that we met. However, for each concept proposed in our ontologies descriptions we provide the sources we were able to reuse.

3 ONTOLOGIES SPECIFICATIONS

We will quickly remind the use case description (see D7.1 for detailed description). Then we will describe the models that are needed for this use-case and the design of the related ontologies.

3.1 Use case reminder

The following subsections will present the context and the objects needing to be described.

3.1.1 C2i context

C2I is an IT and Internet proficiency certificate[14]. It was introduced in French higher education in 2002 to develop and strengthen proficiency in information and communication technologies. The target student population is made of students receiving training in higher education establishments. This Certificate lays out the competencies that students are expected to acquire during their university studies.

In this use case, a student wants to improve one of its C2I competencies thanks to resources. A professor tells him/her he/she could find some resources (LO) on the portal of the university. The student logs into it and is redirected to the search page for C2I resources. Then the following diagram (Figure 1) summarises the process.

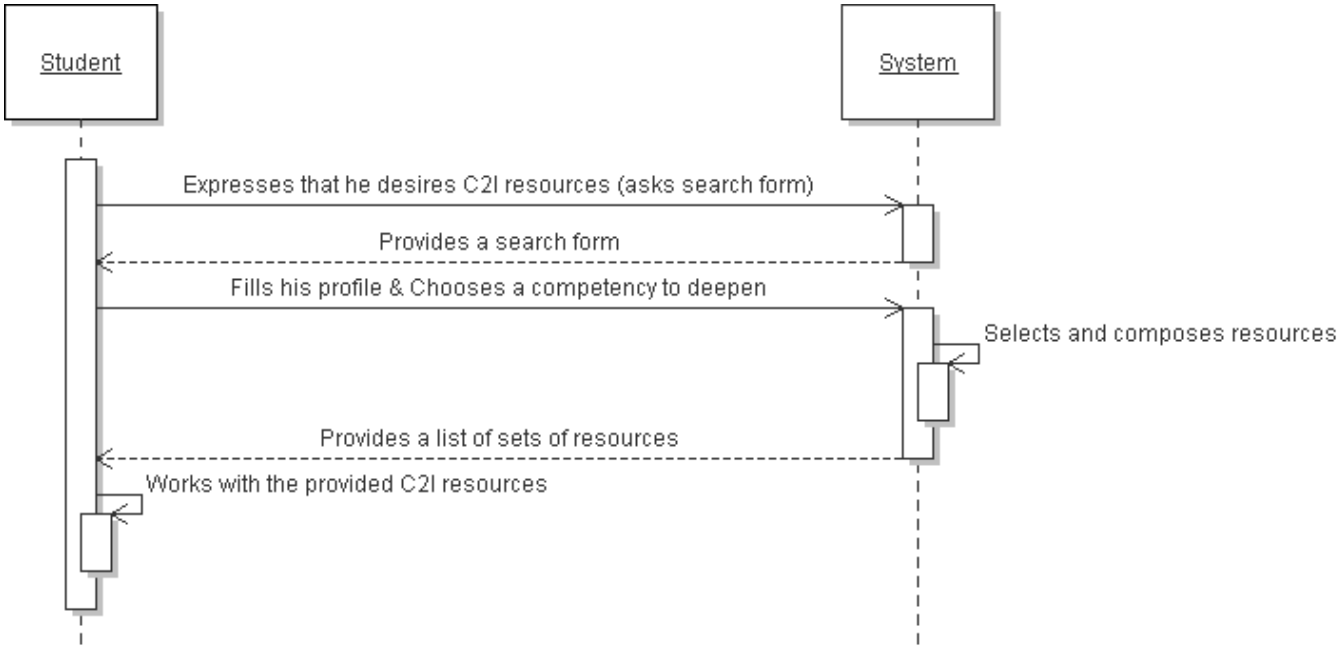


Figure 1: Sequence diagram for student search

[14] French main portal on C2I: http://www2.c2i.education.fr/

3.1.2 Global use of the ontologies

Before detailing each ontology, here is a global presentation of the four ontologies and the relations between them (Figure 2: Relations between ontologies).

Two ontologies are the core of our design. Learning resources are described thanks to s-lom while queries are based on GCS.

The s-lom ontology is a semantic version of LOM, backward interoperable with the IEEE LOM format and moreover adding semantic possibilities as defining a cultural place by referring to a Geographical zone defined in OpenCyc. The GCS (General Competency Schema) ontology deals with competencies to be acquired for a job or for a diploma.

A Learning Object can be described in s-lom with a competency from GCS thanks to the classification section of LOM.

A Learning Object can be described as oriented for a particular public or related to a specific discipline. It is also in the classification section that s-lom is linked to the Discipline ontology.

Finally, gcs enables to attach a competency to a topic from another ontology ("about" relation). In our case, we attached C2I competencies to the tool they used (from the Software ontology). For example, the competency about writing a printing document is attached to the instance of text-processor.

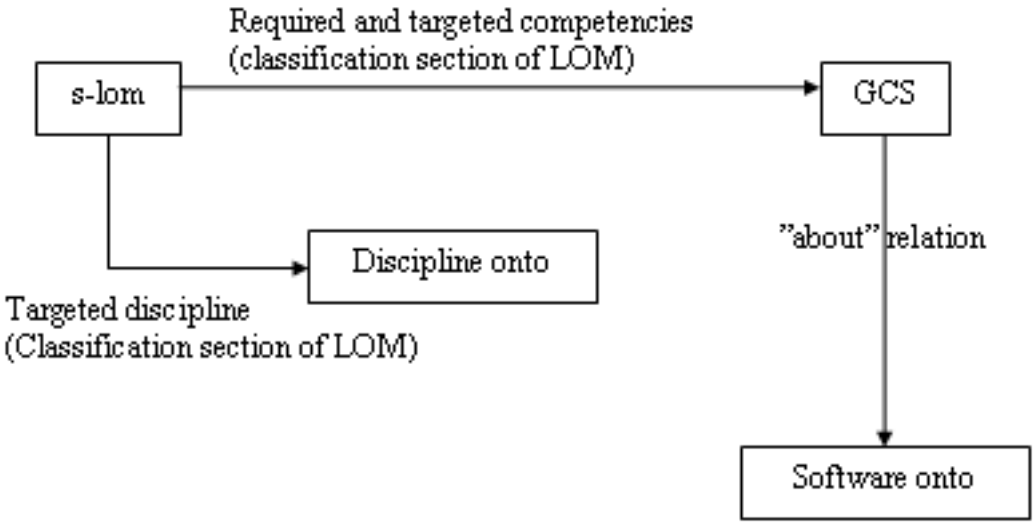


Figure 2: Relations between ontologies

Resolve a query can require to exploit all the ontologies. For example, let's consider a user who looks for a LO to improve a competency related to spreadsheets software. In order to give the most adapted LOs, the LUISA system needs to infer on the **s-lom ontology** used to describe the LOs. Then it would have to compare the instance of the **Discipline ontology**, into the user profile, with the instance of the same ontology into the LOs annotation. Eventually, the system would look for LOs attached to competencies dealing

with spreadsheets (**gcs**). If there is no one, it would extend the search to LOs dealing with the same topic (tool in our specific case) as the competency of the query. Topics are instances from the **Software ontology**.

3.1.3 User's profile

The LUISA querying process relies on several models including a student's profile. A student's profile includes:

- A discipline
- A list of pieces of software describing his/her technological environment
- A list of competencies linked to values expressing his/her level
- A list of LO with which the student has already worked; the system must help the user managing the resources. Therefore, it keeps a record of the documents (LOs) the user has worked with. This list is a set of URLs allowing the user to come back to his/her previous work.

3.2 LO metadata for s-lom ontology

A Learning Object is annotated in s-lom (former LOM/WSML ontology). This is a semantic version of LOM defined in D4.9.

We can see now how LOs will be described according to the LOM[15] (LO metadata standard). The table is adapted from D6.2, section LO Metadata template and consequently provides the academic requirements in the same format as the industrial requirements.

The use of LOM is adapted for our annotation context (resources and searching goals). The last column shows UHP values, indicating the default one, the extension and the links to other ontologies as in fields 4.4.1.1 and 9.1.

Table 1: LOM General field

LOM	Name	Explanation	UHP LO values
1	**General**	This category groups the general information that describes this learning object as a whole.	
1.1	**Identifier**	A globally unique label that identifies this learning object.	
1.1.1	**Catalogue**	The name or designator of the identification or cataloguing scheme for this entry. A namespace scheme.	UHP (default)
1.1.2	**Entry**	The value of the identifier within the identification or cataloguing scheme that designates or identifies this learning object. A namespace specific string.	Example: LO-00078

[15] http://ltsc.ieee.org/wg12/files/LOM_1484_12_1_v1_Final_Draft.pdf

LOM	Name	Explanation	UHP LO values
1.2	**Title**	Name given to this learning object.	Example: “La protection des données confidentielles ”
1.3	**Language**	The primary human language or languages used within this learning object to communicate to the intended user. NOTE:-An indexation or cataloguing tool may provide a useful default.	“fr” (default)
1.4	**Description**	A textual description of the content of this learning object. NOTE: -This description needs not to be in language and terms appropriate for the users of the learning object being described. The description should be in language and terms appropriate for those that decide whether or not the learning object being described is appropriate or relevant for the users.	Example : ”L'objectif de ce module de formation est donc de : - vous transmettre les grands principes du droit de l'informatique ; - vous sensibiliser aux problématiques juridiques relatives à l'usage des nouvelles technologies ; - vous permettre de prendre connaissance des règles régissant les relations et les échanges sur Internet. ”
1.7	**Structure**	Underlying organizational structure of this learning object. **IEEE LOM Vocabulary:** • Collection: a set of objects with no specified relations • Mixed • Linear: a set of objects that are fully ordered. (e.g., with previous and next relationships) • Hierarchical: a set of objects whose relationships can be represented by a tree structure • Networked: a set of objects with relationships that are unspecified: • Branched • Parceled • Atomic: an object that is indivisible	• Collection (default), • Linear, • Atomic
1.8	**Aggregation Level**	The functional granularity of this learning object. **IEEE LOM Vocabulary:** 1 - defined as smallest level of aggregation, e.g. raw media data or fragments. 2 - defined as a collection of atoms, e.g. an HTML document with some embedded pictures or a lesson. 3 - defined as a collection of level 1 resources, e.g. a 'Web' of HTML documents, with an index page that links the pages together or a	2 (more frequent)

LOM	Name	Explanation	UHP LO values
		unit. 4 - defined as the largest level of granularity, e.g. a course.	

