A SEMANTIC DESCRIPTION MODEL FOR THE DEVELOPMENT AND EVALUATION OF PERSONALIZED LEARNING ENVIRONMENTS BASED ON DISTRIBUTED SYSTEMS

by

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Abstract

The objective of this doctoral thesis is to implement and evaluate distributed Virtual Learning Environments (VLEs) supported with semantic models for the description of learning services and their incorporation within learning scenarios based on Grid and Cloud technologies, with features that allow students' personalization and collaboration. These distributed VLEs demand a flexible and coordinated form of sharing network resources, which are dynamically collected by individuals and institutions, and establishing mechanisms for the correct exchange of information and a strict control of the resources to share. Learning services are fundamental components of distributed VLEs representing functions that can be easily reused without knowing the details of how services have been implemented. Search engines to discover resources in a network are based exclusively on technical syntactic categories and parameters. These are commonly far from the concepts used in learning scenarios, which result in students' difficulties in their location and progress in learning activities, especially when learning services are distributed over the web. Semantic modeling of web services promise to automate tasks such as discovery, matching, composition and invocation of services. In carrying out this research was taken into account that the use of distributed technologies and levels of abstraction "per se" are not enough to help motivate students neither provide any considerable improvement as regards the results obtained or the acquisition of new knowledge. In this sense, the use of distributed technology cannot be oblivious to learning objectives. Instead, it must be integrated with certain educational methodologies so that it makes a real difference in student-centered learning activities. Our study showed that when this technology is used to foster activities that include collaboration, interaction, and monitoring of student progress, amongst others, the outcomes are better. In that

sense we identify 3 research issues: (i) design of semantic models for defining learning services, (ii) design of integration and composition models for learning services based on semantic modeling and (iii) implementation of customization schemes of learning tools based on semantic modeling. We formulate the problem of this research work in the form of the following main research question: *Is it possible to develop more efficient semantic models for learning services description to facilitate their detection and allow their integration and composition into various distributed-based learning tools, where collaboration and personalization are the most important features and therefore are focused on the active construction of knowledge?*. As a result of the research conducted we can highlight the main contributions of this work as follows; proposed a semantic description model of service properties, parameters and connections, which facilitates automatic discovery and invocation of services without human interaction and enough information for human search; this model allows locating for learning services of distributed network through semantic description, especially those based on grid computing and cloud computing, allowing a complete semantic description based on functional and non-functional properties of Web services, setting aside the traditional technologies of syntactic search methods; and the semantic model will allow the design of ubiquitous and pervasive learning scenarios will foment the interaction among the users and will allow developing collaborative and personalized learning activities. Our study showed that VLEs built using Semantic Web as a mechanism for searching and locating learning services in a distributed learning environment can offer a better user-friendly experience for students, whereas it proves to be less strenuous on students' cognitive load and better levels of user's usability.

Resumen

El objetivo de esta tesis doctoral es implementar y evaluar Entornos Virtuales de Aprendizaje (EVA) distribuidos con el soporte de modelos semánticos para la descripción de servicios de aprendizaje y su incorporación dentro en escenarios de aprendizaje basados en tecnologías Grid y de Cómputo en la Nube. Estos EVA distribuidos cuentan con funcionalidades que permiten la colaboración y personalización por parte de los estudiantes, así como demandan un intercambio coordinado y flexible de los recursos de la red, los cuales son recolectados de forma dinámica por individuos e instituciones, para los cuales se establecen mecanismos que permiten el correcto intercambio de la información y un control estricto de los recursos a compartir. Los servicios de aprendizaje son componentes fundamentales de los EVA distribuidos, representando funcionalidades que pueden ser fácilmente reutilizados sin conocer los detalles de la forma en que se han implementado. Los mecanismos para localizar estos recursos en la red, están basados exclusivamente en búsquedas sintácticas a partir de categorías y parámetros técnicos de los mismos. Comúnmente estas categorías y parámetros están lejos de los conceptos utilizados por los usuarios de los escenarios de aprendizaje, lo que da lugar a dificultades para que los estudiantes conozcan la ubicación de los servicios y puedan invocarlos, cuestión que puede representar una limitante para la realización de las actividades de aprendizaje, sobre todo cuando estos servicios de aprendizaje se encuentran distribuidos a través de la red. Una de las promesas del modelado semántico de servicios web, es permitir automatizar las tareas de localización, adaptación, composición e invocación de servicios web. En la realización de este trabajo de tesis hemos tomado en cuenta que el uso de las tecnologías distribuidas "per se" no

son suficientes para ayudar a motivar a los estudiantes y que las mismas no proporciona ninguna mejora considerable en el desempeño académico o en la adquisición de nuevos conocimientos. En este sentido, el uso de tecnologías distribuidas no puede ser ajeno a los objetivos de aprendizaje y deben integrarse con ciertas metodologías educativas para que haga una diferencia real en las actividades de aprendizaje que están centradas en el estudiante. En esta tesis se demuestra que cuando se utiliza estas tecnologías para fomentar actividades que incluyen entre otras la colaboración, interacción y seguimiento de los progresos de los estudiantes, los resultados son mejores. Para comprobar esto, en este trabajo hemos identificado 3 temas de investigación: (i) diseño de modelos semánticos para la definición de servicios de aprendizaje, (ii) diseño de modelos de integración y composición de servicios de aprendizaje basado en el modelado semántico y (iii) implementación de esquemas de personalización de herramientas de aprendizaje basado en modelado semántico. Formulamos el problema de investigación principal de este trabajo con la siguiente pregunta de investigación: *¿Es posible el desarrollo de modelos semánticos para la descripción de servicios de aprendizaje distribuidos que faciliten su detección y permitan su integración y composición en diferentes herramientas de aprendizaje, donde la personalización y colaboración son las características más importantes y, por tanto, se centran en la construcción activa del conocimiento?.* Como resultado de esta investigación podemos destacar las siguientes como principales aportaciones de este trabajo; proponer un modelo de descripción semántica de servicios de aprendizaje, que faciliten el descubrimiento e invocación sin la intervención humana y que cuenten con la información suficiente para facilitar la búsqueda con intervención humana; este modelo de descripción semántica basada en las propiedades funcionales y no funcionales de los servicios Web permite la localización de servicios de aprendizaje en redes distribuidas, como es el caso de las basadas en computación grid y cómputo en la nube, dejando de lado las tecnologías tradicionales para los métodos de búsqueda sintácticas ; el modelo semántico permite el diseño de escenarios de aprendizaje pervasivos y ubicuos, fomentando la interacción entre los usuarios y permitiendo el desarrollo de actividades de aprendizaje colaborativo y personalizadas. Nuestro estudio mostró que los EVA construidos usando Web Semántica como un mecanismo para la búsqueda y localización de servicios de aprendizaje en un ambiente de aprendizaje distribuido ofrecen una experiencia más satisfactoria para los estudiantes, mientras que se demuestra que genera una menor carga cognitiva para los estudiantes y mejores niveles de la usabilidad para los usuarios.

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Dedication

I dedicate this thesis to my family, you have been the support to conclude this work, to my mother and Ernesto for their unconditional love, to my daughter Amelie who is my motivation, to Pilar for her love and care, to Jorge, Juan Carlos, Frey, Ana, Jannet, Mayra, Ixchel, Sofia, Oscar, Salvador, Laura and Camila, thanks for being my family.

CHAPTER 1 - Introduction

1.1 Context of the research

Despite of the initial problems on the field of integrating several resources that consolidate Virtual Learning Environments (VLEs) (Weller, 2007), VLEs based on services, open new forms of constructing e-learning systems using technologies that distributed systems provide, which include as their primary requirements the provision of shared services, syndicating heterogeneous resources and taking advantage of the discovery of pertinent content (Booth & Clark, 2009). The paradigm of learning based on distributed systems points to use and to develop collaborative tools promoting interaction and the personalized use of a range learning Services. In that sense, the use of web services has fundamentally changed the way to develop e-learning applications (Page et al., 2005). In the field of VLEs based on distributed systems, on the one hand an important objective to achieve is the correct integration of heterogeneous learning services offered by different organizations in order to develop collaborative learning tools, on a user-centered context. On the other hand, if a single learning service cannot satisfy the functionality required by the user, one should have the possibility to combine existent services to fulfill the requirement. In that sense many efforts have been made to develop methods for discovery, search, matching and composition of web services that use the semantic description of capabilities as a main tool.

In this introductory chapter we define the framework that justifies this doctoral thesis work on Information and Knowledge Society in the Networking Technologies line of research, focused on the development of semantic description models for learning services and the analysis, design, development and evaluation of learning scenarios based on distributed systems.

1.2 Previous research

There have been many efforts to try to build VLEs that make use of the benefits that represent distributed systems, including Grid Computing (Foster et al., 2001) and Cloud computing (Al-Zoube, 2009). In this sense, on the one hand the concept of Learning Grid (Capuano et al., 2008). has emerged which can be considered as an enabling architecture based on three pillars: Grid Computing, Semantics and Educational Modeling allowing the definition and the execution of learning experiences obtained as cooperation and composition of distributed heterogeneous actors, resources and services. On the other hand Cloud computing technology (and the construction of platforms for college education management) not only can improve the utilization resource rate, saving university resources and improving the teaching level, but also can bring new areas of application closer to our life and our study areas.

In chapter 2 we conducted a detailed review of related works for the background and fundamentals of distributed services used on the construction of interactive VLEs. After that, we will review some related efforts on important research issues, such as: semantic modeling of learning services, distributed learning tools integration, and composition and customization of distributed VLEs.

1.3 Statement of the problem

Despite the efforts made in related research work, it is not yet clear how the integration of distributed services can benefit both e-learning systems and students' learning processes. In this sense, we identified 3 research issues: (i) design of semantic models for defining learning services, (ii) design of integration and composition models for learning services based on semantic modeling and (iii) implementation of customization schemes of learning tools based on semantic modeling. Each of these lines and related research questions are described in Chapter 3.

1.4 Objectives, contributions and description of the research methodology

We describe the main objective of this doctoral thesis as follow:

The aim of this thesis is the analysis, design and implementation of semantic models for learning services description to facilitate their location and allowing its integration into the various learning tools based on distributed systems, where the customization and personalization is the most important feature and therefore are focused on the active construction of knowledge. The use of these semantic description models of learning services based on Grid and Cloud computing will support the definition, implementation and evaluation of custom learning scenarios. Such scenarios will have features such as being based on innovative information technologies and will be accessible from anywhere, from any device at any time (Pervasive and ubiquitous computing)

From this main objective, we defined the following detailed objectives:

- Define models based on semantics description standards for learning facilities that have their support in technological capabilities associated with the distributed VLEs and to take the semantic description as an element that enables location of the best resources available on the network.
- Explore how semantic technologies can be used to improve support on learning and in particular the dynamism and interaction between tools, as well as the ability to compose and automatically discover tools and services for high-level learning from others of lower level.
- Define models of customized VLEs based on Grid and Cloud technologies and focus on collaborative learning approaches which are experimental, contextualized and focused on the user and whose main objective is the active construction of knowledge.

- Propose personalized VLEs based on Grid and Cloud technologies that support learning processes in which the student is actively building new ideas or concepts based on past and present knowledge (constructivism).

We can highlight the main contributions of this work as follows:

- Proposed a semantic description model of service properties, parameters and relationship, which facilitates services automatic discovery and invocation without human interaction and enough information for human search.
- This model allows locating of learning services of distributed network through semantic description, especially those based on grid computing and cloud computing, allowing a complete semantic description based on functional and non-functional properties of Web services, setting aside the traditional technologies of syntactic search methods.
- The semantic model will allow the design of ubiquitous and pervasive learning scenarios will foment the interaction among the users and will allow developing collaborative and personalized learning activities.

To achieve the objectives of this thesis, we have followed the research methodology defined by Adrion (1993). This methodology suggests that the research process in software engineering must be followed by a total of four stages. We defined and carried out some activities associated with each stage for solving the working hypothesis:

STAGE 1 - *Observe existing solutions.*

- Review the state of the art of tools that make use of semantic web to enhance learning and ontological models for the description of learning scenarios and specific tools that give support to collaborative learning systems that implement models of semantic description.

- Analysis of different conceptual educational models of interactions and evaluation of whether these approaches can be carried learning environments based on Grid and Cloud computing.
- Survey of existing models for search, comparison and automatic composition of learning services, which implement semantic characteristics of learning stages and that are focused on constructivist theory of learning, in which the student is an active element, facilitate collaboration and interaction between different participants in the learning process and to induce the independent learning.
- Analysis of semantic description models for learning Grid and Cloud applications and those that have been developed specifically to define semantically learning objects within an application of e-learning.

STAGE 2 - *Propose a better solution.*

- Definition of the theoretical framework, and conceptual context in which it was developed and used the tools of e-learning that imoplement distributed services
- Design a conceptual model of interactions for a collaborative environment consisting of learning services.

STAGE 3 -*Developing the new solution*.

- Develop a pattern of semantic description of scenarios for collaborative learning based on distributed services.
- Design proposals for alternative models of search, comparison and automatic composition of services.
- Design of illustrious examples (real scenarios) where the implementation of the model of semantic description of learning situations in real terms.

STATE 4 - *Evaluate the new solution.*

- Implementation and evaluation of the semantic description model in a real collaborative learning scenario based on distributed services and their impact in learning.

1.5 Outline of chapters - Thesis plan

The rest of the document is organized as follows:

In Chapter 2 we make a Literature Review of distributed services architecture and the state of the art of some technological efforts to construct interactive learning environments based on distributed services.

Chapter 3 presents Problem State, where we define the research issues and questions.

Chapter 4 is centered on the design and specification of the semantic description conceptual model for distributed services.

Chapter 5 explore the implementation of semantic model using semantic technologies available and their use for solving learning services problems of location, invocation, composition and orchestration. We present two scenarios of implementation, one for the integration of services based on cloud computing in learning management system, and the other creating portals for online teaching laboratories.

In Chapter 6 we present two experimentation scenarios: on the one hand we implement a integration of Chamilo LMS with Cloud services using semantic technologies on the other hand we present an implementation of the semantic description conceptual model for the design of an optoelectronic educational virtual laboratories based on Semantic Web evaluating the improvements that this infrastructure represents in this type of educational and research activities.

In Chapter 7 we present research findings of experimentation scenarios, evaluating the case studies in terms of cognitive load and usability, showing the benefits that the proposed semantic model generates for learning.

Finally in Chapter 8, we present the conclusions and future work, highlighting the contributions of our proposal to the above-mentioned problems in this field of research and commenting in what aspects our solution is different to other efforts described in chapter 2.

CHAPTER 2 - Literature Review

2.1 Introduction

In the last years there has been a substantial increase in the use of computers and networks, primarily due to faster hardware, more sophisticated software. The VLE is clearly the dominant design in educational technology today, and is nearly ubiquitous in higher education institutions (Wilson et al., 2007). Technologies such as Grid (Foster & Kesselman, 2003) and Cloud computing (Armbrust et al., 2010, Armbrust et al., 2009,) have had more and more impact on the design and implementation of VLEs. These technologies have characteristics as provide shared services, syndication of heterogeneous resources and exploiting the discovery of relevant content, which are some of the most important issues in learning systems requirements. In this chapter we review related works about technologies supporting learning environments based on distributed services including those that allow syntactic and semantic description of learning services. First, we will review some background and fundamentals of distributed services used on the construction of interactive learning environments. Inside that we review the proposed IMS learning abstract framework, the technologies and protocols that enable syntactic and semantic description, discovery and matching of distributed web services, the Learning Grid (Capuano et al., 2008) architecture and Cloud computing on education. After that, we will review some related efforts on important research issues, such as: semantic modeling of learning services, distributed learning tools integration, and composition and customization of distributed learning environments. Finally we conclude with a short discussion of the results of this research work and identify the additional efforts needed to fill the gap that still remains open in these research issues.

2.2 Background and fundamental concepts

A learning service is a granular functional component accessible to other applications via standard interfaces. IMS Global Learning Consortium proposes an abstract framework (IMS Global Learning Consortium, 2003) representing a set of services used to construct an e-learning system in its broadest sense; it focuses more on the support of e-learning systems and covers the possible range of e-Learning architectures that could be constructed from a set of defined services. The Learning Application composition process consists of identifying sub-tasks of the learning process, locating suitable Learning application Services to construct each process, locating suitable Common Services to construct each learning service, formatting the Learning and Common services into a service flow and executing the service flow to achieve a task which is the goal of the learning process.

The abstract learning framework proposes by IMS Global Learning Consortium is shown in Figure 2.1.

One of the design principles for the abstract framework is the adoption of service abstraction to describe the appropriate e-Learning functionality (Figure 2.2).

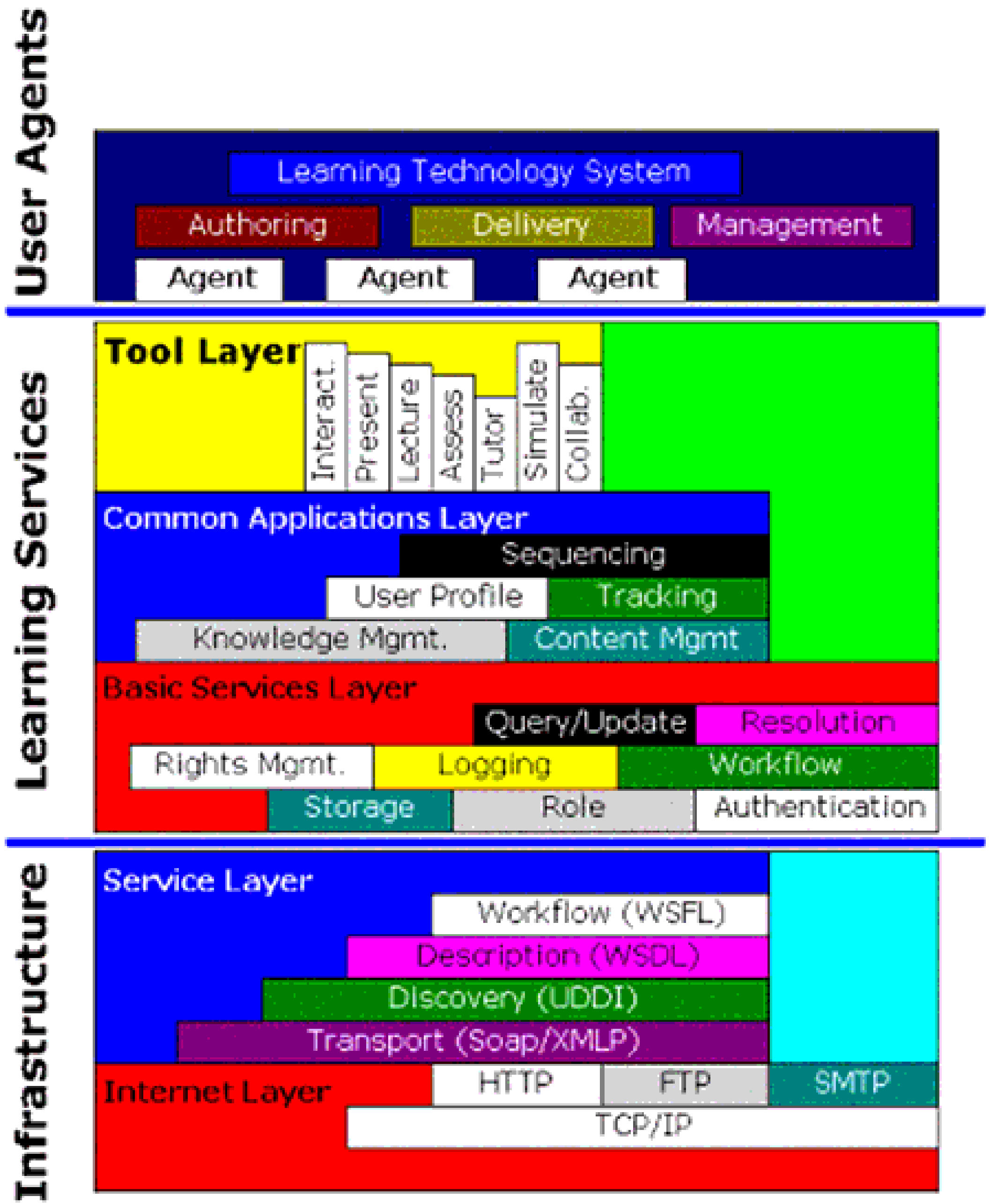


Figure 2.1 IMS Learning Abstract Framework

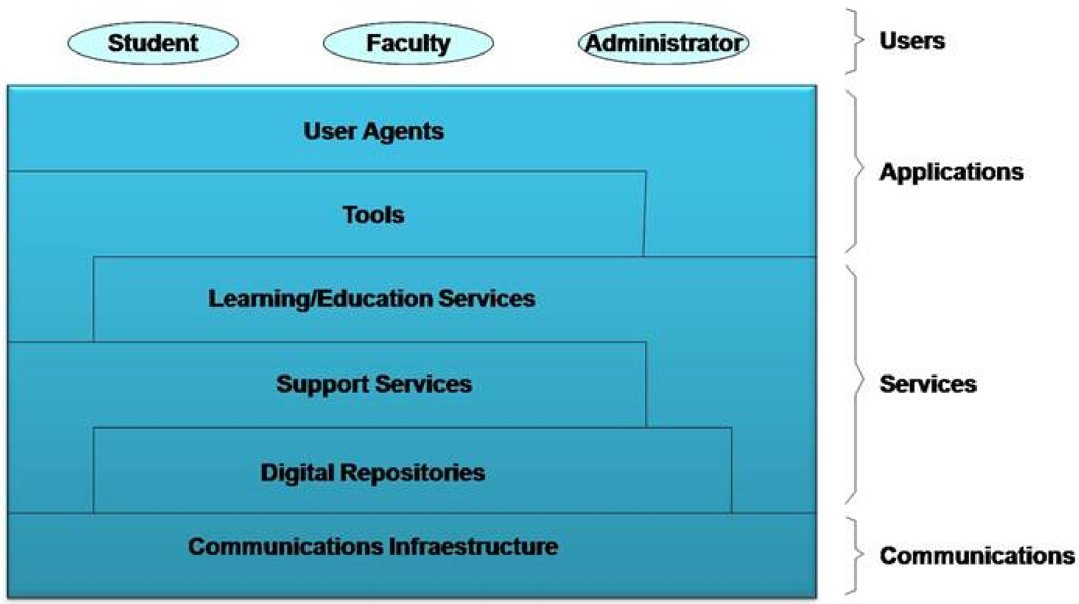


Figure 2.2 A logical architecture for an eLearning system

Access to a service is through the appropriate Service Access Point (SAP). Each service has a single SAP. A Component may support one or more SAPs (in an object oriented representation, a SAP could be supported by one or more operators where the class is itself the definition of the service).

The SAP may consist of one or more objects and each object will, in general, will have more than one operator. Each object is defined using a class definition and consists of a group of attributes and operators. The operators describe how the state of the attributes may be changed. The set of behaviors permitted for each class must also be defined. These behavioral definitions ensure that any implementation of the class provides the same predicted behaviors for the same trigger events. Both the classes and their behaviors are defined in an implementation independent manner;

This approach means that every service (application and common) must be defined using this form of abstraction (Figure 2.3). In many cases the services interact with each other e.g., an application service will use a common service. This interaction is reflected by the service invoking the SAP of the required service.

