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SUPPORTING COMPETENCE DEVELOPMENT PROCESSES ON OPEN LEARNING SYSTEMS THROUGH PERSONALIZATION

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El Dr. Ramon Fabregat Gesa, Titular de Universitat del Departament d'Arquitectura i Tecnologies de Computadors de la Universitat de Girona,

CERTIFICA

Que aquest treball, titulat "Supporting Competence Development Processes on Open Learning Systems through Personalization", que presenta Silvia Margarita Baldiris Navarro per a l'obtenció del títol de doctor, ha estat realizat sota la meva direcció i que compleix els requeriments neccesaris.

Ramon Fabregat Gesa

Girona, 25 de juliol de 2012

Contents

Abstract

As in most economies, the learning objects economy is a science that studies the different actors involved in the dynamics of creating "markets" in which learning objects are produced, published, exchanged and/or reused. There are many motivations for stimulating the development of the LO economy. Probably, the main reason is the possibility to provide the right content, at the right time, to the right learner, according to adequate quality standards in the context of a life-long learning process. However, some barriers for the development of LO economy, such as the granularity and editability of the LO, must be overcome. Furthermore, some enablers, such as Learning Design Generation and Standards Usage must be promoted in order to enhance LO economy which facilitate the exchange of complex learning objects.

This thesis aim for promoting the learning objects economy by offering teacher the possibility of generating adaptive and standardized learning designs using learning objects located over distributed learning objects repositories.

The adaptation of the generated learning design considers two of the most relevant users characteristic: *their competences and their learning styles*. Competence levels are modelled using the categorization defined by the reviewed Bloom taxonomy and a dynamic user modelling process is defined in order to infer the user learning style over the time. This dynamic modelling process uses the historical evidences of the users behaviour in the learning management system. The challenge of modeling dynamically the user required the use of automatic learning techniques and also a novel statistical treatment of the data from the user interaction.

Standardized and Adaptive Learning Design Generation Process, *Designer*, was implemented using HTN planning. Generation process considers a few inputs from the teachers, in particular, those related with the standardized competence definition, the learning objects metadata which will be used in the learning design as well as the data from the initial student model used with adaptation porpuses. The main problem addressed in the generation process is the consideration of the user modelling process in both, at the design time and at the execution time.

In order to promote the reuse of learning objects, the learning designs generation process was enriched through the design of two processes, *the learning objects searching and positioning processes*. These processes permit to look for learning objects in distributed learning objects repositories and to place these retrieved objects in the context of a generated learning design. This is an special issue a little addressed in the state of the art. In this manner, LOOK and LORSE processes are introduced as a mechanism to locate into the generated learning design distributed learning objects according to their relevance with respect to the identified competence micro-contexts.

Due to the complexity of the solutions proposed in this dissertation, it was necessary to define a layered evaluation process that would validate the developed solutions. Thus, the most important dimensions of an Adaptive Hypermedia System were assessed through three layers obtaining promising results in each of the layers considered.

Resumen

Como la mayoría de las economías, la economía de objetos de aprendizaje es una ciencia que estudia los diferentes agentes participantes en la dinámica de creación de "mercados" en los que se producen, publican, intercambian y/o reutilizan objetos de aprendizaje. Existen diferentes motivaciones para estimular el desarrollo de la economía de objetos de aprendizaje. Probablemente la principal razón es la posibilidad de proveer el contenido adecuado, en el tiempo justo, al estudiante adecuado, de acuerdo con estándares de calidad idóneos, todo ello enmarcado en el contexto de un proceso de aprendizaje continuo. De hecho, este es el principal objetivo de la educación. Sin embargo, existen algunas barreras en el desarrollo de la economía de objetos de aprendizaje que deben ser superadas, destacando aquellas asociadas a la granularidad y la editabilidad de los objetos de aprendizaje. Así mismo, algunos facilitadores deben promoverse con el fin de mejorar las dinámicas en la economía de objetos de aprendizaje, entre ellos la generación semi-automatica de diseños de aprendizaje y el uso de estándares tecnológicos que faciliten el intercambio de objetos de aprendizaje complejos.

El principal objetivo de esta tesis es promover la *economía de objetos de aprendizaje* ofreciendo al profesor la posibilidad de generar semi-automaticamente diseños de aprendizaje adaptativos y estandarizados que se alimenten de los objetos de aprendizaje almacenados en repositorios de objetos de aprendizaje distribuidos.

La adaptación de los diseños de aprendizaje generados considera dos de las características de usuario más relevantes: *sus competencias y su estilo de aprendizaje*. Los niveles de competencia son modelados utilizando la categorización definida en la taxonomía revisada de Benjamín Bloom y el estilo de aprendizaje es inferido a través de un proceso de modelado dinámico del usuario basado en evidencias historicas del comportamiento del usuario en el ambiente de aprendizaje. El reto de modelar dinámicamente el usuario requirió de la utilización de técnicas de aprendizaje y tratamientos estadísticos novedosos de las evidencias de interacción del usuario.

El proceso de generación de diseños de aprendizaje adaptativos y estandarizados fue implementado utilizando planificación HTN. El proceso de generación recibe como entrada solo algunos datos que provienen del profesor, en particular, los relacionados con la definición de las competencias estandarizadas, los metadatos de los objetos de aprendizaje que serán utilizados en el diseño y datos provenientes del modelo inicial del estudiante que son usados con fines de adaptación. El principal problema novedoso abordado en el proceso de generación es la consideración tanto en tiempo de diseño como de ejecución de los resultados del proceso de modelado dinámico del usuario.

Con el propósito de favorecer la reutilización de objetos de aprendizaje, el proceso de generación de diseños de aprendizaje es enriquecido a través de la definición de los procesos de procesos de busqueda y posicionamiento de objetos de aprendizaje en el contexto de un diseño de aprendizaje generado, lo cual es un asunto poco abordado en el estado del arte. De esta manera los procesos LOOK y LORSE se diseñan como mecanismos para recuperar y posicionar los objetos de aprendizaje distribuidos de acuerdo con su nivel de relevancia con respecto al micro-contexto de una definición de competencia provista por el profesor.

Debido a la complejidad de las soluciones propuestas en esta disertación fue necesario el planteamiento de un proceso de evaluación por capas que permitiera realizar la validación integral de las propuestas desarrolladas. De esta manera, las dimensiones más importantes de un sistema hipermedia adaptativo fueron evaluadas considerando tres capas, obteniendo resultados prometedores en cada una de las capas consideradas.

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List of Tables

List of Figures

List of Acronyms

ACRONYMS	DESCRIPTION
ICT	Information and Comunication Technologies
VLE	Virtual Learning Environments
LMS	Learning Management System
LO	Learning object
LOE	Learning object economy
LORSE	Distributed Learning Objects Metadata Searching Process
LOOK	Micro-Context based Location Process
IMS-LD	IMS Learning Design
IMS-LIP	IMS Learner Information Profile
IMS-QTI	IMS Question and Test Interoperability
IMS-RDCEO	IMS Reusable Definition of Competence and Educational Objectives
IMS-MD	IMS Metadata
dotLRN	E-learning Platform used for testing scenarios
LS	Learning Style
HTN	Hierarchical Task Network
UoL	Unit of Learning

Part I

Contextualization

1. INTRODUCTION

The purpose of this section is to present the motivation for our research work, identify the main objectiv and provide an overview of the document structure.

1.1. MOTIVATION

Every day, new instructional design theories, as well as learning objects (LO) and services are produced. This increase is the result of a great quantity of research projects for creating guidelines and artefacts to help people learn in a better way. In particular, many approaches are oriented towards supporting the learning and teaching processes in virtual learning environments (VLE).

However, managing technologies in the virtual instructional design process is not a trivial task, the availability of an increasing and sometimes unmanageable level of information and techniques could be, precisely, a main problem for their adoption, which depends on the designer computing skills.

Our goal is to support the competence development process in VLE, which is an elusive and time-consuming task for the instructional designer. In this process, many observable and unobservable variables, which come from internal and external sources such as institutional guidelines, students and teachers' characteristics, technological environment features and the availability of different kind of reusable and distributed related resources available on the Web must be considered.

A well-accepted definition for an instructional design process is the following: the process that should be followed by teachers in order to plan and to prepare the instruction [1].This process is focused on how to teach and address, in an integral way, people's needs, such as cognitive, emotional, social, and physical.

Many different instructional design theories offer guides for teachers to help them to orchestrate the available resources and activities into an instructional design, which is a medium to facilitate the achievement of educational purposes.

The automatic instructional design deals with the idea of supporting teachers in the difficult task of generating virtual learning scenarios; this process could be developed in three different manners: 1) manually, where teachers develop the design completely, 2) semi-automatically, with only a few inputs from the teachers or 3) automatically, without teacher's intervention. Nowadays, automatic and semi-automatic learning design generation is an important topic in the research areas of adaptive learning systems, as well as, technology enhanced learning, in general.

Brusilovsky and Vassileva [2] define two different processes to obtain a suitable course. In the *Adaptive Courseware Generation,* the goal is to generate a static course adapted to the user needs at one specific point of time, considering specific learning goals, as well as the initial level of the student's knowledge. On the other hand, in *Dynamic Courseware Generation,* the system observes the student progress during his/her interaction with the course and dynamically adapts the course according to the specific student's needs and requirements. If the student's performance does not meet the expectations, the course is dynamically re-planned.

Our intention, based on our literature review, is addressing some open research issues for Dynamic Courseware generation which is also well known as *Learning Design Generation*. Related open research issues are described in the following paragraphs, emphasizing in our plans for contributing to the solutions of these open issues.

In the state of the art, some researchers ensure that the dynamic learning style modelling process is an interesting issue to investigate, in particular because there is scientific evidence that demonstrates the correlation between learning style and students preferences for learning objects and services [3], [4]. Existing proposals for Learning Design Generation which use explicitly data about the user learning style. The learning style is frequently inferred through a static user modelling process. In many cases, this user preference is not updated because a dynamic process of learning style modelling has not been considered in the learning design generation process. How this dynamic process affects the generated designs at the design and execution time is not specified in researches on learning design generation.

To address this issue, defining what elements in a learning design are related with the users' learning style preferences, how these elements should be modelled and how these elements should be affected in both the moment of the learning design generation process and the execution time is a must.

To the best of our knowledge, the currently proposed planning approaches for learning design generation are not conditional, i.e. not conditional planning algorithms are used to generate a suitable plan. We do not intend to develop a conditional planning process, our intention is to generate a conditional learning designs mixing planning and technological standards.

However, the big effort developed by International Organization of Standardizations [5] has not been considered in the teachers' normal activities. Many teachers do not know the specifications and standards, and have never considered using them in the learning process only because they never heard about them. Therefore, when teachers are faced to use the standards, they consider them as difficult to use. Those are the most important challenges due to which teachers do not use important standards such as the IMS learning design (IMS-LD) [6].

According to our research, when teachers use the IMS-LD standard in practice, they value positively the quality of the standard in its expressivity. For a teacher, translating the concepts associated to the specification (play metaphor) into a particular learning design is an easy task. However, there are some problems with the IMS-LD adoption that could be classified into two major categories: technical and pedagogical.

From a pedagogical point of view, the lack of formation regarding the decision process related with the learning design process, and the temporal pressure to "conclude the academic program", imply that teachers' performance is generally the result of combination of intuition and routines, more than the result of a combination of theoretical and practical knowledge, which is applied in the learning design rgeneration process [7]. In other words, in many cases, teachers do not have enough knowledge and comprehension to construct units of learning. If they do not understand the process of constructing units of learning according to different learning design theories, then constructing adequate standardized or not standardized units of learning for their students would be impossible for them.

From a technical point of view, problems arise when teachers need to implement the design in an authoring tool and to execute the design in a specific learning environment player. On one hand, authoring tools are not user-friendly in many aspects, e.g. they do not guarantee a successful importation of the IMS-LD package in the learning environment, or that they frequently generate designs with syntax errors which cannot be solved by teachers without experience in using these technologies. In this manner, the teachers experience is blocked. On the other hand, there are not many players or IMS-LD execution environments in order to compare or select among them. The existing IMS-LD execution environments do not cover the details of the specification, and when the user finally has a compiled LD, some errors might occur. In conclusion, generating standardized learning designs is a very good idea; however, executing an IMS Unit of Learning in the preferred learning management system (LMS) is a difficult task.

The problems associated to an adapted learning design generation are accentuated as the complexity in the learning design increases. The creation of adaptive learning designs implies the definition and control of user variables which represent different user features. Monitoring these variables at the design and execution time is a difficult task for teachers [8].

In this context and just to provide the right content, to just the right learner, at just the right time, in the context of a long-life learning process, according with adequate quality standards, solutions oriented to stimulate the global tendency for a *Learning Object Economy* become an important issue. The reuse seen as an opportunity to alleviate the workload for teachers considering previous efforts developed by other teachers such as learning objects creation and activities specifications in the learning design generation process are definitely important.

Promising solutions are those directed to ensure that the necessity for a *Learning Object Economy* becomes a reality, those favoring overcoming of some barriers in the learning object economy as well as those that promote some enablers such as

Learning Design generation and *Standards promotion* [9] specially considering the learning process characteristics and the actors involved in the learning process among them teachers and students.

In particular for solutions focused on teachers some special conditions of this kind of actors should considered, because frecuently teachers don't have the time for developing extra tasks as learning object creation and they often don't have the enough knowledge about technologies for developing these tasks. Whereby, solutions for teachers need to receive only a few set of input from these actors and facilitate them the interaction as soon as possible.

In this dissertation, our contribution aims to alleviate the workload for teachers on creating adaptive courses by reducing the complexity involved in authoring standardized and adaptive learning designs adjusted to their students' characteristics which are inferred through a dynamic user modelling approach favoring the main enablers for a *Learning Object Economy.*

1.2. OBJECTIVE

The objective of this thesis is to contribute in alleviating the workload for teachers on creating adaptive courses by reducing the complexity involved in authoring standardized and adaptive learning designs adjusted to their students' characteristics, in particular, learning style and competences levels.

1.3. OUTLINE OF THE THESIS

This dissertation is organized in three parts, including this one, and additionally the bibliography and appendices. Each part consists of several chapters.

The first part consists of two chapters: the introduction and the state of the art. The introduction describes the motivation of this study. The state of the art presents a rigorous study of related works as well as the open issues identified from that study. First part of this dissertation is relevant because it contextualizes our work into recognized research lines.

The second part consists of four chapters. Chapter 3 specifies integraly our framework for learning design generation as well as each of its constituent elements including the evaluation description. Chapter 4 describes in detail our dynamic user modelling process. Chapter 5 introduces our learning design generation process providing a full description of the techniques used to implement and to validate the process. Finally, Chapter 6 details the contextualized learning objects searching and positioning processes highlighting the obtained results. The second part of this dissertation is relevant because presents in an integral way our solution and its evaluation.

Finally, in the third part, the conclusions and the remarked future work are introduced. The third part of this dissertation is relevant because it offers a general view of the results of our study.

There are also three appendices: the Appendix A contains the author's list of publications, Appendix B the author's list of oriented projects and the Appendix C describes the surveys used in the evaluation.

2. STATE OF THE ART

As mentioned before, the contribution of this dissertation is to relieve the teachers' workload by reducing the complexity and the difficulty of creating adaptive courses.

In this chapter, the state of the art of the following research areas, which are related to this work, is presented.

The state of the art chapter is structured as follows. In section 2.1, the analisys of the state of the art about the user modelling process is introduced. Section 2.2 describes the most relevants contributions in the semi-automatic learning design generation process. In section 2.3 the most important concepts related to learning objects economy are presented. Finally some conclusions are introduced. Each section in the state of the art ends with the presentation of the most important contributions of this dissertation in each related research line.

2.1. USER MODELLING PROCESS

2.1.1 Generalities about the user and context modelling

Information and communication technologies have been adopted in the learning process via the design and development of LMS with the aim to remove some of the barriers featured in traditional face to face settings (e.g. geographic and temporal) and to add potential advantages, such as the possibility of better addressing the individual user's needs in a personalized and inclusive way. However, personalized learning process requires that the user's needs could be identified in a virtual learning environment basically through two special modelling processes, *the user modelling process* and *the context modelling process*.

The user modelling process defines and maintains up-to-date user models [10]. Different categorizations exist for user models types. Brusilovsky and Millan in [10] define two types, *feature-based models* and *stereotype models*. The first one considers changeable users features with the main goal of tracking and representing an up-to-date state for modeled features. The second type defines groups of users that share specifics characteristics. Bull et al [11] define the models as *inspectable, editable or negotiable* according to the capacity of the user to modify them. According to the capacity to represent [12] user models, they could be classified in *Raw data models, Visual models and Decision support models*. A raw data model is a direct view of the internal data representation, a visual model converts the internal representation to a graphical conceptualization, and a decision support model can be defined as a visual representation that allows the user to make pedagogical decisions in the learning process. Figure 1 shows an outline of the most relevant elements to be considered in a user modelling process. In particular, *C1 User Model Types categorization* presents an outline of the most important user models types.

User modelling approaches also have several categorizations. Graf et al [13] classify the user modelling techniques as *dynamic and static* according to the data updating process. In a dynamic user modelling approach we can assume that at a certain point of time (t), a certain amount of data about users' behaviour is available for inferring the model and that additional data are frequently added once a student is using the system for learning; on the other hand, the static user modelling detects the student model in a specific time (t) and only there. Brusilovsky and Millan in [10] introduce *Test based user model, Overlay model and Uncertainty-Based User Modelling*. Test models permit to construct static user models based in validated psychometrics studies. The purpose of the overlay model is to represent an individual user's feature as a subset of the domain model and, for its part, Uncertainty-Based User Modelling use different forms of uncertainty to manage the user model. Baker in [14] classify user modelling approaches as *Super fidelity, High fidelity and Low fidelity* according to the success probability to infer a model with an adequate precision. In Figure 1, in particular, C2. User Modelling Approaches categorization presents an outline of the most important user model types.

User modelling process takes place through the development of different sub modelling processes: *qualitative modelling, quantitative modelling and the evaluation modelling*. Qualitative modelling identifies the features to be modelled and their characterization. Quantitative modelling permits to define how these features could be modelled using a determined scale. On the other hand, the evaluation verifies the validity of the model. Figure 1 shows an outline of the different Stages of Modeling Process.

According to [15], the context could be defined as any information that can be used to characterize the situation of an entity, in our case the user. The possibility to define the context modelling approaches amplifing the possibilities to offer best learning solutions for the users according with the different possibilities of access. Figure 1 presents only some of the context features considered in the state of the art.

In Figure 1, we summarize the main elements of the user and context modelling processes, which were mentioned in previous paragraphs.

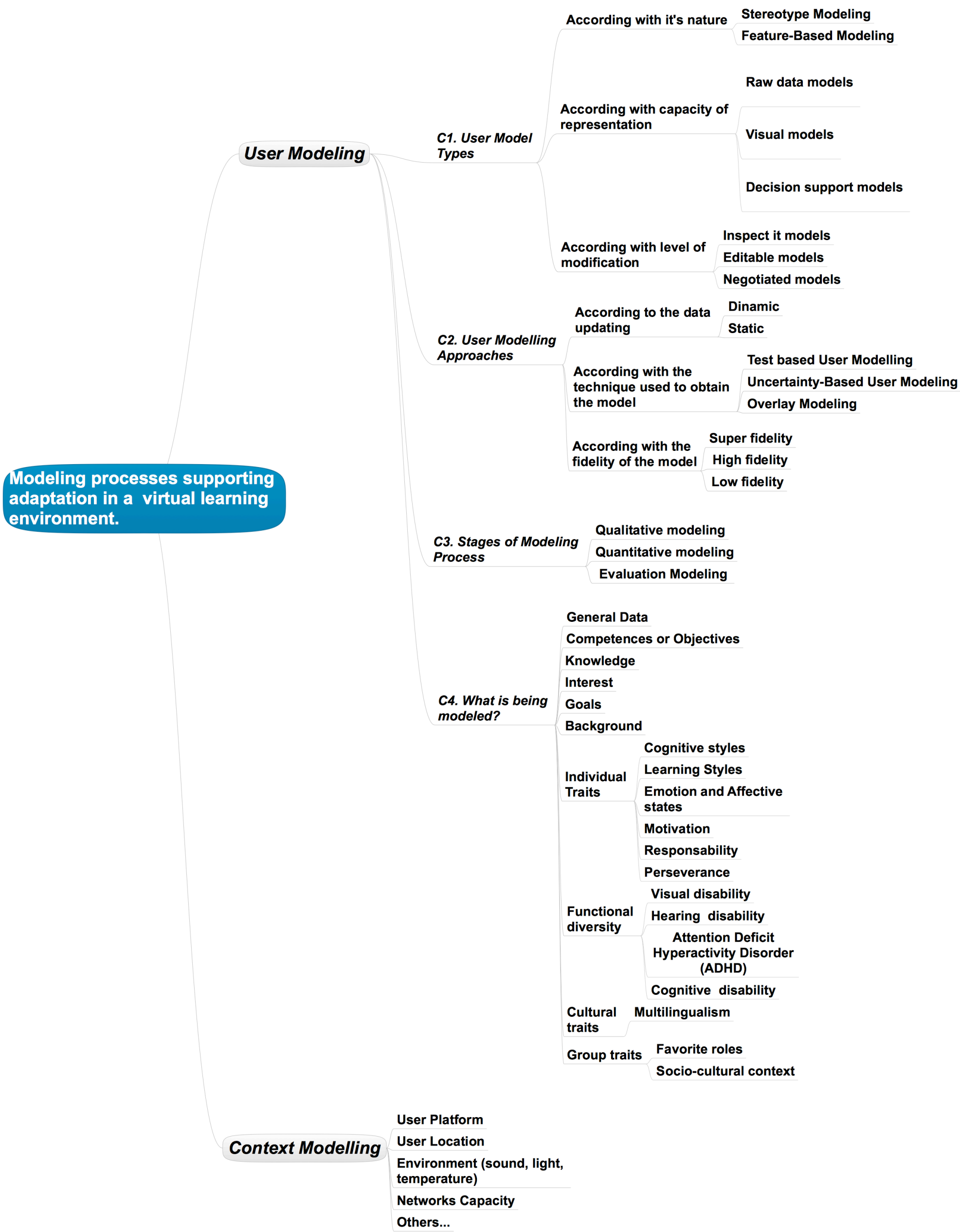


Figure 1. Outline of main elements in user and context modelling process.

2.1.2 User modelling process based on learning styles

Learning style is one of the most common user features used to support adaptation processes in adaptive hypermedia systems. Researches in this area could be divided in the following topics:

- Definition of new learning styles theories and evaluation tools.
- Design of static user modelling approaches based on the result of the application of a particular theory test to users.
- Design of dynamic user modelling approaches based on the users interaction.

In the following sections, we introduce some of the most important approaches in each kind of research in the user modelling process based on learning styles in recent years. We developed a short description about learning styles theories evolution and then we focused the discussions on the static and dynamic user modelling process beginnings for our previous work in the BCDS group.

2.1.2.1 Outline of learning style theories

Learning style characterize the cognitive, affective and physiological traits which serve as relatively stable indicators about how learners perceive, interact and respond in their learning environments [16].

Through the years, different learning style theories have been proposed and validated. Table 1 shows a categorization provided by Curry in [17], in an attempt to offer a framework for the growing number of learning style theories named Onion Model. The Onion Model categorizes the learning style theories in four layers: 1) Personality Dimensions; 2) Information Processing; 3) Social interaction and 4) Instruccional Preferences.

Table 1. Classification of learning style theories according to the Onion Model [17]

LAYER	THEORY AUTHOR	TOOL
Personality Dimensions	Kagan	Matching Familiar Figures Test
	Katz and Henry	Omnipubus Personality Inventory
	Myers-Briggs	Type Indicator
	Keirsey	Temperaments and Characteristics
	Witkin	Embedded Figures Test
Information Procesing	Biggs	Study Process Questionnaire
	Entwhistle and Ramsden	Approaches to Studying
	Felder	Learning Styles Inventory
	Gardner	
	Gregoric Mind Styles	
	Hunt	Paragraph Completion Method
	Kolb	model of Experiential Learning
	Pask	
	Schmeck, Ribich, & Ramanaih	Inventory of Learning Process
	Schroeder	Paragraph Completion Test
Social interaction	Grasha and Reichmann	Student Learning Interest Scales
	Mann	
	Perry	
	Belenky	Women's Ways of Knowing
	Magolda	
Instruccional Preferences	Canfield	Learning Styles Inventory
	Dunn and Dunn	Learning Style Inventory
	Friedman and Stritter	Instructional Preference Questionnaire
	Goldberg	Oregon Instructional Preference Inventory
	Hill	Cognitive Style Interest Scales
	Renzulli and Smith	Learning Style Inventory
	Rezler and Rezmovic	Learning Preference Inventory

Let us highlight the most recently and interesting work that was conceived specifically as a mechanism to use in the adaptation process upon learning platforms, Unified Learning Style Model [18] [19].

Unified Learning Style Model - ULSM [18] [19] offers a basis for an integrative learning style model. By gathering characteristics from the main proposed models in the literature, the ULSM defines the following dimensions of learning style:

- *Perception modality* (Visual preference / Verbal Preferences)
- *Processing information* (Abstract concepts and generalizations / Concrete, Serial / Holistic; Active experimentation / Reflective observation; Careful with details / Not careful with details)
- *Social aspects* (individual work / Team work; competitive / collaborative; introvert / extravert; dependent / independent)
- *Reasoning (*inductive /deductive)
- *Organizing information* (synthetic / analytic)
- *Motivation* (intrinsic vs extrinsic; deep vs strategic vs surface vs resistant)
- *Persistence* (persistent / not-persistent)
- Coordinating instance (affectivity / thinking)

Dimensions of this ULSM learning style theory could be mapped to all dimensions of the Felder's Learning Style Theory which will be explain in more detail in chapter 3.3.

2.1.2.2 Static and dynamic user modelling based on learning style

Next paragrahps present the most relevant contributions in the user modelling process from the state of the art begins for our previous work in the BCDS group. Table 2 shows an outline of the different analized approaches from the state of the art.

BCDS group contribution to user modelling based on learning style

The BCDS group has been involved in some projects that support the current research efforts, whose outcomes are presented in the next paragraphs. We describe the projects: Shaboo [20] and [21], MAS-PLANG [22] which show how user modelling process and adaptation based on learning style were addressed.

Shaboo

Shaboo [20] and [21] is an Adaptive Hypermedia System used to support teaching/learning process on basic concepts of the Objects-Oriented Programming (OOP). Shaboo addresses Felder's user learning style by offering users the learning objects ordered in different ways according to the 'input' Felder Dimension. This means that the order of the delivered contents depends on whether the student has a visual or verbal preference.

Moreover, the user knowledge is inferred by monitoring the objective that the user has achieved. In this way, there are evaluation questions to assess each learning objective. The objectives are classified according to the Bloom Taxonomy [23]. The students' knowledge level controls the navigation space. Students can only study in a specific session learning objects appropriate for their current knowledge levels.

The results of the validation stage showed the improvement of learning results in some tests of the OOP course. In particular, teachers and students considered the use of different types of learning objects as a good didactic strategy to use in the class and to support in homework or extra classes. In more detail, the validation tests showed that the student learning results -measured in percentage- were superior to 80% in each related concept of the course. According to the teachers' opinion, the improvement in the results compared to previous courses was not only quantitative but also qualitative [21].

Shaboo does not implement a dynamic user modelling approach to model the user learning style, but uses Felder's learning style static approach to infer the student learning style. However, Shaboo implements a dynamic and not standardized based evaluation mechanism to define the level of the student according to the defined objectives.

Mas-PlanG

MAS-PLANG is a multi–agent system implemented for improving the adaptive characteristics in the USD platform [22]. Main purpose of USD platform is to deliver didactic content and strategies considering the students' learning styles. USD is an adaptive system where teachers can create and maintain navigable teaching units. Moreover, the students have the possibility to configure the learning environment in aspects such as the form and position of the icons, windows positions, navigations bars and language, among others. MAS-PLANG was implemented by using a two level architecture (information agents and support agents) to help the students through their interaction with the didactic material, while the information agents are in charge of maintaining the student model and evaluating the pedagogical rules in the course.

