Ontology of personal learning environments in the development of thesis project

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ABSTRACT
The thesis is the final step in academic formation of students. Its development may experience some difficulties that cause delays in delivery times. The internet allows students to access relevant and large amounts of information for use in the development of their theses. The internet also allows students to interact with others in order to create knowledge networks. However, exposure to too much information can produce *infoxication*. Therefore, there is a need to organise such information and technological resources. Through a personal learning environment (PLE), students can use current technology and online resources to develop their projects. Furthermore, by means of an ontological model, the underlying knowledge in the domain and environment can be represented in a readable format for machines. This paper presents an ontological model called PLET4Thesis, which has been designed in order to organise the process of thesis development using the elements required to create a PLE.

CCS Concepts
• Computing methodologies→Ontology engineering.

Keywords
Inference rule; ontology; PLE; Protégé; thesis.

1. INTRODUCTION
The thesis is the final step in academic formation of students and it is a process that contains important research work [14]. Students who are developing a thesis are known as ―thesis students". In their research, students can use many information sources and applications that are available on the internet. However, large amounts of information and resources can produce *infoxication* [7]. *Infoxication* refers to an overload of information for users [16]. To find and process the appropriate information can take a long time, which generates errors and delays in finishing a thesis.

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To mitigate *infoxication* and possible delays in thesis completion, it is necessary for students to organise the resources and information that are available to them. The set of services, tools and connections used to reach the goal of a completed thesis is known as a personal learning environment (PLE) [8].

The tools and information resources necessary for the development of a thesis project should be organised in such a way so as to provide the support required by students. In the context of the web of data, which is oriented towards an ecosystem of linked data, ontologies are being used as a model for the organisation of knowledge; in this way, machines can process automatically the content that is signified by this mode of representation.

This paper presents an ontological model called PLET4Thesis, which is designed to guide thesis students in the construction of their PLEs. Ontologies provide the framework necessary to create inference rules-based recommendations of technological, informational and human resources that will guide students during the development of their projects. In this way, some of the difficulties associated with thesis completion, such as an overload of information and scarcity or poor use of technological tools.

The second part of this paper presents the fundamental theoretical aspects of PLEs and ontologies. The third section explains the process of creation of the knowledge model. Following this, the paper discusses the usefulness of ontology for the generation of new knowledge using the set of inference rules defined during its development. The paper ends with the study's conclusions.

2. BACKGROUND
2.1 Personal Learning Environments
A PLE is an approach to how current technology can be used to teach and learn. A PLE goes beyond the simple use of technology; it is also about the philosophical, ethical and pedagogical issues of learning [1, 3]. For Adell and Castañeda, a PLE is a ―set of tools, information sources, connections and activities that each person uses assiduously to learn" [1, p.7].

PLEs have always existed but they were centralised in educational institutions (books or experts), so they were not accessible to all students or practitioners. With the emergence of the internet, information has become more widely dispersed and PLEs have come to be positioned as the means by which a student can learn from the network and on network [6].

A PLE is the result of three basic cognitive processes: reading, reflection and sharing [3]. Learning occurs when the strategies and appropriate tools [15] are harmonically combined according to the cognitive level required by the learner [1].

2.2 Ontologies

The ontological definition for computer science was proposed by Gruber in the early 1990s: ―an ontology is an explicit specification of a conceptualization" [11, p.908]. Another popular definition was proposed by Guarino, who noted that, ―an ontology is an engineering artifact constituted by a specific vocabulary to describe a certain reality" [12]. Therefore, to create ontologies, knowledge must be represented in a way that is readable by computers, while it also has to be consensual and reusable.

Ontologies have become a fundamental part of the semantic web [4], which is an evolution of the document-based web, since ontologies guarantee that computers can access structured collections of information and sets of inference rules that can be used to perform automated reasoning [5].

To support the description of a knowledge domain, an ontology includes the following elements [4][13]:

- Concepts or classes: these refer to a set of object categories;
- Relationships: these are established between concepts of ontology to represent the interactions between them;
- Instances or individuals: these are the objects or members of a class;
- Properties or slots: these are a set of characteristics or attributes of objects;
- Facets: properties can have different facets that describe the type of value, supported values, cardinality and other characteristics that values can take; and
- Axioms: these are the elements that allow the modelling of truths that are always fulfilled.

2.3 Use of ontologies in e-learning

A 2008 study [9] highlighted that the semantic web attempts to respond to the growing challenges faced by online learning, due to the fast growth of the web and its use as an educational platform. The first studies mentioned were published between 1995 and 1996. From 1999, ontologies began to be incorporated into different varieties of educational projects, in particular, various educational systems based on the web.