Table 2: LOM Life cycle field

LOM	Name	Explanation	Example from a UHP LO
2	**Life cycle**	This category describes the history and current state of this learning object and those entities that have affected this learning object during its evolution.	
2.2	**Status**	The completion status or condition of this learning object. **IEEE LOM Vocabulary:** • Draft • Final • Revised • Unavailable	• Draft, if the resource was not originally designed for being displayed on a screen (for example, an exam on paper) • Final
2.3	**Contribute**	Those entities (i.e., people, organizations) that have contributed to the state of this learning object during its life cycle (e.g., creation, editing, publication	
2.3.1	**Role**	Kind of contribution.	"author" or "content provider"
2.3.2	**Entity**	The identification of and information about entities (i.e., people, organizations) contributing to this learning object. The entities shall be ordered as most relevant first.	Example: "author" = vCard{JeanDupont} "content provider" = vCard{UHP} (default)

Table 3: LOM Technical field

LOM	Name	Explanation	Example from a UHP LO
4	**Technical**	This category describes the technical requirements and characteristics of this learning object.	
4.1	**Format**	Technical datatype(s) of all the components of this learning object. This data element shall be used to identify the software needed to access the learning object.	Example: "text/html"
4.3	**Location**	A string that is used to access this learning object. It may be a location (e.g., Universal Resource Locator), or a method that resolves to a location (e.g., Universal Resource Identifier). The first element of this list shall be the preferable location. NOTE:--This is where the learning	Example: http://luisa.uhp-nancy.fr/course/view.php?id=3

LOM	Name	Explanation	Example from a UHP LO
		object described by this metadata instance is physically located.	
4.4	**Requirement**	The technical capabilities necessary for using this learning object.	
4.4.1	**OrComposite**	Grouping of multiple requirements. The composite requirement is satisfied when one of the component requirements is satisfied, i.e., the logical connector is OR.	
4.4.1.1	**Type**	The technology required to use this learning object, e.g., hardware, software, network, etc.	Example: "Browser" (default) Note: in the annotation tool, this field will be linked
4.4.1.2	**Name**	Name of the required technology to use this learning object. NOTE: -The value for this data element may be derived from 4.1:Technical.Format automatically, e.g., "video/mpeg" implies "multi-os".	"Any" (default) PDF or basic HTML are generally interoperable with any browser.

Table 4: LOM Educational field

LOM	Name	Explanation	Example from a UHP LO
5	**Educational**	This category describes the key educational or pedagogic characteristics of this learning object. NOTE:-This is the pedagogical information essential to those involved in achieving a quality learning experience. The audience for this metadata includes teachers, managers, authors, and learners.	
5.2	**Learning resource type**	Specific kind of learning object. The most dominant kind shall be first. NOTE:--The vocabulary terms are defined as in the OED:1989[16] and as used by educational communities of practice. **IEEE LOM Vocabulary:** • exercise • simulation • questionnaire • diagram • figure • graph • index • slide • table	• exercise • questionnaire (stands here for multiple choice questionnaire MCQ that could be corrected by an automatic system) • exam • lecture • self assessment ("these are questions as "do you know how to send an email?" The learner has to answer honestly because it is not corrected by the system.) Note: The computed list of resources given by the system should be built according to some trivial pedagogic principles. For instance, the system could offer a presentation of the target competency, exercises and finally tests. The pedagogical types help fulfilling this

[16] OED:1989 Oxford English Dictionary, 2nd Ed. 1989

LOM	Name	Explanation	Example from a UHP LO
		• narrative text • exam • experiment • problem statement • self assessment • lecture	requirement. For the composition feature (LUISA, prototype 2), "Lecture" is considered as theory entity, "exercise" and "questionnaire" as trainings entities, and "exam" and "self-assessment" as evaluation ones. (These categories could evolve according to the implementation of the composition feature.)
5.6	**Context**	The principal environment within which the learning and use of this learning object is intended to take place.	"Higher Education" (default)
5.7	**Typical Age Range**	Age of the typical intended user. This data element shall refer to developmental age, if that would be different from chronological age. NOTE 1:--The age of the learner is important for finding learning objects, especially for school age learners and their teachers.	"18-" (default)
5.11	**Language**	The human language used by the typical intended user of this learning object.	"fr" (default)

Table 5: LOM Rights field

LOM	Name	Explanation	Example from a UHP LO
6	**Rights**	This category describes the intellectual property rights and conditions of use for this learning object. NOTE:--The intent is to reuse results of ongoing work in the Intellectual Property Rights and e-commerce communities. This category currently provides the absolute minimum level of detail only.	
6.1	**Cost**	Whether use of this learning object requires payment.	"No" (default)
6.2	**Other Restrictions**	Whether copyright or other restrictions apply to the use of this learning object. **IEEE LOM Vocabulary:** "Yes" or "No"	"Yes" is the LO cannot be spread outside the university. "No" if the author agrees explicitly to let the LO be accessed from outside the university.

Table 6: LOM Relation Field

LOM	Name	Explanation	Example from a UHP LO
7	**Relation**	This category defines the relationship between this learning object and other learning objects, if any. To define multiple relationships, there may be multiple instances of this category. If there is more than one target learning object, then each target shall have a new	

LOM	Name	Explanation	Example from a UHP LO
		relationship instance.	
7.1	**Kind**	Nature of the relationship between this learning object and the target learning object, identified by the field 7.2:Relation.Resource. Based on Dublin Core	"requires" or "isrequiredby" (For example, an exercise requires a link to a data file)
7.2	**Resource**	The target learning object that this relationship references.	
7.2.1	**Identifier**	A globally unique label that identifies the target learning object.	
7.2.1.1	**Catalog**	The name or designator of the identification or cataloging scheme for this entry. A namespace scheme.	"UHP" (default)
7.2.1.2	**Entry**	The value of the identifier within the identification or cataloging scheme that designates or identifies the target learning object. A namespace specific string.	LO-00140
7.2.2	**Description**	Description of the target learning object.	"Données de l'exercice" ("Data for the exercise")

Table 7: LOM Classification field

LOM	Name	Explanation	Example from a UHP LO
9	**Classification**	This category describes where this learning object falls within a particular classification system. To define multiple classifications, there may be multiple instances of this category.	
9.1	**Purpose**	The purpose of classifying this learning object.	• "RequiredCompetencies" • "TargetCompetencies" • "TechnicalRequirements" • "Discipline"
9.2	**Taxon Path**	A taxonomic path in a specific classification system. Each succeeding level is a refinement in the definition of the preceding level. There may be different paths, in the same or different classifications, which describe the same characteristic.	
9.2.1	**Source**	The name of the classification system. This data element may use any recognized "official" taxonomy or any user-defined taxonomy.	"UHP" (default)
9.2.2.1	**Id**	The identifier of the taxon, such as a number or letter combination provided by the source of the taxonomy.	For example: "C2I-A12" (Competency A12)

Note: The LOM vocabulary could be extended to open activity or replaced by the CELEBRATE vocabulary in order to take account of this category of learning resources.

From an implementation viewpoint, the link between the general LOM ontology and the UHP changes are listed in appendices.

3.3 UHP Competency ontology

In this section, we provide the specification of the UHP competency ontology derived from GCS (see WSML code in appendices).

3.3.1 What links to this ontology?

A **user profile** is modelled by the C2I competencies associated with values representing the user level of mastering for each competency.

A **LO** description contains 2 metadata fields referring to the competency ontology:

- Targeted competencies, which expresses the competencies reached after working with the LO and assimilating its content.
- Required competencies, which expresses the competencies required in order to work with the LO.

The **GUI** uses the competency ontology in order to display the tree of competencies whose nodes are selected by the user to formulate a query.

3.3.2 Where does this ontology come from?

The C2I competency ontology is built as instances of the General Competency Schema (GCS), ex-GCO (General Competency Ontology) (see D4.11 and Sicilia 2005).

Hereafter are the basic elements of the ontology:

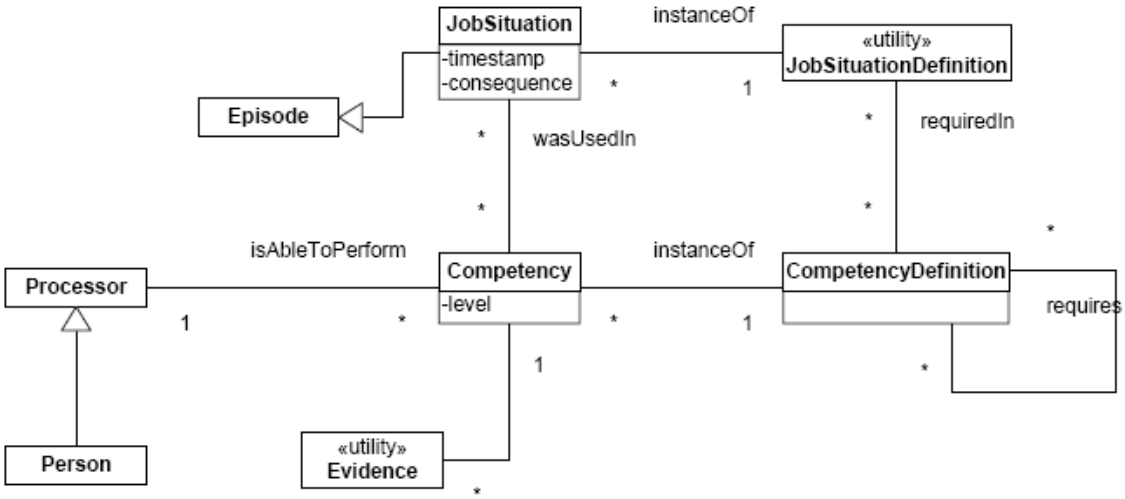


Figure 3: Basic elements of GCS

And hereafter are the elements to measure competencies:

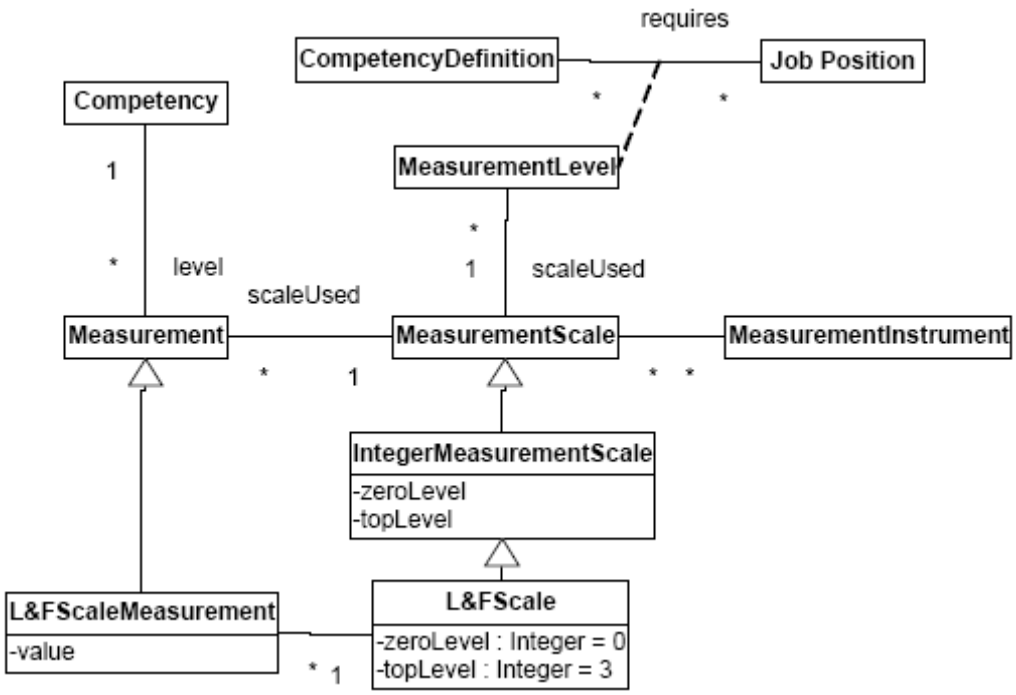


Figure 4: Modeling competency measurements

3.3.3 Ontology definition

We use the following concepts (and their relations) in GCS:

- CompetencyDefinition and Competency
- Processor and Person
- Measurement, MeasurementScale and IntegerMeasurementScale
- JobPositionDefinition, JobPosition

3.3.3.1 CompetencyDefinition

Each C2I competency is an instance of *CompetencyDefinition*.

The subcompetencies are *details* of their father. For example, “B2.1: Distinguish the different types of search engines” and “B2.2: Design the requests.” are *details* (components) of “B2: Search of information.”

To acquire a competency, acquiring subcompetencies is necessary and sufficient. So each CompetencyDefinition is *completelyDefined*.

Some *competencyDefinition* require other *competencyDefinition*. For example, “B4: Realize documents for printing.” requires “B1: Control his environment of work.”

Table 8: Concept of CompetencyDefinition (see D4.11)

competencyDefinition	Generic definition of a competency. It is related with neither specific job situation nor specific individual.

	Attributes	A competency definition is completely defined if it is explicitly indicated and if the existence of all the elements (definitions) that compose the competency is a necessary and sufficient condition to describe the competency (*completelyDefined*).
		To acquire a competency definition it could be required to acquire other/s competency definition/s (*requires*).
		A competency definition can provide a more detailed description to an existing one (*details*).

3.3.3.2 *Competency*

CompetencyDefinitions are stereotyped descriptions of competencies. A student's profile includes *Competencies* which are *instances* of *CompetencyDefinitions*. A level is associated to each *Competency*.

For example, a student has not acquired Competency B3. So he/she *isAbleToPerform* Competency B3 with *level* 0.

Table 9: Concept of Competency

competency	A discrete and specific competence of an individual that is able to exhibit some competencies in a specific context.	
	Attributes	A competency is always an instance of a competency definition (*instanceOf*)
		The competency is required with a concrete degree of expertise (*level*)

3.3.3.3 *Processor and Person*

In the Basic use case, the users are students. So in GCS, the students are instances of *Person* which inherited from *Processor*.

Table 10: Concept of Processor

processor	One that processes (human or software).	
	Attributes	isAbleToPerform competency

Table 11: Concept of Person

person	Human being.

3.3.3.4 *Measurement and measurement scale*

In a basic use case, competencies can be basically levelled for a user:

- 0: the user has not at all the competency
- 1: the user has some part of the competency
- 2: the user has the C2I level for the competency
- 3: the user's level is better than the C2I level

In GCS, this scale corresponds to an instance of *IntegerMeasurementScale* between 0 and 3. Each competency is measured according to this scale.

Table 12: Concepts of Measurement and MeasurementScale

measurement	A figure, extent, level or amount obtained by measuring.	
	Attributes	A measurement is obtained using a specific measurement scale (*scaleUsed*).
		A measurement has associated a specific value expressed in a given measurement scale (*currentValue*).
measurementScale	Something graduated when used as a measure or rule.	
	Attributes	instrumentUsed measurement instrument.

3.3.3.5 *JobPositionDefinition and JobPosition*

GCS contains a professional approach. However we can use the same concepts in the academic context. This is the case for the JobPosition. In our context, we understand it as a position defined by the competencies required to reach it. So we consider the C2I has a kind of JobPosition as obtaining the C2I requires acquiring some competencies.

For the C2I, there is only one JobPositionDefinition, which is to obtain the certificate. Therefore, the C2I JobPosition is defined by all the competencies with a level of 2 (see 3.3.3.4).

Table 13: Concepts of JobPositionDefinition and JobPosition

jobPosition	An employment for which one specific professional profile is needed.	
	Attributes	A specific job position is an instance of a job position definition (*instanceOf*).

jobPositionDefinition	The generic definition of an employment.

See section 7.1 in Appendix for detailed code in WSML.

3.3.4 Instances descriptions

We show hereafter how instances of CompetencyDefinition (CD) and CompetencyElementDefinition are related with “details” and “requires” relations.

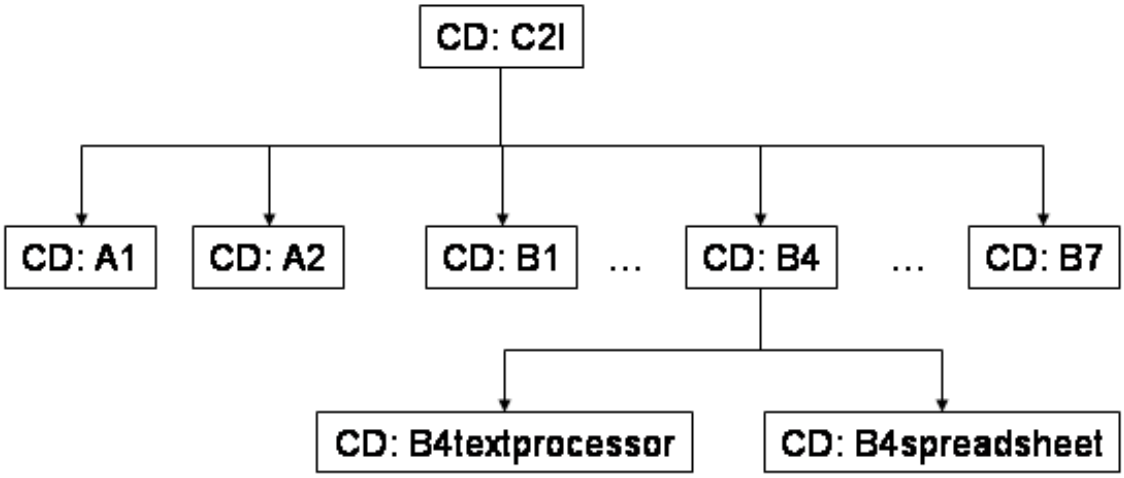


Figure 5: Details relations (CompetencyDefinition level)

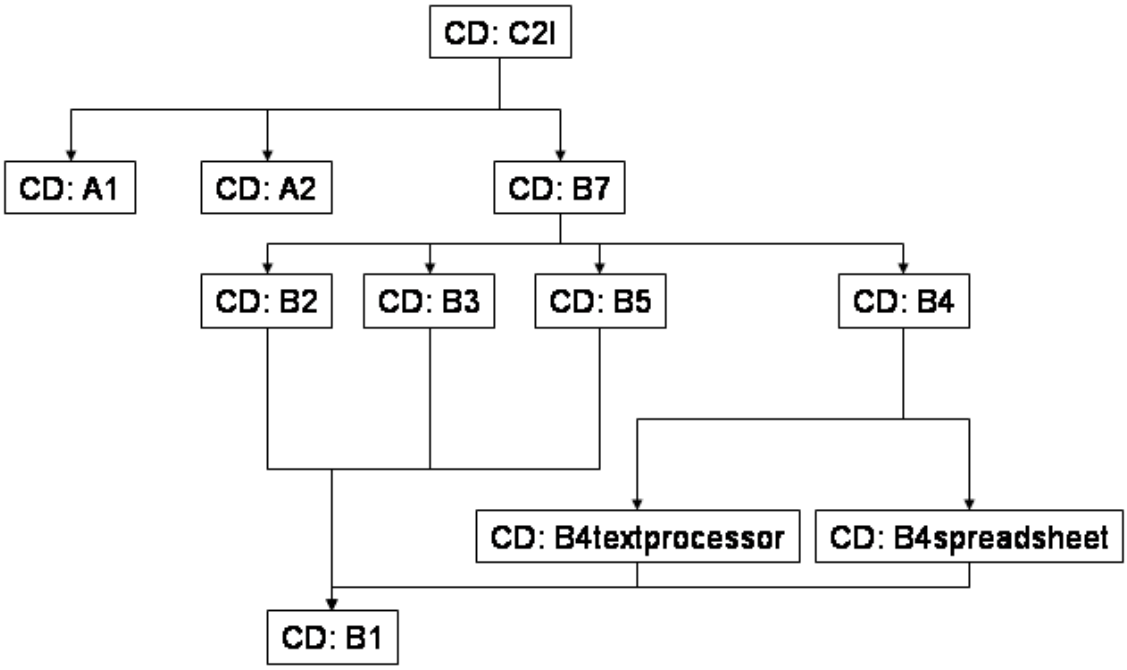


Figure 6: Requires relations (CompetencyDefinition level)

CompetencyDefinition could be decomposed into different CompetencyElementDefinition like KnowledgeElementDefinition. Figure 7 shows how a CompetencyDefinition is related to KnowledgeElementDefinition which are also related to instances of the Software ontology. These relations will be used by the LUISA system to reason on the queries and improve the results.