User modelling based on learning styles in MAS-PLANG is achieved by using HabitatPro [24], which is supported by some artificial intelligence techniques as case-based reasoning and diffuse logic. Felder and Silverman learning style model specifies different student categories according to their skills for processing, perceiving, organizing and assimilating the information.

Contribution to user modelling based on learning style from external sources

The following paragraphs describe the most important approaches in the state of the art about user modelling based on learning style.

Popescu in [25] identifies a significant relation among learning styles according to the Unified Learning Style Model - ULSM and 30 users behaviour patterns upon a learning management system. The user model is basically obtained by the application of a particular instrument for ULSM. The inferred user model support a recommendation mechanism for delivering the most suited learning objects and learning path according to the user learning style [26]. The proposal applies two techniques: 1) the ordering of the LO and 2) the traffic light metaphor. The mechanism was integrated upon WELSA platform where a green colour indicates recommended LO, a black colour the standard LO, and a light grey a not recommended LO. The reported results suggest a high level of satisfaction of the user with the adaptation process. Furthermore, the orders proposed by the system were generally accepted by the students.

Ortigosa in [27] defines a classification task in order to minimize the number of necessary questions to define the learning style according to the Felder's index of learning style. This research argues that a big number of questions were needed to be answered by the users in the test. The results suggested that an average of 5 questions for each Felder dimension were enough for defining the user learning style using this approach.

Paredes in [28] proposed a mixed adaptation mechanism based on perception and processing Felder's dimensions over TANGOW [29]. Knowledge in TANGOW is represented by Teaching Task Rules. According to the tendency of user processing dimension (Sequential and Global), the sequencing of the course structure is modified. Sequential users receive the course structure in a particular order while global users in any order using different operators for this purpose (AND OR ANY). For the perception dimension, two different kinds of instruction, exposition and exemplification, are considered. Preference of sensitive users for the exemplification is assumed.

Martin in [30] proposed an adaptation mechanism for collaborative learning tasks considering the entry, perception and processing Felder's dimensions over TANGOW [29]. The entry dimension permits to adapt the workspace according to the learning style of the group; processing dimension address the group formation and perception dimension defines the presence or absence of collaborative learning activities. Results reported in [31] do not indicate statistically significant correlations of addressing learning styles when students are working together. This shows that some groups of students working better than others. Study shows that performance increases when the students are distributed in heterogeneous groups and it doesn't show a decision pattern about the group selection according to the learning style.

Carmona in [32], [33], [34] and [35] defines a Bayesian network in order to update the user learning styles through monitoring the interactions in the adaptive system. For each dimension of the Felder's learning style, a Bayesian network is created. The defined variables are the user learning styles, learning objects features and a classification of learning objects provided by the students. A network relates learning styles with the learning objects features and with the user rating, assuming that variables are indicators of changes in the users' learning style. The decision process is modelled as a Bayesian Classifier for developing a recommendation task, which defines if a learning object is appropriate or not for a particular user. Input data for different classifiers are the user features, learning object features and a class defined by an expert. The update of class attributes implicate, necessarily, that the students rate the learning objects.

Garcia in [36] implements a Bayesian Network (BN) with the purpose of detecting learning styles. He uses the user recorded interaction in the learning management system to determine the conditional parameters of the BN in combination with experts' opinions. Consequently, the Bayesian model is continuously updated as new information about the student's interaction with the system is obtained until eventually, the model reaches equilibrium. Network variables correspond with the Felder learning style itself, the dimensions of user learning style (perception, processing and understanding) and different factors that are analysed in the student's behaviour for addressing each particular dimension of Felder. Results suggest that the proposed mechanism determines the perception style with high precision, finding some mismatches in the understanding and processing dimensions. They show forums and chats as good tools to identify active learners and big courses as the adequate contexts to detect sequential and global learners.

Graf in [37] and [3] establish significant relations between user behaviours and the dimensions of Felder learning styles through some experiences upon Moodle. Inferred relations are inputs to an approach for detecting learning styles in learning management systems [38] [37].The proposed architecture consists of a data extraction component that receives as an input the patterns corresponding to different user features. The teacher can define the location of the required information through an editor. With this information, raw data are generated for the extractor using the stored information in the system database. Raw data are input for the calculation component charged to define the user learning style. On the other hand, Graf in [39] proposes a model to define learning style based in the sum of hits corresponding to the observed behaviour of an user in the learning management system. Hits are related to patterns and dimensions of Felder learning styles. Precision of the approach is obtained based on the similitude measured among the learning style inferred and the results of the ILS questionnaire. Reported results show a range from 73.33 to 79.33 of similitude for each Felder dimension. Finally, in [13] Graf proposes that monitoring is necessary if the learning style model changes over the time. Three steps for developing the update are defined: first, the calculation of the learning styles dynamically over time, second, the deviation of the students learning style and third, the decision about if the learning style has changed.

Derntl in [40] Analyses the relationship between the student blogging behaviour and its learning style. Results suggest that the learning style that affects the most on blogging behaviour was found for the active/reflective dimension. A significant effect was found for the sequential/global dimension; sequential learners tend to write longer posts than global learners. Another conclusion is that active learners prefer to write blogs while reflective prefer to read other them.

Table 2 shows a summary of the main approaches developed in last few years that are related with our proposed work.

Table 2. Summary related work about user modelling based on learning style

PROJECT	SYSTEMS	LEARNING STYLES THEORY	DYNAMIC USER MODELLING MECHANISM	USER MODELLING SCORE	ADAPTATION CONSTITUENT
Moreno [20], [21]	SHABOO	Felder	Not	ILS Results	Learning Resource Ordering according Entry dimension
Peña [22]	MAS PLANG	Felder	Not	Result or Felder's ILS	Deliver the most adequate activities throught Case-Based Reasoning inference
Popescu [4], [18], [19], [25], [26], [31]	WELSA	ULSM- Unified Learning Style Model	Not	User model according to ULSM- Unified Learning Style Model	Learning Objects and path Recommendations using traffic light metaphor
Ortigosa [27]	Not reported	Felder	Classification Task C4.5 Algorithms	Felder user model Modified	not reported
Paredes [28], [41]	TANGOW	Felder	Not	ILS Results	Curriculum sequencing
Martín and Alfonseca [30], [31]	TANGOW	Felder	Not	ILS Results	Collaborative Learning takes adaptation through Rules defined by teacher
Carmona and Castillo [32–35]	GIAS's System	Felder	Bayesian Network	Felder user model Modified	Learning Objects Recommendations through Bayesian Classifier
Garcia [36]	Not reported	Felder	Bayesian Network	Felder user model Modified	not reported
Graf [3], [13], [37–39], [42–44]	MOODLE	Felder	Patterns identification	Felder user model based on user behaviour	not reported

2.1.3 Our contribution to user modelling base on learning style

In the context of virtual learning environments, finding proposals addressing both problems at the same time, user modelling and adaptation processes based on learning styles for a standardized learning design is very difficult as is possible to observe in Table 2. Additionally for the teachers, these processes require huge amounts of time and effort in the course construction, which most of the times is not recognized by the educational institutions.

We propose a combination between static and dynamic user models based on learning styles to enrich and to support the automatic generation of an adaptive IMS learning design (LD) in order to reduce the amount of time and efforts for teachers to provide learners with personalized learning experiences. Our solution addresses not only the problem to infer the user learning style over the time but how this update affects the learning design over the time.

The analysis of the state of the art provides us with important conclusions and scientifically validated data in order to propose:

- A static user model based on learning style and a decision process based on teachers opinions, which support the delivery of learning objects types according to the user preference. The main characteristic of this model is the consideration of teachers' opinion as input for generating a classification task which supports a decision process about the students preference over the learning objects types. This process has not been considered in the state of the art.
- A dynamic user modelling process based on the analysis of user behaviours to support the decision about if the user preference on learning objects types has changed over the time. Our proposal include an interesting analysis of the standard deviations of the data from the users behaviour for redefining the students learning style which has not been considered in the state of the art.

Static user model allow us to support the creation of an initial learning design adjusted to students preferences for the learning objects types and on the other hand dynamic user modelling allow us to update the learning design considering how the students' preferences change over the time. Both processes have not been considered in the state of the art in an integral way.

2.2. AUTOMATIC LEARNING DESIGN APPROACHES

Automatic course generation has been one of the most interesting research areas during the last decades. In this section, the most important approaches and technical details in this area, as well as the relevant open issues are described.

2.2.1 Approaches in the state of the art

Karampiperis in [45] proposed an approach based on k*nowledge ontology and learning object metadata* which, by using the available information, generates an optimum learning path. The proposed *knowledge ontology* is considered as a concept network, where the concepts could have different relations such as *consist of, similar to, opposite of and related with*. These relations have a particular semantic mean. On the other hand, *learning resources* establish a net through the relation among the *Relations label* in the metadata of each particular resource. Different kinds of relations are considered such as *is part of, reference, is based on and requires*.

A general net of objects is obtained for connecting the concepts throught the *Classification Label* in the LO metadata. This general graph is optimized using a period of time associated to each learning object as an optimization criterion. Considering a weighted and directed acyclic graph (DAG), the shortest path algorithm is executed and the optimum learning path is obtained. The testing process of the approach was developed using the Computer Curricula Design for Computer Science [46]. The evaluation criterion is based on the number of learning objects correctly located in the final design performed by an expert and by the system.

Continuing with his work, Karampiperis in [47] introduced an adaptive learning object selection approach where they proposed a mechanism to filter learning objects before they are sequenced. They designed a framework that attempts to construct a suitability function that maps learning objects characteristics over learner features and vice-versa. To do that, they used the IEEE LOM characteristics of a reference set of learning objects, the IMS LIP characteristics of a set of learners and the suitability preference of an expert for each of the learning objects over the whole reference set of learners. After suitability functions are defined for the set of learning objects, learners' extrapolation is used to generalize the approach for all other learners and LOs.

Finally, in [48] Karampiperis presented a modified optimization problem attending the change of the curricular tendency to competences definition and its development. This approach generate learning paths based on competences definitions following these steps: 1) generation of the all possible learning paths for developing the desired competences based on the relation among Competence Development Program, the elements of the Competence Ontology and the learning resources. 2) Selection of the optimum learning path using the suitability function mentioned in [47] for weighting each connection of the graphs. This is also performed using the shortest path algorithms.

Some reflexions about this approach are the following:

- This approach generates an instructional plan based only in the cognitive domain; the approach does not offer an integral learning process considering other important domains such as affective and collaborative domain.
- The authors did not report the user modelling process or mechanism to track the user behaviour dynamically which is an important issue in a competence development process.
- Any technological specification is used in order to guarantee the interoperability of the generated designs.

Following approaches use planning algorithms for the generation process. These approaches are special because they we selected planning as generation technique.

Duque in [49] and [50] proposes a multi-agent system for planning and executing virtual personalized courses. This thesis introduces a general framework for the course generation based on the identification of the common elements through the different Instructional Design theories and supports by the use of HTN planning as well as the design of a particular user modelling process. The proposed framework was implemented using a set of intelligent agents based on JADE platform, and a particular scenario was developed but the validation process was not reported.

The most important users' features considered by the User Modelling process are users personal data, academic profile, psycho-pedagogical profile (Vark and Felder's models), and historical performance. Other users' features such as Psychological characteristics (Multiple Intelligences Model), mood, context and environment are also taken into account. For these characteristics, the initial capture and update process is mentioned as well as the possibilities to develop each of them, though not all of the mentioned processes were developed in the project.

Instructional Design Generation was based on HTN planning. Educative objectives of a particular course compose the task to be achieved (T); the initial state (S) consists of the Objectives achieved by a particular student and by the student features inferred according to the user modelling process. An interesting pre-Planning process is proposed in order to construct the planning domain. The process received as input the learning objectives and the metadata of the Unit of learning in order to construct the methods and operators to be used in the process of generating the personalized plan. Planning domain indicated that the actions that should have been developed by the student began in the state (S) for reaching T.

Some reflexions about this approach are the following:

- Both the methods used to update dynamically user model and how the instructional design is updated according to the updating the user modelling process are not clear.
- Evidence about the integration of this approach with a learning management system has not been reported.
- The approach does not consider the generations of conditional paths, one plan is created in a particular time for a particular user. When the tasks are developed, a re-planning process takes place.
- The searching process over different repositories for selecting learning objects according with student profile or teachers interest is not considered.
- The research does not considers the use of any specification or standard to represent different elements or actors associated to the learning process.

Ullrich in [51] proposed a courseware generation framework, PAIGOS, which generates structured courses that are adapted to a variety of learning goals and to learners' competencies. Ullrich also supports the generation process by the use of HTN planning. Operators and methods for generating seven types of courses are introduced. For the course generation, instructional designs ad-hoc approaches are used and the generation process is based in the construction of different kind of blocks that support the generation of the complex types of courses, which consist on optional and mandatory tasks. The domain consists of different methods and operators for inserting sections and resources, methods to select specific kinds of learning objects and for accessing user information; some calls were also implemented to obtain information of external resources such as learning objects into externals repositories. When the plan is generated, then the plan is represented in the OMDOC standard, in particular, using omgroup element to represent collections of resources.

As in interesting issue, the concept of pedagogical objective is introduced. This concept corresponds to the intention to offer student different kind of learning resources to improve their learning. In this manner, pedagogical objectives could be to: 1) Discovering and understanding fundamentals in depth, 2) addressing weak points, 3) increasing mastery of a set of fundamentals by training, 3) offering detailed information, 4) increasing mastery using a single exercise, 5) improve understanding by a sequence of examples and 6) improving understanding using a single example. These pedagogical objectives, user identifiers, resources available are part of the initial state of the planning problem.

The proposal considers the dynamic tasks generation, which are tasks displayed in a time (t) after the plan execution. Resources associated to any dynamic task are assembled when the server that manages the presentation in PAIGOS identifies the existence of theses tasks. Evaluation corresponds to the analysis of the time of plan generation. The integration of this approach with the Web based learning environment ACTIVEMATH was reported.

Some reflexions about this approach are the following:

- The user modelling process is not described in the proposed framework; however, some user variables are taken into account for the course adaptation.
- In the investigation the use of any specification or standard to represent different elements or actors associated to the learning process was not reported.
- Dedicated repository of leanirng object is used to retrieve learning objects, however, distributed repositories are not integrated in the study and specific techniques for retrieval LO adjusted to user is not introduced.

Castillo in [52], using the SIADEX planner, faced the problem of generating dynamically the planning domain based in the learning objects metadata. Planning problem is defined using user profile and the objective to be achieved is in accordance with the specification provided by the teacher. The success of the proposal depends on the exhaustive label of the metadata relations among learning objects because the planning domain is constructed according to these relations. The state of the practice indicates that an uncontrolled and uncharacterized set of learning objects is distributed around the world. This is the reason why this requirement is considered the principal limitation of this approach. On the other hand, conditional planning is not reported and the analysis of the student performance is not developed in the plan execution time.

Addressing the problem of the conditional IMS-LD generation, Morales in [53] introduce a new approach that extends the last one by proposing a multi-plan generation approach. The process is divided in three steps: 1) in the first one, the necessary data (goals information into IMS QTIs, resource information, student information) are retrieved from the LMS, in this case Moodle; 2) in the second one, the information obtained in the first step is converted into pedagogical rules described in a configuration file only for one intermediate objective; sequences and conditions are recovered and included in the planning domain; 3) in the last step, the planning process is performed, sequences and conditions defined through the execution of the hierarchical planner are carried out to obtain a new learning design that is added to the previous one. This process is repeated until the last goal is addressed through planning. When the plan is completed, the plan is shown through Reload tool to the students.

Some reflexions about this approach are the following:

- It is difficult to understand the testing process of this approach using reload because generally to test this kind of approaches a friendly environment for users is necessary.

- The user modelling process is not addressed in the proposed approach; however, some users' variables are taken into account for the course adaptation.
- The searching process over different repositories for selecting learning objects according with students' profile or teachers' interest is not considered.

De Marcos in [54] proposed to model the problem of identifying the best set of learning objects for supporting the creation of the competence based curricular designs as a satisfaction of constraints problem and to solve it using Particle Swarm Optimization. The problem input was a graph inferred using the references in the learning object to the desired and pre-required competences in the metadata.

Table 3 and Table 4 present an outline which abstracts the most important characteristics of the analized approaches from the state of the art. Columns in the tables represent each considered characteristics with analysis purposes.

Table 3 is focused on the solutions themselves and how they were constructed; it describes the selected approaches on terms of:

- Generation Techniques indicate the learning design generation technique used for each approach.
- Implementation Algorithms indicate the specific algorithms used to implement the learning design generation process.
- Testing Type presents the type of evaluation used to validate the learning design generation process.
- Conditional Planning indicates if the generation process uses conditional planning algorithms.
- Access to Distributed Learning Objects Repositories indicates if the solution looking for distributed learning objects types.
- Didactic Differentiation indicates if the approaches consider different instructional theories.

Table 4 is focused in the relation of the solutions with the user modelling process and with the use of standards; it describes the selected approaches in term of:

- User Modelling Process indicates if the approaches include a particular user modelling process.
- Explicit Student Profile indicates if the user model is defined explicitly.
- Dynamic User Modelling based on Learning Style indicates if the approaches infer the user learning style over the time.
- Dynamic User Modelling based on Competence if the approaches infer the user competences over the time.
- Use of standars indicates if the approaches include the use of any standards.

Table 3. Comparisons among different approaches in the state of the art considering learning design generation process

AUTHORS	GENERATION TECHNIQUE	IMPLEMENTATION ALGORITHMS	TESTING TYPE	CONDITIONAL PLANNING	ACCESS TO DISTRIBUTED LOR	DIDACTIC DIFFERENTATION
Karampiperis et al. [45], [48]	Shortest path	Dijkstra Algorithm	Comparison among experts learning design generation and designs generated by the system.	NO	NO	NO
Duque et al. in [49], [55]	HTN Planning	JSHOP 2 PLANNER	Not reported	NO	NO	NO
Ullrich et al. in [51], [56]	HTN Planning	JSHOP 2 PLANNER	Processing time	NO	NO	LIMITED SCENARIOS
Castillo and Morales in [52], [53]	HTN Planning	SIADEX PLANNER	TEST Scenarios	NO	NO	NO
De Marcos in [54], [57]	Satisfaction of Constrain Problem	Particle Swarm Optimization	Function fitness (goodness of a Solutions)	NO	NO	NO

Table 4. Comparisons among different approaches in the state of the art considering learning design generation process

AUTHORS	USER MODELLING PROCESS	EXPLICIT STUDENT PROFILE	DINAMIC USER MODELLING BASED ON LEARNING STYLE	DINAMIC USER MODELLING BASED ON COMPETENCE LEVELS	STANDARDS
Karampiperis et al. [45], [48]	NO	YES	NO	NO	NO
Duque et al. in [49], [55]	YES	YES	NO	NO	NO
Ullrich et al. in [51], [56]	NO	YES	NO	NO	NO
Castillo and Morales in [52], [53]	NO	YES	NO	YES	YES
De Marcos in [54], [57]	NO	NO	NO	NO	NO

Following paragrhaps describe the most important conclusions:

- These researches have been conducted by using user models in order to adapt the learning designs to the needs of learners but typically the inferences of user variables do not supported a dynamic user modelling process.
- The current approaches do not typically consider the use of conditional planning algorithms. In most cases, one plan is created at a particular time for a particular user and when the proposed tasks are completed or some criteria are met, a re-planning process takes place.
- The mentioned approaches do not typically use specifications or standards to represent different elements or actors associated to the learning process which makes the interoperability between systems as well as the exchange of information in a globalized world difficult.
- Only one of the analized approaches considers the access to a distributed LOR. With the increasing number of LO, the possibility to offer to teachers the opportunity of accesing in an easy way distributed learning objects is a relevant issue.
- No less important is the limited evaluations techniques for this kind of solution. It is neccesary an integral evaluation where the different dimensions of the generation process could be considered.
- Finally, teachers' preferences have not been considered in the mentioned proposals. The consideration of teachers' preferences related to instructional theories to support learning designs generations is still interesting open issue.

2.2.2 Our contribution to Learning Design Generation Process

Based on the overview presented in Table 3 and Table 4 our main contribution is *Designer* [58], [59], [60], [61] an approach to help teachers in designing courses via a semi-automatic design process based on competence definitions, dynamic user modelling and adaptation tasks. The main elements of our approach include:

1. The generation of a standardized and conditional learning design adjusted to IMS Learning Design specification.
2. The use of planning techniques for the automatic generation of learning designs that consider the users' competences and learning styles at the design time and also at the execution time.
3. The specification of a dynamic user modelling process based on the user competences and learning styles which could be integrated into the generated design process at the execution time.

4. The introduction of searching processes over different LOR for selecting and positioning learning objects to support a contextualized learning design process.

Designer includes into the design generation process elements not considered before in the state of the art such as a dynamic user modelling process based on learning style affecting the learning path offered to students as well as the possibility for the teacher to count with external learning objects previously contextualized for a generated learning design. Not less important are both, the innovative evaluation proposed to validate Designer as well as the use of different standards to represent the information from different elements or actors associated to the learning process.

Another important element to highlight in our study is the introduction of an innovative validation process composed by different layers not considered at all in the state of the art. Each layer involves different actors in the learning and teaching processes in order to validate each component of our solution.

2.3. DISTRIBUTED LEARNING OBJECTS

2.3.1 Learning Objects Economy

Through the years, the concept of learning object has been thought and re- thought by many diverse and qualified people. The IEEE Learning Technology Standards Committee (LTSC) [62], in its work about the Learning Object Metadata Standard [63], defines a learning object as any object, digital or non-digital, that may be used for learning, education or training. This definition covers almost everything as a learning object, but not any available thing is a learning object. According to Polsani [64], a LO needs to be accessible, reusable and interoperable, but also a learning object needs to be wrapped in a learning intention.

Wiley [65] reinforces the concept of reuse introducing the term of "object" from the Object Oriented Programming paradigm of computer science, where one "object" is understood as a component that can be reused in multiple contexts. In this manner, a learning object is presented as a small instructional component that can be reused in different learning contexts, when required. This remark is important to us because our proposal is based on the idea of the learning object economy [9], where reuse is a key element.

Learning object economy are marketplaces for the sharing and reuse of LO. As in any economy, different actors play different roles in the learning object economy. Ochoa, in [66], identifies the following eight actors: *Market-Makers, Authors, Resellers, Publishers, Teachers, End Users, Assemblers and Regulators*. *Market-Makers* provide support to interchange LO, some examples are Learning Object Repositories (LOR), Open Courseware sites, Learning Object Technologies researchers and trainers. *Authors* are LO creators, as teachers or learning designers. *Resellers* are those who have acquired the right to exploit the LO, as universities or private companies. *Publishers* are those who have the publication rights of the LO. *Teachers* are usually Authors or End-Users. *End-Users* utilize the LO for learning. *Assemblers* reuse small LO to construct most complex ones. Finally, *Regulators* set the rules by which the sharing in the economy takes place.

Offering a learning process for all is the main motivation for stimulating the development of the learning object economy. However, to ensure that the learning object economy becomes a reality, some barriers in the learning object economy must be overcome, as shown in [9]. We are going to focus the discussion only on two major categories of barriers: technical and pedagogical.

There are two main *technical barriers* for reuse: granularity and editability. Granularity refers to how big should a learning object be. In this sense, Wiley in [65] introduces two different points of views for facing the decision: efficiency and instructional point of view. The author indicates, from the efficiency point of view, the decision regarding learning object granularity can be viewed as a trade-off between the possible benefits of reuse at the expense of cataloguing, in contrast with the instructional point of view, where the major issues to be considered are the scope and sequence.

Editability refers to the possibility that any aspect of a learning object can be changed if available in a suitable form. Editability allows the LO granularity to be changed. There are many distributed LO that are not editable; in fact, this is one of the most common excuses provided by teachers for not reusing.

Counting with editable and open LO requires the agreement among the LO economy actors. In particular, referred to the right author management, which would increase the creator's confidence. On the other hand, the implementation of author tools to support LO editability, which addresses the accessibility issues in the content, is one of the most important issues in this economy.

Barriers from pedagogical view are basically related to the LO context. According to [15], context could be defined as any information that can be used to characterize the situation of an entity, in our case the LO. Yet, context in education is essential. However, practically, context in LO inhibits reuse. Addressing the context allows to use LO in different scenarios. Small granularity facilitates driving the context issues, and LO editability could permit teachers to contextualize the LO according to the learners necessities.

As well as the barriers, some enablers must be promoted in order to develop a learning object economy: Learning Design generation and Standards promotion.

Learning Design generation. "Learning design" is the term coined for a movement looking for more consistent approaches in describing and documenting teaching practice to facilitate not only communication and sharing, but also the improvement of teaching practice. However, there is currently no standard definition for learning design [67]. A well-accepted definition for an instructional design process is the following: the process that should be followed by teachers in order to plan and to prepare the instruction [1]. This process should address, in an integral way, the people's needs, such as cognitive, emotional, social, and physical. Given that LO are just content, to have real learning experiences, those contents need to be administrated in order to achieve a pedagogical and adequate sequence. The adequate pedagogical theories and techniques need to be in place in order to assure that the LO has a real impact [8].

Standards promotion. If a global learning object economy is the goal, there must be common-agreed standards that enable the sharing of LO between heterogeneous systems [66]. Important organizations/groups such as The IEEE Learning Technology Standards Committee (LTSC) [62], IMS Global Learning Consortium [68], Dublin Core Metadata Initiative [69] among others, have been concerned in proposing approaches for learning object standardization. Almost all elements, actors and processes of the learning process have been objects of standardization. Table 5 summarizes the analysis developed in [70] about different standards and organizations involved in their creation, which has been accepted and validated in the international scope.

Table 5. Overview technological standards

SPECIFICATION OR STANDARD	ORGANIZATIONS	YEAR
COMPETENCES, EDUCATIONAL OBJECTIVES OR PORPUSE		
IMS Reusable Definition of Competency or Educational Objectives [71]	IMS Global Learning Consortium	2003
Competencies [72]	HR-XML Consortium Library	2007
Conceptual Reference Model for Competencies and Related Objects [73]	The International Organization for Standardization (ISO)	2008
LO METADATA AND LEARNING OBJECT REPOSITORIES		
IMS Metadata [74]	IMS Global Learning Consortium	2001
IEEE Learning Object Metadata (LOM) [63]	IEEE Learning Technology Standards Committee (LTSC)	2002
Dublin Core Metadata [69]	Dublin Core Metadata Initiative	2001
Digital Repository Interoperability (DRI) [75]	IMS Global Learning Consortium	2003
LEARNING DESINGS		
IMS Content Packaging [76]	IMS Global Learning Consortium	2004
Sharable Content Object Reference Model (SCORM) [77]	Advanced Distributed Learning Initiative (ADL)	2004
IMS Learning Design (IMS-LD) [6]	IMS Global Learning Consortium	2003
ASSESSMENT		
Question and Test Interoperability (QTI) [78]	IMS Global Learning Consortium	2003
IMS ePortafolio [79]	IMS Global Learning Consortium	2005
Educational Model for Assessment [80]	Educational Technology Expertise Centre OTEC from Open University of the Netherlands	2006

2.3.2 Learning objects relevance

Borlund in [81], mentioned three central conclusions from the nature of relevance and its role in information behaviour:

- Relevance is a multidimensional cognitive concept whose meaning is largely dependent on users' perceptions of information;
- Relevance is a dynamic concept that depends on users' judgements of quality of the relationship between information and information need at a certain point in time;
- Relevance is a complex but systematic and measurable concept if approached conceptually and operationally from the user's perspective.

Saracevic [82] distinguishes between five basic types of relevance:

1. System or algorithmic relevance, which describes the relation between the query (terms) and the collection of information objects expressed by the retrieved information object(s);
2. A topical-like type, associated with aboutness;
3. Pertinence or cognitive relevance, related to the information need as perceived by the user;
4. Situational relevance, depending on the task interpretation; and
5. Motivational and affective, which is goal-oriented.

Ochoa, in [66], uses a modified Saracevic categorization (eliminating motivational and affective dimension) as the basis to define a set of complete metrics for LO relevance identification. These metrics are shown in Table 6.