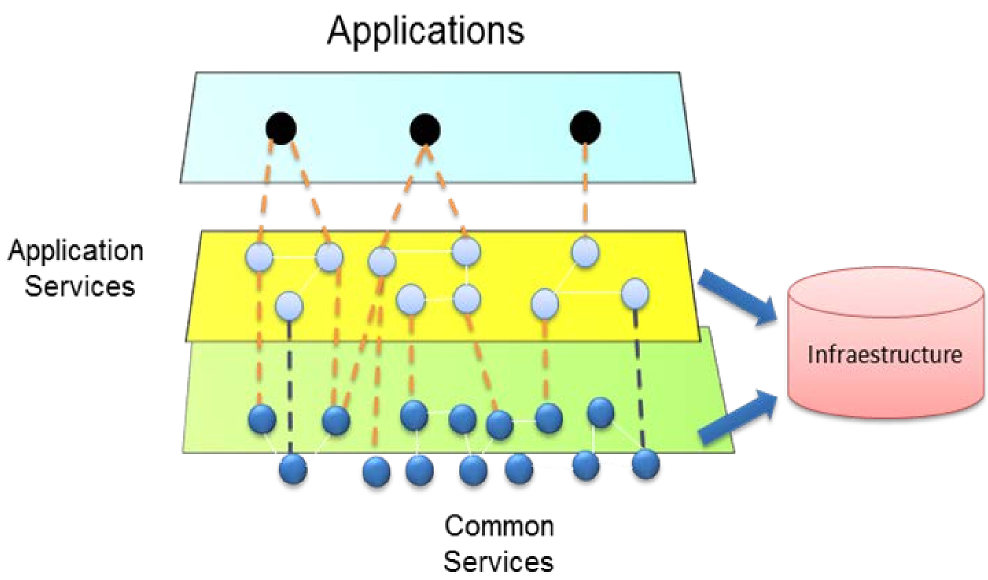


Figure 2.3 IMS Abstract Framework

The core stage is the composition of learning web services and their adaptation to the needs of a learner or group of learners. Such a composition is carried out by retrieving previously registered objects. Once composed and packaged as learning objects, these composite processes can be executed and then instantiated and adapted to the learner's particular needs.

These adaptations can be realized, either by predefined rules implemented into the process description and driven by the learner behavior, or in a supervised manner. In the later case, the instructional designer can return to the composition tools to adapt the process.

2.2.1 Learning Services Architecture

Learning services infrastructure is based on several key characteristics. All other design details follow from these:

- Distributed Services: Learning services architecture is based on a collection of distributed services, with each service (be it a component or an information source) providing one or more separately identifiable features for the user. The architecture makes no assumptions about either logical or physical integration of services. Each service is considered to be independent and each could be provided by one or more service processors located anywhere on the internet.

- Open Communications: All components and services are interconnected via a messaging scheme. Messages (request and responses) are XML data, and the messaging scheme is based on XML message encapsulation. All message formats and service protocols are published in an open directory, enabling any component to discover and communicate with any other component.

- Standards Based: Whenever possible, the services, protocols and data formats should rely on established or emerging standards. Standards for core infrastructure and internet protocols are well established. Various application level standards are under development. In all cases, approaches that are compatible with an overall web model of distributed services and XML-formatted information bindings are preferred.

- Web Interfaces: All components for use, operations, maintenance and content development must be accessible via web-enabled devices, using web (http) protocols for access.

- COTS Components: Core components, such as database management, directory services, mail services, web server and web application servers are assumed to be available for direct use. In addition, application level services with appropriate interfaces are available or can be adopted for core services such as groupware, e-commerce, content management, news and event management.

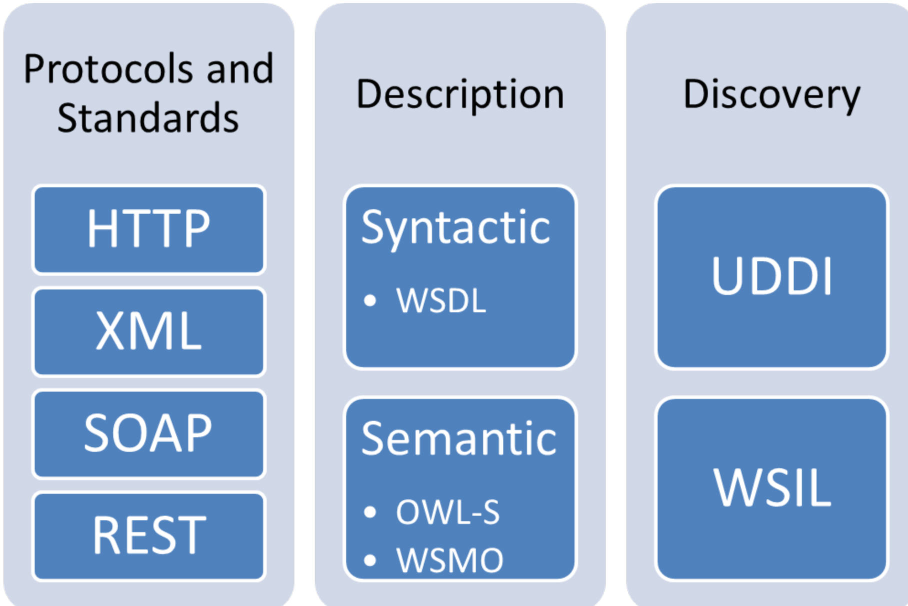


Figure 2.4 Learning Services Architecture

Learning services infrastructure is based on widely accepted technologies and commonly web standards. Standards for core infrastructure and internet protocols are well established. A variety of application level standards of the learning services architecture (Figure 2.4) are under development. In all cases, approaches that are compatible with an overall web model of distributed services and XML-formatted information bindings are preferred. Some of the core concepts of the Web services approach include:

- Accessible over the Internet, Web services communicate through platform-independent Web protocols, facilitating the integration of heterogeneous environments.

- Web services standards define an interface and communication protocol that can be invoked from an application client or provided through a server.

- The Web Services Description Language (WSDL) (Christensen et al. , 2001) adds a layer of abstraction between implementation and interface, providing a loosely coupled application that results in future flexibility.

2.2.2 Protocols and Standards

In contrast to building large, closed, learning technology systems, the focus of the learning services architecture is on a flexible design that provides interoperability of components and learning content, and that relies on open standards (both learning technology standards and common web and network standards) for information exchange, behavior descriptions and component integration. Web services are built upon open, often already widely adopted standards.

Typically, these standards are maintained by independent, non-profit standards organizations composed of a diverse membership. Some of the protocols and standards related with learning services are:

- HTTP: The Hypertext Transfer Protocol (HTTP) (Fielding et al., 2009) is an application-level protocol for distributed, collaborative, hypermedia information systems. HTTP has been in use by the World-Wide Web global information initiative since 1990. The HTTP protocol is a request/response proto-col. A client sends a request to the server in the form of a request method, URI, and protocol version, followed by a MIME-like message containing request modifiers, client information, and possible body content over a connection with a server. The server responds with a status line, including the message's protocol version and a success or error code, followed by a MIME-like message containing server information, entity meta-information, and possible entity-body content. There are a new version of HTTP (2.0) (Belshe et al., 2015), where applications have an improved impact on network congestion due to the use of fewer TCP connections to achieve the same effect.

- XML: Extensible Markup Language (XML) (Bray et al., 1998) is a simple, very flexible text format derived from SGML (ISO 8879). Originally designed to meet the challenges of large-scale electronic publishing, XML is also playing an increasingly important role in the exchange of a wide variety of data on the Web and elsewhere. By offering a standard, flexible and inherently extensible data format, XML significantly reduces the burden of deploying the many technologies needed to ensure the success of Web services.

- SOAP: Simple Object Access Protocol (SOAP) (Mein et al., 2002) is a standard that represents a lightweight "envelope" containing the message payload as it moves between service producers and consumers. It is an XML-based standard that describes the contents of a message and how to process it, and offers a transport binding for exchanging messages.

- REST: Representational State Transfer (REST) (Fielding, 2009) is a software architecture style consisting of guidelines and best practices for creating scalable web services. REST is a coordinated set of constraints applied to the design of components in a distributed hypermedia system that can lead to a more performant and maintainable architecture. REST has gained widespread acceptance across the Web as a simpler alternative to SOAP and WSDL-based Web services. RESTful systems typically, but not always, communicate over the Hypertext Transfer Protocol with the same HTTP verbs (GET, POST, PUT, DELETE, etc.) used by web browsers to retrieve web pages and send data to remote servers.

2.2.3 Syntactic Web Services Description

In the learning services architecture, it becomes increasingly possible and important to be able to describe the communications in some structured way. WSDL is a specification to describe networked XML-based services. It provides a simple way for service providers to describe the basic format of requests to their systems regardless of the underlying protocol (such as Simple Object Access Protocol) or encoding (such as Multipurpose Internet Messaging Extensions).

WSDL describes the functional information of services such as input parameters, output parameters, service providers and service locations. However, it is limited in supporting the discovery, execution, composition and interoperation of Web services.

WSDL cannot provide semantic information of Web services that enable the semantic description of services capabilities.

A WSDL document defines services as collections of network endpoints, or ports. In WSDL, the abstract definition of endpoints and messages is separated from their concrete network deployment or data format bindings. It specifies the location of the service and the operations (or methods) the service exposes. WSDL document defines a web service using these major elements (Figure 2.5).

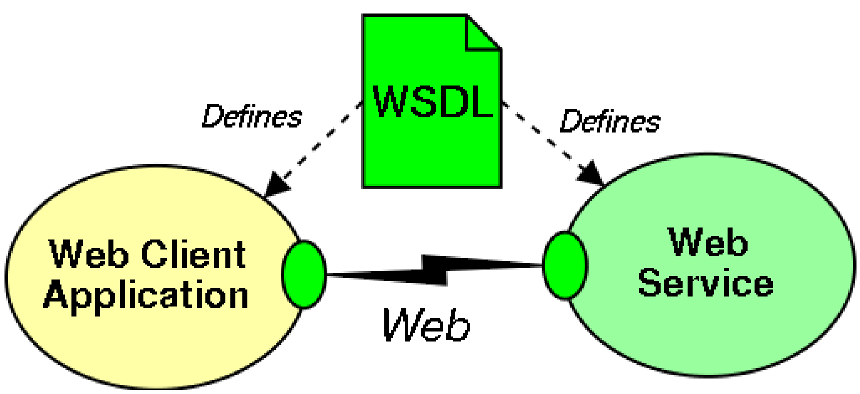


Figure 2.5 WSDL

- The <portType> element is the most important WSDL element. It defines a web service, the operations that can be performed, and the messages that are involved. The port defines the connection point to a web service. It can be compared to a function library (or a module, or a class) in a traditional programming language. Each operation can be compared to a function in a traditional programming language.

- The <message> element defines the data elements of an operation. Each message can consist of one or more parts. The parts can be compared to the parameters of a function call in a traditional programming language.

- The <types> element defines the data type that is used by the web service. For maximum platform neutrality, WSDL uses XML Schema syntax to define data types.

- The <binding> element defines the message format and protocol details for each port. A WSDL port describes the interfaces (legal operations) exposed by a web service.

There are two major problems with the use of WSDL (Verborgh et al., 2013). First, WSDL only provides the mechanisms to characterize the technical implementation of Web services. It does not provide the means to capture the functionality of a service. Secondly, in practice, a WSDL description is used to generate module source code automatically, which is then compiled into a larger program. If the description changes, the program no longer works, even if such a change leaves the functionality intact.

2.2.4 Semantic Description of Web Services

An ontology has been defined (Guber, 1993) as a specification of a conceptualization consisting of a collection of concepts, properties and interrelationships between concepts that can exist for an agent or a community of agents. From our point of view an ontology is a set of terms of interest in a particular information domain and the relationships among them. They can characterize knowledge in an application or domain-specific manner (domain ontologies) or in a domain-independent manner (upper ontologies) (Guarino, 1997).

Semantic Web Service technology promises to automate web service discovery, composition and integration, tasks that currently need to be performed manually despite the quickly increasing number of on-line services. The complexity of the reasoning tasks that can be performed with semantic web service descriptions is conditioned by several factors. First, all web services in a domain should use concepts from the same domain ontology in their descriptions. Otherwise the issue of ontology mapping has to be solved which is a very difficult problem in itself. This requires that domain ontologies should be generic enough to provide the needed concepts by any web service in a certain domain. Second, the richness of the available knowledge is crucial for performing complex reasoning. Therefore, the domain ontology should be rich in semantics. We conclude that such quality domain ontologies are at least as important as generic web service description ontologies.

2.2.5 Web Ontology Language (OWL)

The Web Ontology Language (OWL) (Patel-Schneider et al., 2004), is intended to provide a language that can be used to describe the classes and relations between them that are inherent in Web documents and applications. The use of this language to formalize a domain by defining classes, properties about those classes, axioms involving properties and classes, individuals and properties about those individuals. The OWL language provides three increasingly expressive sublanguages designed for use by specific communities of implementers and users:

- OWL Lite supports those users primarily needing a classification hierarchy and simple constraint features.

-OWL-DL supports those users who want the maximum expressiveness without losing computational completeness (all entailments are guaranteed to be computed) and decidability (all computations will finish in finite time) of reasoning systems.

- OWL Full is meant for users who want maximum expressiveness and the syntactic freedom of RDF with no computational guarantees.

In OWL 2 (Motik et al., 2009), there are three sublanguages of the language. OWL 2 EL is a fragment that has polynomial time reasoning complexity; OWL 2 QL is designed to enable easier access and query to data stored in databases; OWL 2 RL is a rule subset of OWL 2.

2.2.6 Semantic Markup for Web Services (OWL-S)

Semantic Web and Knowledge technologies provides an expressive and semantically enriched description of services, by the use of ontology description languages as OWL-S (Martin et al., 2004), and allows for automatic selection, location and composition of services in order to achieve the required objectives. It is based on the Resource Description Framework (RDF), which integrates a variety of applications using XML for syntax and URIs for naming.

OWL-S is motivated by the need to provide three essential types of knowledge about a service, each characterized by the question it answers (Figure 2.6):

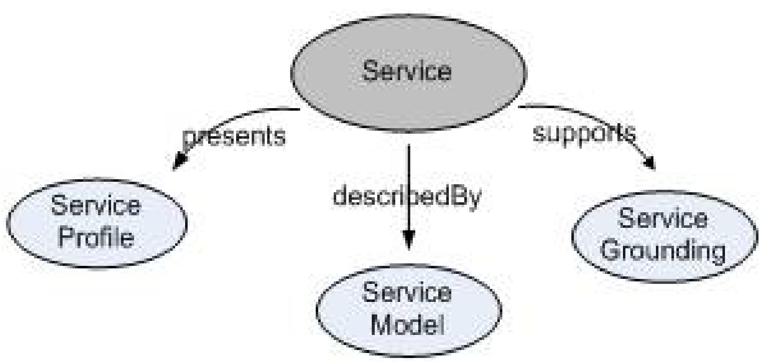


Figure 2.6 Semantic Web Services Description (OWL-S)

- What does the service provide for prospective clients? The Service Profile describes what the service does by specifying the input and output types, preconditions and effects.
- How is it used? The Process Model describes how the service works.
- How does one interact with it? The Grounding contains the details of how an agent can access a service by specifying a communications protocol, parameters to be used in the protocol and the serialization techniques to be employed for the communication.

In order to make its capabilities known to service requesters (Sycara & Vaculín, 2009), a service provider advertises its capabilities with infrastructure registries, or more precisely middle agents, that record which agents are present in the system. UDDI registries are an example of a middle agent, with the limitation that it can make limited use of the information provided by the OWL-S Profile. The OWL-S/UDDI Matchmaker is another example, which combines UDDI and OWL-S Service Profile descriptions. The OWL-S/UDDI matchmaker supports flexible semantic matching between advertisement and requests on the basis of ontologies available to the services and the matchmaking engine. After a requester has found the contact details of a provider through matchmaking, then the requester and the provider interact directly with one another.

2.2.7 The Web Service Modeling Ontology (WSMO)

The Web Service Modeling Ontology (WSMO) (Roman et al., 2007, Fensel el al., 2011a) provides ontological specifications for the core elements of Semantic Web services. In fact, Semantic Web services (Fensel et al., 2011b) aim at an integrated technology for the next generation of the Web by combining Semantic Web technologies and Web services, thereby turning the Internet from an information repository for human consumption into a world-wide system for distributed Web computing. Therefore, appropriate frameworks for Semantic Web services need to integrate the basic Web design principles, those defined for the Semantic Web, as well as design principles for distributed, service-orientated computing of the Web.

The Ontology element itself defines the conceptual model used by all WSMO elements. Hence the description of WSMO as a meta-ontology. It is an ontology that defines how other ontologies can be constructed. WSMO's conceptual model is given semantics through a layered family of logical languages, collectively known as the Web Service Modeling Language (WSML) (De Bruijn et al., 2007). WSML has a frame-like syntax which means that information about a class and its attributes, or a relation and its parameters, or an instance and its attribute values are grouped together in individual syntactic constructs. This is intended to help with readability of WSML in comparison with OWL or RDF which use XML as their primary syntax and where information about a class, relation or axiom can be spread across several constructs (that said, an XML syntax is also available for WSML). Also in contrast with OWL, WSML attributes are generally defined locally to a class. This is the recommended usage but does not always have to be the case. Attribute identifiers are globally unique and it is possible, if necessary to define global attributes using axioms.

2.2.8 Evolution of OWL-S to WSMO

Vipul et al. (2008) comment that of the models for semantically annotating Web Services, WSMO and OWL-S are the most closely related. Both aim at the provision of a comprehensive conceptual model for Semantic Web Services. WSMO describe how an important foundation point of the work on WSMO was the mode provided by OWL-S but maintain that OWL-S has a number of serious fundamental flaws that give rise to problems when attempting to use the ontology in practice. In WSMO the viewpoint of service requester and service provider are distinctly represented by the complementary concepts of goals and Web Services. This separation is adopted from the research in the problem-solving domain and is a clear point of distinction between the OWL-S and WSMO models.

WSMO provides a conceptual model for the description of Web services. WSMO distinguishes between user goals, which are descriptions of the desires of the requester, and Web service descriptions, which are descriptions of the functionality and interface of the service offered by the provider. This is one of the distinctions between OWL-S and WSMO. In OWL-S the service concept is used to describe both services and requests for services. Although from a modeling view-point WSMO goals and Web Services contain the same structure, they represent different perspectives in the conceptual model and for this reason are kept separate. Figure 2.7 presents the elements of a Web service description, namely non-functional properties, a capability, a choreography and an orchestration. The term interface is used to describe the combination of the choreography and orchestration of a service.

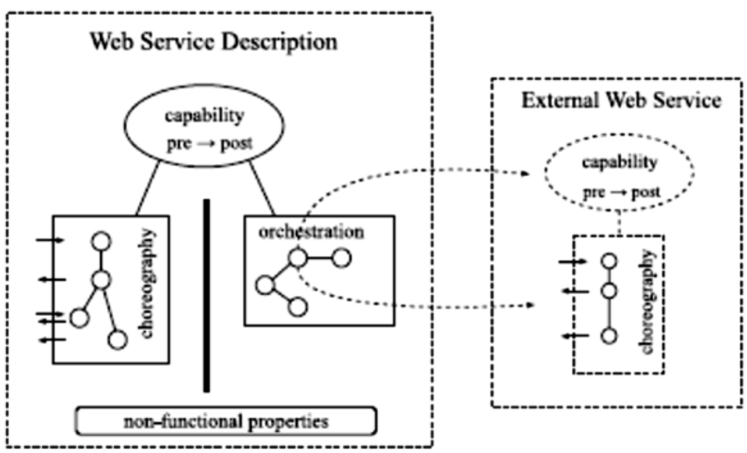


Figure 2.7. Elements of WSMO Web service description.

WSMO makes a distinction between the inputs and outputs of the service, and the state of the world. Based on these considerations a capability description comprises four main elements. Preconditions describe conditions on the state of the information space prior to execution. There are additional conditions that must hold in the real world in order for the service to successfully execute. These conditions, called Assumptions, are not necessarily checked by the service before execution but are crucial to the successful execution of the service. Postconditions describe conditions on the state of the information space after execution has occurred, thus describing properties of the outputs of the service, as well as the relationship between the inputs and the outputs. Effects are conditions that are guaranteed to hold in the real world after execution. The interface of a Web service specifies how to interact with the service in terms of a choreography, this choreography essentially provides information about the relationships between different operations on the Web service. The interface of a Web service description also contains an orchestration description. An orchestration specifies which services this service relies upon to provide its functionality.

2.2.9 Other Semantic Web Services Initiatives

The Semantic Web Services Framework (SWSF) (Battle et al., 2005) is an attempt towards a Semantic Web service annotation framework that greatly profits from previous work with its roots in OWL-S and the Process Specification Language (PSL). SWSF is based on two major components: an ontology (or conceptual model) and a language used to axiomatize it.

Compared with WSMO, OWL-S, and SWSF, WSDL-S (Akkiraju et al., 2005) is a rather minimalist approach which aims at a direct extension of the existing “traditional” Web service descriptions in WSDL with semantics. This approach offers multiple advantages over OWL-S. First, users can describe, in an upwardly compatible way, both the semantics and operation level details in WSDL- a language that the developer community is familiar with. Second, by externalizing the semantic domain models, we take an agnostic approach to ontology representation languages. This allows Web service developers to annotate their Web services with their choice of ontology language (such as UML or OWL) unlike in OWL-S. This is significant because the ability to reuse existing domain models expressed in modeling languages like UML can greatly alleviate the need to separately model semantics. Finally, it is relatively easy to update the existing tooling around the WSDL specification to accommodate our incremental approach.

The ontology bootstrapping (Segev & Sheng, 2012) process is based on analyzing a web service using three different methods, where each method represents a different perspective of viewing the web service. As a result, the process provides a more accurate definition of the ontology and yields better results.

2.2.10 Linked Data

The term Linked Data (Berners-Lee et al., 2009) refers to a set of best practices for publishing and connecting structured data on the Web. These best practices have been adopted by an increasing number of data providers, leading to the creation of a global data space containing billions of assertions “the Web of Data”. Linked Data uses the Resource Description Framework (RDF) data model and other standards related to RDF, just as it uses HTTP. Linked Data is built upon RDF but is not the same as RDF. Linked Data is separated from RDF by the four Linked Data principles (Wood et al., 2014) :

- Use URIs as names for things.
- Use HTTP URIs so that people can look up those names.
- When someone looks up a URI, provide useful information, using the standards RDF and SPARQL (Prud’Hommeaux & Seaborne 2008).
- Include links to other URIs, so people can discover more things.

2.2.11 Web Services Discovery

Discovery is the process of finding Web services with a given capability. In general, discovery requires that Web services advertise their capabilities with a registry, and that requesting services query the registry for Web services with particular capabilities. The role of the registry is both to store the advertisements of capabilities and to perform a match between the request and the advertisements.

The Universal Description, Discovery, and Integration (UDDI) protocol (Van Steenderen, 2000) defines a standard method for publishing and discovering the network-based software components of a service-oriented architecture (SOA). UDDI is advanced by the OASIS UDDI Specification Technical Committee. The specification defines a group of Web services and programmatic interfaces for publishing, retrieving, and managing information about services (Figure 2.8).

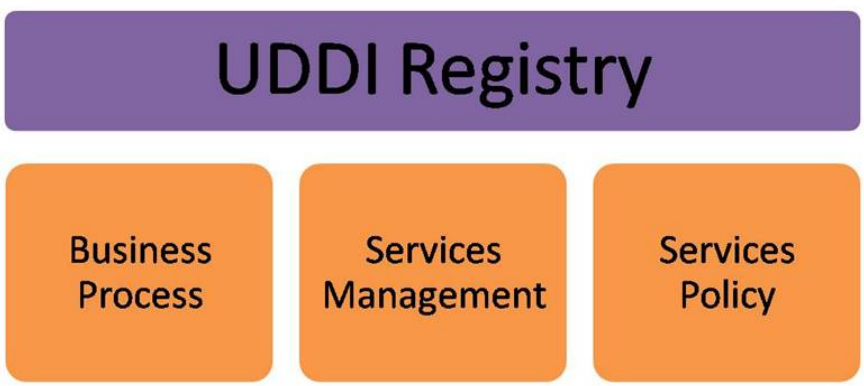


Figure 2.8 UDDI Registry

Another Web Services Discovery specification is WSIL (Ballinger et al., 2001) that *"… provides an XML format for assisting in the inspection of a site for available services and a set of rules for how inspection related information should be made available for consumption. A WS-Inspection document provides a means for aggregating references to pre-existing service* *description documents which have been authored in any number of formats. These inspection documents are then made available at the point-of-offering for the service as well as through references which may be placed within a content medium such as HTML".*

2.2.12 Semantic Web Services Discovery

In general, a semantic discovery process relies on semantic annotations, containing high-level abstract descriptions of service requirements and behavior. The achievement of dynamic composition and automation of services involves discovering new services at run time by software components without human interaction (Paliwal et al., 2012). SOAP provides a description of message transport mechanisms, whereas WSDL describes the interface used by each learning service. However, neither SOAP nor WSDL are of any help for the automatic location of learning services on the basis of their capabilities. There are some works that aim to improve the semantic services capability of discovery. On the one hand, Paolucci (2002) focuses primarily on comparing inputs and outputs of a service as semantic concepts represented in OWL to improve UDDI. Metadata is an essential element in semantic discovery with the capability to expand service descriptions with additional information. Paolucci comments that in order to enable the automation of this process we need a meaningful description of the service and its parameters that can be processed automatically by tools. This implies the possibility to process the context of description by discovery engines.