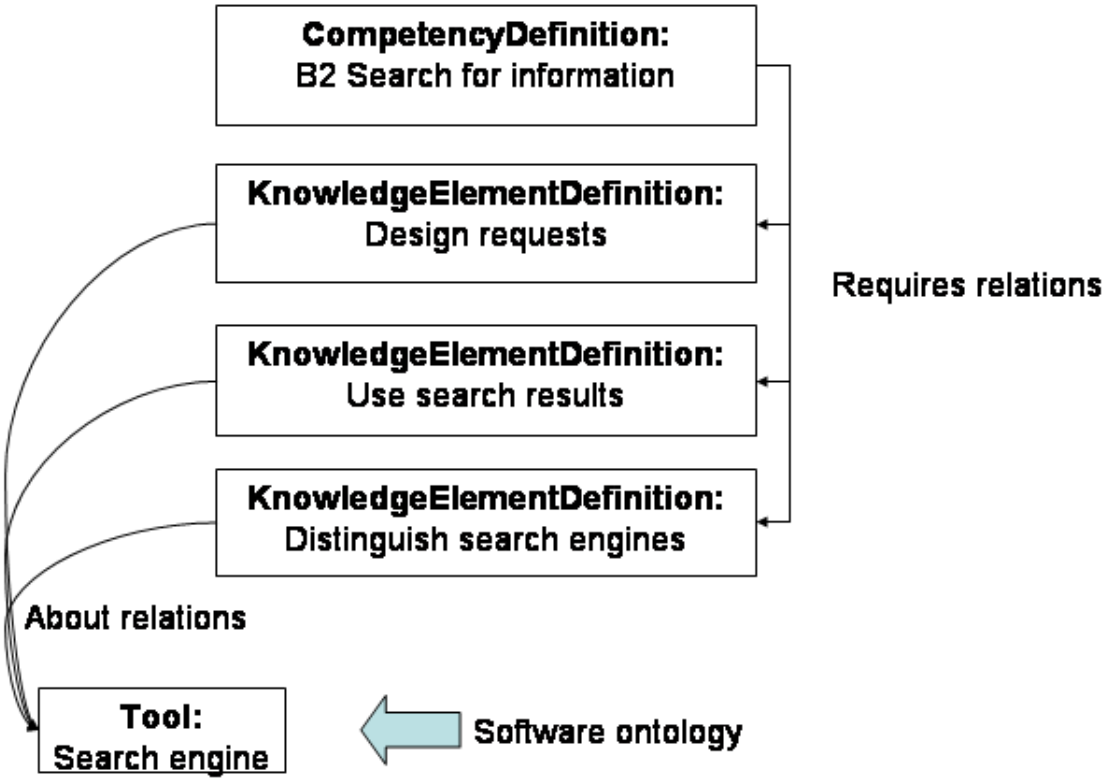


Figure 7: Requires relations (KnowledgeElementDefinition level)

Note: the "requires" relation can be used among instances of CompetencyDefinition (Figure 6) or between instances of CompetencyDefinition and CompetencyElementDefinition like the knowledge one (Figure 7).

3.4 Discipline ontology

3.4.1 What links to this ontology?

A C2I Learning Object can deal with data related to a given discipline. For example, a test targeting the spreadsheet competency can use data from Biology. It will be more adapted to people studying Biology than to students in Mathematics for instance.

So each LO is described with a metadata field called **Preferred Discipline** linking to a discipline ontology.

In the same way, students' profiles include a metadata field for the discipline studied as a major one at the university.

3.4.2 Where does this ontology come from?

Sumo or Cyc provide concepts related to fields of study. Nevertheless, these concepts are not organised as they are in UHP. An old university has an organisation linked to its historical context. Therefore, each university or each country has a specific manner to classify disciplines.

In the basic use case, a LO is annotated according to an ontology derived from Cyc. This ontology was the closest to the UHP's vision of Disciplines. We can reuse the FieldOfStudy class as referred to in this ontology. We notice a subclass named ScientificFieldOfStudy in Cyc. However the subclasses are not identical, neither are the hierarchical and relational links. We will take as much as possible from the Cyc ontology and complete it, if necessary, with instances adapted to our university.

3.4.3 Ontology definition

In our view, a *FieldOfStudy* can be composed of other *FieldOfStudy*. For example, the field of *Health* contains the field of *Medicine* and the field of *Pharmacology*. Thanks to the relations between the fields, it is possible to calculate a tree-proximity between them. Thus, two disciplines with the same father-discipline are closer than two disciplines, which are cousins (same grand-father-discipline). With the possibility to calculate such a distance an additional way of proposing resources is possible in the basic use-case. If there is no resource in the student's discipline about a subject, maybe a resource from a close field of study could interest him/her.

Moreover, some relations exist between fields of study across the compositions. As modelled in Cyc, Physics belongs to hard sciences but Mathematics doesn't. However, Physics use advanced mathematical tools so there is a relation from Physics to Mathematics. An interesting point is that this relation is not symmetric; Mathematics doesn't use concepts of Physics. This relation could allow to apply transitive inferences during the inference process.

Table 14: Concept of FieldOfStudy

FieldOfStudy	Each instance of FieldOfStudy is a particular area of study, with its own distinctive set of theories, hypotheses, and problems.	
	Attributes	A field of study has a name
		A field of study can be linked to another one if the last one is used to study the first one. (*linkedTo*).

3.4.4 Instances descriptions

We will now see how are the main disciplines are organised in UHP in a simplified view.

- Mathematics-Computer Science*
    - Mathematics
    - Computer Science
- Physics_and_Chemistry sciences*
    - Physics (linked to Mathematics)
    - Biophysics
    - Chemical Engineering
- Health*
    - Medicine (linked to Biology)
    - Pharmacology (linked to Biology)
    - Dentistry
    - Ergonomics
- Life sciences*
    - Biology
    - Biogeography
- Sport sciences

Cyc contains these fields of study. However, the interesting point in the basic use case is the organisation of these concepts. Many of these concepts are in the *ScientificFieldOfStudy* in Cyc (an asterisk shows the concepts not existing in Cyc). In our case, we have to create categories. That is why at the same time we reuse the terminal concepts, we add the missing ones.

The following figure describes the fields of study.

Table 15 : Sub-concepts of FieldOfStudy

Mathematics-Computer Science	Field of study composed of Mathematics and Computer Science.	
Mathematics		
Computer Science		
Physics_and_chemistry Sciences	Field of study composed of Physics, BioPhysics and Chemical Engineering.	
Physics		
	LinkedTo	Mathematics
BioPhysics		

Chemical Engineering		
Health	Field of study composed of Medicine, Pharmacology, dentistry and ergonomics.	
Medicine		
	LinkedTo	Biology
Pharmacology		
	LinkedTo	Biology
Dentistry		
Ergonomics		
Life Sciences	Field of study composed of biology and biogeography.	
Biology		
Biogeography		
Sport sciences		

See section 7.3 in Appendices for detailed code in WSML

In more sophisticated use-cases, the list of disciplines and subdisciplines will be expanded.

3.5 Software ontology (or computer literacy ontology)

3.5.1 What links to this ontology?

The software ontology is used in two contexts. First, it allows to check if software required by LOs is adapted to user's software. Secondly, it allows to complete a query by competency with a query by domain/tool.

An activity about text-processor using Microsoft Word cannot be executed if this piece of software is not installed on the student's computer. In order to solve this problem, we propose this technical environment ontology. The idea is to model inside the ontology basic knowledge about software and operating systems interoperability.

The user's profile contains the Operating Systems and pieces of software he/she can access.

Each LO is annotated with the pieces of software it requires.

3.5.2 Where does this ontology come from?

There are ontologies on Technical environment like Ontology of Computing Services[17], a mid-level ontology inheriting from the upper ontology SUMO[18]. But

[17] http://sigmakee.cvs.sourceforge.net/*checkout*/sigmakee/KBs/QoSontology.kif

they are not adapted to our needs. For instance, the Ontology of Computing Services has very fine grained concepts like ImageResolution but no concept like License or Version. So we decided to create a small application ontology based on the software concept of WordNet.

3.5.3 Ontology definition

The single concept is the Software one.

Table 16: Software concept

Software	(computer science) written programs or procedures or rules and associated documentation pertaining to the operation of a computer system and that are stored in read/write memory. [WordNet]	
	Attributes	A piece of Software has a name. (*name*)
		The user knows how he/she can modify or redistribute a piece of Software by reading the License. It can be '*free*' or '*proprietary*'. (*licenseType*)
		A piece of Software is not interoperable with every other ones. For example, Word XP requires Windows XP to be launched. Thus each piece of Software is associated with a list of required pieces of Software. (*interoperableWith*)

The following figure provides a summary. See section 7.4 in Appendices for detailed code in WSML.