Table 6. Summary of Relevance metrics [66]

TYPE	METRIC	DESCRIPTION	INPUTS
Topical Relevance	Basic Topical Relevance (BT)	Number of times the object has been previously selected from the result list when the same (or similar) query terms have been used	Queries of which the system keeps record.
	Course-Similarity Topical Relevance (CST)	Number of time that LO in the list have been used in the universe of courses.	Courses
	Internal Topical Relevance (IT)	The sum of the hub value of the courses where the object has been used.	Courses
Personal Relevance	Basic Personal Relevance Ranking (BP)	Analyses the characteristics of the previously used LO , in particular, the relative frequencies for the different metadata field values.	Metadata from the Learning object used for a particular user.
	User-Similarity Personal Relevance Ranking (USP)	Number of times similar users have reused the objects in the result list.	Information about Learning object use and its metadata.
Situational Relevance Ranking Metrics	Basic Situational Relevance Ranking (BS)	Cosine distance between the TF-IDF vector of contextual keywords and the TF-IDF vector of word in the text field of the metadata.	Description of the course, lesson or activity and the learning object metadata.
	Context Similarity Situational Relevance Ranking (CSS)	Analyses the objects that have already been used under similar conditions. Frequencies for different fields in the LO metadata.	Information about Learning object use and its metadata.

2.3.3 Learning Objects Repositories

LOR are defined as systems that enable users to locate, evaluate and manage learning objects through the use of "metadata", namely descriptors or tags that systematically describe many aspects of a given learning object, from its technical to its pedagogical characteristics [83]. When the repository stores only the LO metadata, the repository is named Learning Object Metadata Repository (LOMR).

LOR frequently give an abstract interface for humans and other systems which allow them access for LO using some particular criteria.

Educational institutions have increasingly understood the importance to use learning object repositories as essential tools to store and maintain the produced knowledge of their human resource. Often, these institutions implemented their repositories as instances of validated architectures such as Fedora Commons [84] or Dspace [85].

Table 7 shows only some of the large amount of repositories around the world, considering that each educational institution has a particular system to store the knowledge developed by their human resources.

Table 7. Learning objects repositories and Learning Object Referatories

REPOSITORY	URL	SCOPE	LOCATION	TYPE
ARIADNE Knowledge Pool System	http://www.ariadne-eu.org	University	Regional (Europe)	Diverse
Connexions	http://www.cnx.org	University & Other	International	Courses
MLX: Maricopa Learning Exchange	http://www.mcli.dist.maricopa.edu/mlx			Diverse
OER Commons	http://www.oercommons.org/	All Sectors	International	Courses
LRE	http://lreforschools.eun.org/	Primary and Secondary Education	Regional (Europe)	Courses
Le@rning Federation	http://econtent.thelearningfederation.edu.au/	All Sectors	National (Australia)	Diverse
JORUM	http://resources.jorum.ac.uk/	Higher Education	National (UK)	Diverse
e-yliko	http://www.e-yliko.gr	Primary and Secondary Education	National (Greece)	Diverse
The Canadian LD Repository	http://www.idld.org	All Sectors	National (Canada)	Learning Designs
LAMS Repository	http://lamscommunity.org/lamscentral/	All Sectors	International	Learning Designs
The Learning Designs Repository	http://www.learningdesigns.uow.edu.au/	All Sectors	National (Australia)	Learning Designs

REPOSITORY	URL	SCOPE	LOCATION	TYPE
iCOPER LD Repository	(http://www.icoper.org/reposit ory/learning-design)	All Sectors	Regional (Europe)	Learning Designs
COSMOS LD Repository	(http://www.cosmosportal.eu/)	School and Higher Education	Regional (Europe)	Learning Designs
Merlot	http://www.merlot.org	All Sectors	International	Various (Metadata)
Intute	http://www.intute.ac.uk	University	International	Various (Metadata)
BioDiTRL Biological Digital Teaching Resource Library	ttp://bio-ditrl.sunsite.ualberta.ca/	University	Canada	Compone nts
Curriki Global Education & Learning Community	http://www.curriki.org/	K12	International	Various
ESCOT: Educational Software Components of Tomorrow	http://www.escot.org/	Middle School		Lessons
Exploratories	http://www.cs.brown.edu/explo ratories/ freeSoftware/home.html	University		Lessons
Exploratorium Digital Library	http://www.exploratorium.edu/ educate/ dl.html	All levels		Various
Explore Learning with Gismos	http://www.explorelearning.co m/	K12		Lessons
Fathom archive	http://www.fathom.com/	University		Lessons
Free-ed Net	http://www.free-ed.net/free-ed/	ComColle ge		Courses
General Physics Java Applets	http://www.surendranath.org/	University		Lessons
Geometry	http://www.geom.uiuc.edu/	University		Lessons

REPOSITORY	URL	SCOPE	LOCATION	TYPE
Center U. of Minnesota				
Harvey Project	http://opencourse.org/Collaboratories/ harveyproject	University		Lessons
Illumina: National Science Digital Library	http://www.ilumina-dlib.org/	University		Various
Repositorio de Objetos de Aprendizaje Basado agentes (OBAA)	http://www.portalobaa.org/obaac/padrao-obaa	University and schools	Brasil	Various
IU: The UC Berkeley Interactive University Project	http://interactiveu.berkeley.edu:8000/ DLMIndex/	University & K12	USA	Lessons
LOLA Exchange: Wesleyan U	http://www.lolaexchange.org/	University		Lessons
MIT Open Courseware	http://ocw.mit.edu/	University		Courses
Colombia aprende	www.colombiaaprende.edu.co/	University and schools	Colombia	Various
OVAUNICOR	http://ovaunicor.aves.edu.co/	University	Colombia	Lessons
National Learning Network UK	http://www.nln.ac.uk/Materials/default. Asp	Upper Secondary	UK	Lessons
National Repository of Online Courses (Monterey Institute)	http://www.montereyinstitute.org/nroc/ index.html	All levels	Mexico	Courses & lessons
Open Course Collaboratories	http://opencourse.org/	University	US	Lessons
Open Learning Initiative (OLI) Carnegie Mellon	http://www.cmu.edu/oli/	University 1st Yr.		Courses
PBS Teacher	http://www.pbs.org/teachersour	PreK-12	US	Various

REPOSITORY	URL	SCOPE	LOCATION	TYPE
Source	ce/			
CITIDEL	www.citidel.org/	University	International	Various Metadata
DLESE: Digital Library for Earth System Education	http://www.dlese.org/	All levels	International	Various Metadata
CAREO: Campus Alberta Repository of Educational Objects	http://careo.ucalgary.ca	University & others	Canada	Various Metadata

2.3.4 Contribution to Learning Object Economy

We aim to stimulate the enablers of the learning object economy supporting the standardized and adapted learning design generation. Our investigation promotes LO reuse through accessing distributed learning objects repositories (DLOR) as sources of LO with diverse granularity, which could be elements in a generated learning design [86]. Our contribution in this dissertation is the definition of two different processes, the Distributed Learning Objects Metadata Searching Process (LORSE) [87] and the Micro-Context based Positioning Process (LOOK) [88].

Distributed Learning Objects Metadata Searching is a mechanism to promote reuse. This process is supported by agent technologies and its main purpose is looking for external LO, not developed by the teachers, which could be used as inputs in a learning design generation process. Micro-Context based Positioning Process analysis of the learning objects' Micro-Context (in the LOR) and its features current Micro-Contexts (in the learning design), considering disambiguation techniques in order to establish the most promising micro-context for the LO in a learning design supporting the placing of the object in its correct context.

As shown in Table 3, the access to distributed learning objects repositories is one of the issues less considered in the learning design generation process. As well, the question about how to contextualize a retrieved learning object from a distributed and uncontrolled LOR in the ambit of a learning design has been little addressed. Our solution takes advantage of the possibilities involved in the use of intelligent agents for supporting the creation of a federation of LOR and on the other hand we introduce a specific process based in the analysis of the learning objects micro-context for deciding where the learning objects should be positioned in a previously generated learning design.

2.4. CONCLUSIONS TO THE CHAPTER

In this chapter the most important approaches from the state of the art were analized. Open issues in each research line were described as well as the most important contributions of the thesis in each research line.

In the next part of this dissertation our solution for alleviating the workload for teachers on creating adaptive courses is presented.

Part II

Adaptive and Standardized Learning Design Generation

It's not about the tools, it's using the tools
to facilitate teaching and learning processes
Andrew Churches

3. FRAMEWORK FOR SEMI-AUTOMATIC LEARNING DESIGN GENERATION

As mentioned before, the main objective of this dissertation is to contribute in alleviating the workload for teachers on creating adaptive courses by reducing the complexity involved in authoring standardized and adaptive learning designs adjusted to their students' characteristics, in particular, learning style and competences levels.

Motivation to develop this study came from different domains, the competences development process, user modelling research line and learning design generation research line, all of them in the context of technologies enhanced learning. Motivations move us to propose and implement our solutions which are condensed into a framework for semi-automatic learning design generation. The porpuse of this chapter is to provide the most important details about preliminary studies supporting our motivations, introduce our framework to learning design generation as well as its associated evaluation.

The rest of the chapter is structured as follow. In section 3.1. results from preliminary studies, which permit to support important decisions, are presented. Section 3.2. describes our framework for learning design generation. This section details each framework element and process and also presents the detail about how the framework will be evaluated. Finally, in the section 3.3. some conclusions are introduced.

3.1. PRELIMINARY STUDIES

3.1.1 Conclusions from the virtual competence development process analisys

As described in [70], in the last decade, an increasing interest for competence development process have been occurring [89],[90],[91],[92] and also, the number of definitions about the competence concept has been popping up.

The competence development process has become one of the most common paradigms used to address learning-teaching processes, regardless of the education modality, i.e. traditional classes, those totally virtualized and supported in a virtual learning environment, or mixed approaches (blended learning).

To consider a competence process implies to think in the contextual situation of the users, focusing the efforts in addressing their specials needs through the following phases:

- Competences Definitions Process, which is the consensus process between academy and productive sectors with the society in order to jointly define educational purposes. Those purposes are designed to achieve quality performances in the context. Agreed competences orient the educational programs definitions in a particular region. This process permits adjusting the educational offer to the interests of each sector and the community in general.
- Competences Normalizations, which is the process to establish a common language among different competences' stakeholders. In this process, the previous competences definitions are characterized, verified and standardized.
- Curricular Design based on Competences, which is the process that should be followed by teachers in order to plan and to prepare the instruction [1] to motivate the student to achieve a desired level of competences. This process should address, in an integral way, the people's needs, such as cognitive, emotional, social, and physical.
- Competences Certification, which is the formal recognition of the achievement of the desired competences level for the student. Usually, the certification is provided by a legal and recognized institution.

Figure 2 summarizes our vision about the top-level elements, which made up the competence development process in a VLE context.

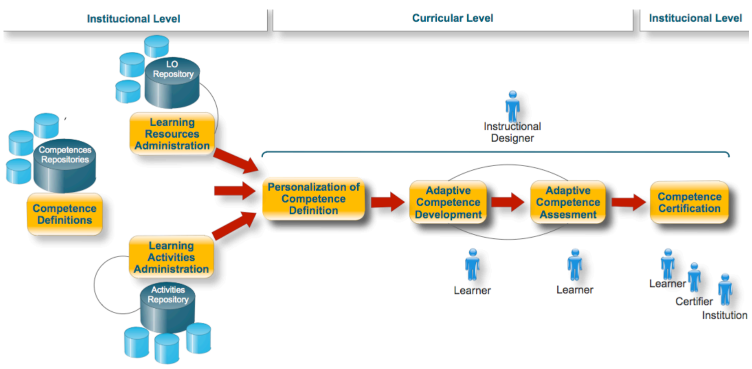


Figure 2. Competence Development and Assessment Processes

As shown in Figure 2, our focus is dealing with the existence of different, distributed, and reusable resource types such as competence definitions, learning objects and learning activities specifications. Some of these resources could be provided by the institution itself or obtained from external resources. Using as inputs these different types of resource, the principal task of the *Learning Designer* is to personalize the learning process in order to attend a specific learning proposal at hand. This learning design process, which considers the delivery of instruction adjusted to specific user features, should be a semi-automatic process. This semi-automatic process allows the teacher to focus on didactical issues instead of having to deal with addressing all possible user individual characteristics or with accessing different sources of distributed resources.

One of the most important issues from the pedagogical point of view is the lack of Teachers' training in the decision making process referred to the learning design process [7]. Learning design decisions often are made as a result of the intuition and routines more than theoretical or practice knowledge consciously applied. For this reason, we consider appropriate a solution for supporting the creation of customized learning designs in order to address a semi-automatic Standardized Adaptive Competence Development and Assessment process.

The main elements of our approach are as follows:

- The use of a standardized and reusable competence definition model as a mechanism to define the learning purpose and to obtain the necessary information that should be provided by the teacher in order to generate a semi-automatic, reusable and standardized leaning design.
- The acquisition of the knowledge about the user through the implementation of a user modelling process based on intelligent agents and machine learning techniques. This process is in charge of maintaining the user model to support the adaptation of the learning scenario for each particular user in the learning design executing time.
- The use of the planning techniques for the learning design generation.
- The implementation of different mechanisms to integrate heterogeneous systems such as web services or agents technologies.

3.1.2 Identifing relevant characteristics of both learning process actors and learning process

3.1.2.1 General description of the exploratory study

In our research, our main purpose, as mentioned before, is to alleviate the workload for designers of adaptive courses or teachers in authoring pedagogically adequate adaptive learning designs. If to this initial complexity, both the necessity to address the particular user features (i.e. learning style and competences) and the user context (i.e.

device capabilities and situation in the course) are added, our approach becomes more relevant (and important) but also it turns into a more difficult task.

In this manner, one of the most important questions to solve in our proposal is which users' features are relevant for teachers in order to provide adaptation in a virtual learning environment. For this reason, we developed an exploratory study with 47 teachers from Latin America and Europe with the purpose to identify those features.

The exploratory study permit us to identify teacher opinions and also some differences in perception between the Latin American and European teachers' points of view according to the most relevant user features to be taken into account in the learning process, as well as how these user features affect decisions in the learning design generation process.

Five universities have participated in the study. In South America, the study was carried out in three Colombian institutions: the University of Cordoba [93], the University of Magdalena [94] and the Tecnar Institute [95]. In Europe, the study was carried out in three Spanish universities, the University of Girona [96], National University for Distance Education [97] and the Carlos III of Madrid University [98].

The population involved in the study consists on 47 teachers from different knowledge areas, such as computer science, pedagogy, economy, mathematics, among others, which undertake instructional design tasks amongst their activities. General characteristics of the sample are shown in Table 8.

Table 8. Sample Description for the exploratory Study

POPULATION FEATURES	
Number professors and tutors	47
Distribution in gender (M/F)	19 Male (40%) – 28 Female (60%)
Age range	25-60 years old
Experience Duration	8 hours
Type	Workshop
Knowledge Areas	Humanities
	Engineers

Figure 3 shows other relevant characteristics of this sample. As could be observed a balanced sample with respect to continent of origin (America and Europe) and the nature of the career (Humanities and Engineers) was defined. An important characteristic of this sample is the pedagogical expertise of teachers which suport the relevance of teachers opinion.

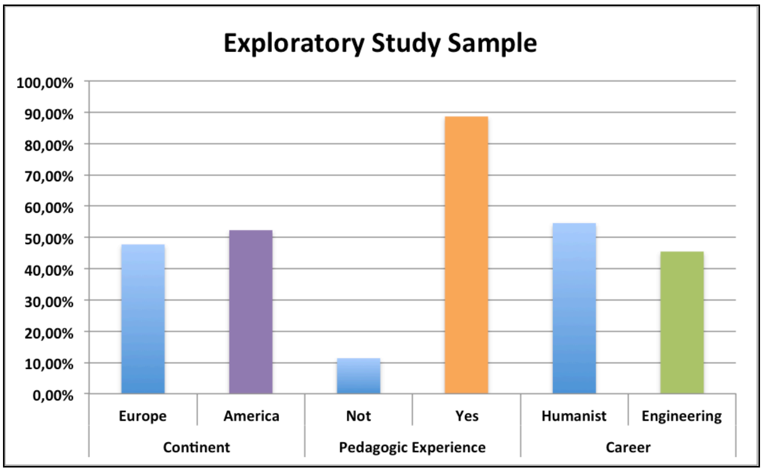


Figure 3. Sample Continent, Pedagogical Experience and Career

The purpose of the study was to identify which users' features American and European teachers considered important to be addressed in the learning process, which elements in the virtual learning process the teachers considered important to be addressed in the adaptation process and, also, how the identified users features could affect the learning process, in particular, a semi-automatic learning design generation.

The methodology used for capturing the teachers' opinion was:

- A brainstorming in small groups for the identification of the users' features American and European teachers considered important to be addressed in the specific learning process and which elements in the virtual learning process the teachers considered important to be addressed in the adaptation process. Conclusions were specified in a formal survey.
- A brainstorming in small groups to detect how the identified users features could affect the learning process, in particular, a semi-automatic learning design generation. Conclusions were specified in a formal survey.

3.1.2.2 Relevant student characteristics for user modelling and adaptation process, an exploratory study

In small groups, moderated by one person, the teachers had the opportunity to discusse about which students features they considered important to be addressed in the learning process. Teachers were free to propose the features that they considered important. This task was developed for one hour. Teachers' opinions were specified in a survey which they delivered to the general moderator.

Considering the surveys delivered by the teachers involved in our study we identied and systematized teachers' opinions extracting of the surveys all of the students' characteristics identified for teachers. We developed a frecuency analisys with the systematized data.

Table 9 shows a summary of the user features defined by the teachers as well as the description provided by teachers for each characteristic is introduced. Figure 4 shows the frequency diagram obtained from the analysis.

Some important conclusions are inferred through the statistical analysis of the data.

Comparing the results with the variables in the state of the art, some variables such as Previous Knowledge, Personal Data, Expectative, interests, ***competences*** and motivations, and the ***User Learning Style*** remain the most preferred by teachers to be addressed in the learning process. It is possible to observe these characteristics in red colors in Figure 4.

Desired and Achieved Competences (Transverse and Specifics) have become important for the teachers because of the actual tendency on modelling learning process based on competences (See column 7 with red color in Figure 4).

Note in Figure 4 the teachers' concerns for the available technologies and the possibility for their students to access those technologies (See column 30 with green color in Figure 4). In particular, in South American Universities, people have special limitations for accessing Internet; this is an example of why the location of the user and other features about his/her context become so important. Not only the availability and access to the technology is an important issue for the teachers, but also the adequate use of them. In this sense, features such as TICs Knowledge, capacity of communication are important in the context of virtual learning environments.

The appearance of a set of features related to functional limitations of the people, such as deficits in executive functions, physical limitations, cognitive disabilities and learning difficulties is an important issue. Governments around of the world, the European Commission, the UNESCO, as well as different international associations have created politics for addressing the diversity of the human beings, in particular, in the educational system. These global policies have permitted people who never had had the opportunity to access the educational system to access the system in the same conditions as people who were already in the system.

A curious data inferred by the study was the importance given by the South-American Teachers to features such as proactivity, level of commitment and responsibility with the learning process, and also to Socio-Cultural Elements and Social Stratification. European teachers included in the study do not consider these features.

Table 9. User and context features identifed by teachers in the explorative study

	NAME OF THE USER FEATURES	DESCRIPTION
UMF1	Field formation of interest	Professional career
UMF2	Work Activity	Current work activities
UMF3	Job Opportunities	Future and possible work activities
UMF4	Previous Knowledge	Essential Knowledge acquired in previous formal or informal educational programmes
UMF5	Personal Data	General data such as nationality, language, age, etc.
UMF6	Learning Style	Learning style characterize the cognitive, affective and physiological traits which serve as relatively stable indicators about how learners perceive, interact and respond in their learning environments [16].
UMF7	Desired and Achieved Competences (Transverse and Specifics)	Competences are complex processes that people put into play in order to solve problems and to carry out activities.
UMF8	Affective Necessities	Which could reflect in the attention necessity of the people in the learning environment.
UMF9	Expectative, interests and motivations	To define why people decide to take an educational program.
UMF10	Available time	Hours available for learning.
UMF11	Communicative competences	Special types of Transverse competences related to the communications process people need to demonstrate in specifics context.
UMF12	Capacity to manage virtual tools	Level of expertise in the use of this kind of tools.
UMF13	TICs Knowledge	Level of expertise in the use of Information and Comunication Technology.
UMF14	Study Level	Technical, Technologic, University
UMF15	Disabilities	Physical limitations, Cognitive Disabilities
UMF16	Skills of reading and writing	Capacity to read or write in a specific language.
UMF17	Proactivity	Ability to anticipate the challenges
UMF18	Level of commitment and responsibility	Implication of the student in the learning process
UMF19	Basic Competences	Essential competences necessary to live.
UMF20	Creativity	Capacity to create new ideas or concepts to solve real problems.
UMF21	Skills on Information Searching Process	Capacity to obtain good results in searching processes.
UMF22	Attention Level	Capacity to identify relevant information in a particular context.

	NAME OF THE USER FEATURES	DESCRIPTION
UMF23	Predominate intelligences	According to the Multiple intelligence theory.
UMF24	Interaction history	Records about the user behaviour.
UMF25	Level of Good personal relations	Capacity to establish good relationships.
UMF26	Level of skills on team work	Capacity to work in groups.
UMF27	People Preferred Work	Preferred domain of work
UMF28	Location	Current place for accessing learning environment
UMF29	Technology Access Conditions	Limitations for accessing technologies
UMF30	Technology Access Level	Capacity of connections, bandwidth, etc.
UMF31	Socio-Cultural Elements	Peculiarities of the user's culture
UMF32	Social stratum	Population segment in which the user belongs

Figure 4 shows the importance given by the teachers to each user feature.

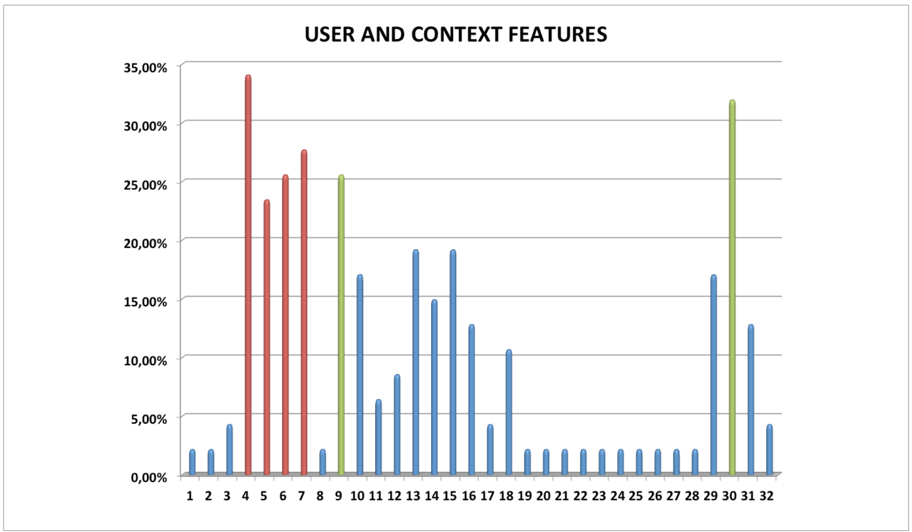


Figure 4. Importance of the user and context features according to the teachers' opinions in the explorative study

The relevance of these features for the South-American teachers is related to the culture diversity in the American continent and the growth of social differences among people.

In order to test our framework for the learning design generation process we have selected two of the most important users features reaffirmed for the teachers involved in our study, the competences and the user learning styles. However, the framework could be extended to other users features.

3.1.2.3 Relevant characteristics of the adaptation process for adaptation purpose, from an exploratory study

The next part of the exploratory study was the brainstorming in small groups, in which the participants were asked to comment about: which elements in the virtual learning process they considered important to be addressed in the adaptation process and how the identified users features could affect the learning process, in particular, a semi-automatic learning design generation? Other reflections that emerged in the study were if the teachers knew what learning design was, how they would develop it in the context of a virtual environment, and if, in their opinion, an automatic course generation in the context of a virtual environment was important.

As in the previous study one person moderated the small groups and in theses groups the teachers had the opportunity to loosely discusse about the proposed questions for one hour. Teachers' opinions were specified in a survey which they delivered to the general moderator.

Considering the surveys delivered by the teachers involved in our study we identified and systematized teachers' opinions extracting the main features teachers considered important to take into account in the automatic learning design generation process from the surveys. This data were specified in Table 10. On the other hand, Table 11 describes the conclusions about the implication of the user's features in the learning design generation process. These descriptions support our defined adaptation decision.

The following paragraphs describe the conclusions of this study.

For teachers, defining the user's features that could be addressed in the learning process was easy, but the definition about how these users' features should affect the learning design was not. Many of them had an ad-hoc definition about what learning design is, what a learning design theory is, and most teachers considered the generation of the adapted learning design a difficult and not trivial task. However, something that was clear for them was that they had many different types of resources and services that they could use in the virtual learning process.

An important conclusion from the teachers is that the proposal of a semi-automatic learning design in a virtual learning environment, in particular, the reutilization of the distributed learning resources was a good idea. They highlighted that reusing the effort of many teachers around the world could support different teacher tasks, among them, the learning design generation process, reducing the necessary time for searching or constructing adequate complex learning objects for their courses in a manual way.

Table 10. Features to take into account in the automatic learning design generation

LEARNING PROCESS ELEMENTS	DESCRIPTION
Learning modality	Traditional Face-to-Face, Blended Learning or Totally Virtual
Level of complexity of the course	Related with the number of subjects associated to the course.
Educative credit definition	Scale to measure and share the units of the curriculum.
Competence definitions	Purposes of the learning process.
Design of content-action and assessment activities considering the necessary time to spend in performing the activities.	Content itself for developing or assessing the learning process.
Different Learning objects type and their hierarchy organization	Curriculum sequencing
Strengthening and deepening activities	Activities to strengthen and deepen learning
Activities to increase independent learning	Activities to increase autonomous learning.
Consider the necessary bibliography	Bibliography Section as a resource
Consider Motivational Activities	To increase the interest of the user for the learning process
Teamwork activities	Group activities
Communicative activities	Participative, collaborative and cooperative learning activities.

Table 11. Implication of the users features in the learning design generation

USER FEATURE	IMPLICATION IN THE LEARNING DESIGN
Previous Knowledge	Reduce the space of learning objects according to a specific taxonomy of knowledge.
Competence Level	Define learning resources according to the specific user competence level taken into account the ***knowledge domain***.
Student Motivation	Insertion of motivational activities or use of some strategy to improve the motivation level.
Available time	Could help to define the character of the learning activities, it means if the student has little time activities should be shorter and fragmented.
Attention level	For people with low level of attention could be interesting to highlight the most important content and activities.
Technical level of use of the TICs	Propose additional activities to improve the level of adequate use of the TICs for people with low level. Offer recommendations about the use of the TICs.
Access to mobile devices	Exploit the mobility of these devices
Learning Style	Adjust learning content according to the preferences of the user, for example, the form to display the content or the learning object type.
Previous Qualifications	Anticipate future difficulties or strengths.
Communicative competence	Define the intensity and the form of use of synchronous and asynchronous communication tools.

Additionally, we asked teachers about the knowledge they may have on standardized learning design generation. Then, we present teachers the most important features of the IMS Learning Design Specification and asked them about the expressivity of the specification model to the learning design process elements. Figure 5 shows the obtained results.

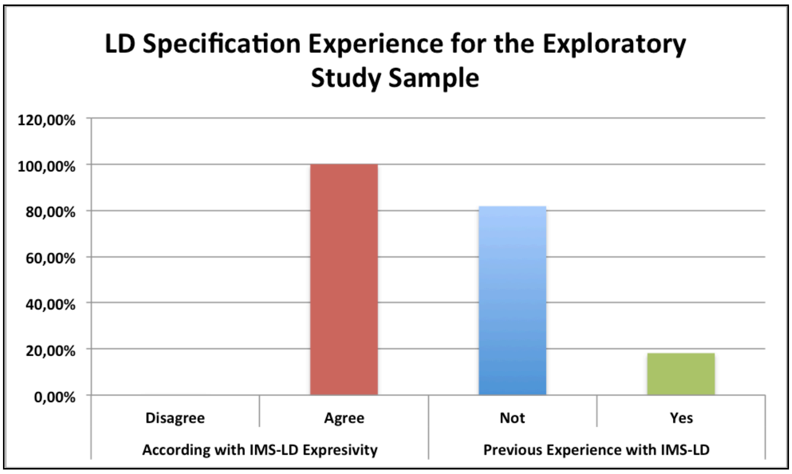


Figure 5. Teachers experience on IMS Learning Design Specification

Our study allowed us to conclude that teachers involved were completely agreed with the IMS Learning design expressivity understood it as the specification capacity for representing their necessities for developing a learning design.