One of the most important contributions in this field is developed by Rao & Su (2005) where they propose an integration of UDDI with OWL-S (Figure 2.9). They comment: "*In order to combine OWL-S and UDDI, we need embed an OWL-S profile description in a UDDI data structure, and we need to augment the UDDI registry with an OWL-S Matchmaking component, for processing OWL-S profile information. On receiving an advertisement through* *the publish port the UDDI component, in the OWL-S/UDDI matchmaker, processes it like any other UDDI advertisement. If the advertisement contains OWL-S Profile information, it forwards the advertisement to the matchmaking component. The matchmaker component classifies the advertisement based on the semantic information present in the advertisement. A client can use the UDDI's inquiry port to access the searching functionality provided by the UDDI registry, however these searches neither use the semantic information present in the advertisement nor the capability description provided by the OWLS Profile information. Hence we extended the UDDI registry by adding a capability port to solve the above problem. As a consequence, we also extended the UDDI API to access the capability search functionality of the OWL-S/UDDI matchmaker."*

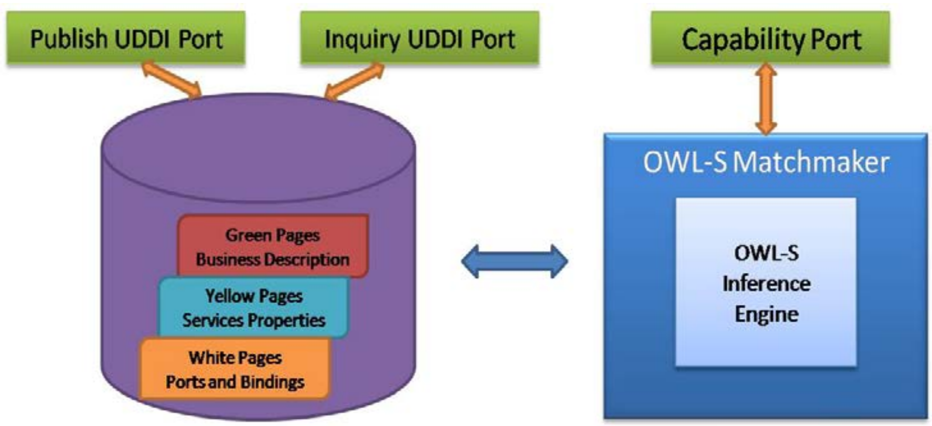


Figure 2.9. Architecture of UDDI/OWL-S Registry

These approaches try to adhere to the current standards while trying to maximize semantic representations required for automation.

2.2.13 Semantically Matching of Web Services

Fensel et al. (2006) have identified five matchmaking notions for functional discovery as shown in Figure 2.10. "*.. The important characteristic of these notions is that each one denotes a* *different logical relationship that must hold true when considering whether a Web service is suitable for achieving a given goal. For instance, an Exact Match holds if and only if each possible ontology instance that can satisfy the Web service also satisfies the goal, and there exists no possible ontology instance that satisfies only the goal or the Web service. In contrast, an Intersection Match holds if there exists one possible instance that can satisfy both the goal and the Web service…"*

In that sense Di Martino (2006) classifies the major approaches to schema matching:

- *Instance vs schema*: matching approaches can consider instance data (i.e., data contents) or only schema-level information.
- *Element vs structure matching*: match can be performed for individual schema elements, such as attributes, or for combinations of elements, such as complex schema structures.
- *Language vs constraint*: a matcher can use a linguistic based approach (e.g., based on names and textual descriptions of schema elements) or a constraint-based approach (e.g., based on keys and relationships).
- *Matching cardinality*: the overall match result may relate one or more elements of one schema to one or more elements of the other, yielding four cases: 1:1, 1:n, n:1, n:m. In addition, each mapping element may interrelate one or more elements of the two schemas. Furthermore, there may be different match cardinalities at the instance level.
- *Auxiliary information*: most matchers rely not only on the input schemas S1 and S2 but also on auxiliary information, such as dictionaries, global schemas, previous matching decisions, and user input.

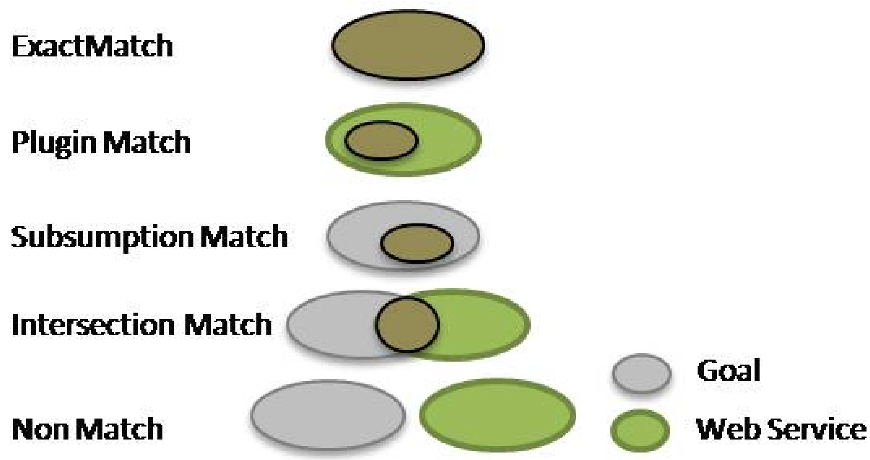


Figure 2.10. Matchmaking notions for semantically enabled discovery

In the same work, there is a detailed development of web services matching procedures for locating the most suitable Web Services, combining and integrating a number of matching algorithms, and adopting two principal approaches: the structural matching approach and the linguistic or syntactic approach. This work focuses on the issue of searching a Web Service with required functionalities and addressing a specific application domain, by means of an ontology-based semantic description.

The negotiation before selection of any web service provider agent is based upon the multiple attributes of web service. This process of making a joint decision by two or more parties resulting into a mutually acceptable agreement on some matter involving multiple attributes is called as multi-attribute negotiation (Kumar, 2012).

2.3 Supporting distributed learning environments through grid and cloud technologies

2.3.1 Four aspects to define the function of learning scenarios

There are four aspects to highlight the function of learning scenarios, they are: collaborative technologies, distributed learning, ubiquitous computing in education and pervasive computing. It is important to define the scope of these issues to understand how they influence learning environments. Below we detail each of these elements.

Collaborative technologies.

Grabowski et al. (2008) report that these technologies are traditionally defined as tools that enable individuals to jointly engage in the active production of shared knowledge. New collaborative technologies are rooted in this heritage, and are defined as those technologies such as wearable, ubiquitous, and mobile computing that offer their users the benefits of any-time, any-space, any-distance communication and collaboration. When first introduced, new collaborative technologies were described as differing from existing audio and video systems in terms of media richness, or the degree to which a technology offers multiple cues, immediate feedback, natural language interfaces, and message personalization. Media richness theory proposes that communication effectiveness improves if the technology used by participants matches the information processing requirements of the tasks to be performed, and suggests that rich media is appropriate for equivocal communication activities, such as negotiation, belief monitoring, analysis, decision-making and reflective interaction. Similarly, media richness theory suggests that leaner media is appropriate for unequivocal activities, such as message passing, identifying information, or storing text, data, or messages. When technology capabilities are matched appropriately to task and environmental requirements, media richness theory suggests that user performance and processes will be enhanced. Many studies have been undertaken to study the impact of conventional technologies on users. Unfortunately, few of these studies have examined the impact of newer collaborative technologies on users who use them frequently; users engaged in distributed learning.

Distributed learning.

Distributed learning is the process by which individuals acquire knowledge and understanding, primarily through social interactions across time and/or geographic distance, using information and communication technologies. Distributed learning involves the social creation of knowledge through instructional strategies that emphasize small-group learning among students: Learning arises from the opportunity for the group members to monitor each other's thinking, opinions, and beliefs, while also obtaining and providing feedback for clarification and enhancement of comprehension. An individual's exposure to the group members' points of view may challenge his/her understanding, and can motivate further learning. Thus, in collaborative distributed environments, learning occurs through communication and collaborative interactions, often those that are technology-mediated. New collaborative technologies such as mobile computing are increasingly being used in distributed learning environments to enhance learning and to facilitate knowledge exchange, communication, participation, and community building. However, the impacts of technology introduction in distributed learning settings have been portrayed in contradictory ways: on one hand, technologies have been found to be integrative, connecting disparate others and mitigating location effects of distance or geography, increasing the power of marginal group members, providing rich communities, providing support not found in traditional learning environments, and nurturing the development of online community between participants, increasing the flow of information, as well as enhancing group support, commitment, cooperation and satisfaction with the group effort. On the other hand, collaborative technologies have been criticized for providing a reduced cues environment ill-suited to emotional, expressive, or complex communications, and for providing an environment with longer decision times, anti-social flaming behaviors, and decreased social involvement. The critical literature acknowledges that collaborative technologies foster interactions among participants, but there are questions about whether the increased or enhanced interactions promote knowledge exchange and/or learning because of the absence of non-verbal cues, which limits the modes of communication among participants. Early work in assessing technology impacts in distributed learning environments measured student performance outcomes, such as grades on tests or grade point averages (GPAs). In other studies, a comparison was made between learning outcomes (students' grades and/or perceived learning) in a distributed environment and learning outcomes obtained in a traditional face-to-face environment. More recently, collaborative technology has been seen to impact both cognitive and perceived learning outcomes in distributed settings. Cognitive learning involves changes in an individual's mental models; that is, internal representations of knowledge elements comprising a domain as well as interrelationships among those knowledge elements. Perceived learning involves changes in a learner's perceptions of skill and knowledge levels before and after the learning experience. Approaches to the measurement of these two variables differ: cognitive learning measures are often outcome or performance related, while perceived learning measures are often process-related.

Ubiquitous computing in education

Kolomvatsos (2007) detects that the use of ubiquitous computing in education has characteristics very important in learning. He comments that an educational policy can be based on these features in order to achieve a high level of learning. These features are:

• Information Access: Students have access to their documents, and also to various information sources from everywhere. All students may search the information needed in order to complete a task. Of course, the initiative is on them. They pose questions and take the results. The final step is to combine the results and extract the final conclusion.

• Time and Place Immediacy: This feature is allocated in the place and time in which the information can be reached. Whenever and wherever a student needs to access information is feasible. There are no limits in time or in place. This has the advantage of easy and useful access to resources, increasing the productivity of the work.

• Interactivity: Students are able to interact with teachers or experts with a synchronous or asynchronous communication. Hence, they have the opportunity to approach other people's knowledge, without the one teacher's limitation, of the traditional system. They may search, find, and pose questions to specific domain experts, and afterward combine the answers to effectively build their knowledge.

• Student Activation: A system in which all students have their own device and work by themselves demands activation. Every student has to work and learn, experimenting with software and searching to find the information needed to complete specific tasks.

• Adaptability: Learners can get the right information at the right time and at the right place. In this direction, the Intelligent Agent technology may be very useful. Intelligent software may learn from the owner's habits or instructions and work as its representative, searching and find information. Even further, this software can be used to adapt the information presented to the users based on their learning style.

Pervasive computing

A fundamental functionality of pervasive computing applications (Loureiro et al., 2008) is to present users with relevant information or services at the right place and in the right time, in a seamless way. In this process, two key inputs are involved: the needs and interests of the user and the information available both in the environment and in their devices. The former allows the applications to define what sort of information would be relevant to the user. The latter is the source from where such information will be retrieved.

2.3.2 The Learning Grid

Capuano et al. (2008) describe the paradigm of learning based on Grid as follows:

A Learning Grid is an enabling architecture based on three pillars: Grid Computing, Semantics and Educational Modeling allowing the definition and the execution of learning experiences obtained as cooperation and composition of distributed heterogeneous actors, resources and services.

According to this, they define a layered architecture for the Learning Grid and explain how it can be used as a basis to provide Learning Services and Applications (Figure 2.12):

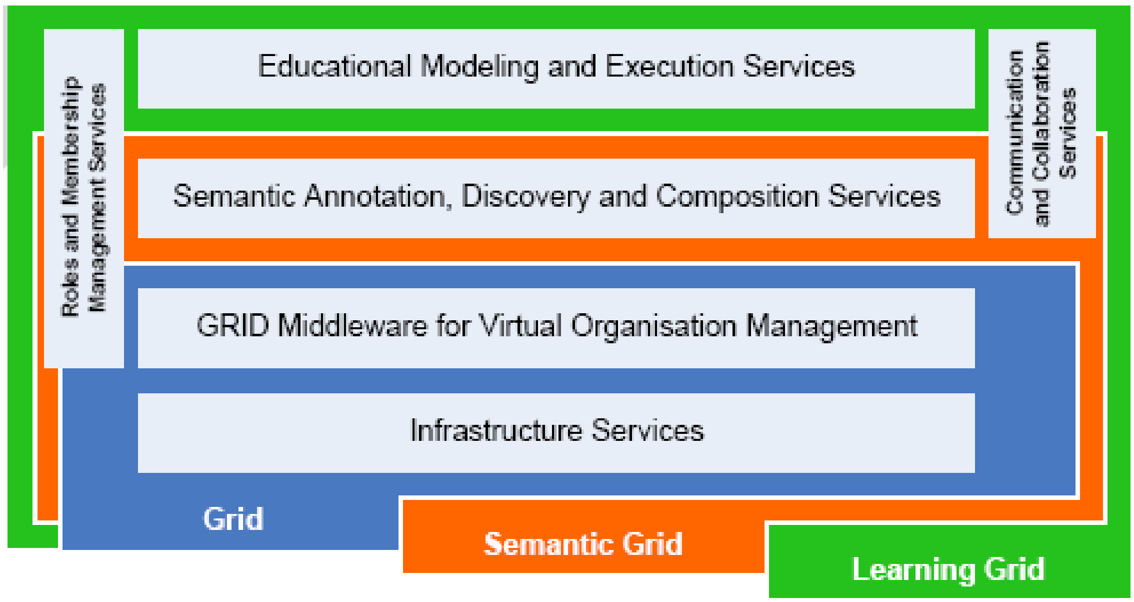


Figure 2.11 Architecture of a Learning Grid

A Grid is composed by Infrastructure Services plus a Grid Middleware for VO Management; a Semantic Grid is composed by a Grid plus Semantic Annotation, Discovery and Composition Services; a Learning Grid is composed by a Semantic Grid plus Educational Modeling and Execution Services plus a set of "environment" services described below to support the creation, the operation, the evolution and the maintenance of a learning community:

• The Role and Membership Management Services manage users, groups, roles and membership inside VOs on the Learning Grid by supporting the Grid Middleware for VO Management as well as Semantic Annotation, Discovery and Composition Services and Educational Modeling and Execution Services;

• The Communication and Collaboration Services provide tools to support communication and collaboration among participants in groups, communities and actors involved in learning experiences by supporting Semantic Annotation, Discovery and Composition Services and Educational Modeling and Execution Services.

The characteristics of technologies applied to learning Grid scenarios will mean a great advantage for learning process, chiefly to increase the efficiency of learning for individuals and groups and to contribute to a deeper understanding of the learning process by exploring links between human learning, cognition, and technologies.

2.3.3 Cloud Computing in Education

In education, cloud computing technology (and the construction of platforms for college education management) not only can improve the utilization resource rate, saving university resources and improving the teaching level, but also can bring new areas of application closer to our life and our study areas (Huang et al., 2013).

In this regard, Manro et al. (2011) highlights how cloud computing can be used to solve educational problems with some software as a service (SaaS), such as Facebook, Twitter, Google Docs, etc., which is somehow the cloud scheme that most universities are already implementing. Each type of cloud has some kind of Application Program Interface (API) that can be used to access resources, configure, control and release them when no longer needed. Based on this, further analysis highlights the convenience that online students access data and applications from any device connected to the Web via cloud computing. Some of the major benefits identified are: robust service, quick and effective communication with anytime-anywhere access and global collaboration. Notwithstanding these advantages, this work only proposed the basic use of these Cloud technologies in the traditional way and does not comment on how these technologies can be used to the design and development of effective and well-grounded learning systems and educational technology applications.

Vaquero (2011) presents an evaluation of the real benefits of cloud computing for a course on networks using cloud PaaS (Platform as a Service) where providers offers a development environment to application developers and IaaS (Infrastructure as a Service) where providers offer computers – physical or (more often) virtual machines – and other resources. The results show that the introduction of Cloud technology is adequate to maintain students' attention and save time in the tasks related to the use of technologies to support education. However, the use of Cloud technology and levels of abstraction "per se" are not enough to help motivate students neither provide any considerable improvement as regards the results obtained or the acquisition of new knowledge by students. In this sense, the use Cloud technology cannot be oblivious to the learning objectives and must be integrated with certain educational methodology so that it makes the difference in student-centered learning activities.

2.4 Three research areas and related work

From the advantages of distributed systems for construction of virtual learning environments as well as the possibilities of semantic description techniques to bring benefits to learning tools, we detected three major research: the use of semantic models for building distributed learning systems, integration and composition of learning tools from learning services, and the customization of distributed learning tools according to user profile and access limitations. Below we will discuss related research work related with each of these three areas.

2.4.1 Semantic Modeling of Learning Services

Using ontology technologies such as RDF, OWL, OWL-S and WSMO, it is possible to create semantically rich data models that are denominated semantic schemas. RDF is the basic building block for supporting the vision of the Semantic Web (Yu, 2014). RDF is made up of triples (subject-predicate-object), where subjects and objects are entities, and predicates indicate relationships between those entities. The subject and object of a triple can also be predicates.

Users can define their own properties, as well as their own classes. Instances of these classes can then be created and described with values for related properties. Each triple forms a graph with two nodes connected by an edge. Each instance can have several properties, and that graph can be expanded to have many nodes connected to the central instance. Finally, when two instances are connected via a property value, their respective sub-graphs become connected.

The usage of ontologies (Vipul et al., 2008) is of interest whenever the costs that arise through terminological disagreements and misunderstandings while not using ontologies exceed the costs for providing ontologies and formalized descriptions of situations. There are a number of characteristics of settings where use of ontologies appears promising:

1. Important heterogeneous (and possibly imprecise) vocabularies

2. Small to medium sized domain.

3. Multitude of participants with overlapping interests.

4. Long-term interest in understanding of vocabulary and corresponding data

5. Many and/or (rather) expensive transactions

Finding services with desired features becomes every time more challenging because the number of Web services is continually increasing. Current standards in Web Services communities (including UDDI and WSDL) do not directly support semantic description and discovery of services. Semantic discovery is the process of discovering services capable of meaningful interactions, even though the languages or structures which they are described may be different.

Luo et al. (2006) describe a platform of e-learning based on Grid service technologies. In this platform the supply of virtual learning services designated for students, instructors and course suppliers is based on the resource administration for group collaboration based on Grid, allowing ubiquitous access to information and taking advantage of the potentiality of the computer systems. On the one hand, the advantage of this proposal is that it is the first one that elaborates on the use of Grid resources and their description through Grid and web services technologies, in particular WSDL. On the other hand, it dictates the need for the development of a semantic model description that enables a more complete description of learning resources.

Some efforts in learning services semantic description are made by Vega-Gorgojo et al. (2005) with semantic search of Learning Services in a Grid Based Collaborative System. This work proposes a Grid services-based tool, called Gridcole, which can serve for the support of collaborative learning, thus extending and endowing it with an innovative, pervasive and ubiquitous projection. This method is based on a conceptual model of learning interaction that allows educators to search for services in an easy and suitable way without knowing about the functional specification of services and they only need information related to collaborative learning activities. This ontological description for collaborative work tools allows teachers and students to make a manual search of the diverse resources that these tools provide within a Grid environment with the minimum of technical knowledge. About their model the authors said: *"…the ontology should allow to describe what types of activities does a particular tool support, either individual or collaborative. This issue is expressed independently of the type of learning tool, as shown pictorially in Figure..."* (Figure 2.12).

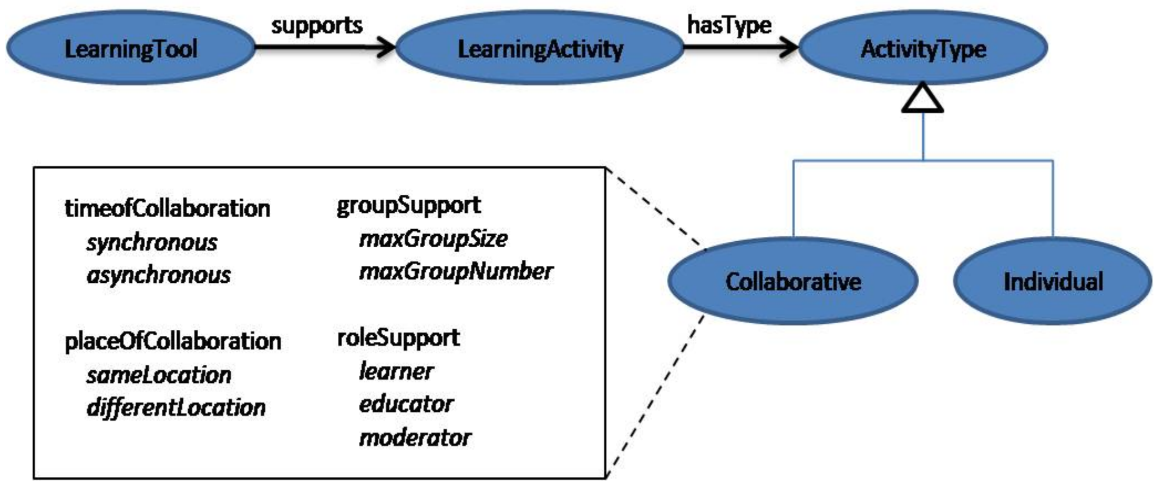


Figure 2.12. Information model of the ontology of learning tools

As an evolution of this work, OntoolCole was developed (Vega-Gorgojo et al. 2006), which incorporates an artifact module, a task-level coordination module and the description of static information resources, further improving the capabilities to describe complex CSCL tools such as stateful applications or decomposable group tasks. Subsequently OntoolSearch was developed (Vega-Gorgojo et al. 2010), a new search system that can be employed by educators in order to find suitable tools for supporting collaborative learning settings.

Another related work is OntoEdu (Guangzuo et al., 2004) where ontologies are used to describe concepts of a networked education platform and their relations. OntoEdu is a flexible platform for online learning which is based on diverse technologies like ubiquous computing, ontology engineering, semantic Web and distributed computing. In OntoEdu, the education ontology includes two big parts: activity ontology (AO) and a material ontology (MO). The AO is implemented based on a service oriented approach with metadata descriptions using the OWL-S model. This project is oriented towards adaptability and automatic composition of the function user requested. It is compound of five parts: user adaptation, automatic composition, educative ontologies, a module of services and a module of contents; among these parts the educative ontology is the main one. The main objectives of OntoEdu are to obtain reusability of concepts, adaptability for users and devices, automatic composition, as well as scalability in functionality and performance (Figure 2.13).