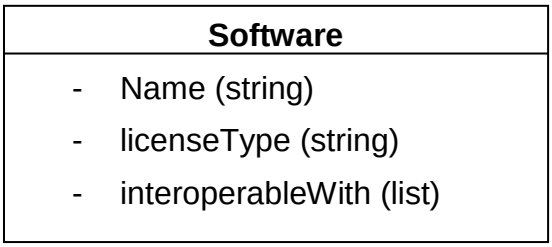


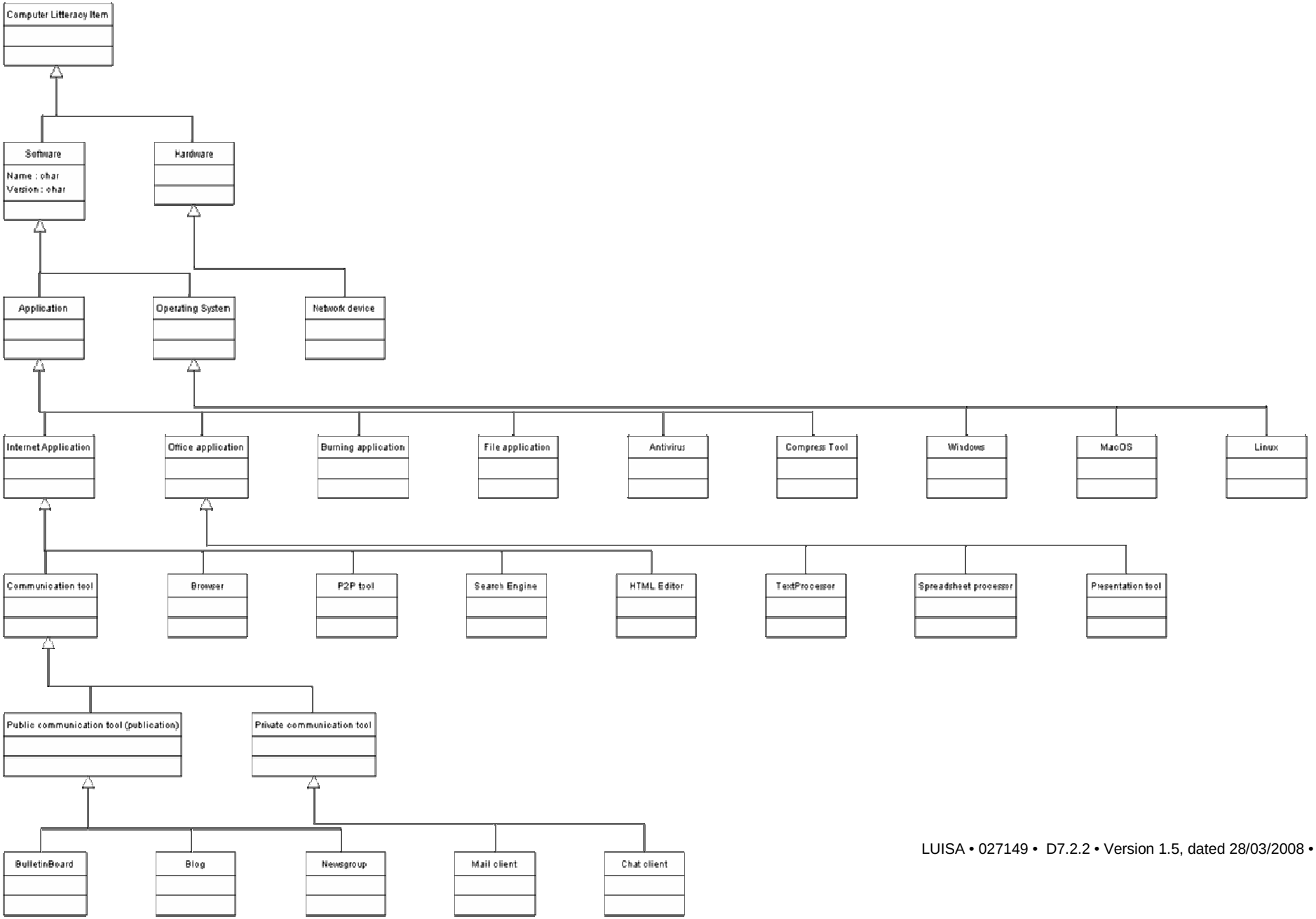
Figure 8 : The software model

3.5.4 Instances descriptions

Hereafter is the schema with **instances of the Software ontology** (See WSML code in appendices for relation of interoperability between instances).

Note: the pdfreader instance was added later under the Office application Class.

[18] http://www.ontologyportal.org/


Computer Litteracy Item
Software
Name : char
Version : char
Hardware
Application
Operating System
Network device
Internet Application
Office application
Burning application
File application
Antivirus
Compress Tool
Windows
MacOS
Linux
Communication tool
Browser
P2P tool
Search Engine
HTML Editor
TextProcessor
Spreadsheet processor
Presentation tool
Public communication tool (publication)
Private communication tool
BulletinBoard
Blog
Newsgroup
Mail client
Chat client

4 FIRST USE OF THE ONTOLOGIES

In order to allow a better understanding of the previously described ontologies, we provide now an example of their current use in the LUISA prototype.

During the annotation phase, the ontologies were used in the annotation tool. Indeed this tool (ELUISA) fills some elements of the interface with instances coming from ontologies. In Figure 9, we see the topic of an LO as a dropdown listbox automatically filled with instances of the software ontology. In next versions, the annotation tool will provide an improved visualisation of instances by showing them in a hierarchical way for example.

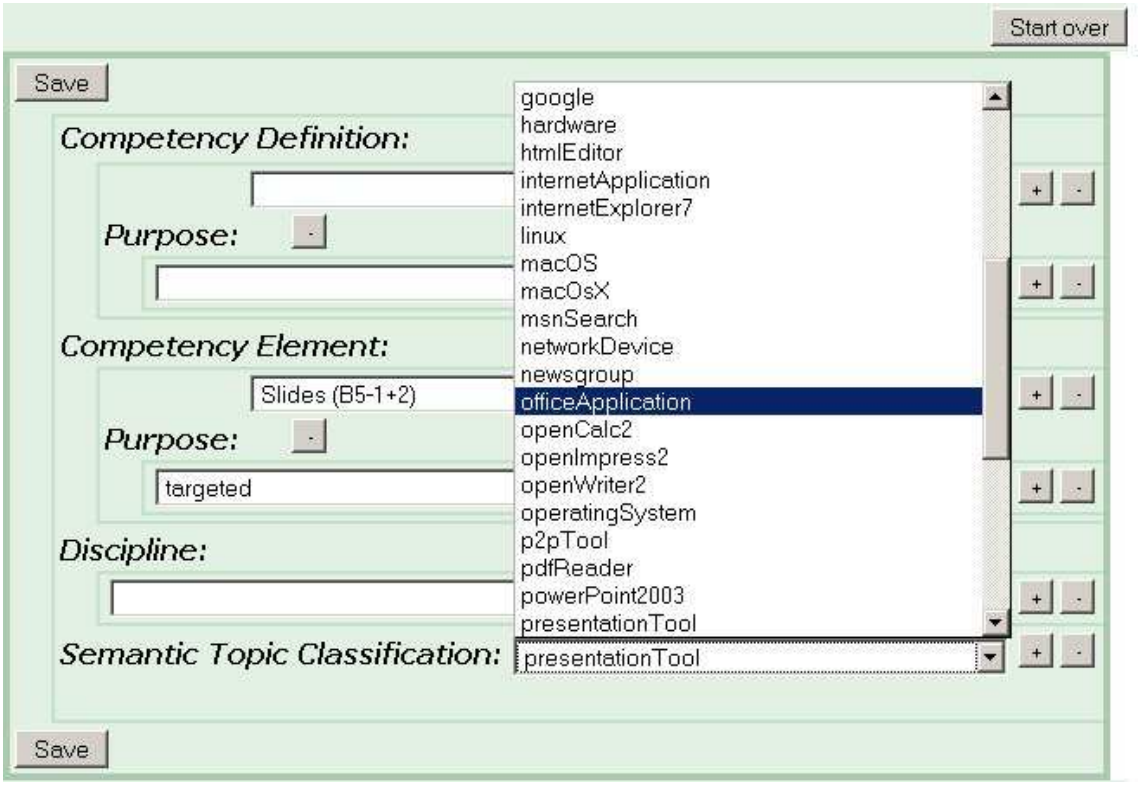


Figure 9: Screenshot illustrating a field filled with instances from ontologies, in the annotation tool.

ELUISA is based on SHAME, a flexible annotation tool. Indeed, SHAME is based on ontologies and on configuration files called Annotation Profile. In these profiles, an administrator can define the interface of the annotation tool by selecting some concepts of the ontologies and by configuring how these concepts will be filled by the person who will annotate. In Figure 9, we see a drop-down list filled for the concept Semantic Topic Classification of s-lom adapted for UHP. The administrator has configured this field as a drop-down list filled by the instances of the concept. However, the administrator could have configured it in other way, as a free text field for example.

5 ADVANCED USE: SEVERAL LORS WITH SEVERAL DISCIPLINE ONTOLOGIES

5.1 Context

In the basic use case, we chose to annotate Learning Objects with a Discipline ontology close to the organisation of disciplines in UHP. However, we found several ontologies of Disciplines. Each university has its vision of knowledge depending of its past. That is why, in this deliverable, we would like to explain a little bit how searching could be achieved between different LORs using different ontologies of Disciplines.

For example, here is an example of how the concept FieldOfStudy can be modelled in 2 different ways in two different ontologies.

In SUMO:

- Links: FieldOfStudy[19] is a subclass of Proposition.
- Definition: “An academic or applied discipline with recognized experts and with a core of accepted theory or practice. Note that FieldOfStudy is a subclass of Proposition, because a FieldOfStudy is understood to be a body of abstract, informational content, with varying degrees of certainty attached to each element of this content.”
- SubClasses: Only one subclass. Science (which includes Biology, Chemistry, Engineering, MedicalScience, Physics, Physiology, SocialScience)
- Instances: Architecture, Electronics, FieldOfLaw, History, InteriorDesign, Literature, Mathematics, MilitaryScience, Philosophy, Theology,

In Cyc, a request for FieldOfStudy[20] in the Cyc browser provides the following description:

- Definition: “A specialization of AspatialInformationStore. Each instance of FieldOfStudy is a particular area of study, with its own distinctive set of theories, hypotheses, and problems. Instances of FieldOfStudy are typically the subject of teaching and/or research within instances of AcademicDepartment (q.v.), although one AcademicDepartment may cover several instances of FieldOfStudy.”
- SubClasses include AppliedDesignFieldOfStudy, EthnicStudies, FocusedTechnologyField, AreaStudies, LiberalArtsFieldOfStudy, ScientificFieldOfStudy,
- Instances: Many instances are listed, but here are the ones which fit with the UHP vision. In FieldOfStudy (Medicine-FieldOfStudy, Dentistry) and

[19] http://sigma.ontologyportal.org:4010/sigma/Browse.jsp?kb=SUMO&term=FieldOfStudy

[20] http://www.cycfoundation.org/concepts/FieldOfStudy

in ScientificFieldOfStudy (ComputerScience, Mathematics, Biology, Pharmacology, Physics, SportsScience)

In order to execute a query upon LOs described with these two ontologies, there will be a need for mapping between both models. Ontology-mapping is a difficult problem that is actually explored by many works like [Kalfoglou & Schorlemmer 2005] [Gasevic 2006].