3.2. FRAMEWORK FOR SEMI-AUTOMATIC LEARNING DESIGN GENERATION

3.2.1 Description

In our research, we have been working on alleviating the workload for designers of adaptive courses on the complexity involved in authoring adaptive learning designs adjusted to student's characteristics, in particular, competence levels and learning style. Our aim is to offer global and extensible solutions that can interoperate with existing LMS and facilitate the reusability of learning resources. In order to support inter-operability of the user modelling and adaptation, an intensive use of learning specifications and standards is performed. Figure 6 shows the general elements of our framework of generation as well as different technologies and standards linked.

For testing scenarios, we considered two specific user characteristics (i.e. learning style and competences) as was indicated in the motivation. We have also analysed the possibility of considering user context (i.e. device capabilities and situation in the course) as a determinant of adaptation [99] as well as other user's features [100] but to simplify the scenarios presented in this dissertation we did not cover that issue. The main elements in the framework are:

- *Competence Definition Model* permits to define specific and generic competences. Exported to an interoperable xml file, in particular, adjusted to the RDCEO [71] schema, competence definition is an important input of learning design generation process. Competence Definition specifies appropriate performances, i.e. the execution or accomplishment of learning objectives that should be demonstrated by the student in a specific context. We consider two different types of competences: 1) generic or transversal competences and 2) specific competences [92]. Generic competences affect various fields and are transferable to a multitude of functions or training programs. They are focused on the “to be". A special type of generic competences are the collaborative competences. They allow a group of individuals to carry out a job as the result of joint effort and cohesion towards achieving a common goal. On the other hand, specific competences are directly related to a specific occupation and are focused on the "know" and "do”. The individual competences are a particular type of specific competences. Although the definition of generic competences is supported in our work, our proposed framework mainly deals with specific competences.
- *The initial User Model Definition* fixes the initial state of the user model variables. This process could be developed by the teacher through the explicit introduction of the values of the variables, by the student using specific psychometrics tools, or generated automatically. The user model should be stored in an interoperable xml file, in particular, adjusted to the LIP [101]

schema and the model being an important input to the learning design generation process.

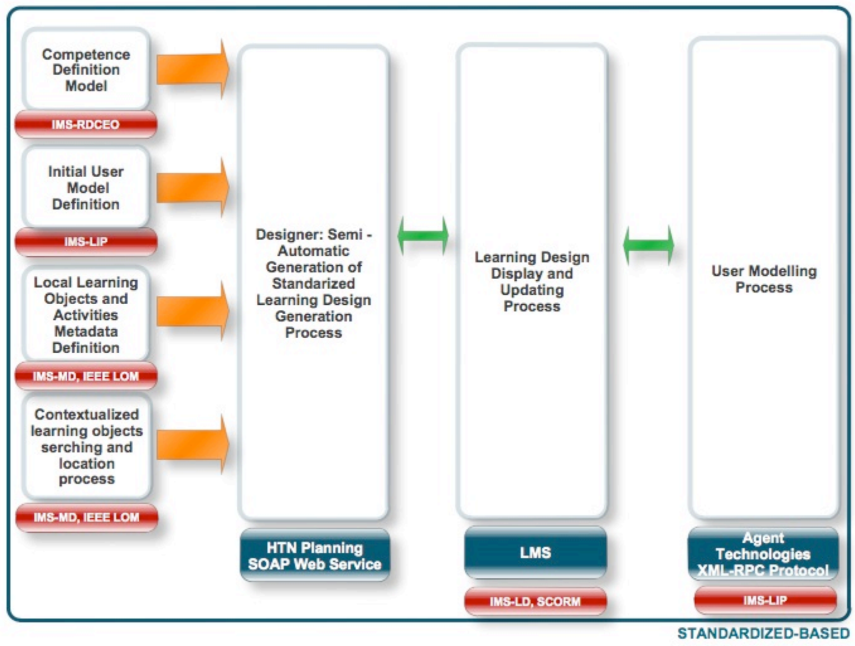


Figure 6. Learning Design Generation Framework

- *The Local Learning Objects and Activity Metadata Definition* is an important input because the information on the learning objects metadata is essential for the generation process. This process is referred to the labelling process developed by teachers on their learning objects (internal objects). This process could be performed manually by teachers or supported automatically. In this dissertation, we consider this information available although we give teachers some implementations as a support.
- *The Contextualized Learning Objects Searching and Positioning Process* is a mechanism to promote a reuse-oriented approach. This process is supported by agents' technologies and its main purpose is to consider external learning objects not developed by the teachers, which could be used for our solution as inputs in the learning design generation process. We propose the analysis of the learning objects metadata considering disambiguation techniques in order to establish the learning objects relevance for a specific micro-context in a learning design.

- *Designer: Semi –Automatic Standardized Learning Design Generation Process* is in charge of designing adapted teaching-learning experiences (i.e. the creation of adaptive learning paths), through the application of the didactical techniques that use data from the models and inputs presented before in order to obtain a flexible design. The generated design could be displayed and updated later according to the performance of the student captured through the user modelling process. In order to support inter-operability, the generated learning design is adjusted to the IMS-LD [6] schema for label B of this specification. IMS-LD Level B permits to implement the defined adaptation based on competence and learning styles.

- *The Learning Design Display and Updating Process* is the process in charge of maintaining learning design execution according to the state of the user model. This process in particular updates the local personal properties defined in the learning design, which maps the state of the user considered features for the particular scenarios considered in this dissertation.

- In the *User Modelling process*, whose purpose is to create and maintain an up-to-date user model, an adaptive system collects data for the user model from various sources that may include implicitly observing user interaction and explicitly requesting direct input from the user. In particular, as introduced before, we consider for evaluation scenarios two user's features (specific competences and learning style). Two particular user modelling process are proposed in order to maintain the model through the learning design execution time; this modelling process is described in chapter 4.

We propose to address the personalization process from two perspectives: design time (when the course is created and composed in the LMS) and run time (when learners are learning in the course). Figure 7 shows a sequence diagram where both perspectives are described.

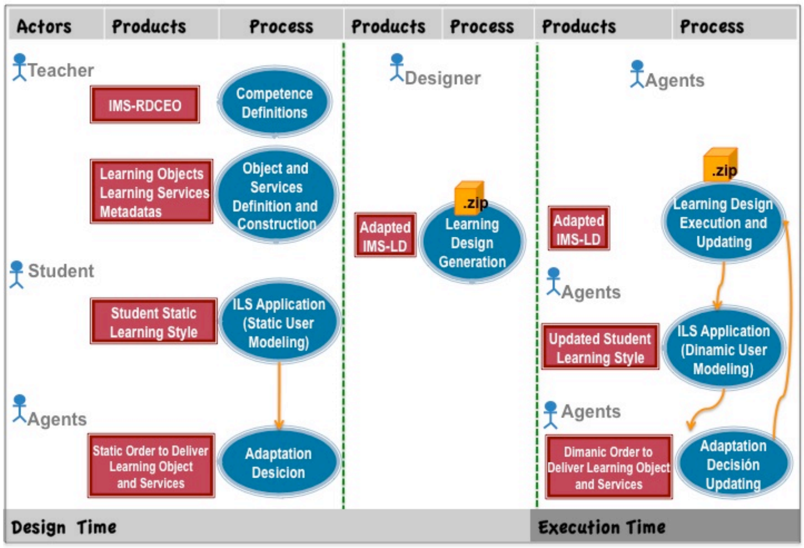


Figure 7. Sequence Diagram to present Design and Execution Time

At the design time, the necessary information for the Designer is developed and constructed. Using different authoring tools, the teachers define the competences; they define learning objects and services, as well as their metadata. On the other hand, students are asked to apply some psychometric tools (i.e. learning style questionnaire), and with this information the Initial User Model Definition is performed. This information is the input for Designer to generate the adapted IMS-LD.

At the execution time, the generated learning design is displayed in the LMS and the user behaviour is monitored. The analysis of user behaviours permits to redefine the user's model. This dynamic information is used in two ways: (1) to update the learning design properties and, therefore, to provide users with a course that is generated based on their most recently identified features state (i.e. learning styles or competences level), and (2) to update the input to the adaptation decision method (i.e. training set for the classification task for learning design adaptation process). Both of these updating processes are triggered based on execution parameters provided by teachers or the LMS administrator.

In the next chapters we will expand the description of three processes which are the main elements in our framework: the user modelling process based on learning style and competences, the learning design generation process and the the Contextualized Learning Objects Searching and Positioning Process. These processes involved the others mentioned in the framework.

On the other hand we consider important to give an overview about the evaluation process used to validate our framework. Evaluation process clarifies the research questions involved in our study. Next section details the proposed process.

3.2.2 Overview of the evaluation for the learning design generation framework

3.2.2.1 Layered Evaluation

According to [102], for an adaptive system evaluation two layers should be considered in order to test all the elements of the adaptive system: *The Interaction Assessment Layer* and the *The Adaptation decision making layer.*

In *The Interaction Assessment Layer* the question to be answered is: are the conclusions drawn by the system concerning the characteristics of the user-computer interaction valid? Or are the user's features successfully detected by the system and stored in the user model?. The objects of the evaluations in this layer include the collection of the user data for analysis and the user model generation. This layer considers the validation of the following issues in the user model: 1) comprehensiveness of the model, 2) redundancy of the model, 3) precision of the model and 4) sensitivity of the modelling process [103].

In *The Adaptation Decision Making Layer* the question to be answered is: *are the adaptation decisions valid and meaningful for the selected assessment results?* This evaluates the impact of the adaptation process in the specific domain of the applications. The objects of evaluations in this layer are 1) the adaptation decision process, 2) the application of the decision taken, and 3) the impact of the adaptation.

In our case, *The Interaction Assessment Layer* basically includes the evaluation of the user modelling process based on learning style. Although we introduce in this dissertation a particular generation process based on competences levels our main contribution in user modelling research line is the dynamic definition of the user learning style over the time. The proposed scenario for this evaluation is described in Table 12.

On the other hand, *The Adaptation Decision Making Laye*r includes the evaluation scenarios of the different adaptive and standardized learning designs. In this layer, the learning design generation process and the Contextualized learning objects searching and positioning process are evaluated. The description of these evaluation scenarios is presented in Table 13 and Table 14.

Evaluation techniques are different for each layer and they were defined according to the nature of each solution. These techniques are explained in detail in the mentioned tables.

Additional to the layers considered in [102] we have introduce a third important layer to the evaluation process, *User satisfaction evaluation layer*. Our main objective in this evaluation layer was to develop a qualitative study, which permit us to achieve a better understanding of potential opportunities for improving our approach and how to support this task in a better way. The used strategy was to develop case studies, which permited us to concentrate in a particular situation. The analysis was based on interviews with teachers, case studies in which the application of a Gap Model instrument [104], [105] for satisfaction evaluation was performed. The Gap Model allowed us to capture the difference between the teachers' expectations and the satisfaction that they really obtained from the offered service.

Table 12. User modelling evaluation scenario

FIRST SCENARIO: USER MODELLING EVALUATION SCENARIO	
OBJETIVES	To verify the proposed user modelling process based on learning style infers the users' learning style in a reasonable way.
ACTOR	Students, who will study freely with the learning objects and learning activities of the course without adaptations. The teacher, who generates the learning design and, who in person, will give a brief virtual introduction to the students about the topics of the course.
RESOURCES	Learning Management System (dotLRN) with standard packages to offer students a learning process. Learning Resources and Learning Activities according to the proposed user modelling process based on learning style.
DESCRIPTION	In this scenario the involved layer is the Interaction Assessment Layer. A course of object Oriented Programming is proposed to the students. The teacher, according to the competence to be achieved by the students, prepares the course structure. The course counts with different learning objects types and activities to address each competence defined for the course. Learning objects are not ordered, the order offered do not consider the preference of the students for the learning objects types; the student freely selects the learning objects that he/she considers important and adequate for his/her learning process. At the beginning of the course the student presents the ILS Test. Through a tracking service, data of the student behaviour in the course are analysed according to the proposed model. The preferences identified by the ILS test results are compared with those provided by the proposed user modelling process. On the other hand, to verify the user modelling process based on the level of competence facilitates the activities of the student in the virtual environment, a particular survey is applied to both teachers and students.

Table 13. IMS-LD Semi-automatic generation evaluation scenario

SECOND SCENARIO: SEMIAUTOMATIC GENERATION OF IMS-LD BASED ON COMPETENCES DEFINITIONS AND LEARNING STYLES	
OBJETIVE	To verify the adaptation based on competence definition supporting the teachers' design task to generate an adapted learning design based on the level of competence of the student. To verify the adaptation based on the user's learning style supporting the teachers' design task to generate an adapted learning design based on the student preferred learning objects types.
ACTORS	Teachers
RESOURCES	Virtual Learning Platform (dotLRN) with special packages needed for the test: Competence package, Learning Object repository, Planning Service. Learning Resources linked to competence definition.
DESCRIPTION	In this scenario the involved layers are *the Adaptation Decision Making Layer* and *the User satisfaction evaluation layer*. The teacher defines the competence of his/her course according to the proposed model. The teacher creates the metadata for each learning resource in the learning platform defining the necessary labels according to the proposed model (*Classification Label, Learning object type*). The teacher manually designs the course learning design using a particular authoring tool. The teacher calls Designer in order to generate the learning design of the course. The course is displayed into the learning management system and after the teacher verifies everything is ok, he/she is able to modify elements of the course. Surveys are provided to obtain feedback from the teacher about three complementary processes: learning and teaching processes specification, semi-automatic learning design generation process, and adaptation process.

Table 14. Contextualized learning objects searching and positioning process scenario

THIRD SCENARIO: CONTEXTUALIZED LEARNING OBJECTS SEARCHING AND POSITIONING PROCESS	
OBJETIVE	To verify if the learning objects searching and positioning processes achieve to contextualize distributed learning objects into the previously generated learning design. To verify that the distributed learning objects from different repositories increase the reuse and the satisfaction of teachers in the learning design process.
ACTORS	Teachers
RESOURCES	Virtual Learning Platform (dotLRN) with special packages needed for the test: Competence package, Learning object repository, Planning Service, ILS Package, LIP Service. Learning Resources linked to competence definition.
DESCRIPTION	In this scenario the involved layers are *the Adaptation Decision Making Layer* and *the User satisfaction evaluation layer*. The teacher defines the competence of his/her course according to the proposed model. The teacher creates the metadata for a set of learning resource in the learning platform defining the necessary labels according with the proposed model (*Classification Label, Learning object type*). Definition of different uncontrolled LOR for the testing. Contextualization of learning objects from distributed and uncontrolled LOR is developed. Contextualization of learning objects from distributed and controlled LOR is developed. The analisys of the data according with the obtained results is developed. Teacher's satisfaction is analized.

3.2.2.2 Preparation of scenarios

Two important issues to be considered when an educational testing scenario is developed are: the definition of the course domain where the testing will take place and the learning objects design.

Object Oriented Programming Course Description

An object oriented programming course introduces students the concepts related to object-oriented programming but emphasizing in the Java language. The Competence to be achieved by the students is:

The student will be able to develop simple programming problems using the object *oriented programming paradigm, by adequately applying the basic concepts associated to this paradigm.*

The competence was divided in different competence elements or learning objectives as is shown in Table 15.

Table 15. POO Course competence elements

COMPETENCE ELEMENT	COMPETENCES KNOWLEDGE	COMPETENCE EVIDENCE
The student knows the main characteristics of the object oriented programming and identifies its advantages and weaknesses (Knowledge Level)	Introduction to the OOP OOP definition and features	Qtis about the different basic concepts
The student understands the principal elements of the object oriented programming paradigm according to (Object, class, encapsulation, inheritance, polymorphism) [20]. (Comprehension Level)	Object Class Encapsulation Inheritance Polymorphism	Qtis about the different basic concepts Programming problems
The student applies the knowledge he/she has about the principal elements of the object oriented programming paradigm for proposing possible solutions to basic problems of the real life using the syntax of the JAVA programming language to implement the proposed solution. (Application Level).	Implementation of Object and Classes in JAVA Implementation of Inheritance using JAVA Implementation of Polymorphism using JAVA JAVA API and Problems	Qtis about the topics
The student applies the knowledge he/she has about the principal elements of the object oriented programming paradigm to propose possible solutions of design to basic problems of the real life using UML. (Analysis Level)	UML Definition UML Models Class Diagram Sequence Diagram Activity Diagram	Qtis about the topics
The student is able to construct solutions for basic problems of the real life using reusable software components (Synthesis Level)	Software Development based on components	Qtis about the topics

After achieving the first three competence elements, the student will be available to apply the main concepts of object-oriented programming using the Java language for solving small real problems. The last two competence elements allow the student to use the Unified Modelling Language as a mechanism to specify the products of the development process.

Learning Objects Design process

In order to attend the neccesities of the proposed user modelling based on learning style, we have developed a set of learning objects to support the learning process in the Object Oriented Programming Course. Each type of learning object has a specific pedagogical intention. This kind of learning objects are exercise, simulations, diagrams, figures, graphs, indexes, slides, tables, narrative texts, experiments, problem statements, lectures, questionnaires, exams and self-assessments. Description of the different kind of learning objects is presented in the following paragrahps.

- Exams or formal assessment

Exams or formal assessments are based on Question and Test Interoperability Specification. They are the tools used for calculating the user competence level. This test was development using the Bloom theory to construct evaluations. Figure 8 shows a view of assessment package upon dotLRN platform user to design this kind of learning objects.

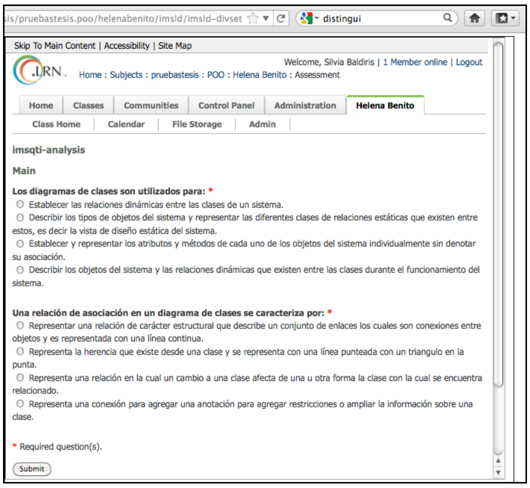
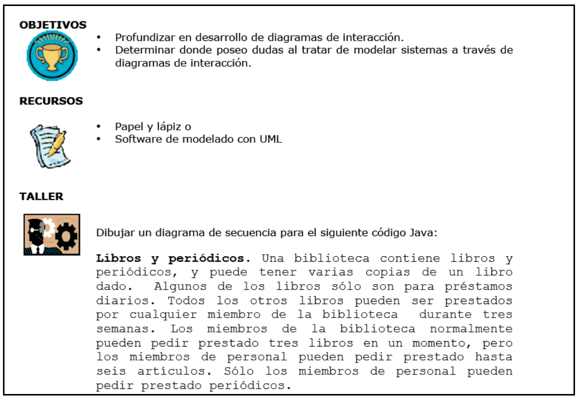


Figure 8. OOP Course Exams or formal assessment

- Exercises

Exercises have been developed with the purpose of promoting an active learning in the student. Some of them could be developed in the virtual learning environment; others, out of the VLE using extra tools as Blue J software. Figure 9 present a particular template created to specify in a homogeneus way the exercices.



OBJETIVOS

- Profundizar en desarrollo de diagramas de interacción.
- Determinar donde poseo dudas al tratar de modelar sistemas a través de diagramas de interacción.

RECURSOS

- Papel y lápiz o
- Software de modelado con UML

TALLER

Dibujar un diagrama de secuencia para el siguiente código Java:

Libros y periódicos. Una biblioteca contiene libros y periódicos, y puede tener varias copias de un libro dado. Algunos de los libros sólo son para préstamos diarios. Todos los otros libros pueden ser prestados por cualquier miembro de la biblioteca durante tres semanas. Los miembros de la biblioteca normalmente pueden pedir prestado tres libros en un momento, pero los miembros de personal pueden pedir prestado hasta seis artículos. Sólo los miembros de personal pueden pedir prestado periódicos.

Figure 9. OOP Course Exercices Template

- Simulations

Simulations allow students to experiment and to test the associated concepts through the analysis of a real situation. They have been developed using flash and action scripts and they are visual in order to address visual students. Figure 10 shows a simulation developed using Adobe Flash to simplify the understanding of UML sequence diagram.

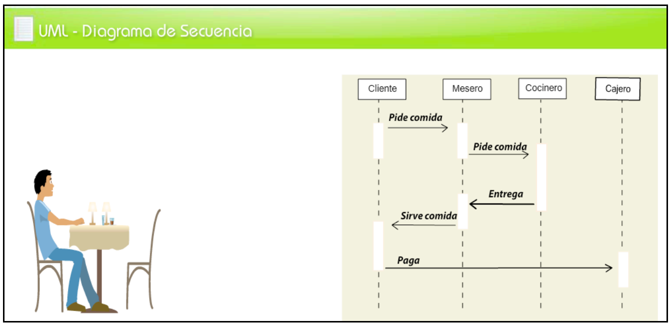


Figure 10. OOP Course Simulations

- Diagrams

Diagrams are graphic schemes to relate new concepts with previous concepts in order to promote significant learning. Figure 11 shows an example of diagram design for the OOP Course.

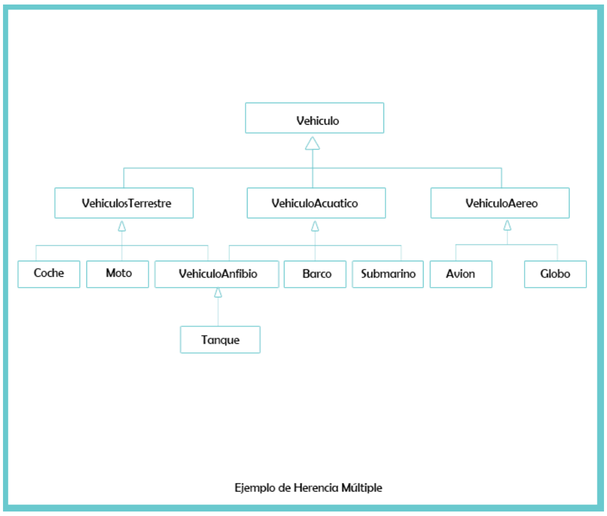


Figure 11. POO Course Diagrams

- Figures

Figures are visually charged images explaining a particular concept and self-contained. Figure 12 present an example of this kind of object that simplifies the understanding of encapsulation concept.

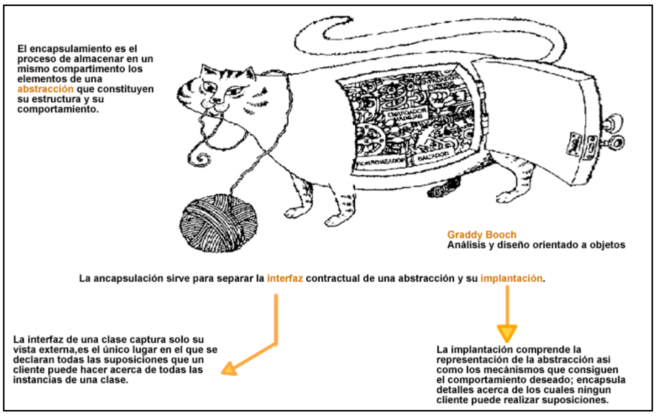


Figure 12. OOP Course Figures

- Graphs

Graphs are developed as concept maps with the purpose to outline the main ideas of the concepts. Figure 13 shows a Graph to simplify the understanding of the concept of object.

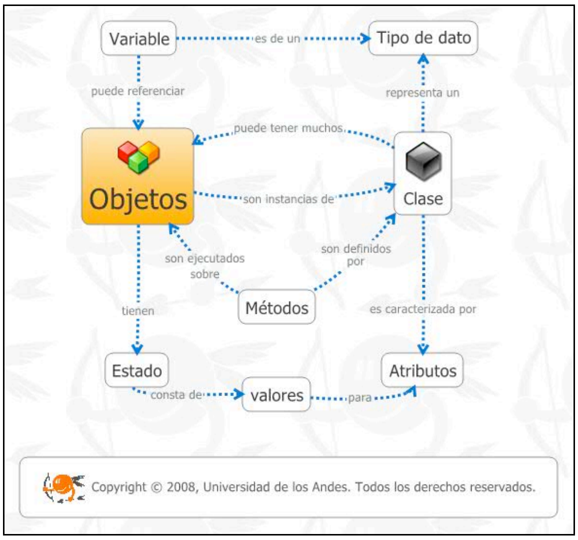


Figure 13. OOP Course Graphs Object

- Slides

Slides show the teachers' point of view about related concepts. Figure 14 shows a slide to simplify the understanding of the concept of UML Model.

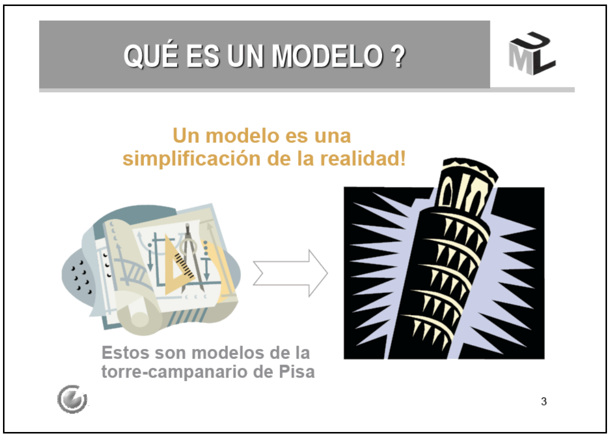


Figure 14. OOP Course Slides

- Narrative texts

Narrative texts are sounds with further explanations and examples related to associated concepts. Figure 15 shows a view of this narrative text. These narratives were recorded in a sound studio and special effects were introduced in the sound to contextualize the student.

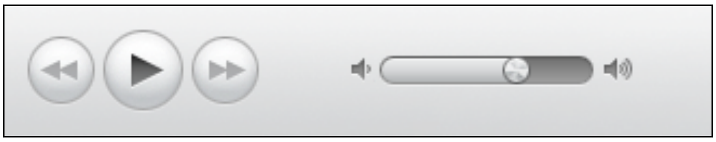


Figure 15. OOP Course Narrative Text

- Problem statements

Problem statements are the description of different practice cases for the specific associated concepts. This kind of objects helps the student to have a real point of view on the course topics. Figure 16 shows an example of an special case of application for a system online to transport ticket sales.

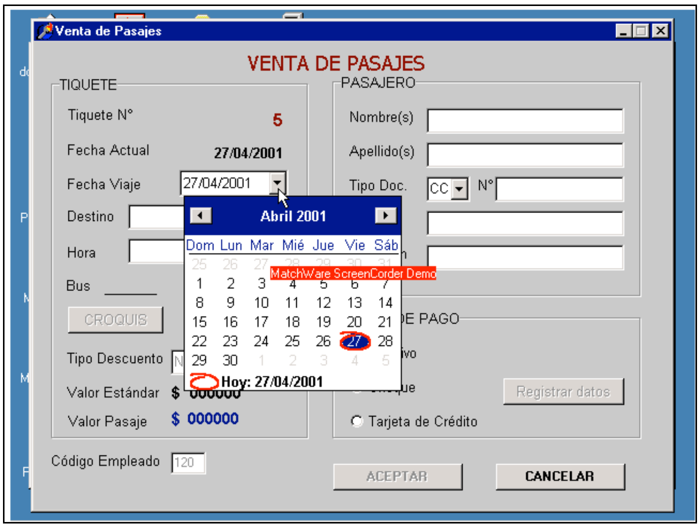


Figure 16. OOP Course Problem Statement

- Lectures

Lectures are documents with textual descriptions of the related concepts. They are detailed documents which allow the students to go in depth deep into the course topics. Figure 17 shows a lecture for easing the understanding of the concept of UML Activity Diagrams.