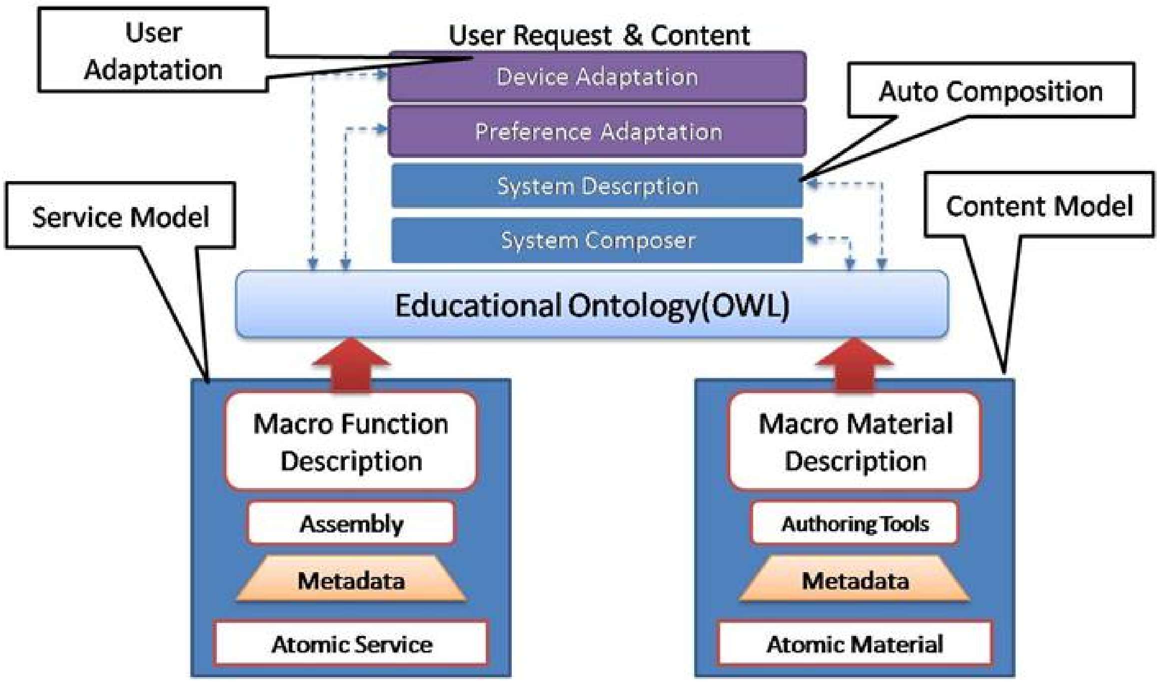


Figure 2.13. A logical architecture of OntoEdu

There is some important research work that concerns semantic search for virtual laboratories. Lab2Go of the Carinthia University of Applied Science (Maier & Niederstätter, 2010) presents a potential solution in the form of an online portal supported by the Semantic Web. The basic idea of the Web portal is a repository that offers a common framework to collect and describe laboratory data from different laboratory providers located all over the world. They define a general model for online laboratories and a Web repository based on Semantic Web technologies to facilitate the use of new tools to publish and exchange online laboratories and other related resources (Niederstätte & Maier, 2011). The Australian LabShare project (Lowe et al., 2011) was aimed to establish a national laboratory sharing scheme within Australia and set objectives pursuing to create a shared network of remote laboratories. Their ultimate goal was to provide a combination of higher quality labs, greater student flexibility, improved educational outcomes, improved financial sustainability as well as enhanced scalability in terms of coping with student loads. Among the benefits of this project, we can highlight the significant reductions in capital investment, greater flexibility in laboratory resources, improved consistency and, most importantly, improved learning quality. Library of Labs (Lila) (Richter et al., 2011) has been a European Community funded project to network remote experiments and virtual laboratories. The goal of this project has been the composition and dissemination of a European infrastructure for mutual exchange of experimental setups and simulations, specifically targeted at undergraduate studies in engineering and science. Lab2Go, Labshare, Lila and additional interest partners formed the Global Online Lab Consortium (GOLC) and one of its main outcomes has been the establishment of a repository of online labs, whereas a metadata set has been also defined to annotate its content (Grube et al., 2011).

Pfisterer et al. (2011) describe the architecture of a Semantic Web of Things: a service infrastructure that makes the deployment and use of semantic applications involving Internet-connected sensors. With SPITFIRE they provide abstractions for things, fundamental services for search and annotation, as well as integrating sensors and things into the cloud. All this makes sensor data easily accessible for applications via existing mechanisms deployed on the web.

In sum, the works presented above try to provide a solution to the complex problem of learning services semantic description, but they are either limited in semantic expressiveness for matching services or they do not face at all the difficult task of using and integrating low-level learning services to compose more complex ones. Both these features could greatly enhance and facilitate the tutor’s and learners’ labor in a complex web-based learning scenario. For this reason, the main objective of this doctoral thesis is to develop a new model for distributed learning services semantic description whose ultimate aim is to offer a mechanism for automatic Learning Service discovery, invocation, composition and interoperation.

2.4.2 Integration and composition of learning services

Integration has been an important subject of study and research which seek to determine how integration brings a sense of order out of the chaos and disorder created by heterogeneous systems, networks and services (Raj, 2011).

Web service composition (Tong et al., 2011) originated from the necessity to achieve a predetermined goal that cannot be realized by a standalone service. Internally, in a composition, services can interact with each other to exchange parameters, for example a service's result could be another service's input parameter. In the semantic web service composition process, the evaluation of negotiation agreements resulting from the negotiation between the service requester and various service providers can be used for the selection of best service provider (Kumar, 2012).

In general, a framework used for Web service composition (Rao & Su, 2005) (Figure 2.14) describes two kinds of participants, service provider and service requester. It contains the following components: a translator, a process generator, an evaluator, an execution engine and a service repository. The service providers propose Web services for use. The service requesters consume information or services offered by the service providers.

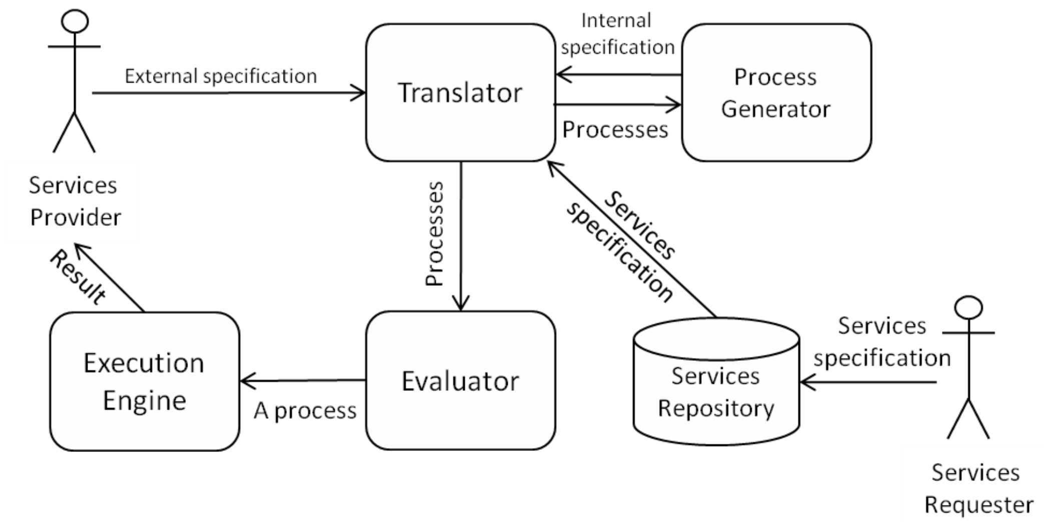


Figure 2.14. The framework of the service composition system

The translator translates between the external languages used by the participants and the internal languages used by the process generator. For each request, the process generator tries to generate a plan that composes the available services in the service repository to fulfill the request. If more than one plan is found, the evaluator evaluates all plans and proposes the best one for execution. The execution engine executes the plan and returns the result to the service provide.

All these learning systems try to take full advantage of integration and composition for the development of learning systems, but we see that they present several problems and limitations, especially those that are related to evaluate the impact that its proposed model of integration and composition for users and for learning itself.

Virtualization efforts try to create learning environments more cost effectively without compromising the level of service or user experience. Such an example is presented by Hu et al. (2011), where a successful change of the use and payment patterns for a Web-based virtual learning environment and pedagogical software was achieved through virtualization and SaaS enablement of web services.

There are also efforts that demonstrate the efficiency and effectiveness of services collaboration in the Cloud. This is the case of AMBAR-C (Awareness-based learning Model for distriButive collaborative enviRonment) (Paletta and Herrero, 2010), a collaboration model used for a multi-agent based system in collaborative Cloud computing environments. In the area of micro-learning applications development, mobile services have a great potential in supporting informal learning processes. Kovachev et al. (2011), propose a tool that makes use of Cloud services to promote ubiquitous learning.

2.4.3 Customization of learning tools

There have been studies that have determined the great impact that customization can have on student performance (Nedungadi and Raman, 2012). Halimi et al. (2014) present how the personalization of students' learning process is achieved through leveraging the use of social semantic web, using resource description framework models, ontologies, social networking and collaborative tagging. This allows new e-learning environments to act as intelligent systems that best fit the needs of their users and especially students according to their interests, preferences, motivations, objectives and knowledge.

In this line, Razmerita et al. (2005) present a work about ontology based user modeling for personalization of Grid learning services. This work describes how the learning services of the semantic Grid should support a user centered, customized, contextualized, experiential and ubiquitous based learning approach. They claim that in order to provide a customized learning process, it is necessary to study and define methodologies that represent the context of learning and student through suitable knowledge structures, such as the ontologies. This work focuses then on the role that customized ontologies may play on a new generation of intelligent services; more specifically, it explores the role of ontologies to obtain Grid based learning services in ELeGI.

PLANT (Li et al., 2008) is a distributed architecture for personalized E-Learning built upon the Edutella network which is a schema based peer to peer system. The main objective of PLANT is to facilitate individual learning on the Internet which abounds in a wide variety of educational resources and services. PLANT allows users to conduct complex queries for best results according to their knowledge back-grounds and learning goals. With the distributed resource evaluation algorithm based on consensus, the quality of education resources can be precisely estimated, which stimulates resources to evolve in the network. By providing a rich set of learning assistant services, individual users can get good support to achieve their learning goals.

Gravier et al. (2012) present a framework using semantic web technologies that support collaborative strategies. In this framework different collaborative policies can be defined to allow users to load the rules associated with each policy. Likewise, the semantic model is used to set access rules on users rather than as an opportunity to use it as a link to external web services and as a semantic search mechanism for instruments and devices that can enhance the functionality of online laboratories.

In all these research is highlighted the importance of assigning user profiles that enable users to access the functionalities of the learning tools according to their needs, privileges and access limitation, but without evaluating the benefits of customization to learning process, allowing learning activities are carried out with greater satisfaction for users.

2.5 Results and Discussion

Despite the efforts made in related research work, there are still open questions related with the three research issues described above, that is, it is not clear how semantic models of learning services, integration and composition of distributed learning services, and customization of learning tools can benefit both learning environments and students' learning processes. In our point of view, a semantic description model should be designed to locate learning services semantically, facilitating collaboration and customization to users and it should give to users a common access point of educational resources that can be accessed anytime, anywhere, and which could be customized for user preferences, profile privileges and access limitations. In the case of the integration and composition of learning tools, a semantic model should facilitate on the one hand the correct integration of heterogeneous services offered by different organizations. On the other hand, if a single service cannot satisfy the functionality required by the user, learning environments should have the possibility to combine existent services to fulfill the requirement.

Given this gap in current literature, next section will focus on specifying the scope of this thesis and defining the open research questions that we will try to respond and thus provide a more effective solution in each of these three research issues.

CHAPTER 3 - Problem state

3.1 Introduction

The previous chapter provided a critical review of the literature focusing on the use of semantic modeling of learning services with respect to the integration and composition of learning services in order to personalize students' learning process. This review identified 3 research issues: (i) design of semantic models for defining learning services, (ii) design of integration and composition models for learning services based on semantic modeling and (iii) implementation of customization schemes of learning tools based on semantic modeling. Based on the limitations of current research on these issues, we formulate the problem of this research work in the form of the following main research question:

> ***Is it possible to develop more efficient semantic models for learning services description to facilitate their detection and allow their integration and composition into various distributed-based learning tools, where customization and personalization are the most important features and therefore are focused on the active construction of knowledge?***

The above research problem is further analyzed in more detailed research questions in the following sections.

3.2 Semantic modeling of learning services

As we discussed in the limitations of related work, the use of semantic description models of learning services based on Grid and Cloud computing should support the definition, implementation and evaluation of custom learning scenarios. As a consequence, an important issue would be the development of innovative learning tools to define semantic description models based on standards, which allow the localization of available resources in a distributed environment. In that sense, we propose to investigate the following research question:

> ***Can we construct efficient semantic description models of distributed learning services based on standards?***

3.3 Integration and Composition models of learning services

As we discussed in related work, there are three main motivations for learning services integration and composition: build a more powerful service using basic existing services, fulfill service requester's requirement better, and enhance resource reuse while reducing the cost and time of a new service development. Despite current efforts, we believe that there remains an important related research gap which refers to explore how semantic technologies can be used to support the improvement of e-learning in general and the dynamism and integration of tools in particular, as well as the possibility to compose and to automatically discover high level tools and learning services based on low level ones. This fact leads us to define the following research question:

> ***Do the technologies involved in the Semantic Web benefit the construction of specific learning tools to encourage composition and integration?***

3.4 Customization schemes of learning tools

As noted in the analysis of several related works, the authors highlight the importance of assigning user profiles that enable users to access the functionalities of the learning tools according to their needs, privileges and access limitation, but without evaluating the benefits of customization to learning process, allowing learning activities to be carried out with greater satisfaction for users. Under these considerations, we believe that an important research issue would be to define personalized learning scenarios based on Grid and Cloud computing, focused on contextualized and user-centered approaches of collaborative learning, and whose main objective is the construction of active knowledge. From this we define the following research question:

> ***Is it possible to develop personalized learning scenarios based on semantic description, allowing adaptive services depending on the student needs?***

3.5 Conclusions

In this chapter we have discussed three research issues that will be further studied in this thesis and we have set a specific research question for each issue. The following chapters present the models we propose for semantic description and composition of learning services as well as the analysis of some real educational use cases in which these technologies have been implemented and tested in order to answer and evaluate the research questions presented in this chapter.

CHAPTER 4 - A conceptual model for the semantic description of learning services

4.1 Introduction

Semantic web on education offers a mechanism to generate annotation registries of a set of diverse learning resources over and above the course materials or objects in a learning environment. These annotations provide access to marked-up resources, which enables ontologically guided or semantic search. Semantic learning services depend on four things: annotated educational resources, a means of reasoning about them, a means of retrieving the most suitable one, and a range of associated services (Stutt & Motta, 2004). In that sense, and based on the research issues discussed in Chapter 3 to build learning scenarios using semantic models that on one hand support customization from user needs and privileges and on the other hand allow integration and composition of learning services, this chapter will detail the important aspects to construct a semantic model for learning services description. Firstly we review some important aspects related with the interactions generated on pervasive and ubiquitous distributed collaborative learning environments, and from there we will distinguish the most important elements of the related ontology. After that we will define a semantic model for learning services that includes two principal components: learning service access point and learning services identification. We will detail the characteristics of each component and finally we will conclude the chapter.

4.2 An ontology for collaborative ubiquitous and pervasive distributed learning environments

A collaborative ubiquitous and pervasive distributed learning environment have containers that make use of diverse technologies based on services whereas at the same time they can be invoked by learning tools and presented to the end user. Figure 4.1 shows the interaction between users and tools based on services and resources provided for this kind of personalized distributed Learning Scenarios.

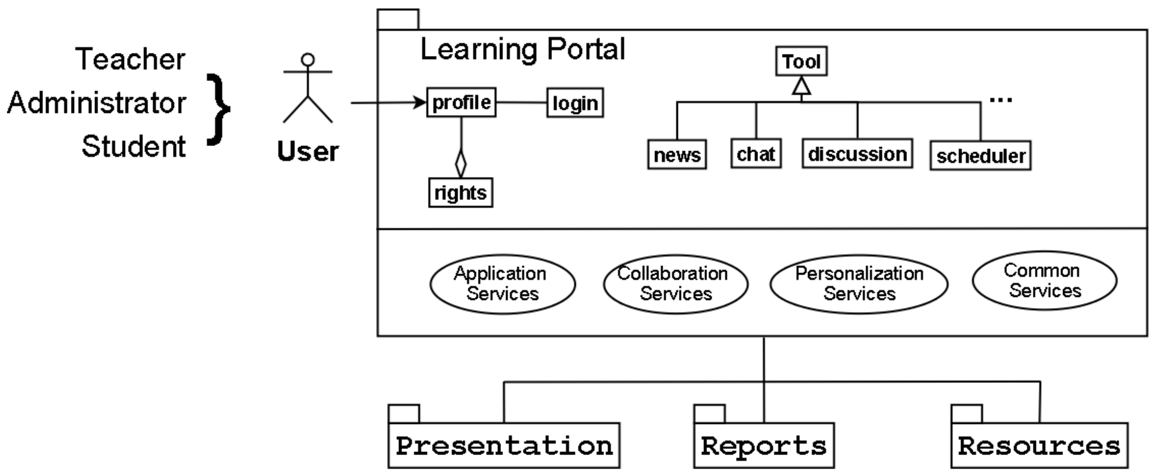


Figure 4.1 Interaction between users and Distributed Learning Environment

4.2.1 Ontological model of interaction

From the aspects analyzed, taking into account the importance they have in the development of distributed virtual learning environments, we have defined an ontological model of interaction describing the elements involved in a collaborative, ubiquitous and pervasive learning scenario is shown in figure 4.2.

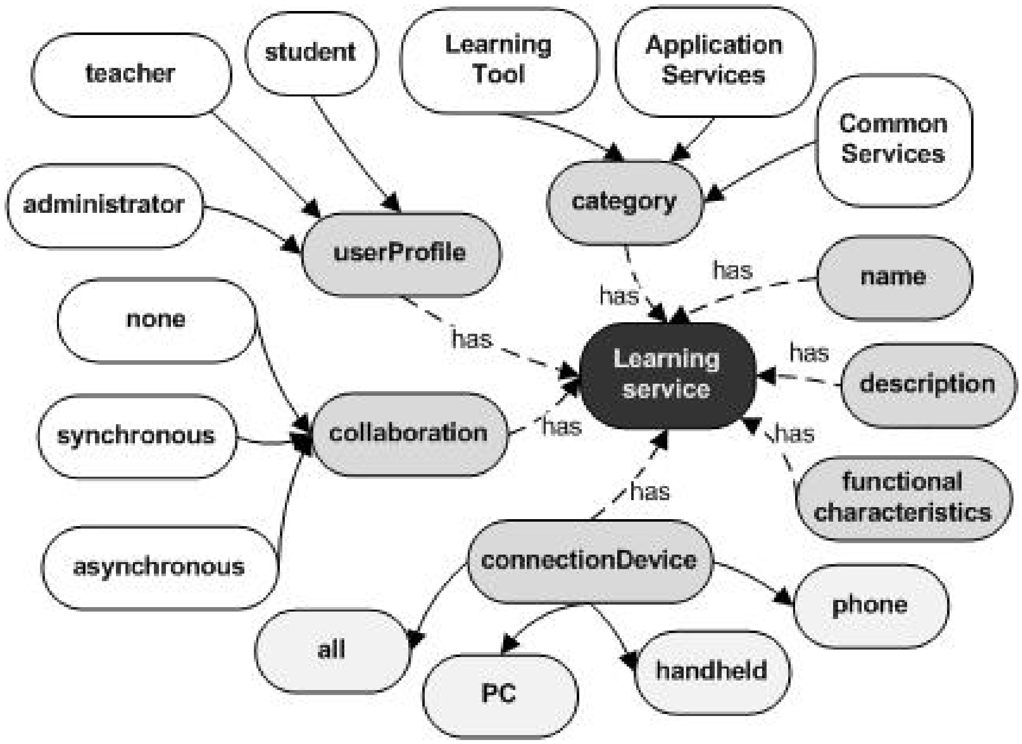


Figure 4.2. Ontological model of a distributed learning environment

4.3 Semantic Description of Learning Services

In Chapter 2, the limitations of syntactic description of web services were discussed. It also were detailed the advantages that the Semantic Web in general and the semantic description of services on particular could generate for learning tools and for students' learning process. In this sense, one of the main objectives of this thesis is propose a mechanism to describe semantically distributed Learning Service (Gutiérrez-Carreón et al., 2006).

From the interaction of user with the learning environment, the main classes of the ontology and their relationships were identified: User, Learning Scenario and Learning Service (Figure 4.3).

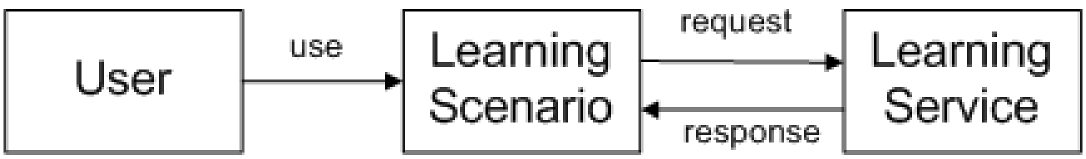


Figure 4.3. Conceptual model with the main classes and their relationships

User: This class defines the person, group or process that uses the learning scenario. Its unique property is *userProfile* that defines the profile that makes use of a service (learner, teacher, another process, etc)

Learning Scenario: This class defines the stage where the learning process is performed. It allows the interaction between users and services requested. Its unique property is *Description* in which the ontology associated with learning scenario can be defined.

Learning Services: It is the main class of the model, where one the one hand, we identify the principle characteristics of Learning Services related to a learning scenario and the activities that support it. On the other hand, we consider Learning Services like a granular functional component with some input information, a functional activity and some output information. In this sense we form two conceptual groups of properties to achieve a complete description of Learning Services: the Learning Services Identification (LSI) and the Learning Services Access Point (LSAP). This constitutes our conceptual model for the semantic description of learning services (Figure 4.4).

Figure 4.4. A conceptual model for Learning Services semantic description.

The LSI element constitutes a set of properties used to define the principle characteristics of a Learning Services. Table 4.1 describes it in more detail.

Table 4.1 Properties of Learning Services Identification .

Property	Description
Name	Name of service
Category	Depending on the learning scenario, services providers could construct the domain of categories for each group of learning services
ConnectionDevice	Type of device that request the service
Collaboration	Type of collaboration in which learning service is involved

The LSAP element is characterized by the most important functional properties of Learning Services and is described in Table 4.2.

Table 4.2 Properties of Learning Services Access Point

Property	Description
Activity	Activity in the learning scenario supported by a service
Related Services	Specifies one or more services related to a service
Process	A service is described as a functional process
Errors	Specifies the errors resulting from the execution of a service
Bindings	Definitions included in a WSDL description of a learning service
URI	Access point for services under REST technology

On the one hand, the LSI contains basic information related to a learning service, allowing a user centric search. This model is generic enough to be implemented in any e-learning framework supported by Learning Service and can be used for describing both low-level and composed services. In that sense, the domain of categories could be adapted to any ontology or taxonomy of services.

For example, if we adopt the IMS Abstract Framework Service's categories from the IMS Global Learning Consortium (2003), we can obtain the class hierarchy of Learning services where learning tools are supported by Common Services and they are in turn supported by Basic Services. Figure 4.5 shows this hierarchy designed on Protégé.