A recent study from 2015 [2] examined the development and use of ontologies in the domain of e-learning systems:

- To model and manage curricular resources with the objective of facilitating the access and retrieval of curricular information and, from the institutional point of view, to be able to determine curricular compliance and use in other processes;
- To describe learning domains from several perspectives, enabling the description and retrieval of learning content;
- To describe students' data or profiles with the aim of producing evaluation services and personalisation; and
- To describe e-learning services through shared vocabularies that facilitate interoperability and data exchange among different educational systems or e-learning systems.

It was not possible to find a specific study that describes the PLE's use for developing a degree or postgraduate thesis student.

3. METHOD

The ontology PLET4Thesis was created according to of the most recognised methodologies used to accomplish this goal, METHONTOLOGY [10], and the ontology is based on the practical guide proposed by Noy and McGuiness [13]. The idea in unifying these two approaches was to initiate a simultaneously formal and agile process for the creation of the ontology.

Figure 1 shows the activities defined by each methodology and the final process: the specification phase defined by METHONTOLOGY is better defined in the resulting agile methodology and the conceptualisation phase has been simplified according to the practical recommendations of Noy and McGuiness [13]. The redefinition of the creation process called agile methodology was due to the fact that the team participating in this proposal shared roles as ontological engineers and as experts in the domain of interest. This helped in the development of a more agile process in creating a formal and consensual ontological model.

3.1 Specification

3.1.1 Define domain and scope

The PLET4Thesis ontology has been designed in order to model the components of a PLE for the development of a thesis project. Academic tutors and thesis students can use it to answer some of the following functional requirements:

- What is the name and contact information of the thesis author?
- What are the phases in which a project has been structured and what is its state?
- What technological and information resources have been used for the development of a thesis during one of its phases?
- Who are the experts in the area of knowledge in which a determined project is being developed?

3.1.2 List important terms

Depending on the requirements defined in the previous step, the most relevant terms of the domain are identified (see Table 1).

Table 1. Main terms of the domain

Co-director	Educational organisation	Read strategy	Status
Concept	Expert	Reflection strategy	Strategy
Deliverable	Phase	Relation strategy	Student
Director	Place	Repository	Technology
Document	Product	Requirement	Thesis project
Event	Project	Researcher	Thesis

3.1.3 Reuse existing ontologies

Before continuing with the construction of the ontological model, the authors considered the identification of existing ontologies and vocabularies to describe the most relevant terms of the domain. Through the popular service, Linked Open Vocabularies (LOV[1]), some approaches to describe the general terms of the ontology were found, such as *thesis*, *person*, *resource* and *document*, among others.

[1] http://lov.okfn.org/dataset/lov

Table 2 lists the main ontological resources and vocabularies that were selected according to their popularity and coherence with the domain.

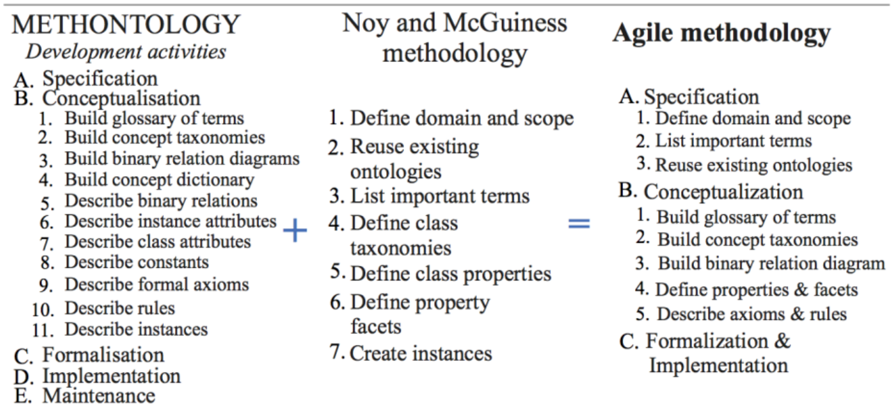

Figure 1. Redefinition of the ontology creation process.

Table 2. Reused ontological resources and metadata schemes

Prefix	Name
bibo	Bibliographic ontology describes bibliographic items
dbo dbp	DBPedia ontology defines entities and facts from Wikipedia
dc/dct	Dublin Core Metadata Element Set & Terms are specifications of all metadata terms maintained by the Dublin Core Metadata Initiative (DCMI)
schema	schema.org defines schemas for structured data on the internet, on web pages, in email messages and beyond
foaf	FOAF vocabulary is used to describe links among people, organisations and information using the web
frapo	FRAPO ontology is used to describe research project administrative information
skos	The Simple Knowledge Organisation System (SKOS) is a common data model for sharing and linking knowledge organisation systems via the semantic web

3.2 Conceptualisation

3.2.1 Build glossary of terms

Each term identified in step two of the specification is described in detail in this step. The explicit specification of each term is the key to eliminating problems of meaning and in constructing the conceptual model of the ontology. Table 3 shows a subset of terms that are explicitly defined.