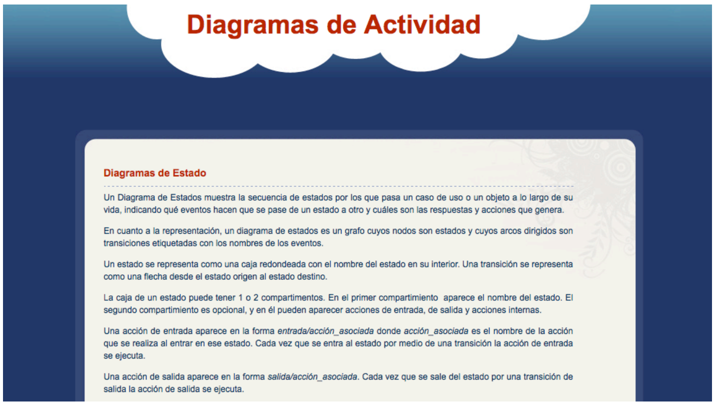


Figure 17. OOP Course Lecture

- Index

Index corresponds to navigation structures. Figure 18 shows the example of the OOP navigation structure.

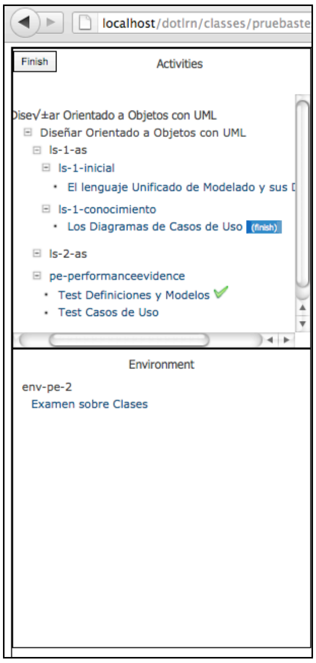


Figure 18. OOP Course Index

- Questionnaires or self-assessments

Questionnaires are tools for informal evaluation processes. These evaluations are not considered as a course summative evaluation. Figure 19 shows an example of self-assessments created as a web page enriched with Java Script.

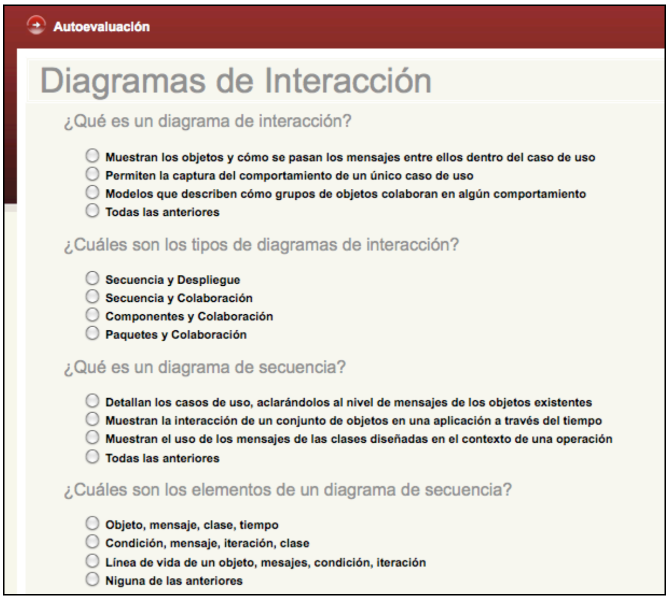


Figure 19. Questionnaires or self-assessments

- Experiments

Experiments are designed with the porpuse to offer students controlled scenarios to prove hypothesis about concepts. Figure 20 shows an example of an experimenting scenario using Blue J Software.

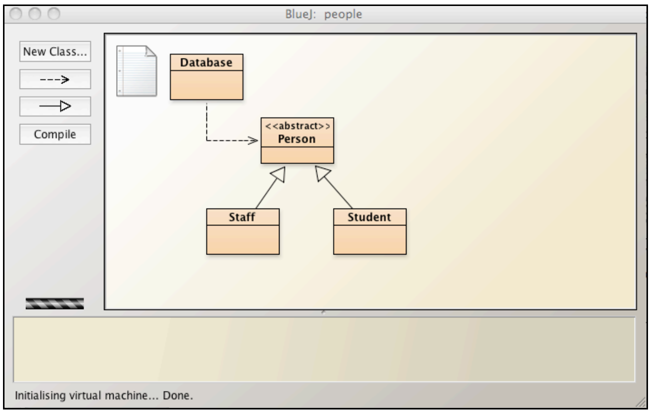


Figure 20. Blue J Controlled scenario for experimenting

3.3. CONCLUSIONS OF THE CHAPTER

In this chapter our framework for semi-automatic learning design generation has been introduced and each component of the framework has been explained.

The introduced framework complexity supposes an adequated evaluation framework which takes into account the most important elements to be considered for evaluating the processes involved. Evaluation framework should include the evaluation of the user modelling process, the generation process and the distributed searching and positioning process. In order to support the evaluation process a modified layered evaluation was described. Three different layers were detailed, The The Interaction Assessment Layer, The Adaptation Decision Making Layer and the User satisfaction evaluation layer.

Finally, scenarios developed to test our proposed solution were introduced and the process of designing learning objects for the scenarios was presented.

As mentioned before, in next chapters we will expand the description of three process which are the core elements in our framework: the User Modelling Process based on Learning Style, the Learning Design Generation Process and the Contextualized Learning Objects Searching and Positioning Process. These processes involve the others mentioned in the framework.

4. USER MODELING BASED ON LEARNING STYLE

Our intention in this chapter is to introduce our solution of a static and dynamic user modelling based on learning styles (LS) to enrich and support the automatic generation of an adaptive IMS learning design (LD) in order to reduce the amount of time and efforts for teachers providing learners with personalized learning experiences.

The analysis of the state of the art provides us with important conclusions and scientifically validated data in order to propose:

- A static user model based on learning style and a decision process based on teachers opinions, which support the delivery of learning object types according to the user's preference.
- A dynamic user modelling process based on the analysis of user's behaviours to support the decision about if the user preference regarding learning objects types has changed over the time.

The rest of the user modelling chapter is structured as follows. In section 4.1. the static user modelling based on learning style is introduced as well as the detail about how this model supports the definition of the students preferences for different learning object types. Section 4.2. describes our dynamic user modelling process and its evaluation. Finally, in section 4.3. some conclusions are introduced.

4.1. PREFERED LEARNING OBJECT TYPE ORDER ACCORDING TO LEARNING STYLE BASED ON TEACHER OPINIONS

4.1.1 Description

Our hypothesis aims to address the user preference in a learning management system, in particular, learning style could be a positive factor to improve learning and the student's satisfaction [4] and [20].

The static approach, published in [106] and [107] proposes the establishment of a relation among the different dimensions of the Felder´s learning style and the different IMS-MD learning objects types to be delivered to students.

The learning style characterize the cognitive, affective and physiological traits which serve as relatively stable indicators about how learners perceive, interact and respond in their learning environments [16].

Felder, in [108], defines the learning style as the strengths characteristic and preferences in the manner people take in and process information, and determines the unique way of learning for each student.

The main reason to choose Felder's Model among the different Learning Style Models in educational research was that Felder's model is one of the most studied models in the technology enhance learning research area. This means Felder's model has one of the biggest scientifically validated data sets about the correlation between the user's behaviours with respect to the dimensions considered in the model. The use of Felder's model permits us to clearly define how and to what extent a type of learning object addresses a particular user learning style.

4.1.2 Static user model based on Felder and Silverman's Learning Style Theory

Felder and Silverman define several dimensions regarding how people process information, and each dimension has two possible values:

- Processing: Active/Reflective
- Perception: Sensory/Intuitive
- Input: Visual/Verbal
- Understanding: Sequential/Global
- Organization: Inductive/Deductive

Organization dimension was removed from Felder Learning Styles Inventory for pedagogical reasons; it is not justified to continue using the traditional deductive instructional paradigm. Table 16 provides a description of each one of these styles.

Overall, for each dimension, people tend to show a preferred behaviour. For example, in the processing dimension a person can be sometimes active and sometimes the contrary, reflective, but frequently a preference (strong or moderate) exists for one category or the other. Most people are *visual* and *sequential* learners [109], [110], [111].

However, a balance of the two values for each dimension and to be able to perform actions in both directions is desirable. In any case, when a preference for one category is strong, the learning process could improve its effectiveness with an instruction adapted to this learning style.

Table 16. Learners' behaviour according to learning style

DIMENSION	STYLE	DESCRIPTION
PROCESSING	ACTIVE	Tend to do best when they can work hands on and actually conduct experiments or manipulate things manually
	REFLECTIVE	Prefer to think things through before they act
PERCEPTION	SENSORY	Gravitate towards concrete facts and figures
	INTUITIVE	Prefer the conceptual and the theoretical to the concrete
INPUT	VISUAL	Prefer to see what they are learning through graphs, diagrams and pictures
	VERBAL	Are most successful when information is heard or read through words
UNDERSTANDING	SEQUENTIAL	Prefer to have information laid out in a linear and orderly fashion.
	GLOBAL	Prefer to see the big picture first

We obtained the students learning style by collecting data directly from the learner using the Index of Learning Styles questionnaire, developed by Felder and Soloman [112]. The objective of this questionnaire is to establish the dominant learning style of each student. The questionnaire is formed by 44 questions. For each of the abovementioned four dimensions there are 11 questions (unordered distributed into the form) about how everyone perceives her/himself, and her/his behaviour. Each question has two possible answers, each one defining a different value in the dimension. Figure 21 presents a scale for representing the possible results of the questionnaire for each one of the dimensions. Taking into account the learner's answers in the context of one dimension, the learner could be situated on one extreme of the scale (when the learner has answered all questions on the same style, the result is 11a or 11b, being *a* and *b* the style of this dimension), or she/he could be on an intermediate zone (1a or 1b). As an example, a result 3a indicates that from the 11 questions, the learner has answered 7 of them on one dimension side and the other 4 questions she/he answered b in the other dimension side.

In order to facilitate the learning styles processing, the six different quantitative values possible for each style (11, 9, 7, 5, 3, 1) are grouped using three qualitative modifiers (strong, moderated, balanced), also named clusters.

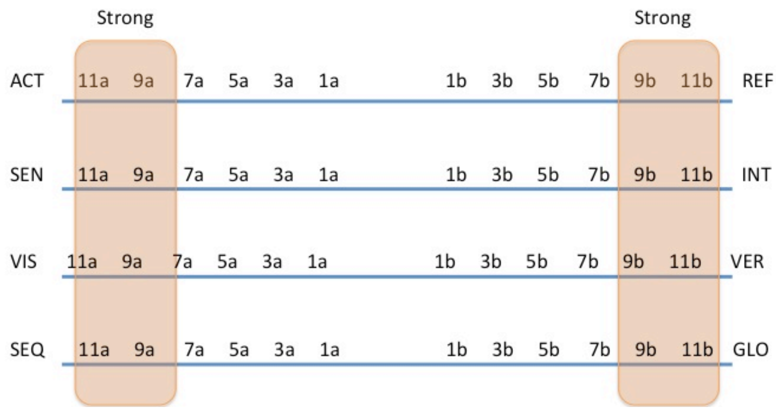


Figure 21. Strong Cluster in the four dimensions of Felder's Learning Styles

The *strong* cluster relates to the extreme values of this scale. This cluster will be the most relevant for adapting the instruction to this dominant style. As an example, Table 17 shows how the clusters are assigned to the Perception dimension, where *a* and *b* have been substituted by sensitive (s) and intuitive (i), respectively.

Table 17. Clusters for Felder's Learning Styles (Perception dimension)

CLUSTER	VALUES	STYLE DESCRIPTION
Balanced	1s, 3s / -3i, -1i	Sensitive / Intuitive
Moderated	5s, 7s / -7i, -5i	Sensitive / Intuitive
Strong	9s, 11s / -9i, -11i	Sensitive / Intuitive

We are using the Index of Learning Style developed upon dotLRN for inferring the user learning style. Figure 22 shows a view of this package.

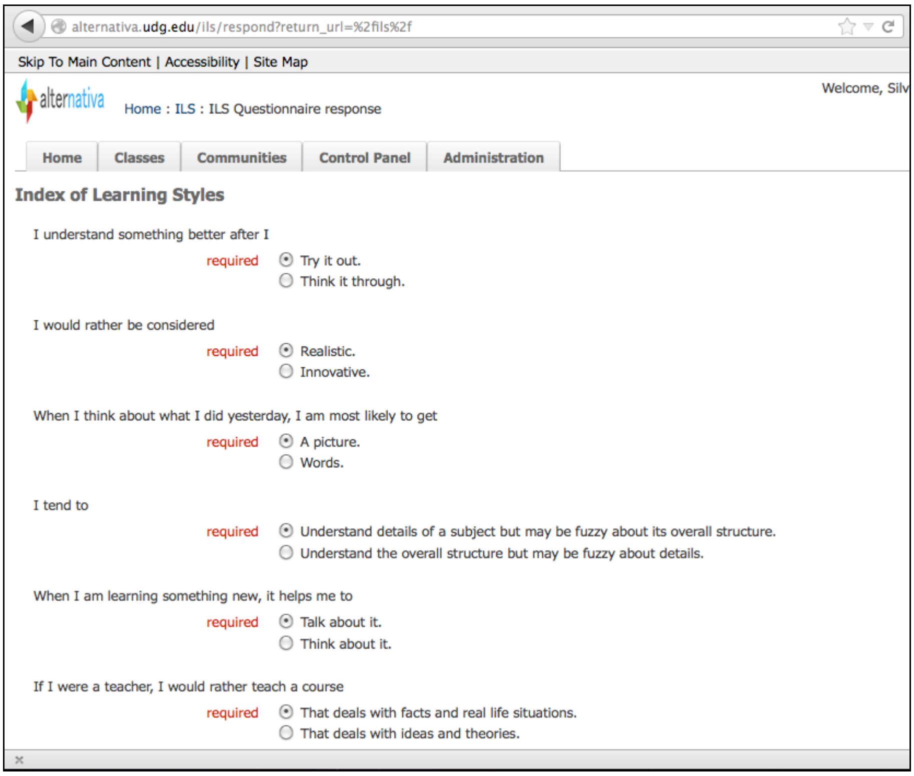


Figure 22. ILS Package upon dotLRN

As a summary, in the Table 18, we introduce different types of learning styles considered in our analysis. For our analysis we consider the tendency in the student style, i.e the student could be visual or verbal or the student could be active or reflexive.

In Table 18 rows indicate each possible learning style and the columns each Felder's dimension. Possible values of the columns are 1 or 0 for each dimension, e.i Visual = 1 and Verbal = 0 and all possible combinations. In this way we considered sixteen different learning styles.

Table 18. Learning Styles

LEARNING STYLE	ENTRY	UNDERSTANDING	PROCESSING	PERCEPTION
	VISUAL/VERBAL	SEQUENTIAL/GLOBAL	ACTIVE/ REFLEXIVE	SENSITIVE/INTUITIVE
1	1	1	1	1
2	1	1	1	0
3	1	1	0	1
4	1	1	0	0
5	1	0	1	1
6	1	0	1	0
7	1	0	0	1
8	1	0	0	0
9	0	1	1	1
10	0	1	1	0
11	0	1	0	1
12	0	1	0	0
13	0	0	1	1
14	0	0	1	0
15	0	0	0	1
16	0	0	0	0

4.1.3 First proposal for defining Preferred Learning Object Types Order

4.1.3.1 Description

We model the problem of delivering the learning objects as a Classification task [113] according to the following premises: 1) Relating each attribute associated to the style to the degree of preference of a resource type and creating a specific attribute to represent a quantitative measurement of the existing relation between the learning style and the learning objects types are both possible; 2) Defining the student learning style preference as a set of six attributes is also possible.

The first issue to address is how to define a relationship between each Felder's dimensions and the different learning object types. In order to address this issue, we select a sample of teachers, who rated learning object types according to their opinion about how these learning object types address the preference of each particular learning style. The criteria to select the sample was the convenience [114], referred to case selection based in the easiest access according to certain conditions or random coincidences. The rating was defined using the scale shown in Table 19.

Table 19. Measure Scale of Preference

PREFERENCE MEASURE	DESCRIPTION
INDIFFERENT (I)	The student does not value that the teacher presents this resource type, because he/she feels the resource type is not needed or does not contribute in his/her learning process.
GOOD (G)	The student likes this resource type as much as others resource types, he/she appreciates that the teacher presents them and he/she thinks that he/she can achieve his/her learning goals. However he/she does not prefer them specifically.
VERY GOOD (VG)	The student love to learn with this resource type and he/she prefers this resource type more than other types. In fact, when the student is learning, she likes to begin analyzing the thematic proposed in these resource types, this means that he/she considers very important that the teacher takes into account this resource type.

The results based in the responses of 3 teachers are shown in Table 20.

Table 20. Experts opinions about relation among LO types and Felder's dimensions

RESOURCE TYPES	LEARNING STYLES							
	PROCESSING		PERCEPTION		UNDERSTANDING		INPUT	
	ACTIVE	REFLECTIVE	INTUITIVE	SENSORY	SEQUENTIAL	GLOBAL	VISUAL	VERBAL
EXERCISE	G	G	VG	G	G	I	G	VG
SIMULATION	VG	I	I	VG	I	G	VG	I
QUESTIONNAIRE	G	I	I	I	G	I	I	I
DIAGRAM	I	G	G	G	G	VG	VG	I
FIGURE	I	G	G	G	G	VG	VG	I
GRAPH	I	G	G	G	G	VG	VG	I
INDEX	I	I	I	I	G	VG	I	G
SLIDE	I	G	G	G	G	VG	VG	G
TABLE	I	I	I	G	G	G	G	G
NARRATIVE TEXT	G	VG	VG	I	I	I	I	VG
EXAM	G	I	I	I	G	I	I	I
EXPERIMENT	VG	G	G	VG	G	I	VG	I
PROBLEM STATEMENT	VG	G	G	VG	I	I	G	VG
SELF ASSESSMENT	G	I	I	I	G	I	I	I
LECTURE	I	VG	VG	I	I	I	I	VG

The second issue to address is which attributes are necessary to define a classification task in order to model students' preferences. The selected attributes for the classification task are described in Table 21.

Table 21. Classification task attributes

ATTRIBUTES	
1. PROCESSING	1. Active
	2. Reflective
2. PERCEPTION	1. Sensory
	2. Intuitive
3. INPUT	1. Visual
	2. Verbal
4. UNDERSTANDING	1. Sequential
	2. Global
5. RESOURCE_TYPE	Exercise, Simulation, Questionnaire, Diagram, Figure, Graph, Index, Slide, Table, Narrative_text, Exam, Experiment, Problem_statement, Self_assessment, Lecture.
6. RELATION_RT_LS (CLASS)	Indiferent, Good, Very_Good

The first 4 attributes correspond to each dimension of the learning styles, and the fifth attribute corresponds to the resource types. *The class* indicates the values that must be learned by the algorithm, which is represented by the Relation_RT_LS attribute, i.e. the quantitative measure of the relationship between resource types and learning styles provide by teachers. Table 22 shows a training example model.

Table 22. Training example

COMPLETE LEARNING STYLE	RESOURCE	RELATION_RT_LS (CLASS)
Active, Intuitive, Global, Verbal	Exercise	Good

For each training example, the class was measured considering the Table 20, and assigning a quantitative value to teachers' opinion in the following manner:

1. Indifferent a value of 0.
2. Good a value of 1.
3. Very Good a value of 2.

Table 23 shows how a training example was built according to these values. This example corresponds to: "a user with learning style: (*Active, Intuitive, Global and Verbal)* has a preference over the *Exercise* LOM type of *Good*".

The class resulting (Relation_RT_LS) was obtained calculating: (1 + 2 + 0 + 1) / 4 = 1,25, which approximates to 1, corresponding to the value "Good". It means that the class for this training sample is Good as is shown in Table 22.

Table 23. Building a training example

RESOURCE TYPE	PROCESSING	PERCEPTION	INPUT	UNDERSTANDING	VALUE	RELATION _RT_LS (CLASS)
	ACTIVE	INTUITIVE	GLOBAL	VERBAL		
EXERCISE	G = 1	VG = 2	I = 0	VG = 2	1,25	Good

Having structured training examples, we proceeded to select the most suitable learning algorithm; we tested the classification algorithms ID3, C4.5 (J48 in WEKA) and Cart (SimpleCart) using the Weka workbench of data mining algorithms [115].

For testing, we constructed several data sources in order to observe the behaviour of the algorithms with different groups of data, and thus, to make a better decision on the selected algorithm. Two different primary sources, teachers and students provided the data. Both types of information were used to generate training examples to support the classification algorithm.

Teachers' opinions are represented as described in Table 20. The Students opinion were captured through a specific survey where we asked them how they measured each learning objects type addressing their learning style, using the same scale that was provided to the teachers.

4.1.3.2 Evaluation

Table 24 summarizes the information about the data sources used to train the algorithms obtained from the available information.

Table 24. Data sources used to evaluate learning algorithms.

DATA SOURCES	TRAINING EXAMPLES
Source 1. Teachers	240
Source 2. Students course 1	135
Source 3. Students course 2	60
Source 4. Students course 1 and 2	195
Source 5. Teachers + Students course 1	375
Source 6. Teachers + Students course 1 and 2	435

To validate the classification algorithm, a cross-validation technique was used, varying M between 5 and 10 in order to obtain groups with a representative number of examples for training and testing the algorithm. In Table 25, the results for source 1, 2 and 3 with M = 10 are presented. For each source and for each algorithm, Table 25 shows the percentage of instance correctly classified (%CC) and the classification precision (%P) as well as the neccesary time to develop the classification.

Table 25. Study for the data sources of teachers and students.

ALGORITHM	SOURCE 1			SOURCE 2			SOURCE 3		
	%CC	%P	T	%CC	%P	T	%CC	%P	T
ID3	86.25	79.4	0	39.3	36.2	0	58.3	34	0
C4.5	*92.08*	92.6	0	49.6	52.5	0	63.3	64	0
CART	85.83	82.8	0.09	*64.4*	64.1	0.05	*71.7*	71.1	0.05

In Table 25, the algorithm C4.5 has the best behaviour for the data Source 1, while for the cases of data Source 2 and Source 3, corresponding to the data provided by students, the best behaviour was obtained using the Cart algorithm, at the expense of using a high processing time for the number of training examples. We also obtained that the precision of the Sources 2 and 3 is considerably less than that of Source 1. This may be due to two reasons: first, few training data (Source 1 = 135 & Source 2 = 60) has being considered and, second, diversity of learning styles was not available in the courses, due to the reduced number of evaluated students.

Table 26 presents the results of the Sources 4, 5 and 6, corresponding to the combination of courses 1 and 2, and the combination of student data with teacher data. With this combination of the data we want to represent a scenario closer to reality. The idea is that training examples will be increased when students interact with the LMS, and in this manner, the model will improve, creating an accurate profile of each preference for a resource type in accordance with the student's learning style.

Table 26. Study for the union of the data sources of teachers and students.

ALGORITHM	SOURCE 4			SOURCE 5			SOURCE 6		
	%CC	%P	T	%CC	%P	T	%CC	%P	T
ID3	44.1	43.1	0	53.8	53.3	0	45.7	46.2	0.02
C4.5	45.13	46.1	0	63.7	58	0	59.3	55.1	0
CART	61.54	61.7	0.09	66.7	62.6	0.17	63.44	63.2	0.31

The data sources used in Table 26 show that the algorithm Cart presents the best behaviour in the number of examples correctly classified (%CC) and the precision (%P), followed closely by the C4.5 algorithm, with very similar results in these two items (%CC y %P). The difference between the two algorithms is in the processing time, the algorithm Cart in all cases (Table 25 and Table 26) shows a rather large delay compared to the C4.5 algorithm. In Figure 23, we also present the confusion matrices for Sources 1, 5 and 6 together with the classification error obtained for each source. The main objective of the confusion matrices is to make easier to observe if the classifiers are not consfusing the clasess.

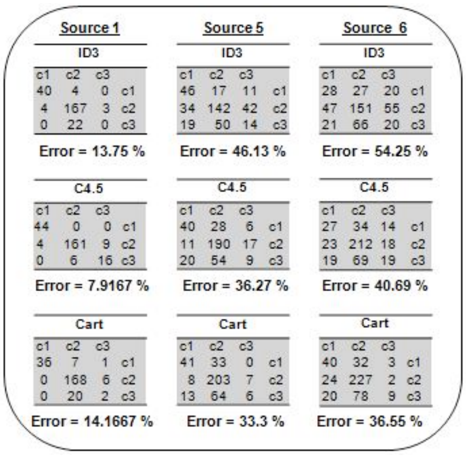


Figure 23. Confusion matrices for the classification models

In Figure 23 the classification errors are high for Sources 5 and 6. This was expected; if there are more real and varied cases that allow the algorithms to improve their learning, those errors will decrease and, therefore, the reliability in models will be increased.

Data were also evaluated with combinatorial methods such as bagging, boosting and stacking, but there was no success on the obtained an improved model. In addition, the processing time is greatly increased by using these methods. When the number of training examples is not large, with these methods is less probable to obtain the desired results. Table 27 provides an overview of the obtained results by using the bagging method for Sources 1, 5 and 6.

Table 27. Percentages applying the Assembly Bagging method.

BAGGING +	SOURCE 1			SOURCE 5			SOURCE 6		
	%CCI	%P	T	%CCI	%P	T	CCI	P	T
ID3	86.3	81.6	0.02	55.2	54.7	0.05	49.2	49	0.05
C4.5	*89.6*	89.8	0.02	62.4	57.7	0.02	57.7	53.8	0.03
CART	87.1	80.1	0.84	67.5	62.2	1.69	62.5	57.5	

The results showed that the C4.5 classification model presents a much better general behaviour than the other two algorithms and combined methods. Tests show that C4.5 has a good predictive capacity and small processing time; therefore, this algorithm was defined to be used in order to obtain the user's preference.

The decision model generated by the classification algorithms is a decision tree, which supports the task of defining the order in which resource types are presented to the student according to their learning style. An example of the generated decision tree is shown in Figure 1.

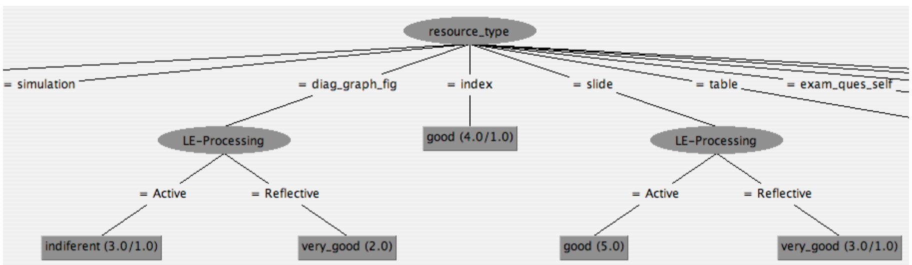


Figure 24. Example of a generated decision tree.

The order can be generated crossing the branches of the generated decision tree. In this manner, in the first instance the resources of the class "very_good" are displayed, then the resources of the class "good" and, finally, the resources of the class "indifferent".

An example of the result generated for analysing the decision tree is presented in Table 28.

Table 28. Example of the generated order

LEARNING PROFILE: ACTIVE, SENSITIVE, GLOBAL, VERBAL	
RESOURCE TYPES	**MEASURE**
Exercise	VG
Simulation	VG
Questionnaire	I
Diagram	G
Figure	G
Graph	G
Index	VG
Slide	VG
Table	G
Narrative Text	VG
Exam	I
Experiment	G
Problem Statement	VG
Self Assessment	I
Lecture	VG

In order to evaluate our static approach in a real context, we develop an experiment within the course “Educational Research” of the Pedagogical bachelor’s degree of the University of Girona. This course has 6 ECTS (credits in the European framework of higher education), 3 theoretical and 3 practical credits. Course was developed during the second term of the year 2010. This subject is mandatory in order to obtain the Bachelor's degree.

We asked for some feedback from the students related to their preferences on the different possible learning object types in order to compare both results to check if there were any correlations among students opinion and the generated order by the classification task. So, they were asked to fill in a questionnaire related to their preferences on the different learning object types, specifying if the level was very good, good or indifferent. Then, we associated the responses obtained in the questionnaire to the previously computed learning styles.