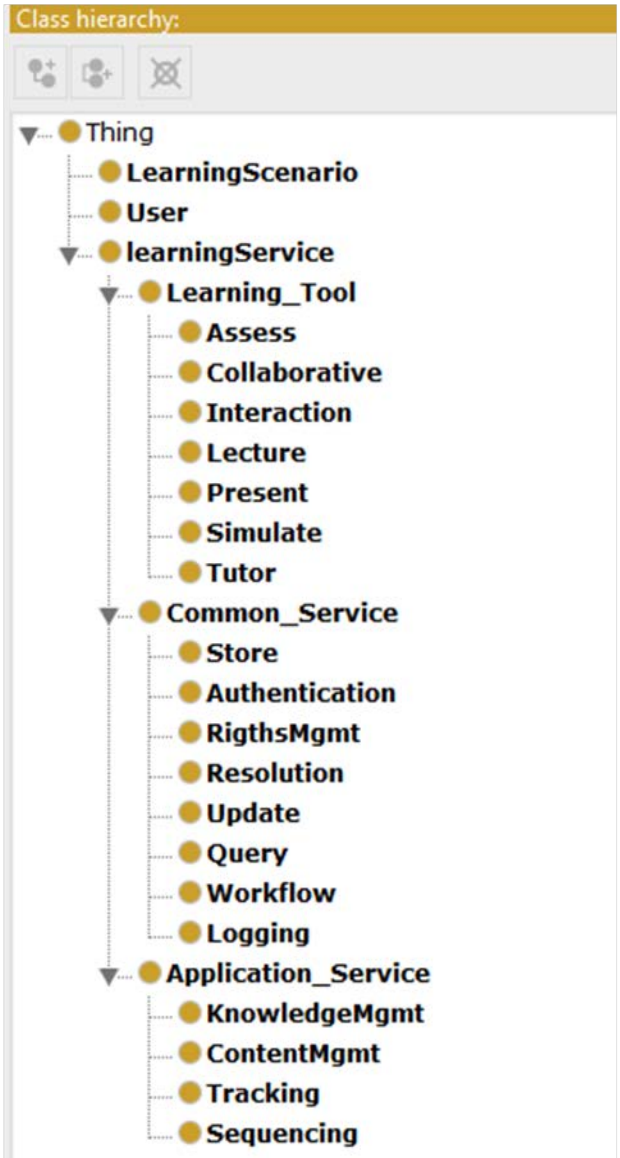


Figure 4.5. Class hierarchy of Semantic model.

On the other hand, LSAP allows the construction of an ontology domain for functional parameters related to the e-learning framework. This semantic description, in combination with the modifications suggested for Ritrovato (2005), allows capability-based search as well as discovery of learning services based on the inputs and preconditions that need to be satisfied and on the outputs and effects that need to be produced. The Bindings element of LSAP is a parameter of WSDL describing the interface of each learning service. Both elements of the model are necessary to deal with the problem of using and integrating low-level services to compose more complex high-level services or tools. In particular, the LSAP describes distributed learning services as processes, which allows one to specify whether a service is an atomic, simple o composite process as well as its relationship with other services. Figure 4.6 shows object property hierarchy designed on Protégé.

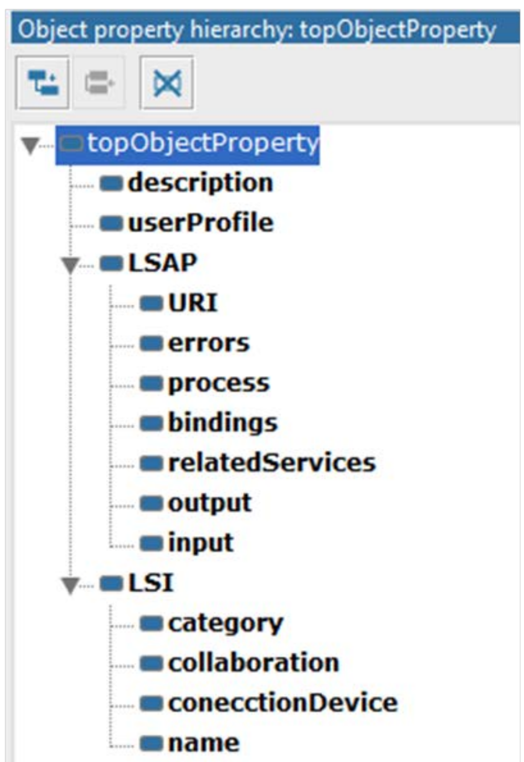


Figure 4.6.Object property hierarchy of Semantic model.

4.4 Relationship and interaction of the proposed model and Linked Data

For the implementation of ontology, we store the information in an RDF container and define the compliance with the principles of Linked Data, which are mentioned in chapter 2. Using a RDF container will allow us to make the handling thereof using SPARQL. This implementation will allow us to further link the container with some of those who are part of The Linked Open Data cloud. If you would like to make an alignment of our ontology with the Linken Data Web, we can use equivalence statements, such as owl:sameAs, as well as other types of linked properties. An Ontology Alignment (Euzenat & Shvaiko 2007) is “a set of correspondences between two or more ontologies,” where a correspondence is “the relation holding, or supposed to hold according to a particular matching algorithm or individual, between entities of different ontologies”. Another alternative for alignment is an algorithm as suggested by Parundekar & Ambite (2010), which produces equivalence and subsumption relationships between classes from ontologies of different Linked Data sources by exploring the space of hypotheses supported by the existing equivalence statements.

4.5 Discussion

If we compare our model and the related works presented in the state of the art chapter, although all works shared efforts, each one deals with the design of ontology and the classes and properties that the ontology incorporates in different ways. In the case of OntoEdu, the authors focus on describing activities and materials to construct an educational ontology. This work doesn’t show evolution or results from the implementation of the ontology. In the case of OntoolCole is focused on the registration of a large number of collaborative tools and their automatic categorization. OntoolSearch use this register to facilitate educators search from the collaborative tools according to their search criteria. In our case, the objective of the ontological model focuses on describing web services with semantic properties so they can be incorporated into learning scenarios, either through its integration with other tools or to facilitate users search.

4.6 Conclusions

In this chapter we have fulfilled one of the research questions described in chapter 3 related with semantic modeling of learning services. This semantic model will allow us to expand the scope and extent the description of learning services. In the following chapters, we will deploy this model into a couple of use cases and evaluate the impact that this model represents in the benefit of the integration and composition of learning tools as well as a support for user customization.

CHAPTER 5 - System Implementation and Deployment

5.1 Introduction

In the previous chapter we have proposed a semantic model for describing learning services which is designed to fulfill two of the main objectives of this work, which are the composition and integration of learning tools and generate learning tools that allow customized according to users' needs and preferences. To achieve these objectives we performed implementation and deployment of the model in two distributed learning environments. In the first instance, the system implementation is done in a use case where learning services mounted into the Cloud are integrated with a learning management system. The second case of implementation will be made to perform online teaching laboratories, where cloud services will be combining with learning services to control laboratory instruments. In both cases the adaptation of the semantic model to meet the system requirements is performed. These implementations are detailed below.

5.2 System deployment: Case 1 - An Approach to Integrate Cloud Services with E-learning Systems across Linked Data

The complexity of integrate Learning Services is on one hand related with the distributed nature of resources and services in a learning environment and, on the other hand, with the difficulty to locate services based only on syntactic information. Due to this, we need to construct mechanisms to describe semantic capabilities of learning services and to develop methods for using that information to discover and match learning services depending on the user needs.

With an ever-increasing list of services that are provided through the Cloud, many critical applications will be deployed and consumed through SaaS (Software as a Service) mechanisms in the near future. However, as with any new technology, the concepts of SaaS and the Cloud have limitations and problems, especially those related with the integration of applications and data sources. Integration has been an important subject of study and research which seek to determine how integration brings a sense of order out of the chaos and disorder created by heterogeneous systems, networks and services (Raj, 2011).

Figure 5.1 illustrates the basic interactions between the service provider, services requester and services directory for dynamic binding of services at runtime (Baun et al. 2011). In particular, a service requester (consumer) can locate a suitable service in a service directory. If a suitable service has been found, the service consumer receives a reference for accessing the service. Then, the service can be called. The service provider replies by sending a message back. Today more and more APIs are being published by the major players in the Web, such as eBay, Amazon and Google. Web applications that consume these APIs are collectively referred as mashups, and they offer interesting experience to web users.

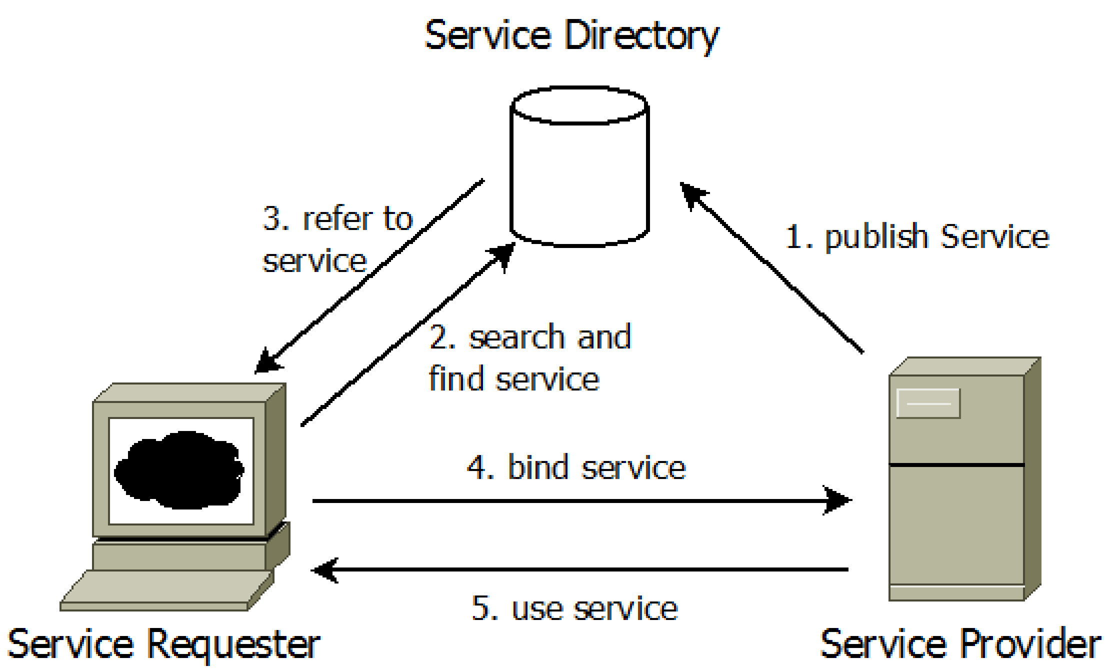


Figure 5.1. Service management through WSDL

However, many activities require additional features which are not caught in the specification of basic services supported by WSDL. Consequently, the so called Semantic Web service standards and composition languages have been defined to provide additional capabilities to service-oriented solutions that require discovery, composition, orchestration, choreography and mapping of web services. The basics of representing the Semantic Web consist of the use of two core standards: the Resource Description Framework (RDF) and the Web Ontology Language (OWL). Additionally, Linked Data (Hogan et al., 2012) refers to data published on the Web in such a way that it is machine readable, it is linked to other external datasets, and it can in turn be linked to from external datasets as well.

In the particular case of learning systems, integration problems are associated with the different understandings that may hold in the educational field and which are related to the particular characteristics of each area of instruction. The functional characteristics of a Cloud service API often do not match the needs that students and teachers may have. For example, , there may be an API that allows users to handle forms and process them, but in the educational field a teacher would try to access this functionality with the aim of providing “evaluation and feedback” to students. In that sense, we propose an alternative approach that makes use of the Semantic Web in general and the semantic description of services in particular to enrich the functional characteristics of the services or API’s with ontological domain characteristics of each area of teaching.

5.2.1 Extension of Semantic Model: Google Apps Tools and APIs

The case needs to be carried out an extension of the semantic model of learning services, including a class structure that allows linking with the structure in which the tools of Google Apps and the libraries of the various services are grouped. To carry out this extension, they were first detected some of the applications that make up the suite of Google Apps, which can be grouped under the categories of communication tools, collaboration tools, security tools and platform extensions (Morel et al., 2011). Table 5.1 shows a set of Google Apps suite of collaborative tools, including categories, applications and description of each application.

Table 5.1 Google Apps suite of collaborative tools

Name of the Application	Description of the Application
Communication Tools	
Gmail	Email by Google. It includes search tools and offers offline access. It also integrates instant messaging and video.
Google Calendar	Calendar and planning tools.
Google Talk	Instant messaging. It also exists as a standalone application and integrates with Gmail.
Collaboration Tools	
Google Docs	An online office suite, which includes a word processor, a spreadsheet, and a presentation tool.
Google Sites	A collaborative web content management tool that borrows from the wiki philosophy.
Google Video	A video sharing tool.
Security Tools	
Postini Services	A set of security (anti-spam, anti-virus, various filters) and mail archiving services
Extensions of the Platform	
Google Apps Market Place	A website for purchasing applications to enhance the Google Apps platform.
Google Apps Engine	A solution for designing and hosting web applications on Google's high-availability infrastructure.

Additionally, services are grouped into libraries or APIs, which is the way we can find them on their website and where the documentation of each library is included. Table 5.2 shows information related with a few libraries that use Google Apps data including name of the API or library, description and the execution context.

Table 5.2 A few APIs that use Google Apps data

Name of the API or Library	**Description**	**Execution Context**
Gmail Gadgets	Allows the design of gadgets that act on the content of mail. They can offer advanced preview features for some audio or video content.	Does not matter
Calendar Gadgets	Allows the design of sophisticated gadgets that use Google Calendar's data and events.	Does not matter
Sites Gadgets	This API allows an aggregation of several external data sources for publication in Google Sites. It allows circumvention of some security restrictions that apply to dynamic web content.	Google Sites
Wave Gadgets	Allows you to design robots and gadgets integrated in Google Wave. Their main purpose is to automate some conversion or translation tasks.	Google Wave
Spreadsheets API	This is for designing gadgets that improve Google Docs or other applications, which use spreadsheet features. It enables designing alternative graphical representations of the content of a spreadsheet or combine the content with other sources.	Google Spreadsheet

From these new features, we extend the basic ontological model of learning services description, adding the class Library, classes related with each category of tools and classes related with each of the APIs used. At the same time we perform the reallocation of classes based on the criteria of specialization and generalization that we believe that have relation. The result of this extension creates a new class hierarchy a segment shown in Figure 5.2

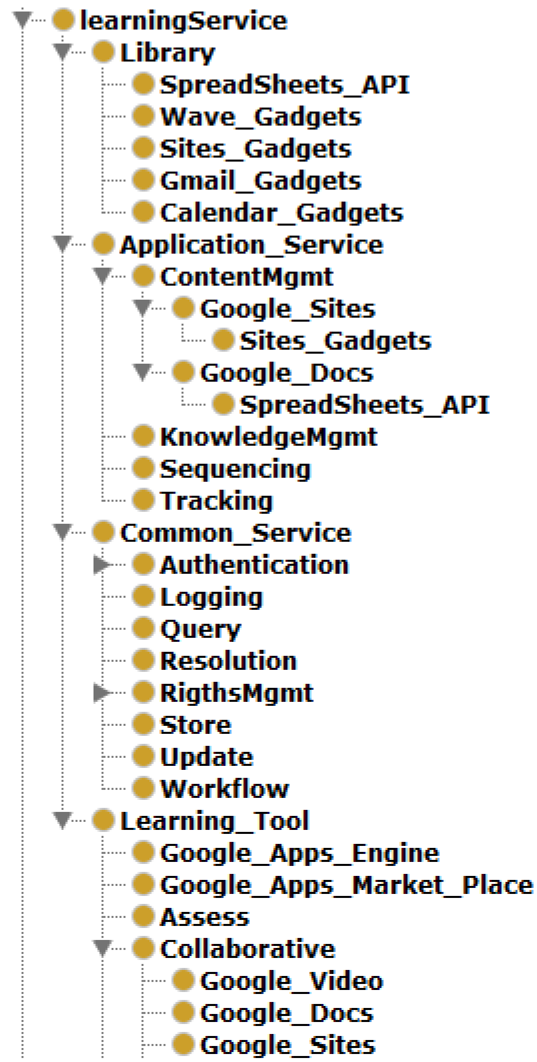


Figure 5.2. Class hierarchy with Google Apps Tools and Libraries

We have taken one of the services associated with the API of Google Sites to show how services are defined in terms of the ontology. The information of the API is shown in Table 5.3 and Table 5.4. In particular we will focus on the feed Site service, whose definition in terms of ontology is shown in Figure 5.3.

Table 5.3 Google Sites API [1]

Google Sites feed types
The Google Sites Data API provides the following types of feeds: • Activity feed • Content feed • Revision feed • Site feed • ACL feed
Site feed
The Site feed is a feed containing descriptions of all activities within a site. This feed's `GET` URI for a site within a particular domain is: https://sites.google.com/feeds/activity/*domainName*/[*siteName*]/ *domainName* is either "site", or a Google Apps domain. All requests to this feed must be authenticated. Supported request types: GET, POST, PUT

Table 5.4 The site feed supports the following (optional) parameters when issuing a GET request for listing sites.

Parameter	Description	Type	Notes
include-all-sites	List all sites that can be at least viewed by the user in the Google Apps domain.	Boolean	This parameter is only applicable when listing sites for a Google Apps domain. Possible values are true or false. Default is false.
with-mappings	Includes the web address mappings in a site entry.	Boolean	Possible values are true or false. Default is false.

[1] https://developers.google.com/google-apps/sites/docs/1.0/reference?hl=es-419

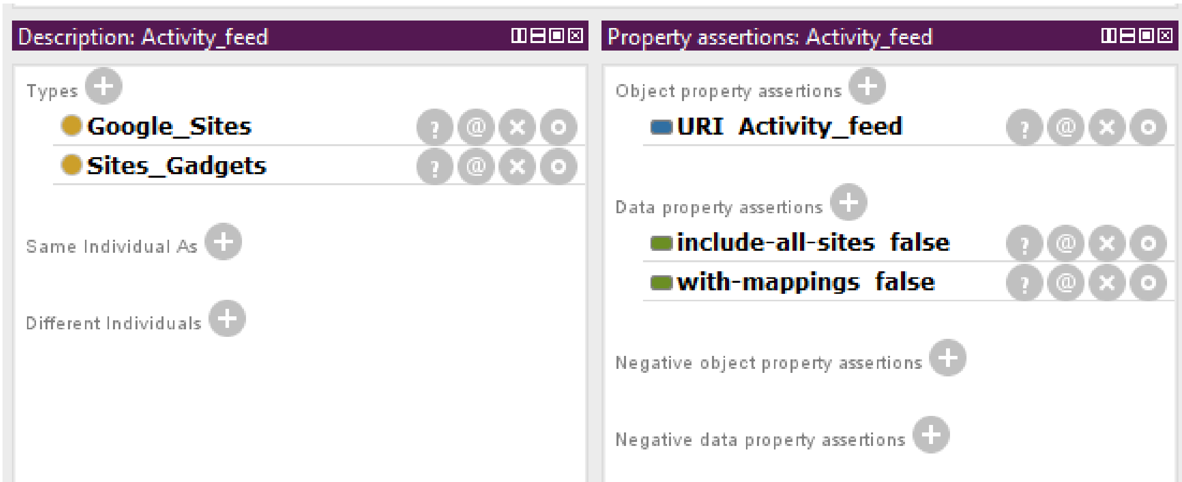
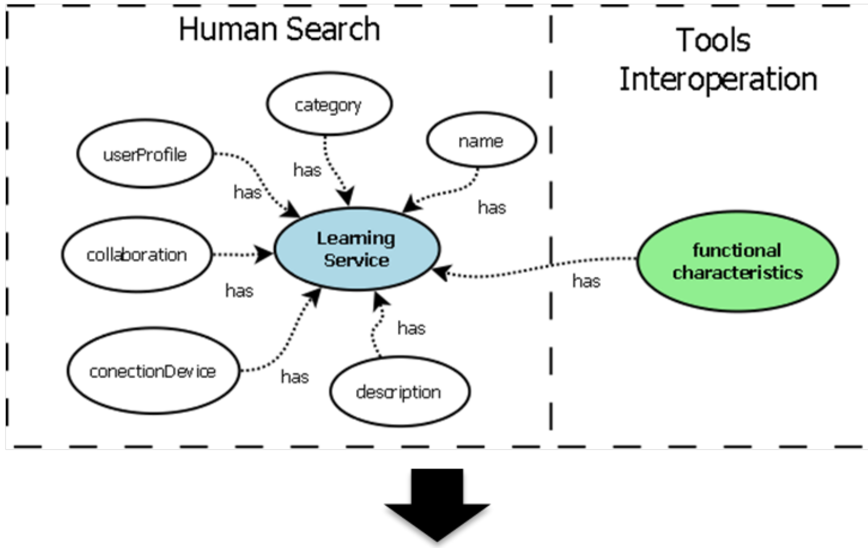


Figure 5.3. Definition of Activity feed service in terms of ontology

More specifically, given a specific teaching area, we propose to employ semantic annotations that will enable us to use the API functionality according to the ontological model used in the corresponding learning scenario, to let "decorate" and facilitate their integration with other tools. In this case, search is also promoted through characteristics that are common for teachers and students. Figure 5.4 shows a graphical representation of the semantics of a learning service, which is the result of a Cloud service API plus the semantic attributes that help us operate it and its OWL class representation.




```xml
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
xmlns:owl="http://www.w3.org/2002/07/owl#"
xmlns:LearningService="http://www.liberoeducacion.com/learningservice#"
xml:base="http://www.liberoeducacion.com/learningservice#">

<owl:Class rdf:about="http://www.liberoeducacion.com/learningservice#Name">
</owl:Class>

<owl:Class rdf:about="http://www.liberoeducacion.com/learningservice#Category">
</owl:Class>

<owl:Class rdf:about="http://www.liberoeducacion.com/learningservice#userProfile">
</owl:Class>

<owl:Class rdf:about="http://www.liberoeducacion.com/learningservice#collaboration">
</owl:Class>
.
.
.
```

Figure 5.4. A semantically represented learning service and its Ontology in OWL

This fact does not affect or interferes with the processes of each service. In the case of search, several features facilitate the human interaction with the service, such as: a service name, a readable description, a service category, a type of collaboration that is designed for the service, a type of connection devices which can display the result of the service, and the user profiles that can access the service. As shown in Figure 5.5, RDF storage is fed with instances of OWL class with defined parameters contained in the description of Cloud services APIs. Subsequently these containers are exploited by mashups to get the services that meet the requirements of users. These results contain functional specifications for invoking them.

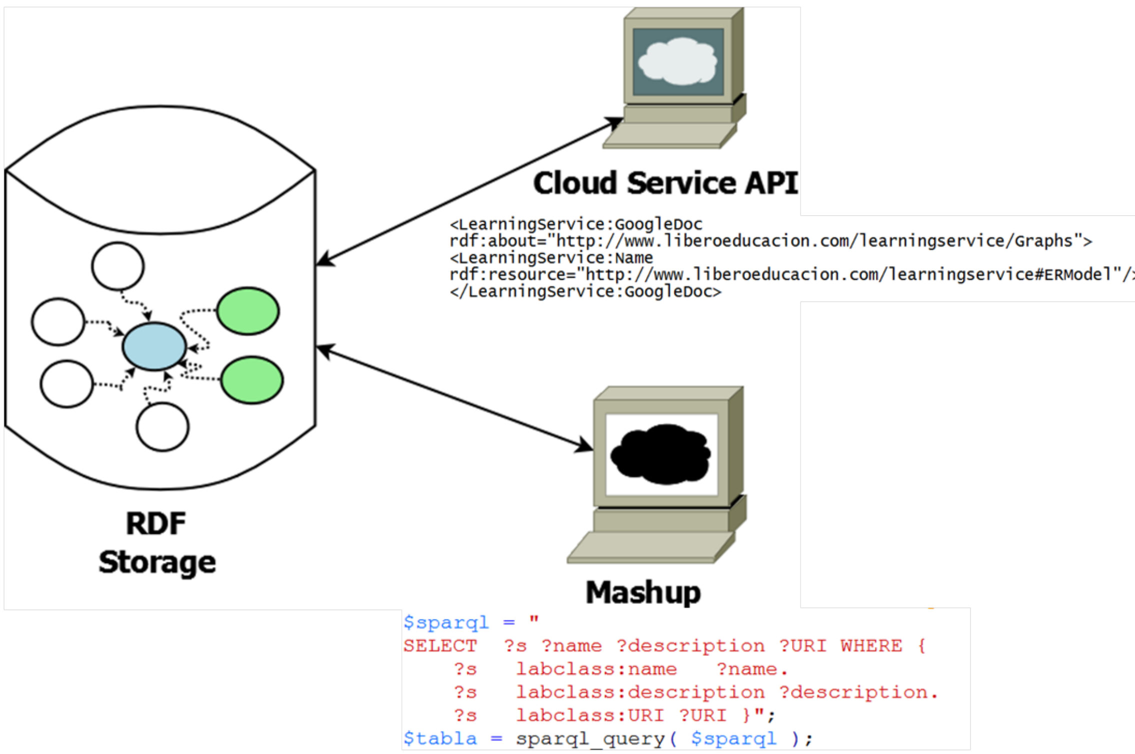


Figure 5.5. RDF Storage fed with OWL instances and exploited with mashups

Comparing our approach with other studies, as the ones mentioned related work, the integration of learning tools with functional Cloud services across semantic models represents significant benefits for the design of learning systems since it establishes common data containers for both applications, far from specific and rigid data models where each is defined separately. The educational impact that represents this type of innovation is that teachers are able to work with an integrated environment which facilitates the interaction between applications and thus provides them better opportunities in developing more solid and useful learning activities. Moreover, students achieve to reduce cognitive load (especially on task performance and the time to complete them) and work in a more user-friendly environment, as we demonstrate in the following sections. This fact does not affect or interferes with the processes of each service. In the case of search, several features facilitate the human interaction with the service, such as: a service name, a readable description, a service category, a type of collaboration that is designed for the service, a type of connection devices which can display the result of the service, and the user profiles that can access the service. As shown in Figure 5.4, RDF storage is fed with instances of OWL class with defined parameters contained in the description of Cloud services APIs.