Table 3. Extract of glossary of terms

Term	Description	Type
Deliverable	A document or any intangible asset that is produced as part of a project	Concept
Expert	All kinds of people who know a lot about a subject	Concept
Phase	A part or step in a process; one part in a series of related events or actions	Concept
Occupation	Position held by a person within an organisation	Data property
Degree title	Title of degree reached or to be attained by a person	Data property

3.2.2 Build concept taxonomies

With the aim of improving the reuse of the present ontological model, some classes were reorganised by defining the taxonomies of concepts.

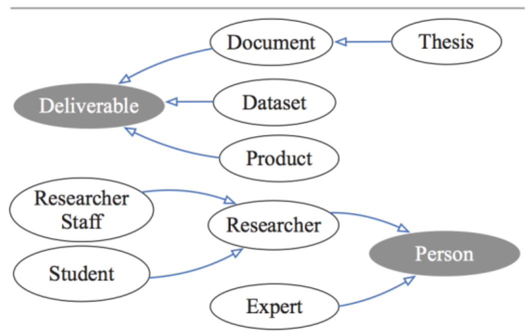

Figure 2. Partial view of concept taxonomy.

According to [19], there are three approaches to defining taxonomies. In this study, a hybrid approach was adopted, Figure 2 illustrates two methods. In the case of the *Deliverable* concept, the top-down approach was used, which begins with the definition of the general concept and then its specialisations are identified—in this case, *Document*, *Dataset* and *Product*. On the other hand, the bottom-up approach begins with the definition of the most specific concepts and these are then grouped into more general ones. Two specific cases are shown in Figure 2, where *Student* and *Researcher Staff* converge into the generic class, *Person*.

3.2.3 Build binary-relation diagram

Links (object properties) among concepts are defined in this step. Figure 3 shows a high-level view of the binary-relation diagram; here, the main classes of the domain and how they are connected can be distinguished.

3.2.4 Define properties and facets

In this step, the authors try to provide a detailed description of the internal structure (attributes or data properties) of the concepts and their relationships. Attributes will provide the necessary information to answer the questions raised in the functional requirements. Relationships will allow for traversing the graph until find some entity or value of interest (see Table 4).

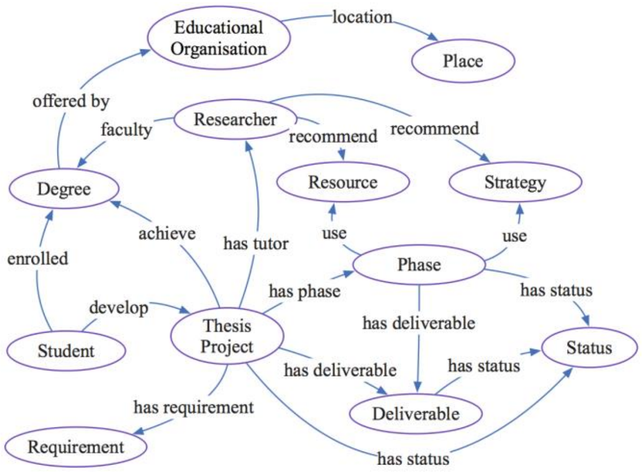

Figure 3. Binary-relation diagram.

Table 4. Extract of facets

Property	Domain	Range	Cardinality
degreeTitle	ThesisProject	String	1
occupation	Researcher	String	N
order	Phase	Integer	1
progress	Phase, Project	String	1
version	Deliverable	String	1

3.2.5 Describe axioms and inference rules

Based on the semantics expressed by each of the ontological terms, two inference rules have been designed, focusing on experts' recommendations (see Table 5) and technology for the development of the project (see Table 6). Through these formulations, the ontology's potential can be tested so recommendations can be generated with the aim of guiding the student during their thesis development.

Table 5. Inference rule for recommending experts

Description	According to the relationships between researchers and domain experts, potential advisors can be identified for the development of a thesis project
Expression	forall(?S) [swpo:Student(?S) and swpo:ResearcherStaff(?R) and plet:ThesisProject(?P) and plet:Expert(?X) and skos:Concept(?C) and plet:hasTutor(?S, ?R) and foaf:knows(?R, ?X) and dct:subject(?R, ?C) and dct:subject(?X, ?C) ⇒ plet:isRecommendTo(?X, ?P)]
Concepts	swpo:Student swpo:ResearcherStaff plet:Expert swpo:Concept
Binary relation	foaf:knows dct:subject plet:isRecommendTo plet:hasTutor
Variables	?S ?R ?P ?X ?C