The goal of the following paragraphs is to describe how the LUISA project and its ontologies tackle the mapping question. We remind that the mapping aspect is a minor one for the LUISA project.

5.2 Short context description

In order to experiment the mapping situation in a concrete way, we considered a search over repositories using EADS and UHP ontologies of competencies. This use-case is described in D7.1.2. EADS and UHP are the two use-case partners of the LUISA project and use ontologies of competencies extended from the same general schema (GCS, see section 3.3).

Suppose that a LOR, that we call LOR-EADS is based on the EADS competencies classification and that a second LOR named LOR-UHP is based on the UHP competencies classification. A service will be required to compute a request that could be usable for searching in both LOR-EADS and LOR-UHP.

As will be described in a more detailed way into D7.3.2 (Use case implementation), the mapping is achieved thanks to an intermediate Web Service which contains “links” created manually. This component can be called by the other semantic ones to provide mapping between instances.

The idea of a query over both LORs is motivated by the fact that UHP and EADS share common competencies like about text processing, for example.

5.3 Instances mapping

Here is the mapping to link competencies from UHP and competencies from EADS.

About\Ontologies[21]	UHP-GCS (uhpGcs.wsml)	EADS-GCS (eadsCompetenciesOntology.wsml)
Windows	b1	eadsCompetencyDefinition_2082
Word	b4textprocessor	eadsCompetencyDefinition_2076
Excel	b4spreadsheet	eadsCompetencyDefinition_2077
Powerpoint	b5	eadsCompetencyDefinition_2078

[21] UHP instances must be preceded by: http://www.uhp-nancy.fr/ontologies/LUISA#

EADS instances must be preceded by: http://eads.org/competencies#

Outlook	b6	eadsCompetencyDefinition_2080
MS Project	b7	eadsCompetencyDefinition_2075

6 CONCLUSION AND PERSPECTIVES

The task of designing ontologies to annotate resources to be used in a research prototype led us to learn several lessons. We will describe them in the following sections; furthermore we will detail how our work on ontologies for academic context could be extended.

6.1 Lessons learnt about designing and sharing ontologies

The following lessons come from our experience built during the creation of ontologies for the LUISA project. These lessons are inline with most of the observations on onto designing. They show what current difficulties still are.

The first difficulty comes from looking for existing ontologies. As detailed in section 2.1, if re-using ontologies is a good practice, it is also a difficult one. Once found an ontology, the model has to be well enough described to be studied. As skimming through vast pages of raw code is a hard task, a detailed documentation must have been also written. For this case, the Cyc documentation and the coming feature to let comments[22] on concepts offers an interesting path.

In the LUISA project, the use of WSML as language to describe ontologies prevented us to re-use well-disseminated ontologies in OWL, to use globally accepted tools as Protégé[23] and decreased our possibility to directly communicate our work with other researchers.

When understandable models have been found, we still have to check if the approach supporting the ontologies matches the approach foreseen by our project. As seen with the ontology of disciplines, in France, organisations are the result of local history for each university. We could re-use a concept from Cyc but have not been able to re-use instances. We had to create new instances corresponding to our context.

In the LUISA project, from the use-case perspective, difficulties in the creation of ontologies arose because of an unstable environment. As with most Research & Development project, the components and use case specifications have been changed several times and so were the ontologies. As explained in D7.1 (defining academic use-cases), the C2I context have been chosen, few months after the start of the project, because of the need of a context dealing with competencies. Consequently, at the beginning of the project we had no sets of resources, no defined tools in addition to no ontologies. In this situation, the construction of ontologies required a little bit more iterative approach of all these moving elements.

Between these two versions of D7.2, we tried not to make evolve too much the models. We could act like this because of the limited[24] number of instances and

[22] http://www.cycfoundation.org/concepts/Ontology

[23] http://protege.stanford.edu/

[24] limited in comparison to huge existing ontologies as defined in section 2.

concepts involved into the ontologies. The annotation made us add some instances like the “PDF reader” into the Software ontology but no concepts were modified. Few relations (as “details” and “requires”) were corrected into the GCS/UHP file as soon as we could test them into the first prototype for the interface. Indeed, as the Graphical User Interface displays parts of the ontology, it adds few constraints that we can’t else imagine without difficulty.

Between use-case partners and technical ones, many people had to modify the ontologies for different reasons. Use-case partners want to add instances stemming from the annotation phase while technical partners want to correct some points about technical properties for example. Consequently, it arose problems to manage different versions and more exactly, to know who modifies which parts, when and for which reasons. In this case, the use of a version management system (as SubVersion[25]) seems a good idea to rule out many errors and mutual incomprehension.

6.2 Extending ontologies

Here is an example of how can ontologies be extended to provide “better” services. The limit, as experimented for the following use case, is the lack of possibility to test prototypes into universities without an engagement from internal partners.

The Bologna process is “a series of reforms needed to make European Higher Education more compatible and comparable, more competitive and more attractive”[26]. The aim “is to provide citizens with choices from a wide and transparent range of high quality courses and benefit from smooth recognition procedures.” According to this process, students are capitalizing credits in order to get a bachelor degree or a master degree. Credits are attached to units of studies, for instance “Algebra1” for a student in mathematics. In a student’s record we find the units he/she has successfully passed. To each unit is attached a list of disciplines, according to the unit description provided by the awarding university. Instead of requesting the field of study from the student as in the described use-case, the system could infer several fields of study from already passed units. This requires a connection with the students’ records information system and unfortunately cannot be experimented by now. However this situation is expected to move in the following years.

Technically, the concept unit of study should be described. Among other attributes, it should include a list of attached disciplines. Moreover, each student registers for preparing one or several diploma. Each diploma is under the responsibility of a given faculty and includes mandatory units of studies.

So the proposed “field_of_study” ontology should be expanded into a global UHP ontology describing the previously mentioned concepts and their inter-relations.

[25] http://subversion.tigris.org/

[26] http://ec.europa.eu/education/policies/educ/bologna/bologna_en.html

In the same way, the concept “person” from GCS which is used to represent a student should be specialized to include a richer student’s profile.

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7 APPENDICES

7.1 CLom-UHP ontology

C-lom is an adaptation of S-lom adding links with GCS. CLom-UHP derived from C-lom by adding links to the software ontology.

```
wsmlVariant _"http://www.wsmo.org/wsml/wsml-syntax/wsml-flight"
namespace { _"http://www.uhp-nancy.fr/ontologies/LUISA#"
 }

ontology uhpLOM2WSML

importsOntology
          { _"http://www.cc.uah.es/ie/ont/cLom#cLom-ont",
            _"http://www.uhp-
nancy.fr/ontologies/LUISA#uhpComputerLiteracy"}

concept uhpLearningObject subConceptOf
_"http://www.cc.uah.es/ie/ont/cLom#cLomlearningObject"
     requirement impliesType _"http://www.uhp-
nancy.fr/ontologies/LUISA/uhpComputerLiteracy#computerLiteracyItem"
     semanticTopicClassificationLO impliesType _"http://www.uhp-
nancy.fr/ontologies/LUISA/uhpComputerLiteracy#computerLiteracyItem"
```