5.3 System deployment: Case 2 - Supporting online teaching laboratories through semantic services

We propose an online teaching laboratory portal (Fig. 5.6), where users can connect from various types of devices, such as personal computers, tablets or cell phones, and have access to a centralized portal offering the resources on a distributed network and services of SaaS providers. The core functionality of the portal is based on a semantic model, which works as a data container for linking the different services available through the interactive learning environment. As main features of this environment we can distinguish instruments and device remote control, a role-based access control module, cloud services supporting collaboration and interaction, as well as semantic search of services depending on functional characteristics according to each type of laboratory. Below we present the semantic model and provide the details of its features.

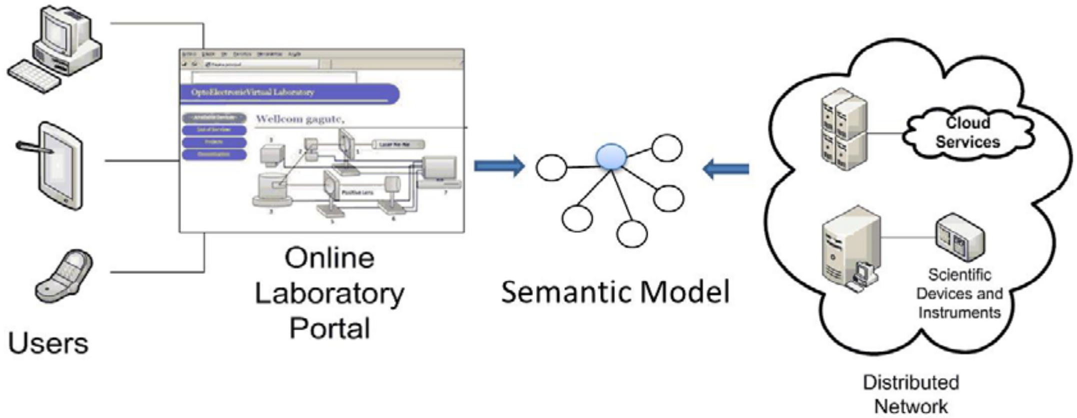


Figure 5.6. Online laboratory portal based on a distributed network

5.3.1 Extension of Semantic model: Optoelectronic laboratory

Our semantic model was implemented in an optoelectronic laboratory intended for both teaching and research. On one hand, this online laboratory was helpful to learn the control of optoelectronic devices through computer equipment (Figure 5.7) and, on the other hand, to access and use equipment managed on servers in various school departments. Each device or instrument is controlled by a computer connected to the Internet. Both students and teachers can control all these devices or instruments in real time, while they manipulate data acquisition as well.

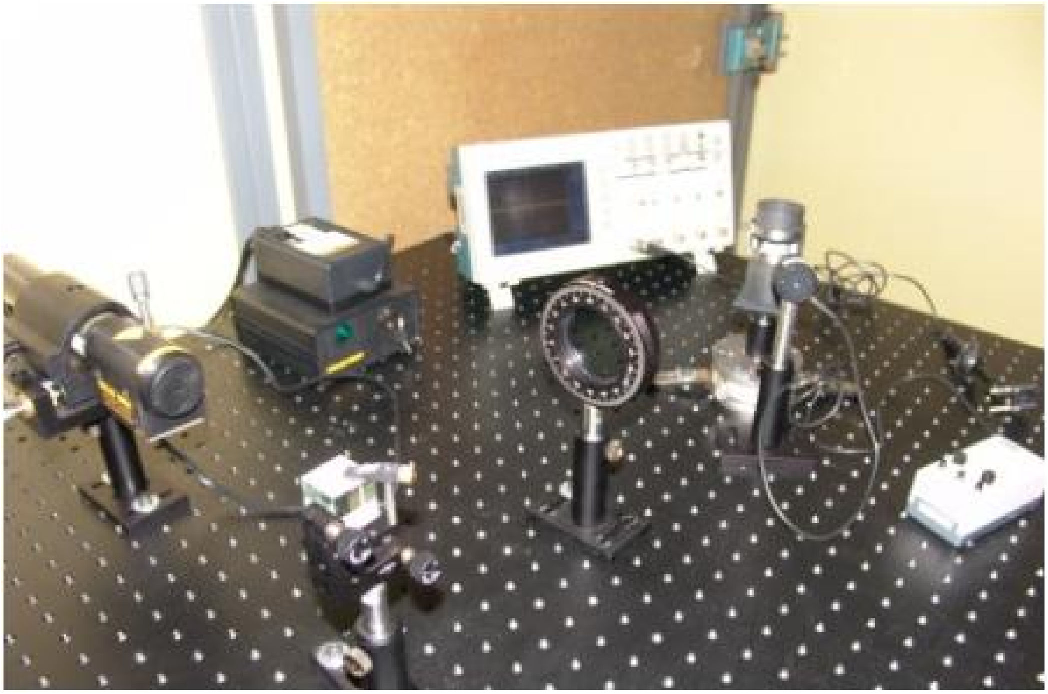


Figure 5.7. The Optoelectronic experimental array

To carry out the implementation for the particular case of an optoelectronic laboratory, the Semantic model was extended to incorporate the definition of the optoelectronic instruments and devices required for the experiments. These classes will allow the integration of the specific elements for this type of laboratory and will incorporate definitions to make them searchable by the learning services, thus facilitating the management and control of a particular instrument or device in the experimental array. The Learning Scenario class is extended with a class called "onlineLaboratory" and this in turn contains a subclass called "optoelectronic" containing two subclasses: "device" and "measuring instrument". Examples of the device subclass include laser amplifiers and lenses, and examples of the measuring instrument subclass include sensor, multimeter, interferometer, oscilloscope and microscope (Figure 5.8).

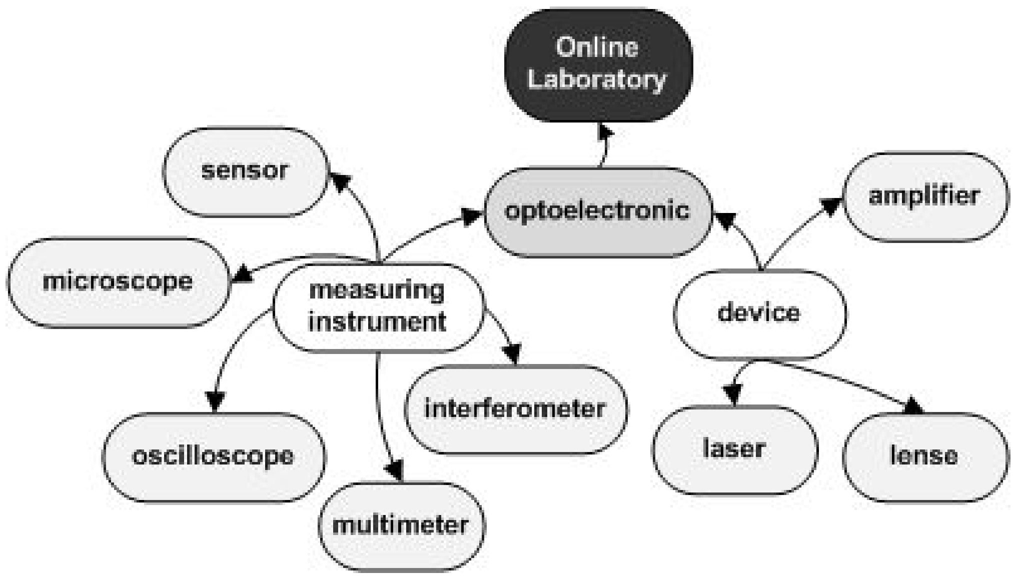


Figure 5.8. Optoelectronic class

Figure 5.9 shows how the class hierarchy has changed, particularly in the learning scenario class, which has been adapted to the stage of laboratories and particularly online classes related to a laboratory in optoelectronics.

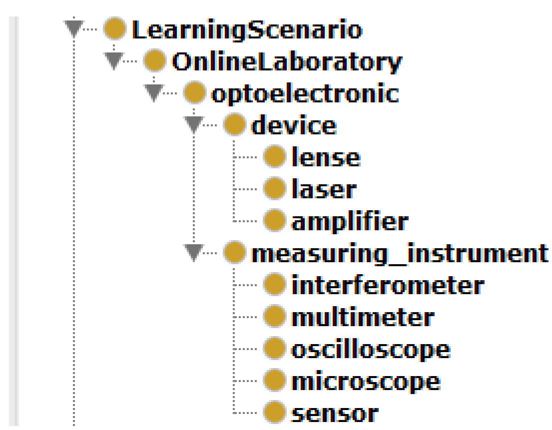


Figure 5.9. Class hierarchy for Online Laboratory

5.3.2 Remote control of instruments and devices

To build a real scenario in which the utility of the Semantic model can be demonstrated, the devices and instruments of the online laboratory will be defined in terms of the service that they provide. For each real instrument, a virtual instrument is designed. Abdulwahed and Nagy (2013) demonstrated how LabVIEW is a reliable mechanism to implement the web services to control the devices and measure instruments. LabVIEW web services use a RESTful architecture (Richardson and Ruby, 2008), which requires a minimal additional markup (Figure 5.10).

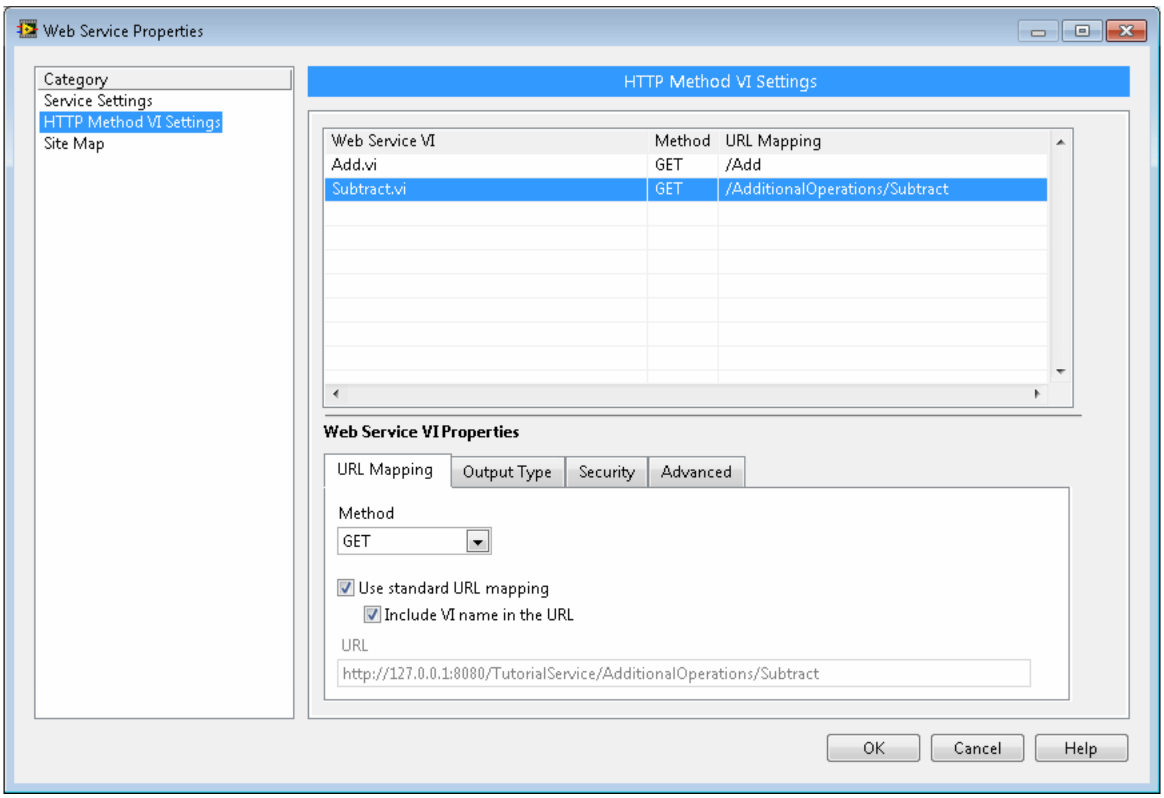


Figure 5.10. LabVIEW Web Service Properties[2]

[2] http:// zone.ni.com/reference/en-XX/help/371361K-01/lvhowto/build_web_service/

The virtual instrument has a URI property as an access point to the RESTful service that controls the real instrument (Figure 5.11). The semantic description of learning service is the result of URI information of the virtual instrument plus the semantic attributes that help us operate it.

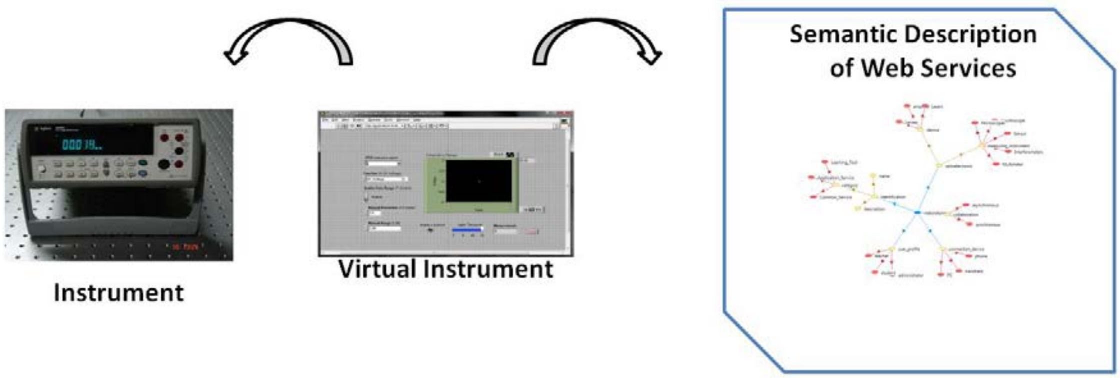


Figure 5.11. Relations of a real instrument with its virtual instrument and its semantic description and functionalities

5.3.3 Access Control and Customization

The role-based access control module allows users validation through username and password. If users are valid, the role or assigned roles are checked and, based on the particular privileges, the features assigned to each role will be displayed or hidden. Likewise, users can select those services that are appropriate to them and they want them to be displayed in their profile, which allows customization for user preferences, profile privileges and access limitations (Figure 5.12).

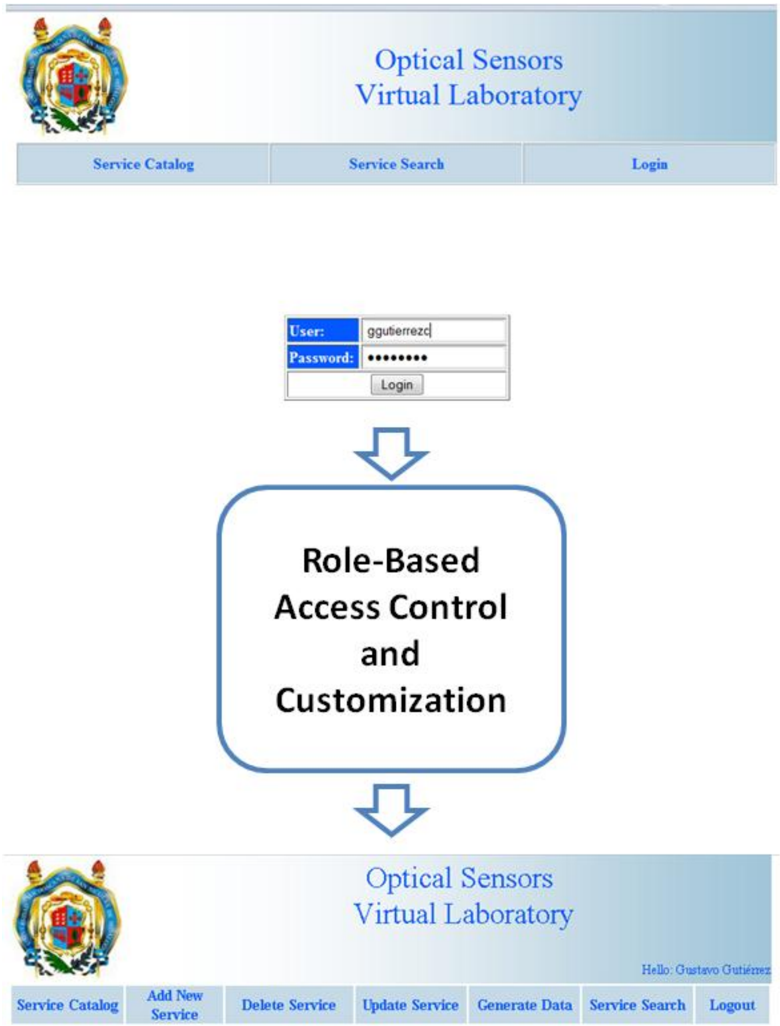


Figure 5.12. Role-Based Access Control and Customization

5.3.4 Collaboration and interaction

An important feature of our model is to allow students to communicate and collaborate with other students and teachers. To this end, we were based on existing cloud computing tools that can be integrated to different environments. In particular we explored the use of Google+ API's (Murphy, 2012) and integrated them into the online teaching laboratory portal, using the semantic description via linked data to store the information required for each API function (Table 5.5). The main communicative and collaborative functions are related with Google

Groups and Hangouts (Figure 5.13). In particular, the semantic description of services is endowed with functional characteristics that enable its easier integration with other tools; for example, this is related to validation parameters, the token generated after validation, error handling and exceptions, etc.

Table 5.5 Google+ Hangouts API [3]

Classes
ApiReadyEvent AppVisibleEvent EnabledParticipantsChangedEvent Participant ParticipantsAddedEvent ParticipantsChangedEvent ParticipantsDisabledEvent ParticipantsEnabledEvent ParticipantsRemovedEvent PreferredLocaleChangedEvent PublicChangedEvent TopicChangedEvent
Functions
getEnabledParticipants getHangoutUrl getHangoutId getLocale getLocalParticipantLocale getPreferredLocale getStartData getParticipantById getParticipantId getLocalParticipant getLocalParticipantId getParticipants getTopic hasAgeRestriction hideApp isApiReady isAppVisible isPublic setWillAutoLoad wasAutoLoaded willAutoLoad
Events
onApiReady onAppVisible onAutoLoadChange onEnabledParticipantsChanged onParticipantsAdded onParticipantsChanged onParticipantsDisabled onParticipantsEnabled onParticipantsRemoved onPreferredLocaleChanged onPublicChanged onTopicChanged

[3] https://developers.google.com/+/hangouts/api/?hl=es-419

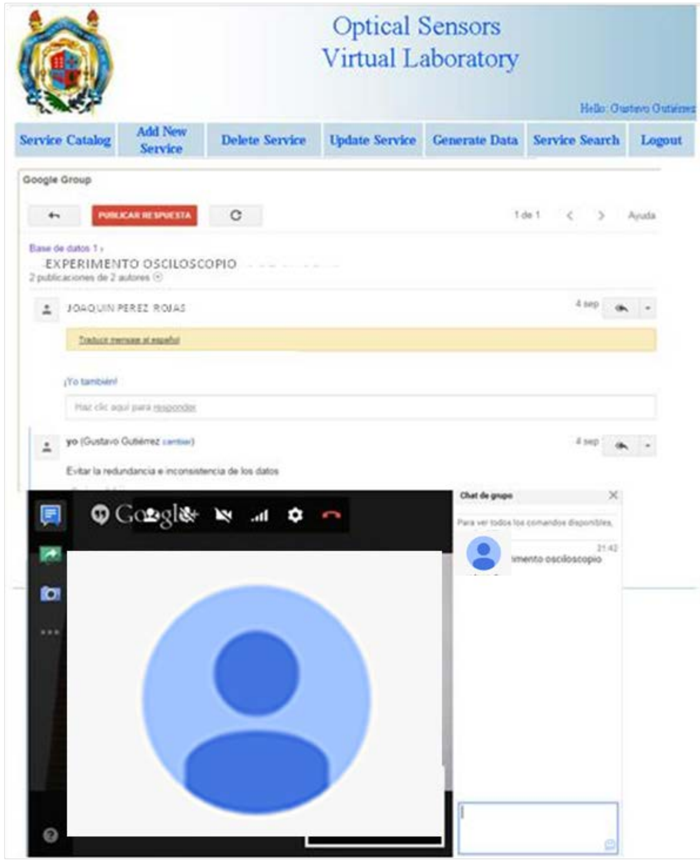


Figure 5.13. Collaboration and interaction

5.3.5 Semantic Searches

In order to get the most benefit from the semantic description of learning services, on one hand the online teaching laboratory enables the laboratory staff to create a semantic model; on the other hand, it allows students, who are not acquainted with the semantics of the laboratory, to carry out an intuitive search of available services and provides them an access point to services. The search of learning services, based on non-functional attributes, depends on a linked data semantic container. This container of semantic information can be used to gather information on each service, which allows searching and querying the parameters required to invoke it. The results contain functional specifications for invoking learning services.

The users are able to perform search and navigation of services based on their categories and semantic classification (Figure 5.14).