We compare the categorization generated by the decision tree about the order preferred by each learning style with the ones obtained from the questionnaire given to the students to get their opinion about their preferences to see if there was any correlation calculated using the Pearson coefficient [116]. We obtained a positive but not significant correlation between the students' opinions and the results of the system. The results indicate that the categorization produced by the system is somewhat similar to the way the students like to receive the learning resource type. The absence of significance could be due to the small number of students in the statistical sample.

The result of the First Study Description permits us to conclude some important ideas summarizes as follow:

1. The Classification task is a good approach to generate the preferred order of students about the learning object types in the context of learning design.
2. The C4.5 classification model shows the best behaviour with respect to other algorithms.
3. The scale used to define the order to deliver the learning object types must be refined because of the number of them. A limited scale of three possible values increases the uncertainty in the generated order.
4. The validation of our approach in the real context with a larger number of users is necessary.

4.1.4 Improving Preferred Learning Object Types Order

4.1.4.1 Description

According to the conclusions of the evaluation developed for our first proposal, we defined some points for improvement:

1. A redefinition of the scale used to categorise the learning object type,
2. The development of study with a larger sample of teachers applying the new scale for classification, and
3. A modification of our classification task. With these tasks we pretend to improve the order generated for the decision mechanism.

The first task to consider is a modification of our first scale of three values in order to improve the generated order making it more discriminatory.

The result of the revision of the scale is shown in Table 29. A scale of nine values permits to classify more accurately the order of the learning object types. The decision was taken considering the number of different learning objects types.

Table 29. New Scale for measuring preference based on learning style

NEW SCALE	VERY GOOD			GOOD			INDIFFERENT		
	VG3	VG2	VG1	G3	G2	G1	I3	I2	I1
	9	8	7	6	5	4	3	2	1

The second task aims to improve the data sets according to the new scale. For addressing this issue, we developed a study in some universities from South America and Europe to capture the teacher's opinion about the preferences of their students for the different possible learning object types.

This study was developed with 30 teachers from different knowledge areas such as engineering, pedagogy, medicine, etc. Data about the population is shown in Table 30.

Table 30. South America and Europe Study

POPULATION FEATURES	
Nº OF USERS	30
DISTRIBUTION IN GENDER (M/F)	13 Male (40%)
	17 Female (60%)
AGE RANGE	25-60 years old
Nº PROFESSORS	30 Teachers
EXPERIENCE DURATION	8 hours
TYPE	Taller
KNOWLEDGE AREAS	Humanities – 60%
	Engineers – 40%

LEARNING STYLE DISTRIBUTION		
DIMENSION	QUANTITY	%
ACTIVE	18	60
REFLECTIVE	12	40
SENSING	19	63,33
INTUITIVE	11	36,66
VISUAL	25	83,33
VERBAL	5	16,66
SEQUENTIAL	14	46,66
GLOBAL	16	53,33

Figure 25 shows the learning style distribution of the population. According to the results, the group trend is to be *Active, Sensing, Visual and Global*. However, the most differenced trend was identified in the *Entry dimension* where 80 % of teachers were visual.

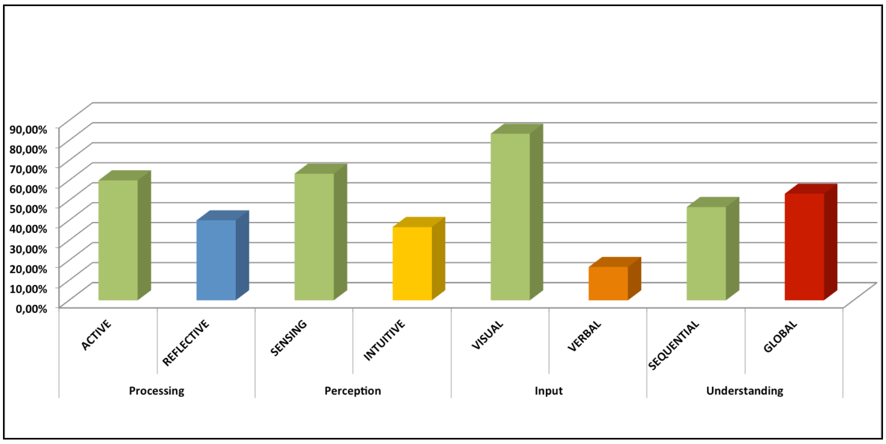


Figure 25. Population Graphical Condensed Learning Styles

Table 31 shows the analysis according to the two larger knowledge areas, Humanities and Engineering.

Table 31. Humanities and Engineering Teachers Learning Styles

HUMANITIES TEACHERS				ENGINEERING TEACHERS		
NO TEACHERS	18			NO TEACHERS	12	
DIMENSION	QUANTITY	%		DIMENSION	QUANTITY	%
ACTIVE	11	39		ACTIVE	7	41,66
REFLECTIVE	7	61,11		REFLECTIVE	5	58,33
SENSING	13	27,77		SENSING	6	50
INTUITIVE	5	72,22		INTUITIVE	6	50
VISUAL	13	27,77		VISUAL	12	0
VERBAL	5	72,22		VERBAL	0	100
SEQUENTIAL	8	55,55		SEQUENTIAL	6	50
GLOBAL	10	44,44		GLOBAL	6	50

The results for the analysed population are in accordance with other associated research, which concludes that engineers are more visual than humanists.

The humanities teachers' tendency to the reflective dimension was expected as well as their verbal tendency. The tendency of humanities teachers to be intuitive can be also highlighted. Figure 26 resumes the conclusions.

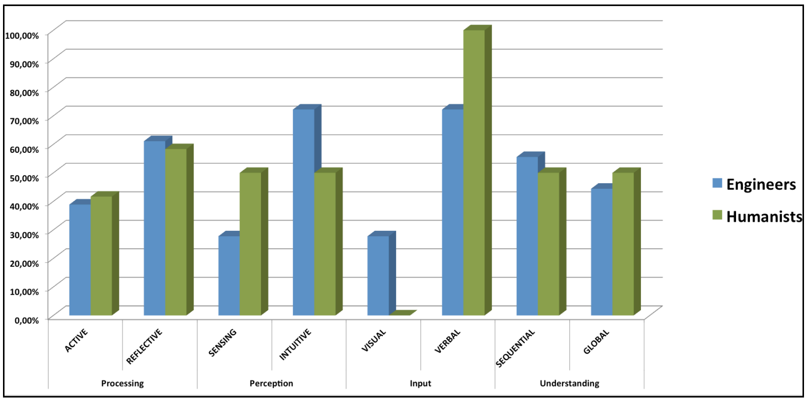


Figure 26. Humanities and Engineering Teachers Learning Styles

Table 32 shows an example of the rating provided by each teacher about the students preference based on the learning style according to the new proposed scale.

Table 32. Rating with the new scale to relate student preferences for the different possible learning object types

	PROCESSING		PERCEPTION		UNDERSTANDING		ENTRY	
	ACTIVE	REFLECTIVE	INTUITIVE	SENSORY	SEQUENTIAL	GLOBAL	VISUAL	VERBAL
EXERCISES	8	7	6	9	8	7	7	8
SIMULATIONS	6	8	7	8	5	5	8	5
QUESTIONNAIRES	5	7	6	6	6	6	5	7
DIAGRAMS	7	7	8	6	8	7	9	6
FIGURES	7	7	7	6	8	7	9	6
GRAPHS	7	7	9	7	6	8	9	6
TABLE OF CONTENTS	6	9	6	8	9	7	6	8
SLIDES	7	9	7	9	9	6	7	9
TABLES	6	8	6	9	7	8	7	7
NARRATIVE TEXT	7	8	6	9	8	5	6	9
EXAMS	6	8	5	7	7	6	6	6
EXPERIMENTS	9	6	8	7	6	8	6	6
STATEMENT	7	9	7	7	9	6	6	8
SELF-ASSESSMENT	5	8	6	6	5	5	5	6
LECTURES	9	8	7	8	8	7	5	8

The third task permits us to focus in redefining the classification task as shown in Table 33.

Table 33. New classification task

LEARNING OBJECT TYPE	INITIAL COMPLETE LEARNING STYLE				LEARNING STYLE PREFERENCE FOR LO TYPES IN EACH FELDER'S DIMENSION				CATEGORICAL PREFERENCE
	EN	UN	PR	PE	P-EN	P-UN	P-PR	P-PE	< I1, I2, I3, G1, G2, G3 VG1, VG2, VG3 >
SIMULATION	1	1	1	1	7	1	7	2	G

Table 33 shows the following attributes:

- Learning Object Type, different types of learning objects included in the analysis.

- Complete Learning Style, Felder's learning style focused in the dominant dimension.
- Learning Style preference of LO in each Felder's Dimension, initial weight of preference according with teachers' opinions, this weight change over the time according to the user modelling process.
- Categorical Preference, three level preference categorization.
- Preferences Weight, average of the weight of preference describe before.

4.1.4.2 Evaluation

With the available data, we built a data set with 18.140 instances according to the abovementioned scheme. This data set was generated through the captured teachers' opinions. For testing, we used the same algorithms, Cart, ID 3 and ID 4.5.

The results presented in Table 34, Table 35 and Table 36 show an increase in the precision of the classification algorithms, which permits a better-generated and more discriminatory order.

Table 34. Cart Algorithm Results

Cart				Correctly Classified Instances 17530 96.61 % Incorrectly Classified Instances 614 3.38 %
	I1, I2, I3	G1, G2, G3	VG1, VG2, VG3	
	7007	157	0	
	138	8723	145	
	0	174	1800	
Precision	0.981	0.963	0.925	
Recall	0.978	0.969	0.912	

Table 35. ID3 Algorithm Results

ID3				Correctly Classified Instances 17307 95.3869 % Incorrectly Classified Instances 108 0.5952 %
	I1, I2, I3	G1, G2, G3	VG1, VG2, VG3	
	7035	15	0	
	22	8530	24	
	0	47	1742	
Precision	0.997	0.993	0.986	
Recall	0.998	0.995	0.974	

Table 36. C4.5 Algorithms Results

C4.5				Correctly Classified Instances 17017 93.78 % Incorrectly Classified Instances 1127 6.21 %
	I1, I2, I3	G1, G2, G3	VG1, VG2, VG3	
	6850	314	0	
	307	8602	97	
	0	409	1565	
Precision	0.957	0.922	0.942	
Recall	0.956	0.955	0.793	

Cart algorithms present the best performance in classification, but in the E-learning context response time is a critical issue. This is a reason to select the C4.5 algorithms which also present a good performance in classification.

4.1.4.3 User modelling process implementation based on multi-agent system

As mentioned before, the adaptation decision consists of crossing across the decision tree generated, to obtain the desired result: the order of the resources according to the user preferences.

In order to implement this adaptation decision, the used technology was a multi-agent system. To develop this multi-agent system, the software of Agent Academy [117] based on the agents development over JADE (Java Agents Development Environment) [118] and the WEKA system [115] was used.

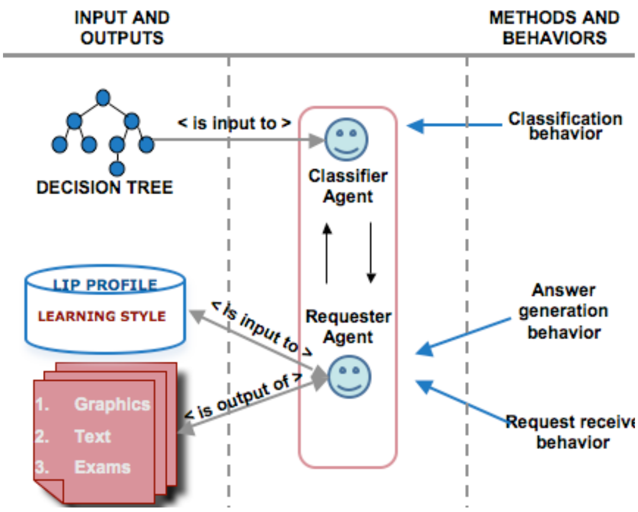


Figure 27. Adaptation model for delivering learning objects ordered according to LS

Figure 27 shows our Multi Agent system (MAS) proposed for implementing the decision mechanism described before. As shown in Figure 27, the MAS consist of two types of intelligent agents:

4. The “classifier agent” that has a *classification behaviour* assigned is responsible of obtaining the decision tree generated by the C4.5 algorithm (or the selected algorithm) in Weka and of delivering an adaptation decision or preferred order of the learning object types according to the learning style of the user.
5. The “requester agent” has two behaviours assigned: 1) to request the learner learning style stored in a database to send it to the “classifier agent” in order to obtain the adaptation decision, 2) to generate the response with the resources order that will be displayed in the LMS.

The main reason for developing a MAS in order to implement the proposed decision mechanism was to ease the communication among weka and the dotLRN. The integration between the MAS and the LMS is illustrated in the model of Figure 28.

The model is conformed by two groups of elements, the first (on the left), which refers to the components of the LMS and the interaction of the user with dotLRN platform and the second (on the right), the group with the components of the MAS that will be integrated with dotLRN using a JAVA web server.

The integration was developed using the XML-RPC protocol through the implementation of a XML-RPC client and server. This protocol allows the exchange of messages through remote calls between heterogeneous systems. In our case, the integration of two systems developed with different technologies, dotLRN platform (TLC) and the MAS (Java). The XML-RPC Client was implemented upon dotLRN and is responsible for requesting a particular service to the XML-RPC server, which was modelled as a web application upon an apache server.

The server receives the request and responds appropriately according to the parameters provided in the request (particular learning style or a list of learning styles). The responses are performed with the appropriate learning object type order for each learning style. The response could be delivered as an xml preference file or as a particular data structure such as a list. The response could be sent directly to dotLRN or placed in a particular location on the server.

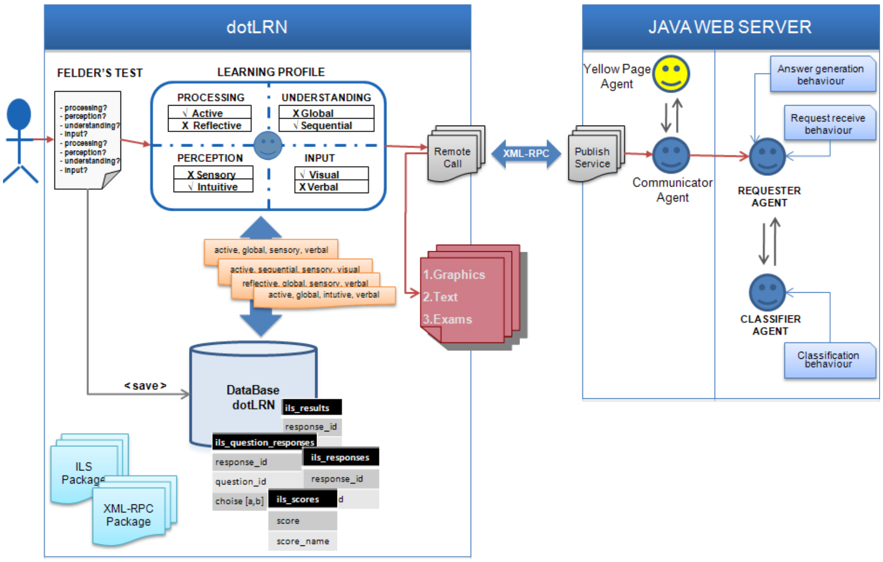


Figure 28. Integration model of the MAS and dotLRN

4.1.4.4 Implementation Results

The adaptation results are reflected in dotLRN through an Unit of Learning (UoL) developed for different courses following guidelines of the IMS-LD learning specification [6].

In this UoL, the user received learning objects in the environments ordered according with his/her learning style. However, the explanation of the design generation process is beyond the scope of this section. Figure 29 and Figure 30 show the results of the generated order.

Figure 29 shows an example of UoL delivered to students with learning style (Active/Intuitive/Sequential/Visual). UoL for this learning style favors resource as exercices, simulations and diagrams preferred for users with this learning style. On the other hand Figure 30 show an example of UoL delivered to students with learning style (Active/Intuitive/Sequential/Verbal). The UoL for this learning style favors resources as lectures but also experiments, problem statemens preferred for users with this learning style.

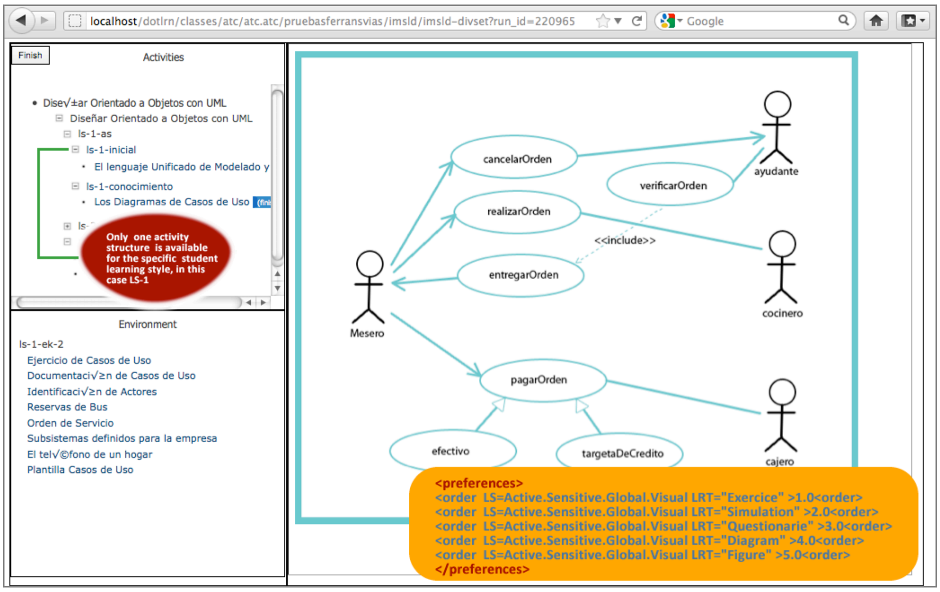


Figure 29. Unit of Learning for the Unified Modelling Language Course

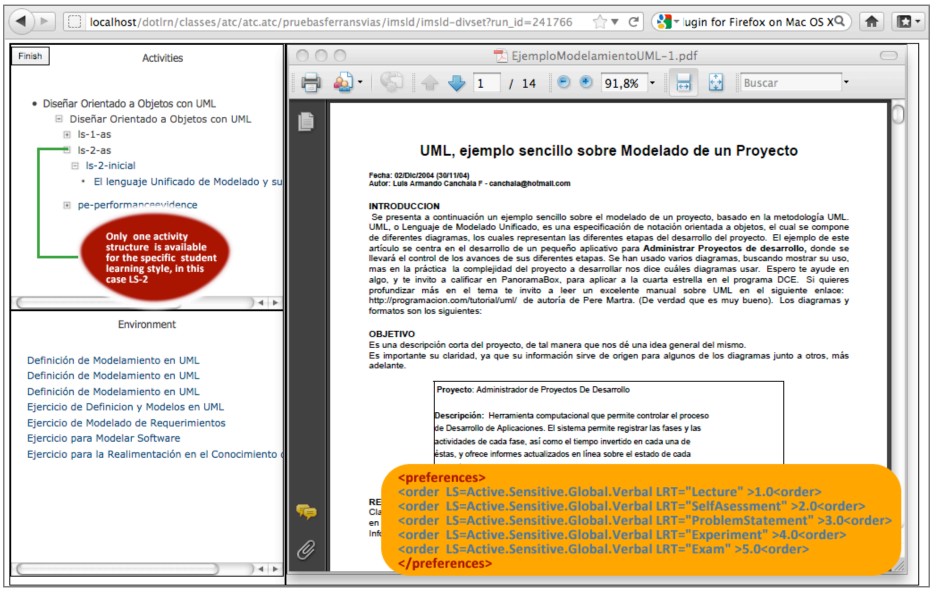


Figure 30. Unit of Learning for the Unified Modelling Language Course

4.2. DINAMIC USER MODELING ON LEARNING STYLES

4.2.1 Description

The static approach for detecting students' preference indicates the capture of the student preference, in particular, the preferred order of learning object type in a specific time (t). A dynamic model takes into account the change of this preference over the time, inferring the change in a specific period of time (t+1).

In [13], Graf define three steps that should be analysed in order to propose a dynamic user model based on the learning style. The first one is the definition of the static model itself. The second one is the comparison of the stored learning style with the current inferred learning style to identify deviations or possible changes. The third one is where a decision about if the user learning style has changed according to the previous analysis is made.

Until now, we are defining a mechanism to deliver ordered learning objects types to users based in both user learning style and experts' opinion. But our hypothesis, based on [20], is that this preference could change according to some factors such as specific learning objects of the course, the course topics, or that the user does not response consciously the ILS test for personal reasons [27]. In this context, we need to monitor the student behaviour for readapting the system to the user changing preferences.

Our problem has some premises to be considered:

- The proposed solution should be oriented to generate a dynamic classification task.
- This task should receive new instances. These new instances should be inferred through the user interaction with the system.
- A mechanism to classify adequately these new instances is needed.

Our problem also has two implications, which imply two different processes:

The first problem is the inference of the user learning style over the time. To address this issue, we developed a solution based on the existing knowledge [36][25][3] that relates the students behaviour in the learning management system with their Felder's learning style dimensions. This solution permits us to infer the values of Felder's dimension through the analysis of the user behaviour over the time. Technically, Tracking and Auditing package TAM upon dotLRN [119] and the server logs are used for capturing specific events in the learning platform and for feeding the variables.

The second problem is to affect the adaptation decision process according to the inferred learning style. This was solved with the integration of the user modelling approach with Designer over the selected learning platform.

4.2.2 User Model based on learning styles through user interactions

We propose to build a dynamic user model based on the studies by Graf et al. [39] and Popescu et al. [25], which relate behaviours of students in a learning management system with their Felder's learning styles. We have analysed different types of possible user interactions (criteria's to detect users' learning styles) and we have identified several significant and agreed relations with the Felder's learning style dimensions from [25] and [39].

Table 37 shows the user interaction variables we are considering for the dynamic user modelling process. First two colunms in the table show the variables and their description and the last three columns represent the conclusions provide for four different authors which have studied the correlation between each variable and the Felder's learning style dimensions.

A positive or negative symbol indicates the sense of the correlation with the predominant side of Felder's dimensions (Perception:Sentitive; Processing:Active; Understanding:Sequential; Entry:Visual). These validated user interaction variables are the basis for the process of creating a measure to represent how the user's learning styles change over time.

Table 37. Defined and Validated variables to the user modelling

DEFINED VARIABLES	DESCRIPTION	GRAF	POPESCU	GARCIA	MARTIN
PERCEPTION VARIABLES (SENSITIVE)					
content_visit (-)	Number of LO Visits	-			
content_stay (-)	Time in LO	-			
Content_Type					
t_Fundamental (Intuitive) (+)			+		
t_Definition (Intuitive) (+)			+		
h_Definition (Intuitive) (+)			+		
concrerte type (+)				+	
example_visit (+)	Examples visits	+	+	+	
example_stay (+)	Time in examples	+	+	+	
selfass_visit (+)	Self-Assestment Visits	+			
selfass_stay (+)	Time doing Self-Assestment	+			
exercise_visit (+)	Exercise Visits	+			

DEFINED VARIABLES	DESCRIPTION	GRAF	POPESCU	GARCIA	MARTIN
Relations about Questions					
ques_detail (+)	Question with Detail	+			
ques_facts (+)	Question about facts	+	+		
ques_concepts (-)	Question about Concepts	-	-		
ques_develop (-)	Question about developments or solutions interpretations	-			
quiz_revision (+)	Question revisions before send it	+		+	
quiz_stay_results (+)	Time seeing the results	+		+	
time to finish an exam and deliver it (+)				+	
answer changes (+)	Number of changes in the answers			+	
Content Media					
t_Image (+)			+		
PROCESSING VARIABLES (ACTIVE)					
content_visit (-)	Visits to Content objects	-			
content_stay (-)	Time in Content objects	-			
outline_stay (-)	Time with outlines	-			
example_stay (-)	Time in Examples	-			
selfass_visit (+)	Visit to Self-Assestment	+			
selfass_stay (-)	Time with Self-Assestment	-			
selfass_twice_wrong (+)		+			
exercise_visit (+)	Visit to Exercises	+			
exercise_stay (+)	Time with Exercises	+			
quiz_stay_results (-)	Time seeing the results	-			

DEFINED VARIABLES	DESCRIPTION	GRAF	POPESCU	GARCIA	MARTIN
forum_visit (-)		-			
forum post (+)		+		+	
Forums student not participate (reflexive) (+)				+	
Forums - student reads the message posted by others (forums) (reflexive) (+)				+	
n_chat_msg (+)	Number of msn chat		+	+	
t_chat (Listen) (+)	Time listen in chat		+	+	
Chat not participation (-)				-	
t_Interactivity (+)			+		
h_Interactivity (+)			+		
mail systems use (+)				+	
mail systems no use (reflexive) (+)				+	
Number of Collaborative Activities (+)					+
UNDERSTANDING VARIABLES (SEQUENTIAL)					
outline_visit (-)	Visit to outlines	-	-		
outline_stay (-)	Time with outlines	-	-		
ques_detail (+)	Question with Detail	+			
ques_overview (-)	Question with Overiew	-			
ques_interpret (-)	Question with interpretation	-			
ques_develop (-)	Question with development	-			
navegation_skip (-)	Frequency of LO types omission	-	-	-	
navegation_overview_visit (-)	Frequency of visiting the Course overview page	-			
navegation_overview_stay (-)	Time in the Course overview page	-			
n_nextButton (+)	Number of click in Next Button		+		

DEFINED VARIABLES	DESCRIPTION	GRAF	POPESCU	GARCIA	MARTIN
t_AdditionalInfo (Global) (+)	Time used for Additional Information		+		
n_returns_LO (Global) (+)	Number of returns to a particular Learning Object		+		
t_Exercise (+)	Time with exercises		+		
exams results while she jumping over the contents (Global) (+)				+	
ENTRY VARIABLES (VISUAL)					
content_visit (-)	Visits to Content objects	-			
ques_graphics (+)	Question based on graphics	+			
ques_text (-)	Question based on text	-			
forum_visits (-)	Forum visits	-			
forum_stay (-)	Time reading on Forums	-			
forum_post (-)		-			
Content Media					
t_Image (+)			+		
t_Image + t_Video (+)			+		
h_Image (+)			+		
h_Image + h_Video (+)			+		
t_Text (verbal) (+)			+		
t_Example (+)			+		

As a detailed case, Table 38 shows an example of one of these identified relations. The positive and negative symbols indicate the high and low occurrence of the respective interaction variable from the viewpoint of a sensing, active, sequential, and visual learning style.

According to the example in Table 38, the variable example_visit models the preference of the user for the learning objects of the type "example". This variable has a significant and positive relationship with the Perception Dimension of the Felder-Silverman learning style model. This criterion is an indicator for a student's sensing tendency. Three research studies [25], [39], and [36] coincided in this conclusion, indicating that sensing students prefer to visit and study with examples.

Table 38. Criteria Example

Criteria	Description	Dimension Side Related	GRAF	POPESCU	GARCIA
example_visit	Number of visits to Examples	Sensitive	+	+	+

Considering different studies, in particular, [31] , [20], which suggest that the student behaviors in a specific variable is adjusted to a normal distribution, we propose to develop a standard deviation analysis in order to infer users' learning style.

We estimate the standard deviation (σ) of the behavior of a particular student with respect to the media (μ) and we locate the student in the Felder's Scale according to table 3.

Table 39. Behaviour standard deviation Vs Felder's Scale Values

POSSIBLE VALUE OF THE STUDENT BEHAVIOUR	CORRESPONDED FELDER'S VALUE
μ	6
$\mu + 1\sigma$	7-8
$\mu + 2\sigma$	9-10
$>= (\mu + 3\sigma)$	11
$\mu - 1\sigma$	5-4
$\mu - 2\sigma$	3-2
$<= (\mu - 3\sigma)$	1

Then, each Felder dimension is analyzed, consolidating the variables associated to each dimension. Equation 1 is used to calculate values for each Felder dimension.

$$DimSide_{ij} = \frac{\sum_{i=1}^{N} Cij}{N}$$

Equation 1. User Modelling based on Learning Style Formula

Where Cij is the value for the variable i applied on the student j; N is the number of analysed variables for each particular Felder dimension. DimSide is calculated for each Felder dimension. In this manner, the sum of all values are expressed in an Eleven Scale [1 … 11] describing the tendency in each particular dimension based on the behaviour of the student in the learning management system.