7.2 GCS-UHP ontology

The following code describes the instances of Competencies from the basic use case according to the General Competency Ontology. See D4.11 “A flexible competency ontology for the description of learning resources“ for a more accurate description of GCS implementation.

```
namespace { _"http://www.uhp-nancy.fr/ontologies/LUISA#",
            rdfs _"http://www.w3.org/2000/01/rdf-schema#",
                gcs _"http://www.cc.uah.es/ie/ont/gcs#"
 }

ontology uhpGCO

importsOntology _"http://www.cc.uah.es/ie/ont/gcs#gcs-ont"

/* The goal of the subconcept hereafter is to allow the "about"
attribute */
concept uhpKnowledgeElementDefinition subConceptOf
gcs#knowledgeElementDefinition
     about impliesType  (1 *) _"http://www.uhp-
nancy.fr/ontologies/LUISA/uhpFieldsOfStudy#uhpFieldOfStudy"

/* The instances */
instance a1 memberOf gcs#competencyDefinition
```

```
nonFunctionalProperties
    rdfs#label hasValue "A1 Be aware of ICT's evolution"
endNonFunctionalProperties
     gcs#completelyDefined hasValue _boolean("true")
     gcs#requires hasValue {k_ICT_evolution, k_ICT_evolution_aware,
k_adaptability, k_interoperability }

instance a2 memberOf gcs#competencyDefinition
nonFunctionalProperties
    rdfs#label hasValue "A2 Comprehend ethical issues"
endNonFunctionalProperties
     gcs#completelyDefined hasValue _boolean("true")
     gcs#requires hasValue {k_politeness, k_critical_mind_on_sources,
k_confidentiality, k_basic_international_laws, k_online_identity }

instance b1 memberOf gcs#competencyDefinition
nonFunctionalProperties
    rdfs#label hasValue "B1 Control one's environment of work"
endNonFunctionalProperties
     gcs#completelyDefined hasValue _boolean("true")
     gcs#requires hasValue {k_desktop, k_filetree, k_select_software,
k_OS_maintenance, k_bookmarks, k_connect_to_network }

instance b2 memberOf gcs#competencyDefinition
nonFunctionalProperties
    rdfs#label hasValue "B2 Search for information"
endNonFunctionalProperties
     gcs#completelyDefined hasValue _boolean("true")
     gcs#requires hasValue {k_design_requests, k_use_search_results,
k_distinguish_search_engine, b1 }

instance b3 memberOf gcs#competencyDefinition
nonFunctionalProperties
    rdfs#label hasValue "B3 Save, secure and back-up one's data in a
local place or on a network"
endNonFunctionalProperties
     gcs#completelyDefined hasValue _boolean("true")
     gcs#requires hasValue {k_find_file_name, k_virus, k_compress,
k_backup, k_transfer_mobile, b1 }

instance k_basic_textprocessor memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Basic Textprocessor (B4-1)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#textProcessor"

instance k_advanced_textprocessor memberOf
uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Advanced Textprocessor (B4-2+3)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#textProcessor"
     gcs#prerequisites hasValue k_basic_textprocessor

instance k_basic_spreadsheet memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Basic Spreadsheet (B4-4)"
```

```
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#spreadsheetProcessor"

instance k_advanced_spreadsheet memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Advanced Spreadsheet (B4-5)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#spreadsheetProcessor"
     gcs#prerequisites hasValue k_basic_spreadsheet

instance b4textprocessor memberOf gcs#competencyDefinition
nonFunctionalProperties
    rdfs#label hasValue "B4>Textprocessor"
endNonFunctionalProperties
     gcs#completelyDefined hasValue _boolean("true")
     gcs#requires hasValue {b1, k_basic_textprocessor,
k_advanced_textprocessor }

instance b4spreadsheet memberOf gcs#competencyDefinition
nonFunctionalProperties
    rdfs#label hasValue "B4>Spreadsheet"
endNonFunctionalProperties
     gcs#completelyDefined hasValue _boolean("true")
     gcs#requires hasValue {b1, k_basic_spreadsheet,
k_advanced_spreadsheet }

instance b4 memberOf gcs#competencyDefinition
nonFunctionalProperties
    rdfs#label hasValue "B4 Realize documents for printing"
endNonFunctionalProperties
     gcs#completelyDefined hasValue _boolean("true")
     gcs#details hasValue {b4textprocessor, b4spreadsheet }

instance b5 memberOf gcs#competencyDefinition
nonFunctionalProperties
    rdfs#label hasValue "B5 Realize offline and online presentations"
endNonFunctionalProperties
     gcs#completelyDefined hasValue _boolean("true")
     gcs#requires hasValue {b1, k_slides, k_online_document }

instance b6 memberOf gcs#competencyDefinition
nonFunctionalProperties
    rdfs#label hasValue "B6 Communicate remotely"
endNonFunctionalProperties
     gcs#completelyDefined hasValue _boolean("true")
     gcs#requires hasValue {k_email, k_newsgroup, k_bulletin_board,
k_chat, k_mobile, b1 }

instance b7 memberOf gcs#competencyDefinition
nonFunctionalProperties
    rdfs#label hasValue  "B7 Realize a collaborative project"
endNonFunctionalProperties
     gcs#completelyDefined hasValue _boolean("true")
     gcs#requires hasValue {k_collaborative_workspace,
k_collaborative_writing, b2, b3, b4, b5, b6, k_document_versioning }

instance c2i memberOf gcs#competencyDefinition
```

```
nonFunctionalProperties
    rdfs#label hasValue "C2I"
endNonFunctionalProperties
     gcs#completelyDefined hasValue _boolean("true")
     gcs#details hasValue {a1, a2, b1, b2, b3, b4, b5, b6, b7 }

instance k_ICT_evolution memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "ICT's evolution (A1-1)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#computerLiteracyItem"

instance k_ICT_evolution_aware memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Aware of ICT's evolution (A1-2)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#computerLiteracyItem"

instance k_adaptability memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Adaptability (A1-3)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#computerLiteracyItem"

instance k_interoperability memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Interoperability (A1-4)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#software"

instance k_basic_international_laws memberOf
uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Basic international laws (A2-1)"
endNonFunctionalProperties
     about hasValue {_"http://www.uhp-
nancy.fr/ontologies/LUISA#p2pTool", _"http://www.uhp-
nancy.fr/ontologies/LUISA#publicCommunicationTool" }

instance k_online_identity memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Online identity (A2-2)"
endNonFunctionalProperties

instance k_confidentiality memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Confidentiality (A2-4)"
endNonFunctionalProperties

instance k_critical_mind_on_sources memberOf
uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Critical mind on sources (A2-5)"
endNonFunctionalProperties
```

```
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#browser"

instance k_politeness memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Politeness (A2-6)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#communicationTool"

instance k_desktop memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Desktop (B1-1)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#operatingSystem"

instance k_filetree memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Filetree (B1-3)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#fileApplication"

instance k_select_software memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Select the most approriate software (B1-4)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#software"

instance k_OS_maintenance memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "OS maintenance (B1-5)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#operatingSystem"

instance k_connect_to_network memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Connection to network (B1-7)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#networkDevice"

instance k_bookmarks memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Bookmarks (B1-6)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#browser"
     gcs#prerequisites hasValue k_connect_to_network

instance k_distinguish_search_engine memberOf
uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Distinguish search engine (B2-1)"
endNonFunctionalProperties
```

```
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#searchEngine"

instance k_design_requests memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Design requests (B2-2)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#searchEngine"

instance k_use_search_results memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Use search results (B2-3)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#searchEngine"

instance k_find_file_name memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Find a file by name (B3-1)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#fileApplication"

instance k_virus memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Virus (B3-2)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#antivirus"

instance k_backup memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Backup (B3-4)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#burningApplication"

instance k_compress memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Compression (B3-5)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#compressTool"

instance k_transfer_mobile memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Transfer with mobile device (B3-6)"
endNonFunctionalProperties

instance k_slides memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Slides (B5-1+2)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#presentationTool"

instance k_online_document memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
```

```
    rdfs#label hasValue "Online documents (B5-3)"
endNonFunctionalProperties
     about hasValue {_"http://www.uhp-
nancy.fr/ontologies/LUISA#browser", _"http://www.uhp-
nancy.fr/ontologies/LUISA#htmlEditor"}

instance k_email memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Email (B6-1)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#emailApplication"

instance k_newsgroup memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Newsgroup (B6-2)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#newsGroup"
     gcs#prerequisites hasValue k_email

instance k_bulletin_board memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Bulletin Board (B6-3)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#bulletinBoard"

instance k_chat memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Chat (B6-4)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#chatApplication"

instance k_mobile memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Mobile system (B6-5)"
endNonFunctionalProperties

instance k_collaborative_workspace memberOf
uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Collaborative workspace (B7-1)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#internetApplication"

instance k_collaborative_writing memberOf
uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Collaborative writing (B7-2)"
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#publicCommunicationTool"

instance k_document_versioning memberOf uhpKnowledgeElementDefinition
nonFunctionalProperties
    rdfs#label hasValue "Document versioning (B7-3)"
```

```
endNonFunctionalProperties
     about hasValue _"http://www.uhp-
nancy.fr/ontologies/LUISA#textProcessor"
```

7.3 FieldsOfStudy ontology

This ontology takes concepts from Cyc but add new intermediate concepts.

```
namespace { _"http://www.uhp-nancy.fr/ontologies/LUISA#",
     wsmostudio _"http://www.wsmostudio.org#",
     rdfs _"http://www.w3.org/2000/01/rdf-schema#"  }

ontology uhpFieldsOfStudy
     nonFunctionalProperties
          wsmostudio#version hasValue "0.6.0"
     endNonFunctionalProperties

importsOntology _"http://www.cc.uah.es/ie/ont/cLom#cLom-ont"

concept uhpFieldOfStudy subConceptOf
_"http://www.cc.uah.es/ie/ont/cLom#ocFieldOfStudy"
     linkedTo impliesType
_"http://www.cc.uah.es/ie/ont/cLom#ocFieldOfStudy"

concept scientificFieldOfStudy subConceptOf uhpFieldOfStudy

concept health subConceptOf scientificFieldOfStudy

concept mathematicsComputerScience subConceptOf scientificFieldOfStudy

concept lifeSciences subConceptOf scientificFieldOfStudy

concept physicsAndChemistrySciences subConceptOf
scientificFieldOfStudy

concept nonScientificFieldOfStudy subConceptOf uhpFieldOfStudy

concept foreignLanguages subConceptOf nonScientificFieldOfStudy

concept enterpriseManagement subConceptOf nonScientificFieldOfStudy

instance sportSciences memberOf scientificFieldOfStudy
           nonFunctionalProperties
               rdfs#label hasValue "sportSciences"
           endNonFunctionalProperties


instance physics memberOf physicsAndChemistrySciences
           nonFunctionalProperties
               rdfs#label hasValue "physics"
           endNonFunctionalProperties
           linkedTo hasValue mathematics

instance biophysics memberOf physicsAndChemistrySciences
           nonFunctionalProperties
```

```
            rdfs#label hasValue "biophysics"
        endNonFunctionalProperties

instance chemicalEngineering memberOf physicsAndChemistrySciences
        nonFunctionalProperties
            rdfs#label hasValue "chemicalEngineering"
        endNonFunctionalProperties

instance chemistry memberOf physicsAndChemistrySciences
        nonFunctionalProperties
            rdfs#label hasValue "chemistry"
        endNonFunctionalProperties

instance geology memberOf physicsAndChemistrySciences
        nonFunctionalProperties
            rdfs#label hasValue "geology"
        endNonFunctionalProperties

instance medicine memberOf health
        nonFunctionalProperties
            rdfs#label hasValue "medicine"
        endNonFunctionalProperties
        linkedTo hasValue biology

instance pharmacology memberOf health

        nonFunctionalProperties
            rdfs#label hasValue "pharmacology"
        endNonFunctionalProperties
        linkedTo hasValue biology

instance dentistry memberOf health
        nonFunctionalProperties
            rdfs#label hasValue "dentistry"
        endNonFunctionalProperties

instance ergonomics memberOf health
        nonFunctionalProperties
            rdfs#label hasValue "ergonomics"
        endNonFunctionalProperties

instance biology memberOf lifeSciences
        nonFunctionalProperties
            rdfs#label hasValue "biology"
        endNonFunctionalProperties

instance biogeography memberOf lifeSciences
        nonFunctionalProperties
            rdfs#label hasValue "biogeography"
        endNonFunctionalProperties

instance mathematics memberOf mathematicsComputerScience
        nonFunctionalProperties
            rdfs#label hasValue "mathematics"
        endNonFunctionalProperties

instance computerScience memberOf mathematicsComputerScience
        nonFunctionalProperties
            rdfs#label hasValue "computerScience"
```

```
            endNonFunctionalProperties

instance frenchAsSecondLanguage memberOf foreignLanguages
            nonFunctionalProperties
                rdfs#label hasValue "frenchAsSecondLanguage"
            endNonFunctionalProperties

instance english memberOf foreignLanguages
            nonFunctionalProperties
                rdfs#label hasValue "english"
            endNonFunctionalProperties

instance spanish memberOf foreignLanguages
            nonFunctionalProperties
                rdfs#label hasValue "spanish"
            endNonFunctionalProperties

instance accountancy memberOf enterpriseManagement
            nonFunctionalProperties
                rdfs#label hasValue "accountancy"
            endNonFunctionalProperties

instance law memberOf enterpriseManagement
            nonFunctionalProperties
                rdfs#label hasValue "law"
            endNonFunctionalProperties

instance marketing memberOf enterpriseManagement
            nonFunctionalProperties
                rdfs#label hasValue "marketing"
            endNonFunctionalProperties

instance humanResources memberOf enterpriseManagement
            nonFunctionalProperties
                rdfs#label hasValue "humanResources"
            endNonFunctionalProperties
```