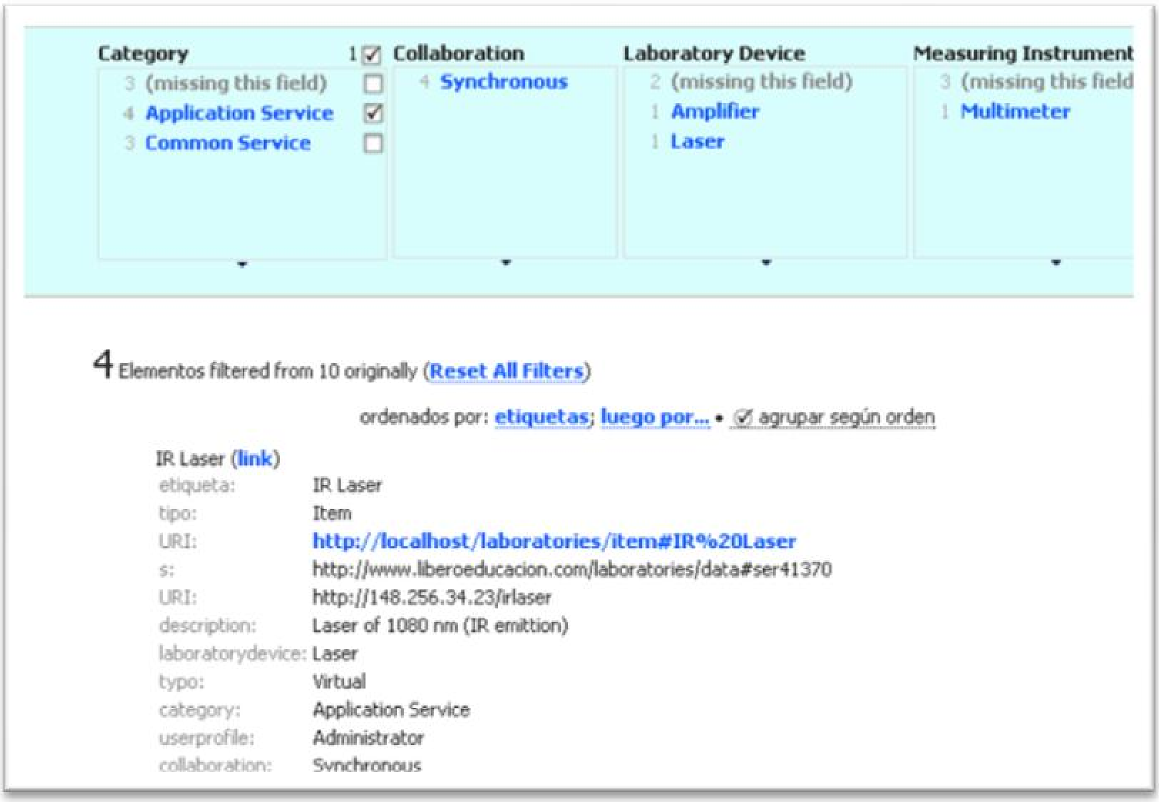


Figure 5.14. Online lab semantic search

5.4 Conclusions

With the aim to test the feasibility of our model of semantic description , in this chapter we have shown the implementation of the semantic model in two use cases, one for the integration of services based on cloud computing in learning management system, and the other creating portals for online teaching laboratories. In order to complete the evaluation process model of semantic description in the next chapter we will propose a stage of experimentation for each use case, which will be subjected to a set of participants to see the benefits that the model can generate in terms cognitive load and usability. Once this is done, we will show the results found and how they impact on achieving the objectives of this thesis.

CHAPTER 6 - Experimentation Scenarios

6.1 Introduction

In the previous chapter the implementation of the semantic model is presented in two use cases on the one hand the integration of learning services based on cloud computing with a learning management system, on the other hand, the construction of teaching laboratories line that allow customization of devices and services available to users. The objective of this chapter is to define detailing experimental scenarios for each of the case studies. In the case of the integration of cloud services with LMS we present a learning scenario with the integration of Cloud SaaS (Google Apps Services) with Chamilo LMS. In the case of online labs, we develop a teaching portal for an optoelectronics laboratory, where users can search the instruments scattered across a distributed network. For each scenario we will make a description of the stage of experimentation, participants and procedure of the experiment to demonstrate how this whole process supports the definition, implementation and evaluation of personalized learning scenarios that could be easier of use for participants allowing interaction and active construction of knowledge.

6.2 Experimentation Scenario I: Integration of Google Apps within the Chamilo Learning Management System

We have designed an experiment which deals with the integration of Google Apps Cloud features (Morel et al. 2011) within the Chamilo Learning Management System. In general, Chamilo supports many different kinds of learning and collaborative activities. It allows one to specify the course objectives, identify learning units, develop materials and presentations for content, build evaluation exercises and on-line tasks, while it provides assistance and collaboration tools that contain synchronous and asynchronous communication (chat and forums), as well as Wikis, blogs, social networks, messages, group management, course management, recycling and more. However, instructors may have specific needs in order to meet particular objectives of a course, for example they may need a tool that is beyond the scope of Chamilo, such as a diagram designer, mail services, a document processor, etc. Such tools are offered by Google Apps and include Google Drive for storage and document creation, Youtube for audiovisual content management, Google Hangouts for handling instant electronic messaging, and live video conferencing capabilities, amongst others.

The main aim of the experiment is to develop semantic mashups to integrate the two systems using Linked Data and taking advantage of the availability of APIs to interact with Google Apps.

6.2.1 Participants

The experiment designed above has been carried out in a class of third-year undergraduate students (N=56) enrolled in the “Management Information Systems” course. This course is of both theoretical and practical type, and the teacher had already taught it in two previous occasions. All students have been using Chamilo as a standard tool to access course documents, submit assignments, attend meetings, and so forth. The students participated in the experience were divided into two groups: an experimental group (N=24) and a control group (N = 32). Students in the experimental group used Chamilo integrated with Cloud services through semantic mashups and Linked Data, whereas the control group was asked to access both tools separately, performing the Cloud services access manually. Both groups of students were instructed by the same teacher. The teacher assigned students specific problems to solve using the project-based learning paradigm and guided students to use Google Drive and Google Docs to share and co-construct documents, Google Groups to carry out structured discussions and Google Calendar to organize task planning and execution. The teacher provided the experimental group students with very specific indications of how and when to use each application, along with Chamilo, which definitely had a positive impact on cognitive load and usability.

6.2.2 Experimental procedure

(1) Three 90-minute sessions over a period of two weeks were conducted, totaling 270 minutes, where all students had the chance to give a general explanation that showed how to access and use Google Apps main applications, such as: Google Drive (including Docs), Gmail, Translate, Calendar, YouTube, Sites, Hangouts, and Maps. Both experimental and control groups used Chamilo for daily course activities.

(2) The learning experiment, that lasted 120 minutes, consisted of three activities that made use of Google Apps:

(a) Generate a site to publish information on an assigned topic, using Google Sites.

(b) Design 2 graphics to incorporate into each personal site using Google Docs.

(c) Incorporate a video explaining the process of designing graphics in each personal site using YouTube.

Finally the site had to be linked to the profile of each student in the Chamilo platform. Students in the experimental group were guided to work using the semantics mashups integrated with Chamilo, while students in the control group worked on their experiment accessing Cloud services manually.

After the end of the learning experiment, all students took a usability questionnaire as well as a questionnaire that examined students' cognitive-load and satisfaction.

6.3 Experimentation Scenario II: Optoelectronic Online Laboratory

Online teaching laboratories allow teachers and students to interact and work collaboratively as a distributed team and represent collections of integrated tools that provide a delivery mechanism for rich learning content, advanced assessment capabilities as well as the reduction of costs for universities and availability 24x7 of a wide range of educational resource for students (Aziz et al., 2009). Huang et. al (2009) describe how one of the essential goals of applying Web 2.0 to interactive e-learning is to enhance learner-center communication and collaboration among participants in Web-based learning. They consider learners who either possess related learning resources or can be assisted to discover and obtain the resources, or are willing to exchange and share such resources with others. A fundamental functionality is to present users with the relevant information or educational functionalities at the right place and the right time, seamlessly. One way to implement these functionalities through computational processes is by using web services, which are platform and language independent in particular those provided through Cloud computing. New challenges need to be considered when adapting web services selection methods to the Cloud computing environments (Le et al., 2014). Software as a Services (SaaS) are mostly Web-based applications; platform as a services (PaaS) are provided for Web service development and are usually accessed via Web interfaces; infrastructure as a services (IaaS) offer virtual environments for platform deployment and can be monitored by Web-based monitoring tools.

The use of ontologies in general and the semantic description of web services in particular is becoming more relevant for interactive learning scenarios, because it provides a mechanism to describe the resources and functional capabilities distributed across networks that can be centralized through portals and presented to students in different types of devices. For the particular case of online teaching laboratories, CloudLabs 1.0 (Thames et al., 2011) provides an interesting framework for remote laboratory infrastructure architectures and design methodologies using technology such as command and control communications, Web 2.0, and cloud computing. This offers a scalable, manageable, and sustainable technological infrastructure-basis for large scale remote laboratory deployment. The framework encompasses the ideas of "Something"-as-a-Service from the cloud computing paradigm.

6.3.1 Experiment Design

The main aim of the experiment is that students use the online laboratory as a collaboration environment that allows them to interact with other students and teachers using the tools provided by Google+ Services. In turn, students will search for tools and devices that they need to use, whereas the validation tool will verify that they have privileges to use it. This search will be performed according to the semantic features which have been assigned to them. The search is based on non-functional information to locate learning services to control instruments or devices. Our research hypothesis, that we want to validate, is that the system provides easy access to the components of the laboratory, improving the sharing of devices and instruments, thus providing good rating in usability, whereas the semantic description is beneficial to students by enabling them to perform effective search for devices and instruments, thus improving the cognitive load-satisfaction relationship. Both features together ultimately provide benefits for learning.

6.3.2 Participants

The online optoelectronic laboratory portal was used for practical work in the courses of Electronics, Analogical-Digital Control, Optical Instrumentation and Optoelectronics taken by undergraduate students (N=25). It could be transferred to any engineering curriculum that includes these courses. Students had knowledge of laboratory instruments and devices and had basic knowledge on virtual instrumentation with LabView.

6.3.3 Experimental procedure

A practical activity is set in which students can perform the control of instruments and devices through a LabView virtual instrument and web services. Once they are familiar with the web services control scheme, the semantic search application is presented, where lab staff has privileges of searching, registering, updating, and deleting semantic information of learning services. Students can only search and browse a catalog of learning services built from their semantic properties.

At the end of the learning experiment, students took a usability questionnaire related to the semantic search as well as a questionnaire that aimed to examining cognitive-load satisfaction related to the collaboration and customization tools.

6.4 Discussion of experimentation scenarios and the experimental procedure

In order to meet the research issues presented in Chapter 3, we designed the experimentation scenarios in order to meet the main objective of the thesis that is related with the use of semantic modeling of learning services with respect to the integration and composition of learning services in order to personalize students' learning process. In the experimental scenario 1, the integration of learning services with LMS systems sought, which satisfies the aim of the thesis to support the improvement of e-learning in general and the dynamism and integration of tools in particular. The experimental procedure of this scenario was tested with a control group and with experimental group, which was proposed to prove that semantic technologies can be used to improve support on learning and in particular the dynamism and interaction between tools, as well as the ability to compose and automatically discover tools and services. In the experimental scenario 2, we focused in probe that the semantic model will allow the design of ubiquitous and pervasive learning scenarios will foment the interaction among the users and will allow developing collaborative and personalized learning activities. The experimental procedure of this scenario was tested with students and teachers using an educational laboratory, giving them a choice of online laboratory, where our goal was to see how a semantic model can improve their learning activities, where we can evaluate the benefits of customization to learning process, allowing learning activities to be carried out with greater satisfaction

6.5 Conclusions

In this chapter we detail actual experimentation scenarios that have been developed to show the benefits of each use case. These learning scenarios were presented to participants who are indicated the experimental procedure to be followed and which were shown later surveys in usability and cognitive load for evaluating scenarios. The next chapter will show the results of these evaluations.

CHAPTER 7 - Research Findings

7.1 Introduction

In the previous chapter we presented a detailed description of the experimentation scenarios which are related to two use cases. This chapter presents the research findings which were addressed and discussed as a function of two variables/levels: system usability and cognitive load. More specifically, we explore how our approach may benefit the learning process at both levels, by defining and measuring specific indicators. In this sense we present the results of our evaluation, based on the control vs. experimental group methodology, and we discuss the impact of these results with respect to the research questions set by this thesis.

7.2 Evaluation axes: Cognitive Load and Usability

As commented above, one of the objectives of this thesis is to determine the benefits that students can get from sematic modeling of learning services, integration of services and customization of learning tools. These benefits may occur at two levels: first, at cognitive load level, we examine whether students that have access to the integrated functionality have less cognitive overhead and thus focus their attention better on learning and, second, at usability level. Usability is defined as the extent to which a user can fulfill a task using a tool effectively, efficiently, and with satisfaction (ISO 9241-11, 1998). In fact, these two goals are interrelated, since the use of a complex educational distributed environment that takes standard usability guidelines and principles into account may contribute to reduce extraneous cognitive load (Hollender et al. 2010). Furthermore, the applicability of existing cognitive-load educational design principles for educational software design should be evaluated empirically. It should not be assumed that Cognitive Load Theory (CLT) and its instructional design principles offer off-the-shelf solutions for educational technology.

The design and use of learning tools for online education must be done carefully when dealing with CLT issues; for instance, Wong et al (2012) found that if we assume that the cognitive load associated with the presentation of complex information could be improved by the use of animations or dual mode presentations, both forms of presentation incidentally introduce transience that also can impose a heavy cognitive load. Despite these shortcomings, there have been successful experiments, in which the consideration and evaluation of cognitive load has represented benefits to the development of learning scenarios (Schrader & Bastiaens, 2012; Moons & De Backer, 2013).

7.2.1 Cognitive Load Evaluation Instruments

To design instruments that allows us to evaluate and take cognitive load into account, we rely on a proposal developed by Bradford (2011), who detected a coefficient for the relationship between satisfaction and cognitive load by separating academic performance (i.e., "learning") from cognitive load and satisfaction. In this sense a survey instrument was designed, which focuses on three indicators to consider: *awareness*, *challenge* and *engagement*.

For the scenario of experimentation 1, we design a survey of 10 items with a 5-point Likert scale. As concerns the *awareness* indicator, four questions were posed to examine whether syllabus and assignment directions were clear, problems were easy to comprehend, supporting materials were helpful, and activities were useful for new cases (questions 1-4). The fact of being aware of all these elements constitutes important means for finding solutions and organizing presentations so as to reduce high memory load and enhance student motivation. With regards to the *challenge* indicator, three questions relate the students' degree of satisfaction with the degree of challenge they face (questions 5 - 7); it is expected that when students are challenged, satisfaction may be their own reward and extra memory requirements (i.e., high cognitive load) seem to be fine. As for the *engagement* indicator, three questions were asked to relate relevance of different types of learning activities to the students' needs and goals (questions 8 - 10). Figure 7.1 presents the 10 questions used in the cognitive load - satisfaction questionnaire. Here we note that although a weak reliability (.49) exists, the coefficient can be provisionally accepted as a new scale, given that follow-up efforts to improve the coefficient are made.

	Strongly disagree 1	2	3	4	Strongly agree 5
1. I think that instructions and guidelines for conducting the experiment were clear					
2. I think that the way to find solution to the problem, the expected deliverables and the evaluation process was understood					
3. I think the explanation sessions and the material presented helped me to solve the problem					
4. I think this activity will be useful for the development of future projects with the tools presented					
5. I consider that the development of this activity challenges my abilities to solve these kinds of problems					
6. I think that the problem solution itself is a significant achievement					
7. I have the ability to solve this problem and more complicated ones of the same type					
8. I think that this experiment is relevant to the course and to my curriculum					
9. I think that communication, discussions or debates with my classmates and the teacher are important					
10. I think that this type of activities encourages me to develop solutions for myself					

Figure 7.1. Questionnaire that examines the relationship of cognitive load – satisfaction

Fort the scenario of experimentation 2, our interest is to determine how the collaboration between users and personalization can generate lower cognitive load among students. That is, given that students have a common access point to laboratory resources that can be accessed anytime and anywhere, and can be customized both to their preferences, privileges and limitations of profile access and to the tools that are needed to keep them collaborating, then this is a fact that improves their learning. Some variables that are important for validating collaboration and customization tools were detected: Varieties of communication forms, such as peer to peer, active discussions or debates, and communication with the instructor, reflect common ways students perceive engagement in a course subject; additionally, course relevancy with the wider field of study, assignment options, and opportunities for own assignment solutions extend the concept of engagement through connections with larger goals and the option of taking ownership of the work produced. A survey of 10 items was implemented with a 5-point Likert scale. Figure 7.2 presents the ten questions used in the cognitive load - satisfaction questionnaire focusing on collaboration and customization features of the online laboratory. Questions 1, 3, 5, 7 and 9 are related to some aspects of the collaboration tools that allow communication between members of the student groups that performed the experiment. Questions 2, 4, 6, 8 and 10 are related to the customization options and access control available in the online lab.

	Strongly disagree				Strongly agree
1. I think the collaboration tools motivates me to participate	1	2	3	4	5
2. I think having access only to the functions according to my profile prevents me from distracting during the experiment	1	2	3	4	5
3. I think the tool enables the collaboration, discussions or debates with my classmates and the teacher	1	2	3	4	5
4. I think the tool allows me to customize the environment according to my needs	1	2	3	4	5
5. I think it's better to work with the online laboratory that enables collaboration than do it in isolation	1	2	3	4	5
6. I think the customization options allows me to run the experiment in my own way	1	2	3	4	5
7. I think the collaboration tools allows instructor's feedback, advice, or guidance to students	1	2	3	4	5
8. I think the customization options give me a more enjoyable learning experience in the development of the experiment	1	2	3	4	5
9. I think the collaboration tools that allow me to stay connected with other people in the experiment make my learning experience more satisfying	1	2	3	4	5
10. I think this kind of personalization tools helps me to be more responsible of my own learning	1	2	3	4	5

Figure 7.2. Questionnaire that examine the influence of collaboration and customization options in the relationship of cognitive load – satisfaction

7.2.2 System Usability Scale

System Usability Scale (SUS) is a simple, ten-item attitude 5 point Likert scale (ranging from 1-'strongly disagree' to 5-'strongly agree'), giving a global view of subjective assessments of usability. It was developed by Brooke (1996) and its validity has been tested by numerous studies both in several websites and Learning Management Systems as well as in other environments, such as mobile ones. It proved to produce very reliable outcomes in relation to other questionnaires, even for a small (N=12-15) sample of participants (Tullis and Stetson 2004). It yields a single score on a scale of 0–100. Extensive studies with the participation of almost 2300 users confirmed that the mean evaluation value has been 70, whereas the top 25% of all scores was measured at 77.8 (Bangor et al. 2008; Bangor et al. 2009). In particular, Bangor et al. (2008) showed the following qualitative interpretation of SUS scores:

- SUS = 51 => Poor/OK
- SUS = 72 => Acceptable/Good
- SUS = 85 => Excellent

Figure 7.3 shows this in more detail.

Adjective	Count	Mean SUS Score	Standard Deviation
Worst Imaginable	4	12.5	13.1
Awful	22	20.3	11.3
Poor	72	35.7	12.6
OK	211	50.9	13.8
Good	345	71.4	11.6
Excellent	289	85.5	10.4
Best Imaginable	16	90.9	13.4

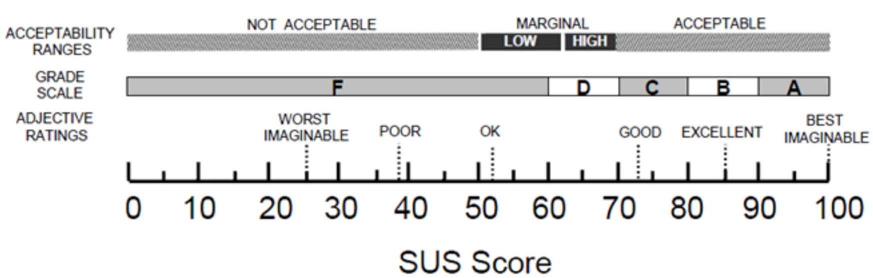
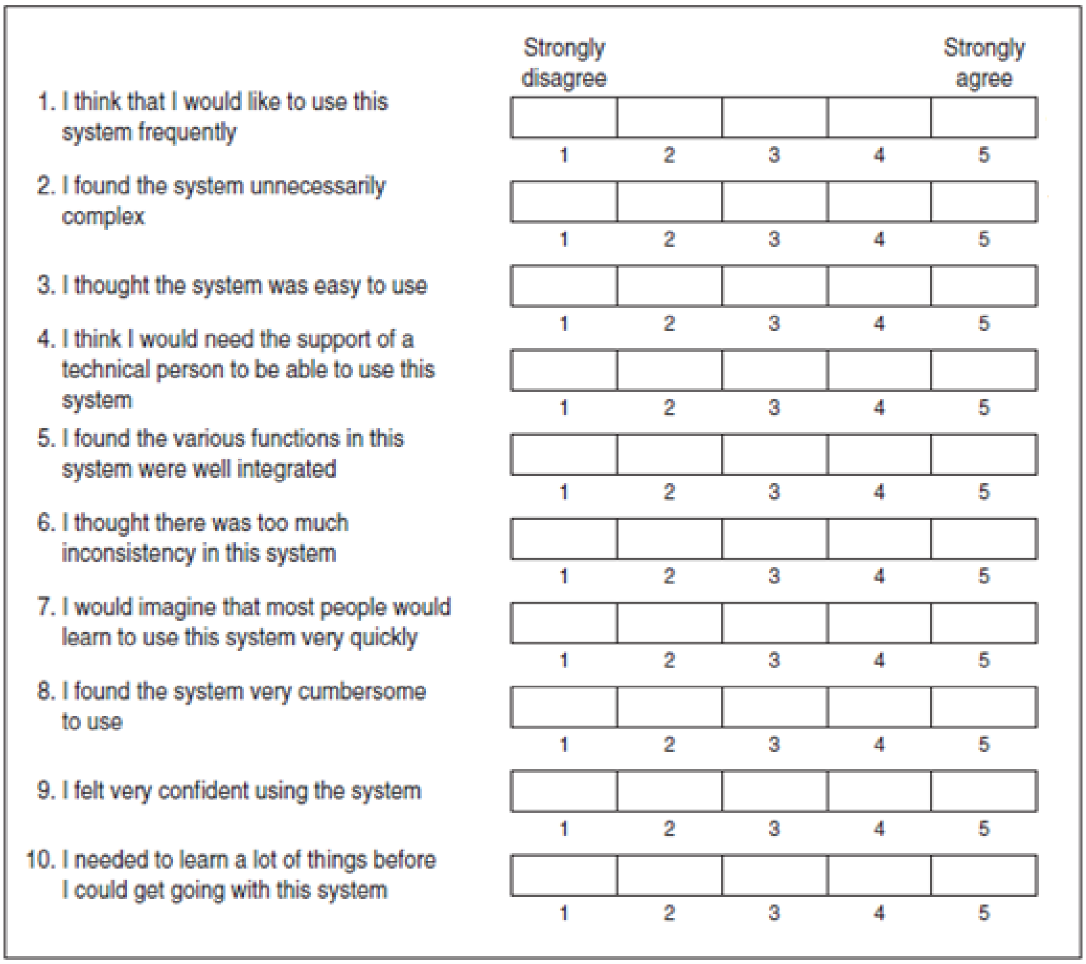


Figure 7.3. SUS Adjective rating - by Bangor et al. (2009)

Finally, Tullis and Albert (2008), after conducting 129 studies, concluded that a score greater than 81.2 implies ranking at the top 10%. They also found that a score greater than 80 implies an increased likelihood of returning to the website and recommending it to a friend or acquaintance.

Figure 7.4 presents the 10 questions used in the SUS questionnaire. From the 10 questions, 5 are positively-worded and 5 are negatively-worded, alternating each positive with a negative question; by alternating positive and negative items, the respondent has to read each statement and make an effort to think whether they agree or disagree with it.



	Strongly disagree 1	2	3	4	Strongly agree 5
1. I think that I would like to use this system frequently					
2. I found the system unnecessarily complex					
3. I thought the system was easy to use					
4. I think I would need the support of a technical person to be able to use this system					
5. I found the various functions in this system were well integrated					
6. I thought there was too much inconsistency in this system					
7. I would imagine that most people would learn to use this system very quickly					
8. I found the system very cumbersome to use					
9. I felt very confident using the system					
10. I needed to learn a lot of things before I could get going with this system					

Figure 7.4. The System Usability Scale (SUS) questionnaire

To calculate the SUS score, we first sum the score contributions from each item. Each item's score contribution will range from 0 to 4. So, for items 1,3,5,7 and 9 the score contribution is the scale position minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the scale position. Finally, we multiply the sum of the scores by 2.5 to obtain the overall value of SUS in the range of 0 to 100.