Table 6. Inference rule for recommending tools

Description	For the development of each stage of the project, depending on its nature, some technological tools may be recommended to the student.
Expression	forall(?S) [swpo:Student(?S) and plet:ThesisProject(?P) and plet:Phase(?H) and plet:ReadTechnology(?T) and foaf:made(?S, ?P) and plet:hasPhase(?P, ?H) and dct:title(?H, ?T) and contain(?t, "Literature Review") ⇒ plet:isRecommendTo(?T, ?H)]
Concepts	swpo:Student plet:ThesisProject plet:Phase plet:ReadTechnology
Binary relation	foaf:made | plet:hasPhase | plet:isRecommendTo
Variables	?S ?P ?H ?T

3.3 Formalisation and implementation

The formalisation of the ontology uses conventions and sentences based on semantic web technologies (such as RDF, RDFS and OWL), with the aim of defining the semantics of entities identified during the conceptualisation stage. In this step, it is also crucial to define the nature of the relationship that joins two equivalent objects in different vocabularies. To illustrate these aspects, the prefix *plet* has been set to point to the base URI of the PLET4Thesis ontology.

Table 7. Extract of formal RDF sentences

Subject	Predicate	Object
plet:Expert	rdfs:subClassOf	schema:Person
plet:Expert	rdfs:subClassOf	foaf:Person
plet:ThesisProject	rdfs:subClassOf	dbo:Project
plet:version	rdf:type	owl:DataProperty
plet:version	rdfs:domain	plet:Deliverable

Using the defined formal model, the computable model using Protégé was created. Protégé is a free, open-source platform and well-known tool in the community.

Finally, Pellet reasoner was used to check consistency of the ontology, i.e., both the final version as well as its intermediate versions were syntactically validated. In addition, through the creation of a set of individuals, authors verified the completeness of the ontology for describing real thesis projects.

4. DISCUSSION

To understand the potential use of the PLET4Thesis ontology, the authors have illustrated two use cases. Figure 4 shows the generation of new facts or new knowledge thanks to the rules of inference defined during the development of the ontology.

In case one, the rule helps to make a recommendation for experts following the logic described here (see Table 5). Student S is developing thesis project P about subject or concept C. Student S has tutor R and tutor R knows expert X. As tutor R and expert X know about topic C, the same topic that is related to thesis project P, then a rules-based inference engine will generate a recommendation: expert X knows theme C and could help with the development of student S's thesis.

In case two, the rule helps to make a recommendation for tools following the logic described here (see Table 6). Student S is developing thesis project P. The thesis project is developed in phases. The current phase of the thesis is the H phase, which has the title ―Literature review”. For the execution of phase H of project P, student S receives the recommendation of a set of technological tools according to the nature of the work that is currently being developed. For example, for the literature review, student S can receive a recommendation to use particular resources, such as Google Scholar.

5. CONCLUSION

The internet has a wide variety of resources and information that can help students effectively and efficiently produce research for a thesis. This huge amount of information can cause *infoxication*. This is why it is necessary that tutors know how to help students in two ways: to guide the students in their thesis and suggest technology, strategies and experts to help the students develop their project more efficiently. The organisation of this information will shape the student's PLE and the ontological model explored in this study can facilitate this work.

Conceived as a project, a thesis is carried out in phases and generates deliverables at the end of each stage. Gaining control of these deliverables, coupled with the optimal use of technologies and strategies, will improve the delivery times for thesis completion. The presented ontology can help to control both aspects.

As a future work, a wiki semantic is being personalised so students and tutors can easily feed the ontology. Subsequently, through semantic technologies, this ensures the generation of new knowledge and the creation of interesting representations for understanding the state of progress of the project.

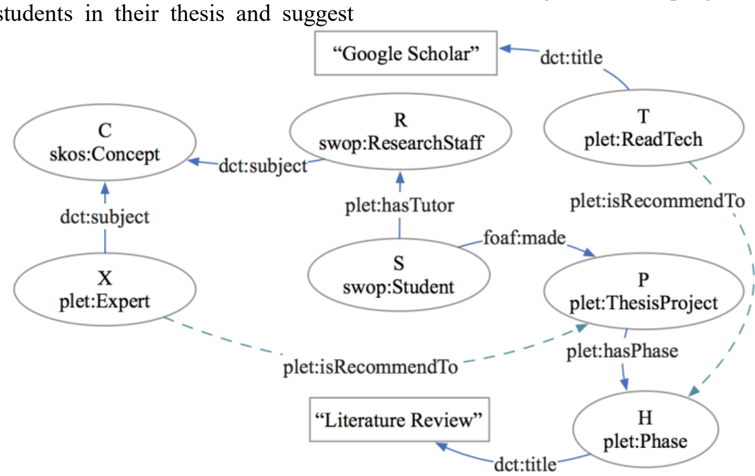

Figure 4. Mechanism of knowledge inference.

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