7.4 Software ontology

The following code is the software ontology in WSML with its instances:

```
namespace { _"http://www.uhp-nancy.fr/ontologies/LUISA#",
     rdfs _"http://www.w3.org/2000/01/rdf-schema#",
     wsmostudio _"http://www.wsmostudio.org#" }

ontology uhpComputerLiteracy
     nonFunctionalProperties
          wsmostudio#version hasValue "0.6.0"
     endNonFunctionalProperties

concept computerLiteracyItem

concept hardware subConceptOf computerLiteracyItem

concept networkDevice subConceptOf hardware
```

```
concept software subConceptOf computerLiteracyItem
     cost impliesType  (0 1) _string
     interoperableWith impliesType computerLiteracyItem

concept operatingSystem subConceptOf software

concept windows subConceptOf operatingSystem

concept macOS subConceptOf operatingSystem

concept linux subConceptOf operatingSystem

concept application subConceptOf software

concept compressTool subConceptOf application

concept antivirus subConceptOf application

concept fileApplication subConceptOf application

concept burningApplication subConceptOf application

concept officeApplication subConceptOf application

concept internetApplication subConceptOf application

concept presentationTool subConceptOf officeApplication

concept spreadsheetProcessor subConceptOf officeApplication

concept textProcessor subConceptOf officeApplication

concept htmlEditor subConceptOf internetApplication

concept searchEngine subConceptOf internetApplication

concept p2pTool subConceptOf internetApplication

concept browser subConceptOf internetApplication

concept communicationTool subConceptOf internetApplication

concept privateCommunicationTool subConceptOf communicationTool

concept publicCommunicationTool subConceptOf communicationTool

concept chatApplication subConceptOf privateCommunicationTool

concept emailApplication subConceptOf privateCommunicationTool

concept newsGroup subConceptOf publicCommunicationTool

concept blog subConceptOf publicCommunicationTool

concept bulletinBoard subConceptOf publicCommunicationTool

instance pdfReader memberOf officeApplication
     nonFunctionalProperties
```

```
          rdfs#label hasValue "pdfReader"
     endNonFunctionalProperties
     cost hasValue "free"

instance word2003 memberOf textProcessor
     nonFunctionalProperties
          rdfs#label hasValue "word2003"
     endNonFunctionalProperties
     cost hasValue "notfree"
     interoperableWith hasValue window

instance excel2003 memberOf spreadsheetProcessor
     nonFunctionalProperties
          rdfs#label hasValue "excel2003"
     endNonFunctionalProperties
     cost hasValue "notfree"
     interoperableWith hasValue window

instance powerPoint2003 memberOf presentationTool
     nonFunctionalProperties
          rdfs#label hasValue "powerPoint2003"
     endNonFunctionalProperties
     cost hasValue "notfree"
     interoperableWith hasValue window

instance ubuntu606 memberOf linux
     nonFunctionalProperties
          rdfs#label hasValue "ubuntu606"
     endNonFunctionalProperties
     cost hasValue "free"

instance macOsX memberOf macOS
     nonFunctionalProperties
          rdfs#label hasValue "macOsX"
     endNonFunctionalProperties
     cost hasValue "notfree"

instance windows98 memberOf windows
     nonFunctionalProperties
          rdfs#label hasValue "windows98"
     endNonFunctionalProperties
     cost hasValue "notfree"

instance windowsMillenium memberOf windows
     nonFunctionalProperties
          rdfs#label hasValue "windowsMillenium"
     endNonFunctionalProperties
     cost hasValue "notfree"

instance windowsXP memberOf windows
     nonFunctionalProperties
          rdfs#label hasValue "windowsXP"
     endNonFunctionalProperties
     cost hasValue "notfree"

instance windowsVista memberOf windows
     nonFunctionalProperties
          rdfs#label hasValue "windowsVista"
     endNonFunctionalProperties
```

```
     cost hasValue "notfree"

instance firefox2 memberOf browser
     nonFunctionalProperties
          rdfs#label hasValue "firefox2"
     endNonFunctionalProperties
     cost hasValue "free"

instance internetExplorer7 memberOf browser
     nonFunctionalProperties
          rdfs#label hasValue "internetExplorer7"
     endNonFunctionalProperties
     interoperableWith hasValue window

instance google memberOf searchEngine
     nonFunctionalProperties
          rdfs#label hasValue "google"
     endNonFunctionalProperties
     cost hasValue "free"

instance yahooSearch memberOf searchEngine
     nonFunctionalProperties
          rdfs#label hasValue "yahooSearch"
     endNonFunctionalProperties
     cost hasValue "free"

instance msnSearch memberOf searchEngine
     nonFunctionalProperties
          rdfs#label hasValue "msnSearch"
     endNonFunctionalProperties
     cost hasValue "free"

instance openWriter2 memberOf textProcessor
     nonFunctionalProperties
          rdfs#label hasValue "openWriter2"
     endNonFunctionalProperties
     cost hasValue "free"
     interoperableWith hasValue {window, macOS, linux }

instance openImpress2 memberOf presentationTool
     nonFunctionalProperties
          rdfs#label hasValue "openImpress2"
     endNonFunctionalProperties
     cost hasValue "free"
     interoperableWith hasValue {window, macOS, linux }

instance openCalc2 memberOf spreadsheetProcessor
     nonFunctionalProperties
          rdfs#label hasValue "openCalc2"
     endNonFunctionalProperties
     cost hasValue "free"
     interoperableWith hasValue {window, macOS, linux }

instance _software memberOf software
     nonFunctionalProperties
          rdfs#label hasValue "software"
     endNonFunctionalProperties

instance _hardware memberOf hardware
```

```
     nonFunctionalProperties
          rdfs#label hasValue "hardware"
     endNonFunctionalProperties

instance _networkDevice memberOf networkDevice
     nonFunctionalProperties
          rdfs#label hasValue "networkDevice"
     endNonFunctionalProperties

instance _application memberOf application
     nonFunctionalProperties
          rdfs#label hasValue "application"
     endNonFunctionalProperties

instance _antivirus memberOf antivirus
     nonFunctionalProperties
          rdfs#label hasValue "antivirus"
     endNonFunctionalProperties

instance _burningApplication memberOf burningApplication
     nonFunctionalProperties
          rdfs#label hasValue "burningApplication"
     endNonFunctionalProperties

instance _compressTool memberOf compressTool
     nonFunctionalProperties
          rdfs#label hasValue "compressTool"
     endNonFunctionalProperties

instance _fileApplication memberOf fileApplication
     nonFunctionalProperties
          rdfs#label hasValue "fileApplication"
     endNonFunctionalProperties

instance _internetApplication memberOf internetApplication
     nonFunctionalProperties
          rdfs#label hasValue "internetApplication"
     endNonFunctionalProperties

instance _officeApplication memberOf officeApplication
     nonFunctionalProperties
          rdfs#label hasValue "officeApplication"
     endNonFunctionalProperties

instance _spreadsheetProcessor memberOf spreadsheetProcessor
     nonFunctionalProperties
          rdfs#label hasValue "spreadsheetProcessor"
     endNonFunctionalProperties

instance _textProcessor memberOf textProcessor
     nonFunctionalProperties
          rdfs#label hasValue "textProcessor"
     endNonFunctionalProperties

instance _browser memberOf browser
     nonFunctionalProperties
          rdfs#label hasValue "browser"
     endNonFunctionalProperties
```

```
instance _communicationTool memberOf communicationTool
     nonFunctionalProperties
          rdfs#label hasValue "communicationTool"
     endNonFunctionalProperties

instance _htmlEditor memberOf htmlEditor
     nonFunctionalProperties
          rdfs#label hasValue "htmlEditor"
     endNonFunctionalProperties

instance _p2pTool memberOf p2pTool
     nonFunctionalProperties
          rdfs#label hasValue "p2pTool"
     endNonFunctionalProperties

instance _searchEngine memberOf searchEngine
     nonFunctionalProperties
          rdfs#label hasValue "searchEngine"
     endNonFunctionalProperties

instance _privateCommunicationTool memberOf privateCommunicationTool
     nonFunctionalProperties
          rdfs#label hasValue "privateCommunicationTool"
     endNonFunctionalProperties

instance _chatApplication memberOf chatApplication
     nonFunctionalProperties
          rdfs#label hasValue "chatApplication"
     endNonFunctionalProperties

instance _emailApplication memberOf emailApplication
     nonFunctionalProperties
          rdfs#label hasValue "emailApplication"
     endNonFunctionalProperties

instance _publicCommunicationTool memberOf publicCommunicationTool
     nonFunctionalProperties
          rdfs#label hasValue "publicCommunicationTool"
     endNonFunctionalProperties

instance _blog memberOf blog
     nonFunctionalProperties
          rdfs#label hasValue "blog"
     endNonFunctionalProperties

instance _bulletinBoard memberOf bulletinBoard
     nonFunctionalProperties
          rdfs#label hasValue "bulletinBoard"
     endNonFunctionalProperties

instance _newsgroup memberOf newsGroup
     nonFunctionalProperties
          rdfs#label hasValue "newsgroup"
     endNonFunctionalProperties

instance _presentationTool memberOf presentationTool
     nonFunctionalProperties
          rdfs#label hasValue "presentationTool"
     endNonFunctionalProperties
```

```
instance _operatingSystem memberOf operatingSystem
     nonFunctionalProperties
          rdfs#label hasValue "operatingSystem"
     endNonFunctionalProperties

instance _linux memberOf linux
     nonFunctionalProperties
          rdfs#label hasValue "linux"
     endNonFunctionalProperties

instance _macOS memberOf macOS
     nonFunctionalProperties
          rdfs#label hasValue "macOS"
     endNonFunctionalProperties

instance _windows memberOf windows
     nonFunctionalProperties
          rdfs#label hasValue "windows"
     endNonFunctionalProperties
```