7.3 Experimentation Scenario 1: Presentation and significance of the results

After students completed the experiment, they were asked to answer the questionnaires of Figure 7.1 and Figure 7.4. The first questionnaire assessed the relationship between satisfaction and cognitive load that students experienced while trying to perform the activities of the experiment. The second questionnaire evaluated the students’ experience in terms of usability of the tool. The descriptive statistical analysis includes the mean, median, mode, standard deviation, variance, skewness, kurtosis, range, maximum, minimum, and sum of the response to each question. These statistics provide an overview of the students' responses to the questionnaire. The values of the responses are those of a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), so they are discrete values used to provide basic statistical calculations such as the mean, standard deviation, variance, skewness and kurtosis, which reflect the trend of values of the responses and the shape of a probability distribution, without representing themselves a specific value within the scale. The case of values, such as mode, median, minimum value, maximum value, sum and range, shows the values of the options in which students responded, giving us a breakdown of the options selected in each response.

The results of the first questionnaire are presented in Tables 7.1 and 7.22 below, which reflect a statistical profile of the students’ answers to each of the questions for both the control and the experimental group. In general, in each of the evaluation criteria, the results of the experimental group were closer to strongly agree compared to the same results of the control group. In particular, to determine the relationship between cognitive load and satisfaction, we examined the three indicators defined above: *awareness*, *challenge* and *engagement.*

In the case of the *awareness* indicator (questions 1-4), based on the responses of each of the groups, we can determine that the experimental group showed a better performance for finding solutions and organization of the presentation. We can conclude that, compared with the control group, the integrated system reduced high memory load and increased the motivation of students. As for the *challenge* indicator (questions 5-7), the experimental group showed a better relationship between the degree of student satisfaction and the level of challenge they face; in this case satisfaction has been students' main reward, which eases the additional memory load required, thus alleviating cognitive load and increasing students' general well-being. As concerns the *engagement* indicator (questions 8-10), the experimental group showed a better perception of the relevance of different types of learning activities with regard to the students' needs and goals, which improves the 'cognitive load – satisfaction' relationship for these students. All in all, we can conclude that students using the integrated system had significant benefits as regards the 'cognitive load- satisfaction' relationship with respect to the control group students that used Google Apps services independently.

Table 7.1 Descriptive statistics estimated for the control group

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
N	32	32	32	32	32	32	32	32	32	32
Mean	3.6875	4.0000	3.8438	4.0625	4.1250	4.2188	3.9375	3.9063	3.9688	3.8438
SE of the mean	.1980	.1619	.1355	.1551	.1838	.1471	.1485	.1701	.1823	.1563
Median	3.5000	4.0000	4.0000	4.0000	5.0000	4.0000	4.0000	4.0000	4.0000	4.0000
Mode	3.00	5.00	4.00	5.00	5.00	5.00	4.00	5.00	5.00	3.00
Standard deviation	1.1198	.9158	.7666	.8776	1.0395	.8322	.8400	.9625	1.0313	.8839
Variance	1.2540	.8387	.5877	.7702	1.0806	.6925	.7056	.9264	1.0635	.7813
Skewness	-.063	-.269	-.179	-.432	-.632	-.801	-.226	-.266	-.499	.024
Kurtosis	-1.429	-1.199	-.270	-.834	-1.129	-.007	-.757	-1.083	-1.001	-1.150
Range	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Minimum	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Maximum	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Sum	118.00	128.00	123.00	130.00	132.00	135.00	126.00	125.00	127.00	123.00

Table 7.2 Descriptive statistics estimated for the experimental group

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
N	24	24	24	24	24	24	24	24	24	24
Mean	4.6250	4.6250	4.2500	4.6667	4.3750	4.6250	4.5417	4.6250	4.6250	4.7083
SE of the mean	.1009	.1009	.1241	9.8E-02	.1320	.1009	.1039	.1009	.1009	9.4E-02
Median	5.0000	5.0000	4.0000	5.0000	4.0000	5.0000	5.0000	5.0000	5.0000	5.0000
Mode	5.00	5.00	4.00	5.00	4.00	5.00	5.00	5.00	5.00	5.00
Standard deviation	.4945	.4945	.6079	.4815	.6469	.4945	.5090	.4945	.4945	.4643
Variance	.2446	.2446	.3696	.2319	.4185	.2446	.2591	.2446	.2446	.2156
Skewness	-.551	-.551	-.158	-.755	-.542	-.551	-.179	-.551	-.551	-.979
Kurtosis	-1.859	-1.859	-.347	-1.568	-.519	-1.859	-2.156	-1.859	-1.859	-1.145
Range	1.00	1.00	2.00	1.00	2.00	1.00	1.00	1.00	1.00	1.00
Minimum	4.00	4.00	3.00	4.00	3.00	4.00	4.00	4.00	4.00	4.00
Maximum	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Sum	111.00	111.00	102.00	112.00	105.00	111.00	109.00	111.00	111.00	113.00

In addition to the questionnaire responses of Tables 7.1 and 7.2 that correspond to a Likert scale with discrete response values ranging from 1 to 5, we considered useful to include frequency tables which show the number (and percentage) of students who answered each of the options (1 strongly disagree, 2 disagree, 3 neutral, 4 agree and 5 strongly agree) associated with each question. Tables 3 and 4 show the frequency tables for the responses of each question for the control and experimental groups respectively.

Table 7.3 shows that the results of the control group fluctuate between the values of 2 representing disagree, to 5 representing totally agree, and are divided into thirds responses between options 3, 4 and 5. In the case of the experimental group, Table 7.4 shows that values range from 3- neutral to 5- strongly agree and the answers are divided into halves on value 4 corresponding to agree and value 5 corresponding to strongly agree. From these results we can highlight some points that indicate that the LMS tool integrated with Cloud services is more useful and effective for the students in the experimental group and, in fact, improves the cognitive load-satisfaction relationship. As a general comment, we can see that in the majority of questions (8 out of 10), all the students (100%) of the experimental group have a positive attitude (i.e., agree or strongly agree). There are only 2 questions (Q3 and Q5) with a few (8.3%) neutral responses. In contrast, students in the control group were not so positive. Even in some instances they expressed disagreement. For example, while in Q1 100% of the experimental group students agree or strongly agree that the instructions and guidelines were clear, only 50% do so in the control group, with 15.6% of students showing disagreement. Similarly, in Q4 only 37.5% of the control group students strongly agree that the knowledge acquired in the experiment will be useful in future projects, against 66.7% in the experimental group, which clearly shows the higher level of satisfaction of the experimental group students. Finally, in Q10 the experimental group shows more confidence to develop these kinds of projects with 70.8% strongly agree against only 28.1% of the control group.

Table 7.3 Frequency table for the control group

Likert scale	2		3		4		5		Total	
	F	%	F	%	F	%	F	%	F	%
Q1	5	15.6	11	34.4	5	15.6	11	34.4	32	100
Q2	1	3.1	10	31.3	9	28.1	12	37.5	32	100
Q3	1	3.1	9	28.1	16	50.0	6	18.8	32	100
Q4	1	3.1	8	25.0	11	34.4	12	37.5	32	100
Q5	2	6.3	9	28.1	4	12.5	17	53.1	32	100
Q6	1	3.1	5	15.6	12	37.5	14	43.8	32	100
Q7	1	3.1	9	28.1	13	40.6	9	28.1	32	100
Q8	2	6.3	10	31.3	9	28.1	11	34.4	32	100
Q9	3	9.4	8	25.0	8	25.0	13	40.6	32	100
Q10	1	3.1	12	37.5	10	31.5	9	28.1	32	100
F – Frequency % - Percentage										

Table 7.4 Frequency table for the experimental group

Likert scale	3		4		5		Total	
	F	%	F	%	F	%	F	%
Q1	0	0	9	37.5	15	62.5	24	100
Q2	0	0	9	37.5	15	62.5	24	100
Q3	2	8.3	14	58.3	8	33.3	24	100
Q4	0	0	8	33.3	16	66.7	24	100
Q5	2	8.3	11	45.8	11	45.8	24	100
Q6	0	0	9	37.5	15	62.5	24	100
Q7	0	0	11	45.8	13	54.2	24	100
Q8	0	0	9	37.5	15	62.5	24	100
Q9	0	0	9	37.5	15	62.5	24	100
Q10	0	0	7	29.2	17	70.8	24	100
F – Frequency % - Percentage								

Finally, we performed the reliability measure of the Cognitive Load instrument based on Cronbach's alpha which considers as acceptable value a coefficient around 0.8. Table 7.5 shows the results for the binding coefficient of the experimental and control groups, as well as their independent values. The results demonstrate that the reliability of the instrument used is quite good in all cases, showing a clear consistency in the case of the experimental group. As a conclusion, the instrument used to address our first research question (i.e., the difference between the cognitive load-satisfaction of the students who learn with an LMS integrated with Cloud services and the students that manually access to both systems separately) proves to be reliable.

Table 7.5 Reliability of Cognitive Load instrument based on the Cronbach's alpha

	Control and experimental	Control	Experimental
Cronbach's alpha	.8604	.7704	.9040

In the case of usability, the analysis reflects the mean SUS score (M) for each one of the groups (Table 7.6). In particular, the mean SUS score is shown for each group, which can be considered acceptable (SUS > 70) for both groups, being in the case of the control group on the grade scale of "good" (SUS >70) and in the case of the experimental group on the grade scale near "excellent" (SUS > 80). Comparing these usability values, we can see that the usability of the integrated system (LMS endowed with Cloud services) built through our semantic description method is further improved, which allows students to have a more satisfying experience in the educational scenario they participated in terms of usability.

Table 7.6 Result value of SUS for Control Group and Experimental Group

	Control Group					Experimental Group			
N	max	Min	M	SD	n	max	Min	M	SD
32	95	57.5	76	8.25	24	95	75	83.3	8.82
n= students, max= maximum value, min = minimum value, M= Mean, SD = standard deviation									

7.4 Experimentation Scenario 2: Presentation and significance of the results

After students completed the experiment, they were asked to answer the questionnaires of Figure 7.2 and Figure 7.4. The first questionnaire assessed the relationship between satisfaction and cognitive load that students experienced while trying to perform the activities of the experiment. This questionnaire tries to know the students' perception of the benefits of customization and collaboration tools in the online laboratory. The second questionnaire evaluated the students' experience in terms of usability of the tool, particularly with the benefits of semantic search. We employed a descriptive statistical analysis that includes the mean, median, mode, standard deviation, variance, skewness, kurtosis, range, maximum, minimum, and sum of the response to each question. These statistics provide an overview of the students' responses to the questionnaire. The values of the responses are those of a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), so they are discrete values used to provide basic statistical calculations such as the mean, standard deviation, variance, skewness and kurtosis, which reflect the trend of values of the responses and the shape of a probability distribution, without representing themselves a specific value within the scale. The case of values, such as mode, median, minimum value, maximum value, sum and range, shows the values of the options in which students responded, giving us a breakdown of the options selected in each response.

The results of the first questionnaire are presented in Table 7.7 which contains the values that reflect the statistical profile of the students' answers to each of the questions. These values are used to determine the relationship between cognitive load and satisfaction from the use of the customization and collaboration tools of the online lab.

Table 7.7 Descriptive statistics estimated for students participated in Questionnaire of Figure 7.2

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
N	25	25	25	25	25	25	25	25	25	25
Mean	4.3200	4.000	4.0800	4.0400	4.4000	4.2800	4.1200	4.2400	4.3200	4.5200
SE of the mean	.1254	.1732	.1724	.1579	.1685	.1291	.1763	.1447	.1705	.1428
Median	4.0000	4.0000	4.0000	4.0000	4.0000	4.0000	4.0000	4.0000	5.0000	5.0000
Mode	4.00	4.00	4.00	4.00	5.00	4.00	4.00	4.00	5.00	5.00
Standard deviation	.6272	.8660	.8622	.7895	.8426	.6455	.8813	.7234	.8524	.7141
Variance	.3933	.7500	.7433	.6233	.7100	.4167	.7767	.5233	.7267	.5100
Skewness	-.345	-.418	-.1010	-.625	-1.049	-.202	-1.042	-1.123	-1.138	-1.195
Kurtosis	-.527	-.560	1.030	.434	.658	-.480	.928	2.563	.735	.145
Range	2.00	3.00	3.00	3.00	3.00	2.00	3.00	3.00	3.00	2.00
Minimum	3.00	2.00	2.00	2.00	2.00	3.00	2.00	2.00	2.00	3.00
Maximum	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Sum	108.00	100.00	102.00	101.00	107.00	105.00	103.00	106.00	108.00	113.00

In addition to the questionnaire responses of Table 7.6 that correspond to a Likert scale with discrete response values ranging from 1 to 5, we considered useful to include frequency tables which show the number (and percentage) of students who answered each of the options (1 strongly disagree, 2 disagree, 3 neutral, 4 agree and 5 strongly agree) associated with each question. Table 7.8 shows the frequency tables for the responses of each question related to collaboration. Table 7.9 shows the frequency tables for the response of each question related to customization.

Table 7.8 Frequency table for questions related to collaboration

Likert scale	2		3		4		5		Total	
	F	%	F	%	F	%	F	%	F	%
Q1	0	0.0	2	8.0	13	52.0	10	40.0	25	100
Q3	2	8.0	2	8.0	13	52.0	8	32.0	25	100
Q5	1	4.0	3	12.0	9	36.0	12	48.0	25	100
Q7	2	8.0	2	8.0	12	48.0	9	36.0	25	100
Q9	1	4.0	3	12.0	8	32.0	13	52.0	25	100
F – Frequency % - Percentage										

Table 7.9 Frequency table for questions related to customization

Likert scale	2		3		4		5		Total	
	F	%	F	%	F	%	F	%	F	%
Q2	1	4.0	6	24.0	10	40.0	8	32.0	25	100
Q4	1	4.0	4	16.0	13	52.0	7	28.0	25	100
Q6	0	0.0	3	12.0	14	56.0	8	32.0	25	100
Q8	1	4.0	1	4.0	14	56.0	9	36.0	25	100
Q10	0	0.0	3	12.0	6	24.0	16	64.0	25	100
F – Frequency % - Percentage										

Finally, we performed the reliability measure of the Cognitive Load instrument based on Cronbach’s alpha which considers as acceptable value a coefficient around 0.8. Table 7.10 shows the result which demonstrates that the reliability of the instrument used is quite good.

Table 7.10 Reliability of Cognitive Load instrument based on the Cronbach’s alpha

Cronbach’s alpha	.8814

In the case of usability, the analysis reflects the mean SUS score (M) (Table 7.11), which can be considered on the grade scale “excellent” (SUS > 80).

Table 7.11 SUS score

n	max	Min	M	SD
25	92.5	80	87.7	2.969

n= students, max= maximum value, min = minimum value, M= Mean, SD = standard deviation

7.5 Findings: Discussion and response to the research questions

With the results obtained for the case of the experimentation scenario 1, with the cognitive load / satisfaction relationship, we can argue that the experimental group has better results for the indicators of *awareness, challenge* and *engagement* than the control group. For each of the questions related to these indicators, the control group students describe their experience as less satisfactory with respect to the experimental group that used the integrated system. Students' satisfaction in the experimental group has, in turn, a positive impact on cognitive load and subsequently on their learning. Furthermore, with regard to usability, both groups consider the development of the experiment as an acceptable experience, though the experimental group expresses greater satisfaction. From these results we can conclude that an LMS integrated with Cloud services is more acceptable and useful than one in which users have to use them as separate tools.

In the experimentation scenario 2 has been shown that the facilitation of customization and collaboration features based on semantic description of services can improve the cognitive load of students when performing experiments on an online lab. In particular, our model supports important issues of students' awareness, challenge and engagement that positively affect their overall performance and satisfaction. This claim is supported by the results presented in Table 7.7 which shows that the trend of students' responses to questionnaire of Figure 7.2 is that most of the group evaluated the tool at the range of "agree" to "strongly agree", as can be appreciated by the values of mode, median and mean. Moreover, the rest of the values (standard deviation, variance, etc.) are very similar in all questions, which indicates that responses to the survey are to some extent homogeneous in all questions. These results show that students consider that the collaboration and personalization functionalities of the tool have facilitated their work. This is further backed up by the results shown in Table 7.8 where it can be observed how students evaluate the tool as regards its collaborative aspects. We note that the best rated questions are 5 and 9, which highlights both the students' desire to work collaboratively using the tool rather than in isolation and their satisfaction from this learning experience. As regards the customization facility provided by the tool, Table 7.9 shows that the best evaluated question 10 assures that personalization enhances students' responsibility for self-regulation of their learning and, consequently, of the associated cognitive load. The reliability of the analysis instrument is demonstrated in Table 7.10 which, based on Cronbach's alpha, shows a very reliable value. Finally, the evaluation of the tool usability shown in Table 7.11 indicates that the minimum value obtained by the students, according to the SUS scale, was 80, which corresponds to a value of "good". Moreover, the maximum value was 92.5, which corresponds to a value of "excellent", being the average of the 25 students tested in 87.7, which corresponds to a value of "excellent". As a conclusion, we see that students are quite satisfied by the functionalities offered by our online laboratory environment both as regards cognitive load and usability issues.

With these results we can determine that the benefits generated by a semantic model for both cases of integration and composition of learning services to the personalization of learning tools is favorable for both systems and users.

CHAPTER 8 - Conclusions, implications and future steps

In this work we have made an effort to develop a Semantic model of learning Services for constructing learning tools based on distributed resources that allow the consolidation of Distributed Learning Environments. Much of this effort is focused on providing students, teachers and administrators with tools to enhance the interaction with each other and to facilitate the development of collaborative activities. In the same way an important issue in the construction of distributed Learning Environments depending on the user profile and preferences.

8.1 Contributions of this research

The major contribution of this thesis is to provide a conceptual model for Semantic description of distributed Learning Services. We have designed, developed and applied such model through two different use cases of learning scenarios. This model represents an alternative for semantic description of service properties, parameters and connections, which facilitates in automatic discovery and invocation of services without human interaction and enough information for human search. In the proposed model, Learning Services are described as a process, which allows services to be invoked as an atomic, simple or composed process. The proposed model also supports a set of characteristics included in the syntactic description. We used the IMS abstract framework layer model to structure a semantic schema which defines distributed resources and services available in a VLE. This schema is used, on the one hand, to compare inputs and outputs and discover related learning services and, on the other hand, to realize a match process based on a structural matching approach and a taxonomy matcher. We implemented our conceptual model in two learning scenarios with semantic capabilities that will allow the design of ubiquitous and pervasive learning. These scenarios foment the interaction among the users and will allow developing collaborative and personalized learning activities. The results of these studies have been reported in the works in the list of the published papers section.

8.2 Review of the main contributions of our research

In that sense the doctoral thesis reported in this paper presents a models that take advantage of the semantic capabilities of Learning Services. We can highlight the main contributions of this work, comparing it with works presented in section 2, as follows:

- We proposed a semantic description model of service properties, parameters and connections, which permits services to be invoked like an atomic, simple or composed process.
- This model allows locating for learning services of distributed network through semantic description, especially those based on grid computing and cloud computing, allowing a complete semantic description based on functional and non-functional properties of Web services, setting aside the traditional technologies of syntactic search methods.
- The semantic model will allow the design of ubiquitous and pervasive learning scenarios that will foment the interaction among the users and will allow developing collaborative and personalized learning activities.

8.3 Implications of our findings

From the experiments and use cases studied, we found the following benefits regarding research issues raised in Chapter 3:

- We have showed the benefits that users can obtain from exploiting the integration capabilities between an LMS and Cloud services by means of a semantic model.
- In the case of teaching portals for online laboratories, the system featured on the one hand has showed high usability since it provided easy access to the components of the laboratory, improving the sharing of devices and instruments. On the other hand, it facilitated students' collaboration as well as customization in the search of devices and instruments, thus improving the cognitive load-satisfaction relationship.
- We have showed how an LMS that integrates with Cloud Services, built out of a semantic description method, has a direct positive impact on students' cognitive load by reducing it and thus increasing students' satisfaction levels. We highlighted how this system shows better usability than one in which tools are used independently.

8.4 Limitations of our research

With regard to the impact that the semantic web for the development of distributed learning environments can have, it is such a broad topic and the scope of this work while important, is limited to the stage where we have focused and there is still much future work that remains to be performed. Still pending many additional features in which a semantic model can impact, both the teaching process and the students' learning performance. It has been necessary to test the model under other scenarios and test them under other conditions, such as making comparisons between syntactic accesses to services against semantic. Similarly, our assessment has focused on the perception of usability and student satisfaction, leaving other variables that may impact both, learning systems and students.

8.5 Future work

Future work is now centered on other important issues that include technical aspects related to the incorporation of new functionalities based on distributed services and the semantic composition of new services from existing ones, as well as methodological aspects that explore new approaches of instructional design to further enhance collaborative and personalized learning. In the same vein, future work is on the way to extend our approach by integrating more learning tools with functionalities that are available in distributed systems, applied in different learning scenarios, with the ultimate aim to provide a comparative study of all the possible benefits, advantages as well as possible limitations.

8.6 List of published papers associated with the thesis

Below is a detailed list of publications for each of research issues outlined in Chapter 3:

8.6.1 Design of semantic models for defining learning services

a. Gutiérrez-Carreón, G., Daradoumis, T., & Jorba, J. (2006, January). Semantic description of grid based learning services. In Frontiers of High Performance Computing and Networking–ISPA 2006 Workshops (pp. 509-518). Springer Berlin Heidelberg.

b. Gutiérrez-Carreón, G., Daradoumis, T., & Jorba, J. (2008). Semantic Description and Matchmaking of Learning Grid Services. The Learning Grid Handbook: Concepts, Technologies and Applications, 2, 39.

8.6.2 Design of integration and composition models for learning services based on semantic modeling

a. Gutiérrez-Carreón, G., Daradoumis, T., & Jorba, J. (2007, January). A conceptual model for grid learning services automatic composition. In On the Move to Meaningful Internet Systems 2007: OTM 2007 Workshops (pp. 40-41). Springer Berlin Heidelberg.

b. Gutiérrez-Carreón, G., Daradoumis, T., & Jorba, J. (2007). Exploring semantic description and matching technologies for enhancing the automatic composition of grid based learning services. In 5th International Workshop on Ontologies and Semantic Web for E-Learning (SWEL'07@ AIED'07) (pp. 36-43).

c. Gutiérrez-Carreón, G., Daradoumis, T., & Jorba, J. (2008, March). Toward a semantic approach for automatic composition of Learning Grid Services. In Complex, Intelligent and Software Intensive Systems, 2008. CISIS 2008. International Conference on (pp. 940-945). IEEE.

d. Gutierrez-Carreon, G., Daradoumis, T., & Jorba, J. (2009). Automatic composition of Learning Grid Portlets: a comparison of syntactic and semantic approaches. International Journal of Grid and Utility Computing, 1(4), 308-315

e. Gutiérrez-Carreón, G., Daradoumis, T., & Jorba, J. (2015). Integrating Learning Services in the Cloud: An Approach that Benefits Both Systems and Learning. Journal of Educational Technology & Society, 18(1), 145-157.

8.6.3 Implementation of customization schemes of learning tools based on semantic modeling.

a. Gutiérrez-Carreón, G., Daradoumis, T., & Jorba, J. (2008). "Learning grid: herramientas de aprendizaje basadas en tecnología grid y web semántica. ". En: Congreso Nacional de Ingeniería y Arquitectura 08 (IA08). 2008. Morelia, Michoacán, México, 27 noviembre. ISBN:978-968-9322-40-5, Pag. 213-220

b. Gutiérrez-Carreón, G., & Jorba, J. (2009). A Semantic Description Model for the Development and Evaluation of Grid-Based, Innovative, Ubiquous and Pervasive Collaborative Learning Scenarios. In Intelligent Collaborative e-Learning Systems and Applications (pp. 171-187). Springer Berlin Heidelberg.

c. Gutiérrez-Carreón, G., Daradoumis, T., Jorba Esteve, J., & Peña-Gomar, M.C. (2009). An infrastructure for educational virtual laboratories based on Semantic Web and Grid Computing. Proceedings of the WebSci'09: Society On-Line, 18-20 March 2009, Athens, Greece.

d. Gutiérrez-Carreón, G. Daradoumis, T., , Jorba Esteve, J. & Peña-Gomar, M.C. (Pending). Supporting online teaching laboratories through semantic services. Multimedia Tools and Applications.

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