The result of the user modelling process is the redefinition of the result of the ILS questionnaire based on the analysis of the user interactions.

The teacher makes the decision about when the user modelling process takes place. He/she can indicate whether the recalculation should take place every day, week, month or semester.

We developed a semiautomatic approach for the learning style decision of change, where teachers are notified by the system if a change in a student's learning style has been detected. Then, the teacher can reflect about whether the user modelling process is adequate for his/her student and decide if the change in the user's learning style should be performed. In order to support teachers, the system provides a similarity measure indicating the quantitative difference among previous and calculated learning styles.

A change in the learning style of a student causes the redefinition of some IMS Learning Design properties that control the presentation of the activity structures developed according to different learning styles in a particular course. This will be explained in the next chapter in more detail.

4.2.3 Evaluation

As mentioned in section 3.2.2.1, the evaluation of the user modelling process based on the learning style is a part of the *interaction assessment layer*, where the purpose is to confirm if the conclusions drawn by the system concerning the characteristics of the user-computer interaction is valid. This means that the purpose of this evaluation was validated by the effectiveness of the user modelling process for inferring students learning style.

4.2.3.1 OOP Course Instance

This scenario was developed with 20 students from University of Cartagena in Colombia. The Object Oriented Programming UoL presented in section 0 was planned as a part of a regular course called Object Oriented Programming, which is a part of the curriculum in the Systems Engineering Program in the University of Cartagena. This course takes two months to be developed with students and all student interaction with the learning objects was recorded in the system.

The UoL was offered in a Blended Learning Modality; two teachers were available, one teacher from the University of Cartagena (Colombia) and other from University of Gerona (Spain).

The students in the course had previous knowledge in programming logic but not in Object Oriented Paradigm Languages.

4.2.3.2 Methodology

Course development

At the beginning of the course, the defined method for the course was explained to students. The course was organized in sessions. Each session had two parts, a virtual session and an independent session developed by students in the virtual learning environment. The virtual session was supervised by the teacher, who explained to students the most important concepts and ideas related to the specific topic of the session. The students developed the independent session as an extra work. The expected time to be spent by the students was 2 extra hours for each hour they were attending virtual sessions.

In the next paragraphs we introduce a description of the first virtual session considering that this session was a bit different from other sessions. We also introduce a description of a regular session.

The first session of the course was a special one because the teacher introduced the general details of the course as well as the Felder's and Silverman Learning Style Theory. The students understood the theory, questions about different Felder dimensions were asked and then, they presented the Index of Learning Style test using the learning platform.

Although students understood Felder's theory, different questions emerged, specially because the native language of the sample was Spanish and in this study we use the English version of the ILS test. For this reason, in some occasions translating some questions of the test to Spanish was necessary.

In the Second session, an introduction to the object oriented programming paradigm was presented. Concepts such as modularity, generalization and others were introduced using examples. The first addressed concept was Object. Additional to the magisterial explanation, different examples using the BlueJ [120] software were presented to students. The student expressed different doubts and comments. Finally, some questions with the intention to improve the following session were asked to students. The session duration was one hour.

Data processing

As mentioned before dotLRN was used as learning managent system to offer a UoL without adaptations to students. It was also mentioned that the Tracking and Auditing module (TAM) upon dotLRN [119] was used to monitor and track the user variables to evaluate our dynamic user modelling process.

The process developed by the study in this environment was as follows:

- According to the information provided by the teacher in the competence definition, a UoL was defined without any kind of adaptation.
- Students took the course using dotLRN with the teacher's support throught the virtual sessions and also asking questions about the process by emails.
- Users learning styles were inferred through the Felder's Index of Learning Style package upon dotLRN.
- Fourty user variables from Table 37 were selected to be monitored and measured by the system, in particular those related to the following users behaviours:
    - Participation of the users while studying with different learning objects types among them those described in section 3.2.2.2.
    - Participation of the users while interacting with collaborative tools as forums and chats.
    - Participation of the users while interacting with assessment tools.
- Selected user variables were organized according to the Felder's dimensions they address.
- For each variable, the average considering all students was calculated.
- With the calculated average, some standards deviations for each variable was calculated (One standard deviation, two standard deviations and Three standard deviations).
- The logic described in table Table 39 was used to define the position of the user behaviour in the Felder's scale. As mentioned in section 4.1.2, Felder's scale measures the tendency of the user in each dimension in a scale of eleven integers numbers. It was the same scale used in our work.
- Considering the position of each variable for each user in the Felder's scale, the consolidated value for each Felder's dimension, for each user was calculated.
- The results obtained in the user modelling process were compared to those obtained from the Index of Learning style as discussed in the results section.

4.2.3.3 Results

The results of the Index of learning style for the sample are shown in Figure 31.

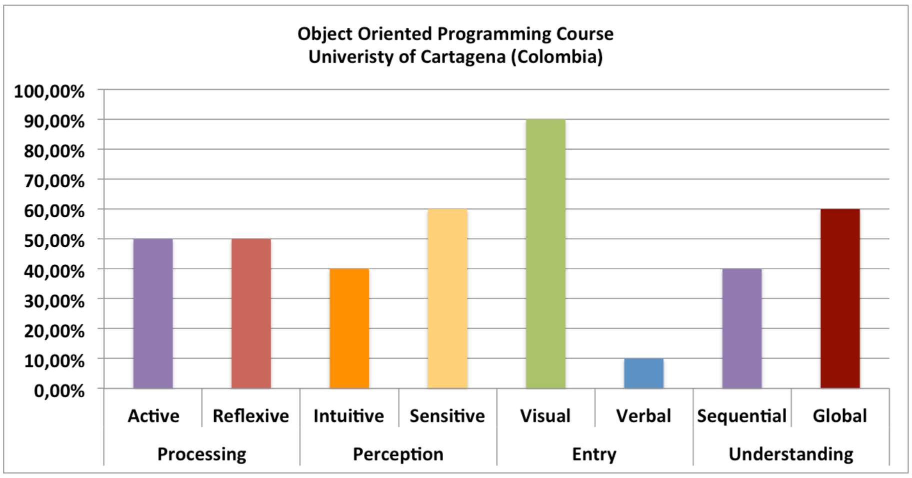


Figure 31. Students Learning Styles

As expected, most of the engineering students in the sample present a tendency to the *visual side* on the *Entry dimension* as well as to the *sensitive side* in the *Perception dimension*. A global side tendency, as in this case, is not frequently found in an engineering course in the Understanding dimension.

Table 40 to Table 43 present the results for a particular student involved in the testing course. Last two columns of the table show the results of ILS test and the User modelling process for this particular student.

Table 40 shows that for the perception dimension, the user modelling process captures the tendency in the user learning style. It means that according to ILS test the user is placed in the sensitive dimension. Also the user modelling process places the user in this dimension.

Table 40. Results of model applied to one student's behaviour for Perception dimension

		FELDER	UM RESULTS
PERCEPTION	SENSITIVE	8	6,8571
	INTUITIVE	3	4,1428

The same manner, Table 41 shows that for the processing dimension, the user modelling process captures the tendency in the user learning style.

Table 41. Results of model applied to one student's behaviour for Processing dimension

		FELDER	UM RESULTS
PROCESSING	ACTIVE	7	6
	REFLECTIVE	4	5

Table 42 shows that for the understanding dimension, the user modelling process does not capture the tendency of the user learning style.

Table 42. Results of model applied to one student's behaviour for Understanding dimension

		FELDER	UM RESULTS
UNDERSTANDING	SEQUENTIAL	5	6
	GLOBAL	6	5

And finally, Table 43 shows that for the Entry dimension, the user modelling process captures the tendency in the user learning style.

Table 43. Results of model applied to one student's behaviour for Entry dimension

		FELDER	UM RESULTS
ENTRY	VISUAL	7	6,1428
	VERBAL	4	4,857

We identified the correspondence between the ILS test and user modelling process for each student. If the tendency in in each dimension of the learning style detection was identified correctly we assign a 100% of correspondence.

For the first student presented before, the user modelling process has a precision of *75%* because the tendency for three dimensions was captured.

As an example we present the consolidated results for three students in Table 44. And in Table 45 we present the precision for the three analized users.

Table 44. User modelling process results of three students

FIRST STUDENT					SECOND STUDENT					THIRD STUDENT			
PERCEPTION DIMENSION					PERCEPTION DIMENSION					PERCEPTION DIMENSION			
UM RESULTS		FELDER			UM RESULTS		FELDER			UM RESULTS		FELDER	
SENSITIVE	INTUITIVE	SENSITIVE	INTUITIVE		SENSITIVE	INTUITIVE	SENSITIVE	INTUITIVE		SENSITIVE	INTUITIVE	SENSITIVE	INTUITIVE
4,571	6,428	2	9		5,857	5,142	10	1		8	3	6,857	4,142
PROCESSING DIMENSION					PROCESSING DIMENSION					PROCESSING DIMENSION			
UM RESULTS		FELDER			UM RESULTS		FELDER			UM RESULTS		FELDER	
ACTIVE	REFLECTIVE	ACTIVE	REFLECTIVE		ACTIVE	REFLECTIVE	ACTIVE	REFLECTIVE		ACTIVE	REFLECTIVE	ACTIVE	REFLECTIVE
6	5	6	5		4	7	3	8		6	5	7	4
UNDERSTANDING DIMENSION					UNDERSTANDING DIMENSION					UNDERSTANDING DIMENSION			
UM RESULTS		FELDER			UM RESULTS		FELDER			UM RESULTS		FELDER	
SEQUENTIAL	GLOBAL	SEQUENTIAL	GLOBAL		SEQUENTIAL	GLOBAL	SEQUENTIAL	GLOBAL		SEQUENTIAL	GLOBAL	SEQUENTIA L	GLOBAL
3	8	6	5		6	5	5	6		6	5	5	6
ENTRY DIMENSION					ENTRY DIMENSION					ENTRY DIMENSION			
UM RESULTS		FELDER			UM RESULTS		FELDER			UM RESULTS		FELDER	
VISUAL	VERBAL	VISUAL	VERBAL		VISUAL	VERBAL	VISUAL	VERBAL		VISUAL	VERBAL	VISUAL	VERBAL
6,714	4,285	6	5		4,428	6,571	9	2		6,142	4,857	7	4

Table 45. Consolidated precision of three users

FELDER DIMENSIONS	FIRST STUDENT	SECOND STUDENT	THIRD STUDENT	PRECISION FOR EACH DIMENSION
PERCEPTION	1	1	1	100%
PROCESSING	1	1	1	100%
UNDERSTANDING	0	1	1	67%
ENTRY	1	0	1	67%
	75%	75%	100%	83%

Finally, Table 46 presents the consolidated data for 20 users involved in our study. Table 46 indicates that for 16 of the 20 users the user modelling process infers successfully the user learning style. Processing dimension present a precision of the 100% which indicates that the tendency in the learning style was captured for 20 users. The Understanding dimension obtained the correspondence lowest, 60%. Finally for Entry dimension a precision of 80% was obtained.

Table 46. Consolidated data of 20 users

DIMENSION	SUCESSFULL	PRECISION
Perception	16	80%
Processing	20	100%
Understanding	12	60%
Entry	16	80%
		80%

4.3. CONCLUSIONS OF THE CHAPTER

In this chapter we introduced a *static and dynamic user modelling process* based on learning style. *Static model* [107], [106] is inferred through the Felder's Index of Learning Style and the Dynamic user modelling process is based on the statistical analysis of the user's interactions in a learning management system. *Dynamic user modelling* [121] considers the correlations among the different users learning style and the available user's interaction in a learning management system.

User modelling process supports the implemented decision process to offer students the available learning objects types ordered according to their user learning preferences. Decision process is based on the use of classification techniques with the purpose to use a decision tree in order to infer the preferred order to deliver the learning objects types to users. Classification algorithms testing throws promising results for the proposed classification task.

Dynamic user modelling process was tested in a real course with 20 students from the University of Cartagena. Study throws good results (prediction of 80%) for the dynamic user learning style inference. Dynamic user model is the base for the adaptation based on learning style offered to users. In this manner, the learning object type order change for each user in the generated learning design according to the change in the user model over the time.

5. LEARNING DESIGN GENERATION PROCESS

In the lifelong learning context, the efficiency of learning is measured according to the users' achievement of the target competences. However, in a virtual learning environment supporting the competence development process ends up being an elusive and time-consuming task for teachers or instructional designer. Furthermore, tailoring courses to the individual learner's needs and preferences has high potential to improve the learning process of learners. However, again, this is a time-consuming and complex task for teachers and instructional designers. In this chapter, we introduce *Designer*, an approach for teachers to help them designing courses via a semi-automatic design process based on HTN planning. As mentioned in section 3.2. Designer considers a few inputs from teachers on generation of learning designs, the competence definitions and the learning objects metadata as well as user model data.

The rest of the chapter describes each element involved in the generation process as follows. In section 5.1. the competence model supporting the generation process is presented. Section 5.2. introduces the process for labelling learning objects and the different tools implemented to support this task. Section 5.3. details the generation process itself emphasizing in modelling the generation problem as a planning problem. Layared valuation is presented in section 5.4. for describing a qualitative and quantitative study which demonstrated the effectiveness of *Designer* in supporting teachers to create adaptive courses. Finally, in section 5.5. some conclusions are introduced.

5.1. THE COMPETENCE DEFINITION MODEL

5.1.1 The model

The Competence Definition Model provides a structure for defining learning purposes in a virtual learning environment. *Designer* will use this structure in order to generate a suitable learning design based on user competences and learning style. The model was created by analysing different methodologies for the creation of Competences Based Instructional Designs [1], [90], [91].

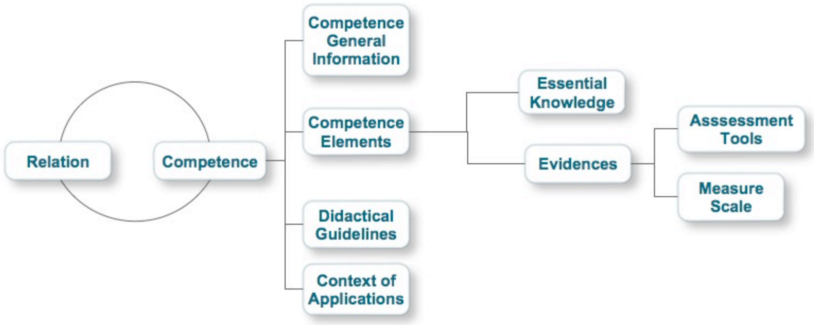


Figure 32. Competence Definition Model

We have divided the competence definition into categories, as shown in Figure 32. The main Category is *Competence*, which includes the other categories. One competence could be related to others through the *Relation Category. Relations* allow to define the competences taxonomy for the association of different competences, in particular, Prerequisite, Composition, and Similarity Measure Relations.

The Competence General Information provides general data about the competence. This information consist of: Identifier, Version, Title, Locator, Description, Type, Date of creation, Force, Duration of Creation Process, Language, Creator, Font, Right, Format, Taxonomy Reference.

Competence Elements are smaller learning purposes, i.e. specific and concrete results of the learning process. This elements should be categorized by a particular taxonomy such as Bloom Taxonomy of Educative Objectives [23].

For each particular competence element, two information categories are defined:

- Essential Knowledges, which the student should bring into play in a specific context to demonstrate the acquisition of the competence. Essential Knowledge could be categorized according to some classification scheme, e.g. declarative, procedural and heuristics or implicit and explicit [122].
- Competence Evidences are mechanisms to measure the level of achievement of each particular element. Both in corresponding assessment tool and scale of measurement are also defined.

Didactical Guidelines refers to information provided by the teacher about the best *didactical strategies* to support the competences development.

Context of application covers information about the area of application of the competence, physical conditions, environmental conditions or other context features.

Competence definition provides a compilation of relevant aspects considered in the learning process design. This information provides a sequence structure considered when generating the learning design process.

The language used to represent the competence was IMS Reusable Definition of Competence and Learning Objective (RDCEO) [71] considering the flexibility offered by this language for the competence representation [70] and its facility to be related to other knowledge specifications about the user. Figure 33 presents the elements provided by the RDCEO specification.

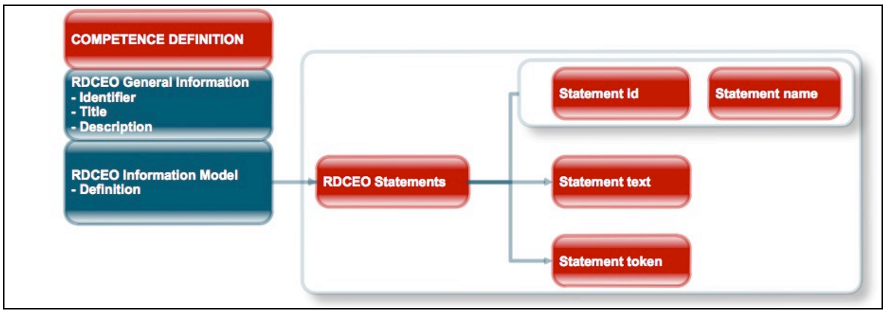


Figure 33. Overview IMS-RDCEO specification [71]

Figure 34 describes the mapping between the IMS RDCEO information model and our competence definition model.

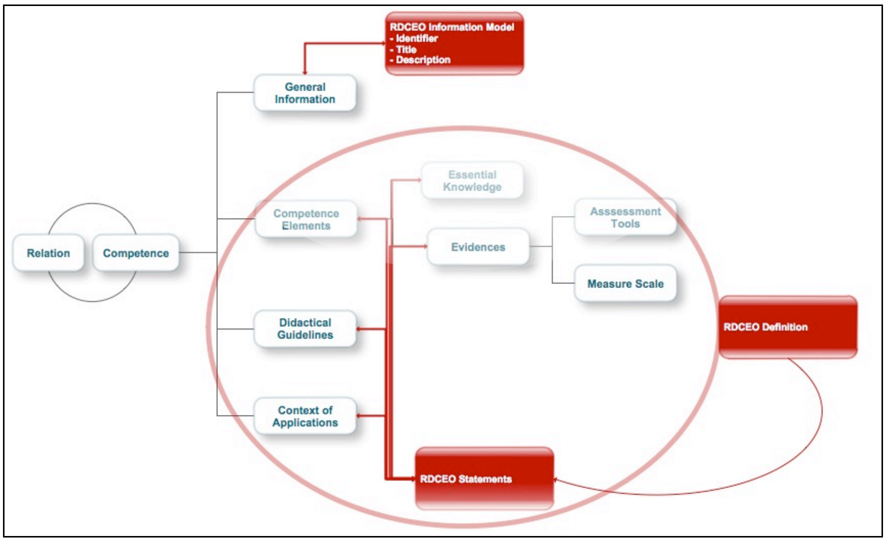


Figure 34. Mapping Competence definition to IMS RDCEO

5.1.2 Model implementation

As a contribution to the Openacs Community, a specific package to support competence definition was developed. Figure 35, Figure 36, Figure 37, and Figure 38 show a collage of different views of the package.

Figure 35 shows the administration view of the competence porlet. When the user clicks over the Competence Administration link a list of all available competence defined for the course is shown.

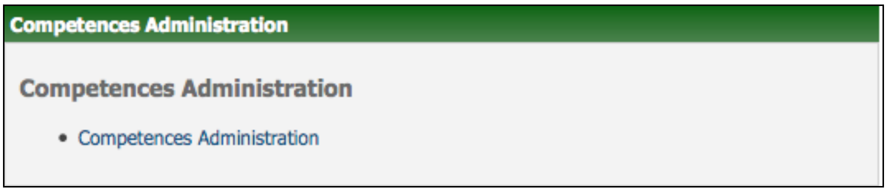
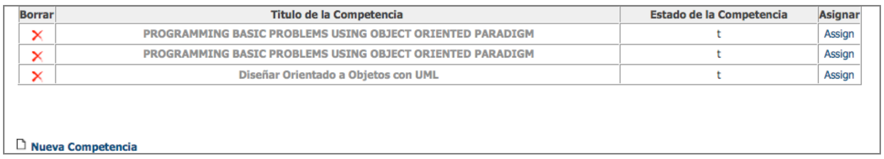


Figure 35. Competence Package Porlet

Figure 36 shows the list of available competences. Some relevant information is shown to users such as the competence title and the competence state. When the user clicks on the title, the defined competence elements for an specific competence are presented to users.

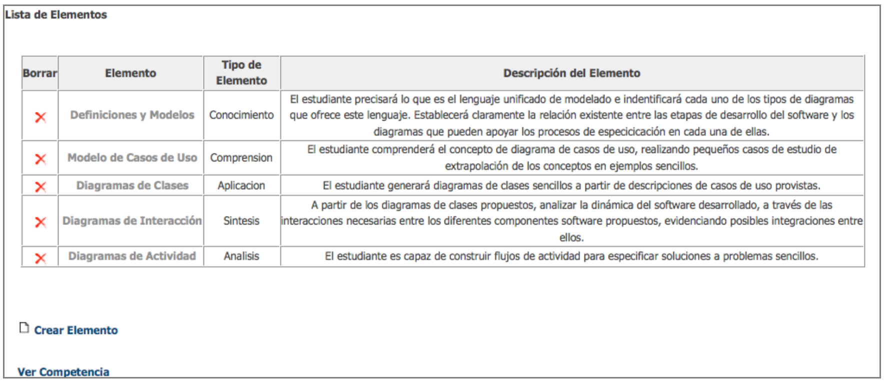


Borrar	Titulo de la Competencia	Estado de la Competencia	Asignar
×	PROGRAMMING BASIC PROBLEMS USING OBJECT ORIENTED PARADIGM	t	Assign
×	PROGRAMMING BASIC PROBLEMS USING OBJECT ORIENTED PARADIGM	t	Assign
×	Diseñar Orientado a Objetos con UML	t	Assign

Nueva Competencia

Figure 36. View of available competences

Figure 37 shows a list of the competence elements of a specific competence. Element Title, the associated Bloom level and the element description is shown to the user. Each competence element has competence knowledge and competence elements associated. When the user clicks on the element title in the list these information is presented to the user.


Lista de Elementos

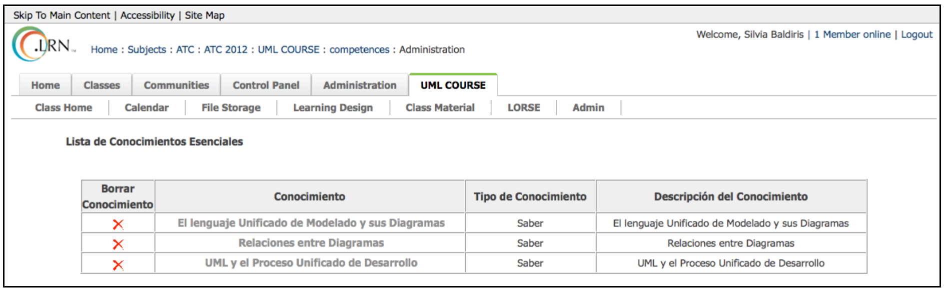
Borrar	Elemento	Tipo de Elemento	Descripción del Elemento
×	Definiciones y Modelos	Conocimiento	El estudiante precisará lo que es el lenguaje unificado de modelado e indentificará cada uno de los tipos de diagramas que ofrece este lenguaje. Establecerá claramente la relación existente entre las etapas de desarrollo del software y los diagramas que pueden apoyar los procesos de especicicación en cada una de ellas.
×	Modelo de Casos de Uso	Comprension	El estudiante comprenderá el concepto de diagrama de casos de uso, realizando pequeños casos de estudio de extrapolación de los conceptos en ejemplos sencillos.
×	Diagramas de Clases	Aplicacion	El estudiante generará diagramas de clases sencillos a partir de descripciones de casos de uso provistas.
×	Diagramas de Interacción	Sintesis	A partir de los diagramas de clases propuestos, analizar la dinámica del software desarrollado, a través de las interacciones necesarias entre los diferentes componentes software propuestos, evidenciando posibles integraciones entre ellos.
×	Diagramas de Actividad	Analisis	El estudiante es capaz de construir flujos de actividad para especificar soluciones a problemas sencillos.

Crear Elemento

Ver Competencia

Figure 37. Competence Elements List for a Specific Competence Definition

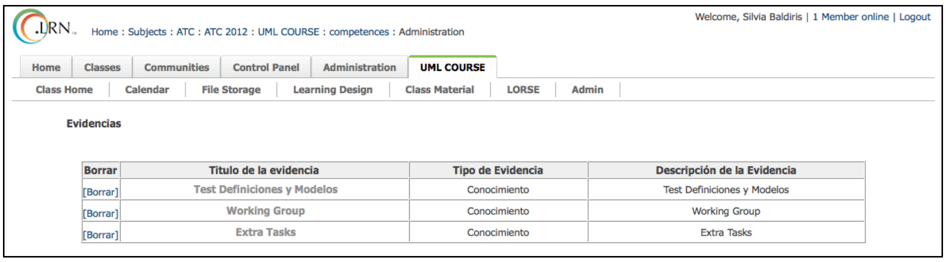
Figure 38 shows the list of the competence knowledges of a specific competence element. Knowledge could be modified if the user clicks on the knowledge title.



Borrar Conocimiento	Conocimiento	Tipo de Conocimiento	Descripción del Conocimiento
×	El lenguaje Unificado de Modelado y sus Diagramas	Saber	El lenguaje Unificado de Modelado y sus Diagramas
×	Relaciones entre Diagramas	Saber	Relaciones entre Diagramas
×	UML y el Proceso Unificado de Desarrollo	Saber	UML y el Proceso Unificado de Desarrollo

Figure 38. Particular Competence Knowledge Definition

At the same manner, Figure 39 shows the list of the competence evidences for a specific competence element. Evidence could be modified if the user clicks over the evidence title.



Borrar	Titulo de la evidencia	Tipo de Evidencia	Descripción de la Evidencia
[Borrar]	Test Definiciones y Modelos	Conocimiento	Test Definiciones y Modelos
[Borrar]	Working Group	Conocimiento	Working Group
[Borrar]	Extra Tasks	Conocimiento	Extra Tasks

Figure 39. Competence Evidence Definition

After the competence have been defined by the teacher, the competence package permits him to export the definition into a IMS RDCEO xml file, which is available for the learning design generation process. The export process was developed using libxml, which enables SQL/XML support in postgresql.

5.2. LEARNING OBJECTS METADATA DEFINITION PROCESS

IMS Metadata (IMS–MD) [74] was the specification chosen to label learning objects considering the expressivity capacity of the specification for the particular necessities in the generation process.

As mentioned before, the competence definition model is the basis for the automatic course-structure generation. Competence element, in particular, Essential Knowledges and Evidences, are used for defining the activities in the learning design.

Learning resources have been modelled as atomic units related to Essential Knowledge and Evidences through the <classification> label from the learning object metadata. Additionally, some relations could be defined among learning resources through the <relation> label from the IMS–MD. These relations affect the sequencing of activities in the generated learning design.

In order to provide a solution for the teachers in the labelling process of learning objects, two implementations were developed.

On one hand, a modification of the Openacs content repository [123] was implemented in order to allow the teacher to link a metadata with the content they uploaded in the repository. Figure 40 and Figure 41 present a view of the Learning Content Repository Modification.

Figure 40 shows a view of the dotLRN content repository modification. As it is possible to observe in figure, different folders have been created to store the competence definition file, the learning objects metadata and other important files.

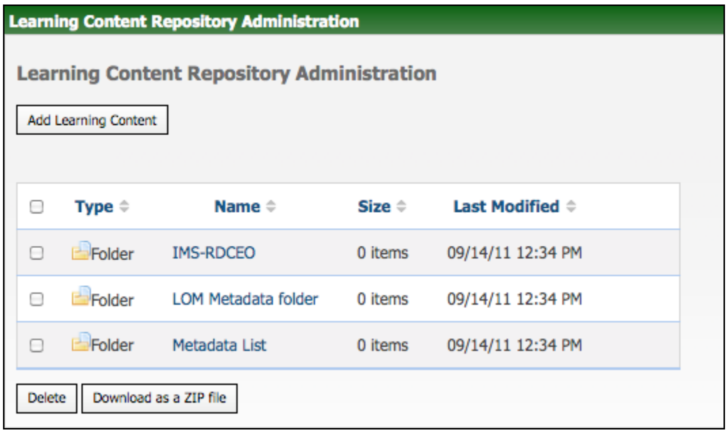


Figure 40. Learning Content Repository Modification

Figure 41 shows a view of the dotLRN content repository for uploading LO. Open ACS only support the metadata definition for Scorm Packages, we have developed a package modification in order to permit the metadata definition of atomic resources. In this manner, for each particular LO type the user can define a specific metadata.

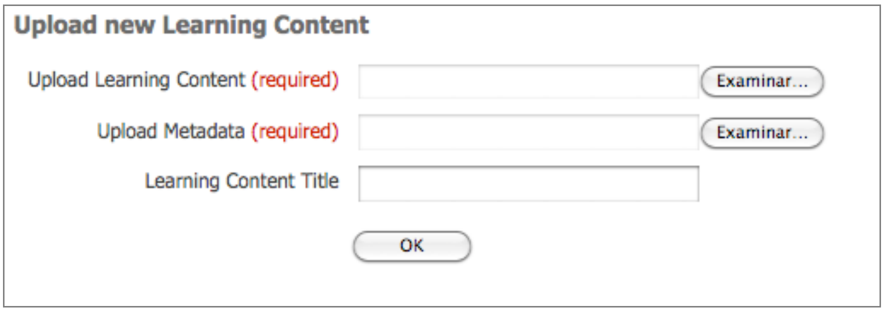


Figure 41. Learning Content Repository Modification Upload View

On the other hand, an extension of the Fedora Commons Repository was developed in order to allow teachers to define in a friendly way an IMS Metadata xml file of their learning objects upon this framework. This implementation is presented in Figure 42.

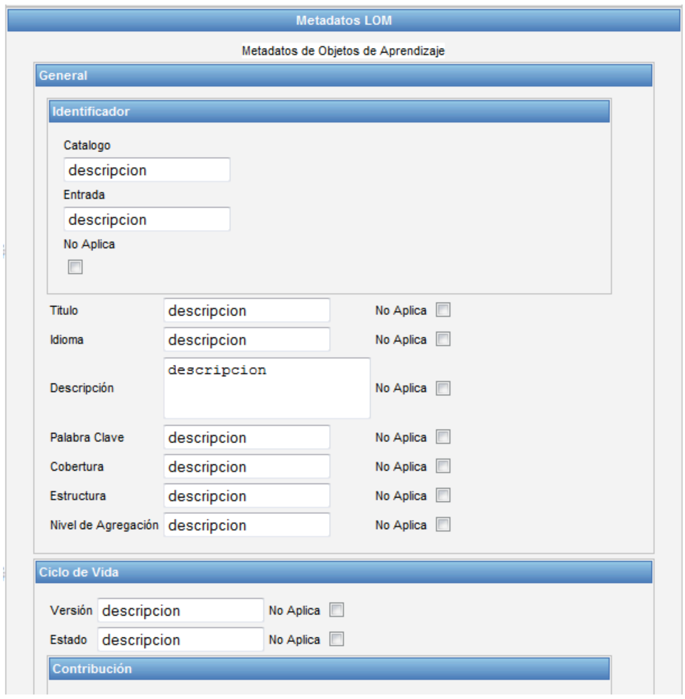


Figure 42. IMS MD Edition mode upon Fedora Commons Repository

Using this learning object repository framework, different versions of each object can be specified and also different metadata specifications can be used for labelling the resources. The stored learning objects can be used in the semi-automatic learning design generation process.

5.3. SEMI-AUTOMATIC GENERATION THROUGHT SCENARIOS

Using the Competence Definition Model and the Learning Object Metadata as inputs, the learning design generation process takes place.

5.3.1 Learning Design conforms with Learning Design Speficiation

IMS Learning Design Specification (IMS-LD) [6] suggests a standardized language to represent and execute Units of Learning (UoL) in the context of a virtual environment. According to the second level of this specification, UoL can be personalized by aggregation of condition. Figure 43 presents the most import elements for modelling a UoL according with IMS-LS specification.

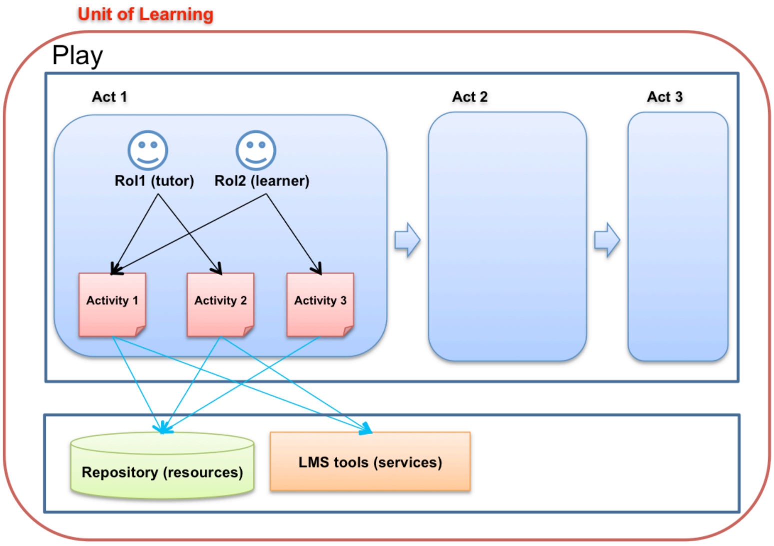


Figure 43. IMS Learning Design Unit of Learning Elements

IMS LD conceptual model propose a movie metaphors for UoL creation. Each "*E-learning movie*" has a concept model oriented to its design (method) and it could be studied by different groups of students (runs). Different actors could play different roles (students, teacher or tutors) in different movie parts (Acts). These acts consist of different activities available for different roles (role-part). These activities are developed in adequate environments, which are enriched with the necessary learning resources and activities that facilitate the learning process. Several activities could be organized into Activity Structures.

The porpuse is to create a personalized UoL considering the level of competence of the users as well as their leaning style. Adaptation based on competence implies to construct activity structures in the IMS learning design for each competence level and to monitor the action of the users in the UoL in order to perceive the user change in the level of competence. On the other hand, adaptation based on learning styles implies the organization of the learning objects and activities in a particular course in the student preferred order with respect to his/her learning styles. We have addressed this problem by the automatic creation of different Activity Structures for each particular learning style. Formal description of the process is introduced in the next section.

5.3.2 Description the formal process

Let us consider a set X = $\{x_1, x_2, x_3 \dots x_n\}$ representing the *students* interested on achieving *specific competences* C = $\{c_{1,CL}, c_{2,CL}, c_{3,CL} \dots c_{n,CL}\}$. These students could have several interests for achieving different competences (*C*) in different levels (*CL*). In this manner the desired competence for the c_1 could be differente that the desired level to be obtained for the c_2. On the other hand, the competence levels could be defined by using the Bloom's taxonomy or other classification schemes, in which CL = {L_i, L_r, L_u, L_a, L_{an}, L_{ev}, L_{cr}}, or by using any other classification system. In this way, L_i, L_k, indicate *initial level* and *understanding level* respectivally.

Competences are divided into *competence elements* defined to ease the monitoring of the competence acquisition. Each competence element is also categorized in an adequate level of competence, e.g. C_1E = { $ce_{1,Li}$, $ce_{2,Lco}$, $ce_{3,Lcp}$, … $ce_{1,Lev}$ }. In this manner, $ce_{1,Li}$ indicates that the competence element 1 for the competence 1 has the initial level associated. The user desires to obtain this level for this competence element.

On other hand, as mentioned before, each *Competence element* is associated with a set of *Competence Knowledge* and *Competence Evidences*.

Competences Knowledge represents the essential knowledge necessary to be acquired by the student. These knowledges support the performance of the student in a specific context where she should demonstrate the acquisition of the competence, e.g. C_1E_1K {$k_{1,1}$, $k_{1,2}$, $k_{1,3}$ … $k_{1,n}$}. $k_{1,n}$ represent the *knowledge n* for the competence element 1 in the competence 1.

Competence evidence is a mechanism to measure the level of achievement of each particular element. For example, C_1E_1E {$e_{1,1}$, $e_{1,2}$, $e_{1,3}$ … $e_{1,n}$} represent evidence (1 to n) for the competence element 1 in the competence 1.

We define the *Learning style* as the possible combination of Felder's dimension LS_i = E x P_{er} x P_{ro} x U_{nd} where E= {visual, verbal}, P_{er}= {intuitive, sensitive} P_{ro}= {active, reflexive}, U_{nd} = {global, sequential}.

Learning Design Sequencing is based on activities where each *activity* could be divided in *sub-activities*. The simplest unit of aggregation is the *learning object* and the most complex is the *Activities Structures*. Our solution considers the highest level of activities structure referred to the corresponding *learning style activities structure*. Each competence represents an *Activity structure* or a set of activities in the learning design ASbyC = {AS_{c1}, AS_{c2}, AS_{c3}, … AS_{cn}}. Competence elements define *Sub Activity structure* ASbyCE = {$AS_{ce1,1}$ … $AS_{ce1,n}$, $AS_{ce2,1}$… $AS_{ce2,n}$, … , AS_{cen1}, AS_{nm}}. Activity structures for the competence elements consist of Competence Knowledge Activities and Competence Evidence Activities. For each knowledge and evidence defined in each competence element, an activity and a set of learning Objects are defined.

The learning design sequence offered to students depends of the students's profile, in particular, the level of competences at the beginning of the course and the learning styles.

Sequences Adaptation based on learning style consider the preference of the different learning styles for different learning objects and service types. Objects and service types could be defined as OST = {ost_1, ost_2… ost_n}. Preference for each the objects and service types could be defined as PLS = $ost_{i,j,k} = \{ost_{1,1,1}, ost_{2,1,1}, \ldots ost_{n,m,w}\}$, where i = object type; j=learning style and k=preferred order of the learning style for the object or service type.

Then, for each profile P_i a sequence based on learning style and competence SbLEC (LS,C) is defined. This initial sequence changes over the time as preference due to learning style and competence change.

In summary, $\mathrm{SbLEC} \subset \mathrm{ASbyC} \subset \mathrm{ASbyCE}$, learning object types and services are ordered in ASbyCE according to PLS.

The next section describes how this formulation is translated into a planning domain.

5.3.3 Generation based on competence definitions

5.3.3.1 Scenario Description

The first scenario aims to automatically construct the learning design of a course based on the competence the teacher wants the students to achieve.

For the specific competences monitoring a maximum of seven levels of competences are considered. Levels are related to one or more Bloom objective types: initial, remembering, understanding, applying, analysing, evaluating, creating.

The purpose of the learning design generation is to construct an activity structure in the IMS learning design for each of this competence level. Competence Levels are modelled in the IMS learning design as properties whose state is monitoring and updating. According to this context, we have defined a planning problem that searches a conditional plan for a specific course that permits students to gradually achieve the competence levels proposed by the teachers in the course design, in particular, in the competence definition. The planning process is based on the analysis of the information available about the competence and the learning resources metadata according to the appropriate specifications: IMS Reusable Definition of Competency or Educational Objective (RDCEO) [71] and IMS Metadata (MD) [74].

When a student takes a course, the course competence is monitored as the learner carries on the activities. As a result of this monitoring, the user competence levels are stored and updated in the student profile (in the IMS-LIP [101] and also in the LSM).

LIP competences are always related to a RDCEO competence definition, which indicates how the competence should be achieved.

The following information is available for the planning problem:

1. The competence hierarchy, in particular, the elements associated to the competence, categorized according to Bloom.

2. The learning objects that address these elements, in particular, for addresing the associated competence knowledges, and

3. The evidences (e.g. questionnaire, practical activities), which have been modelled as learning objects, to be used for verifying the progress in the competence acquisition.

As mentioned before, the learning objects are stored in a repository, and each of them has an IMS-MD associated that relates the object to the elements in the competence definition, specifically we are using the classification label for this association.

With all the aforementioned components, a planning engine can be executed to build the structure that corresponds to an adapted learning design in the IMS LD specification. The process is presented in Figure 44.

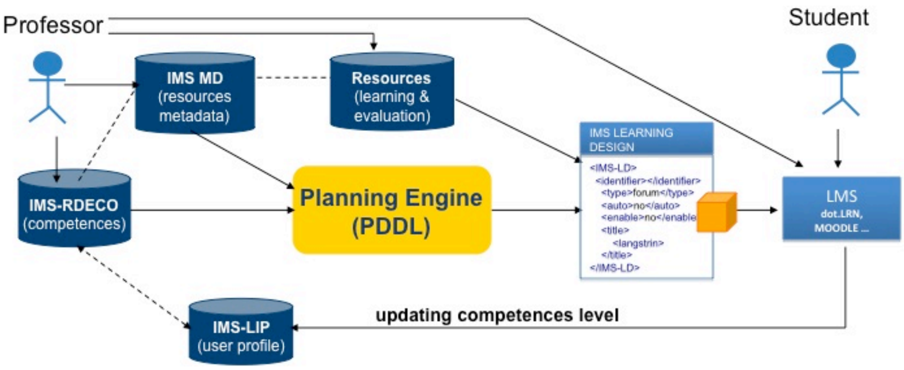


Figure 44. Learning Design Generation based on competence definitions

To support the achievement of each competence, an IMS-LD activity structure, which consists on several sub activities structures for each element in the competence definition, is generated.

In order to test the conceptual modelling, an HTN planner was used. HTN planning [124] represents a plan as a set of tasks (task networks) to be performed. Methods divide non-primitive tasks into sub-tasks until a primitive level has been obtained. Primitive tasks are those that can be carried out directly.

We have used HTN planning because the course domain for this scenario, in particular, the competence definition, has a hierarchical structure. The passing from course domain to the planning domain was an intuitive step as described in next sections.

We have taken up the idea described in [51], where the author defines the concept of building blocks as a basic element, which are the basis for the generation of his scenarios. Building blocks in our proposal basically correspond to the structural elements associated to the IMS-LD specification.

5.3.3.2 Planning problem

The main purpose of this scenario is the generation of an adequate course for all the students registered to a class that take into account the definition of the competence provided by the teacher.

The planning problem declares the initial stage of the world (represented as a set of logical atoms that are assumed to be true at the time when the plan executor will begin executing the plan), the initial task network (a set of tasks to be performed), and a domain description which contains, methods, operator and axioms. Main method in the domain analyses the initial stage and the goal in order to generate a suitable plan. The initial state of the world is constructed using the procedure getMetadata to analyse the learning objects metadata files and convert them into a term list named *resources*. A set of methods is created in order to take the information from *resources* list and recursively add the learning resources and their attributes in the state of the world. The identifier of the desired competence to be achieved in the course defines the *goal*.

5.3.3.3 Planning domain

Operators

In the planning domain we define two types of operators: basic operators and structural operators.

Basic operators are the most important operators defined in the planning domain because they define the expected actions to be developed by the user. These operators are:

- (:operator (!insert-Learning-Activity ?idactivity ?titleactivity ?idresource ?isv) inserts the Learning Activities in the plan.
- (:operator (!insert-Resource ?env ?e) inserts a learning resource in the plan.
- (:operator (!insert-Property ?f ?g ?h), which inserts a local user property in the LD.
- (:operator (!insert-Condition ?g) inserts a condition in the method of the LD.

The planner uses some Structural Operators in order to generate a learning design according to the IMS-LD Specification as follows:

- The (:operator (!insert-Learning-Design ?id ?level ?sequence-used ?uri ?title) is used to create an Activity structure of the highest level that contains all of the other blocks.
- To open and close an activity structure block in the LD, the (:operator (!start-Activity-Structure ?b) and the (:operator (!end-Activity-Structure) have been created.
- The (:operator (!start-Environments) and the (:operator (!end-Environments) are used to open and close environments block in the LD.
- The (:operator (!start-Properties) and the (:operator (!end-Properties) are used to open and close the block of properties in the LD.
- The (:operator (!start-Conditions) and the (:operator (!end-Conditions) are used to open and close the block of conditions in the LD Method.
- The (:operator (!start-Resources) and the (:operator (!end-Resources) are used to open and close the block of conditions in the LD Method.

Methods

The main method in the planning domain is *generateIMSLD*, which uses the information provided by the *getOrganization Call Terms* from the competence definition in particular from the IMS-RDCEO associated file and converts this information into a term list named *organization.*

generateIMSLD iterated recursively the *organization* list structure in order to construct the plan. The principal method used for this purpose is (:method (analyzerStatements (?head . ?tail)). This method calls the adequate methods to construct the necessary block sets in which consist the plan, as shown in Figure 45.

```
(:method (analyzerStatements (?head . ?tail))
    ()
    (
     (analyzerStatement ?head)
     (!start-Activity-Structure performanceevidence)
       (analyzerPer ?tail)
     (!end-Activity-Structure)
     (!start-Environments)
       (insEnvironment)
     (!end-Environments)
     (!start-Properties)
       (insProperties ?head)
     (!end-Properties)
     (!start-Conditions)
       (insConditions ?head)
     (!end-Conditions)
     ;;(analyzerStatements ?tail)
    )   )
```

Figure 45. Method analyzerStatements

The analyzerStatement method is recursively executed to construct the Activity Structures and Activities. Activity Structures are associated to the Competence Levels of the Competence Elements and on the other hand the Activities correspond to the Essential Knowledge in the competence definition.

The analyzerPer method creates the Activity structure associated to the Performance activities which correspond to the Evidences in the competence definition. One evaluation activity is created for each competence level addressed in the plan.

When the activities are created, the resources associated to each particular activity are identified. The method insEnvironment creates one environment for each Activity and then associates all of the resources identified above to this environment.

The method insProperties creates one local-personal-property for each competence level existing in the competence definition. As mentioned before, the Competence Elements have a specific Bloom level associated.

The insConditions Method defines the conditions in the Method element in the LD. One condition for each competence level is created.

5.3.4 Generation based on competences and learning styles

Our interest in this scenario is to extend the adaptation proposed in the above scenario, which is basically founded on the competence definition, by including over this new scenario the adaptation process based on learning style.

The main purpose of the adaptation process based on learning style is to select the best order to present the learning resource types according to the learning style information according to the conclusions presented in [4].

As shown in the Figure 46, the main difference between this scenario and the first one is the use of information about the possible users learning style in order to generate a learning design. Generation process take into account at the design time all students learning style involved in the course generating all possible sequences and at the execution time selects the adequate sequence according to a particular student preference.

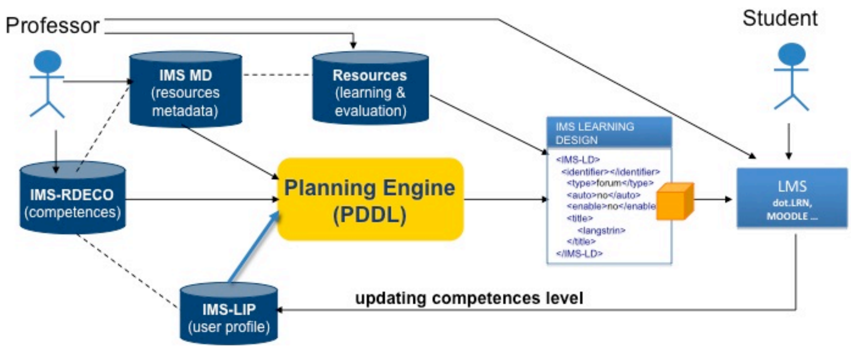


Figure 46. Learning Design Generation based on competences definitions and Learning styles

In the context of the planning domain, in order to include the adaptation based on learning style, we have created another method called *getPreferences* for obtaining the information related to the student’s preference, in particular, the preference of each learning style for the different learning objects types.

The preferences are registered in a xml file and they are provided by a set of intelligent agents responsible for the user modelling process [121]. A preference file has the basic structure shown in Figure 47.

```
<preference>
<order learningstyle="Active.Sensitive.Global.Visual"
learningresourcetype="Exercise">1.0</order>
</preference >
```

Figure 47. Structure of a Preference File

The result provided by *getPreferences* is assigned to a list called preference to be processed by the method listPreference. Each element of the list contains a learning style, a learning resource type and the preferred order. listPreference inserts in the world each list element in the following manner: *(property (?idls ((?rt ?idlrt) (?order ?val)))).*

The listMetadataLS method was added to the planning domain to complement the listMetadata method mentioned in the first scenario. Considering that each learning object type has associated a particular preference, to associate this preference to each learning object in the domain according to the learning object type associated was necessary. For each learning resource a property was created *(property (?idls ?idres (?rt ?idlrt)))*. This property inserts in the world each learning object associating it a learning style. Then crossing this information with the provided by listPreference using property (?idls ((?rt ?idlrt) (?order ?val))));; the order for each learning object is defined. This order is included in the state of the world by the *insertRecPre method* presented in the Figure 48 using (!!setProperty (?idres (?idls ?val))).

```
(:method (insertRecPre ?idls ?idres)
    (
     (property (?idls ?idres (?rt ?idlrt)));; from listMetadata
     (property (?idls ((?rt ?idlrt) (?order ?val))));; from getPreference
    )
    (
     (!!setProperty (?idres (?idls ?val)))
    )
    ()
    ()
  )
```

Figure 48. Method to define the matching among the learning resources and learning style

After last step, the relation between each resource and the learning style is available to be used in order to generate a suitable plan based on the learning style because each resource in the domain has a preference according to each learning style.

In this moment, the procedure to generate a learning design begins. The method analyzerStatementStyleLevel has been included in the domain and the *analyzerStatements* method mentioned in the last scenario has been modified. *analyzerStatements* is shows in Figure 49.

The analyzerStatementStyleLevel is included in the analyzerStatements method for creating a high level activity structure in the LD associated to each learning style.

If the information about learning style exists in the state of the world, the *analyzerStatementStyle* method is executed; if not, the *analyzerStatement* method is executed as described before and the adaptation is only performed for addressing the competence level.

```
(:method (analyzerStatements (?head . ?tail))
     ()
     (
      (analyzerStatementStyleLevel ?head)
      (!start-Activity-Structure (1 performanceevidence))
        (analyzerPer ?tail)
      (!end-Activity-Structure)
      (!start-Environments)
        (insEnvironment)
      (!end-Environments)
      (!start-Properties)
        (insProperty ?head)
      (!end-Properties)
      (!start-Conditions)
        (insConditions1 ?head)
      (!end-Conditions)
     )
  )
```

Figure 49. analyzerStatements method

The analyzerStatementStyle calls analyzerStatement for each learning style that exist in the state of the world creating an activity structure in the plan for each associated learning style. According to this preference, the learning objects are ordered in the environments. Figure 50 shows how this process is done.

```
:sort-by ?val MyComparator (and (property (?idls ?resource (?taxonid ?idtaxon)))
(property (?resource (?idls ?val))))
```

Figure 50. Selecting and ordering the resources according to the level of competence and learning styles

The (property (?idls ?resource (?taxonid ?idtaxon))) searches for learning objects associated to a particular competence knowledge and (property (?resource (?idls ?val)))) searches for learning objects associated to a particular learning style. Mixing both *properties*, the adequate set of learning objects is obtained. *sort-by ?val* orders the select resources according to the value of the preference.

The properties for the level of competence are the same as in the first scenario, but we have added boolean personal properties to support the selection of the adequate sequence for each student according to her learning style. For each student only one of these properties should be "true" at the execution time.

Conditions have also been modified adding a condition for each learning style in the LD. The insConditions that controls the High level Activity Structure associated to the learning design is created in the plan.

5.3.5 Integration upon dotLRN Learning Management System

Figure 51 shows the process for integrating our solution upon dotLRN platform. Left side of the Figure 51 shows the main elements on dotLRN to support the learning design generation process as well as their inputs and outputs. Right side shows the components involved in the Designer Service.

The Designer Client v1.0 Package implements a web service client in order to send planning requests to the *Designer* and processes its responses. The parameters that the Designer Client sends in its requests are the IMS-RDCEO of a course generated by the Competences Package and the list of learning content metadata URLs associated to the course. The Designer responds with an adapted course, which the planner client automatically loads and deploys in the learners' unit of learning.

If the teacher decides to offer a student also adaptation based on the learning style, the user modelling process based on learning style should be executed before calling Designer. The user modelling process based on learning style generates a Preference file, which is an input for this particular adaptation.

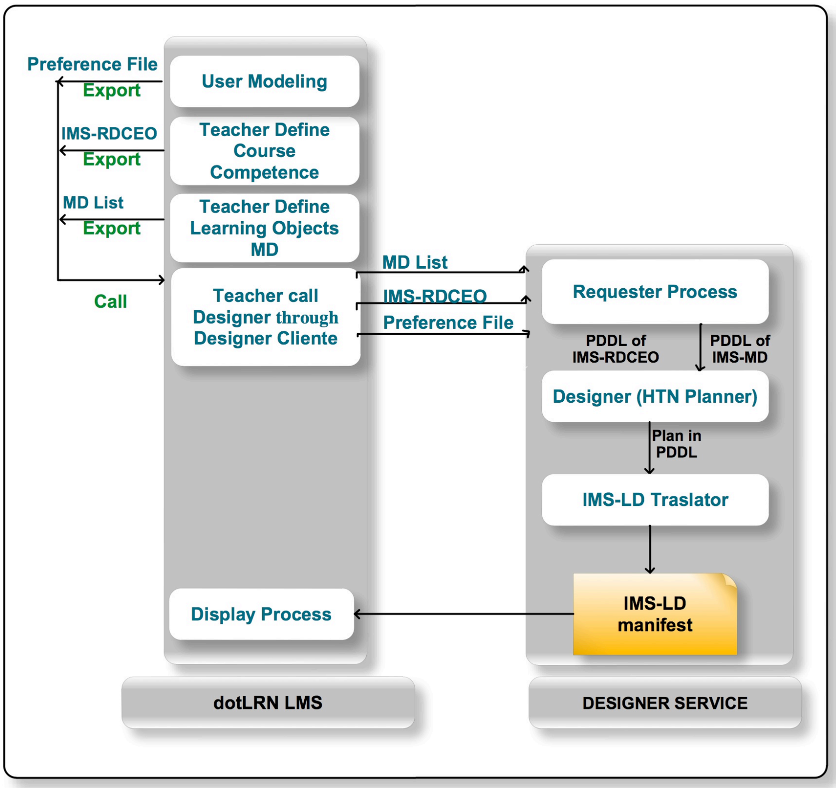


Figure 51. Designer Integration Framework

The Design Service *v1.0* implements a planning web service based on the Simple Object Access Protocol (SOAP) [125], which responds to adaptation requests and sends a reply with an IMS-LD unit of learning to be displayed in the context of a virtual course upon dotLRN.

In order to generate the adapted unit of learning according to the user learning style, developing a modification in the Display Process, i.e. in the IMS-LD player upon dotLRN, was necessary. This modification affects the mechanism of personal property values assignment. Creating a process to initialize the value of the local personal properties for each student according to the ILS results and according to the LIP competence records was also necessary.

5.3.6 Implementations results

Following figures show the achieved implementation of our framework upon dotLRN. Figure 52 shows the IMS – LD manifest uploading process in dotLRN when the the system is reading the IMS manifest document, which specify the UoL.

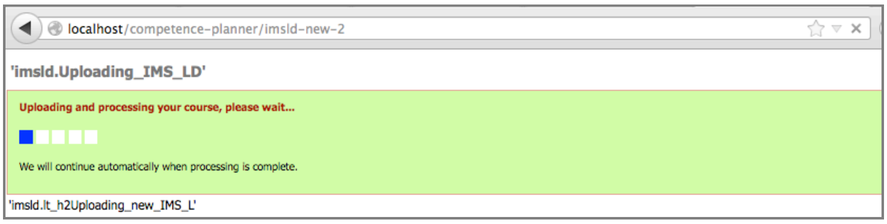


Figure 52. IMS LD upload process

Figure 53 indicates the IMS – LD manifest generated by Designer has been read in dotLRN. In the figure is possible to observe the most relevant information about the UoL, the title, IML – LD Level, associated roles, total defined activity structure as well as the learning and support activities.

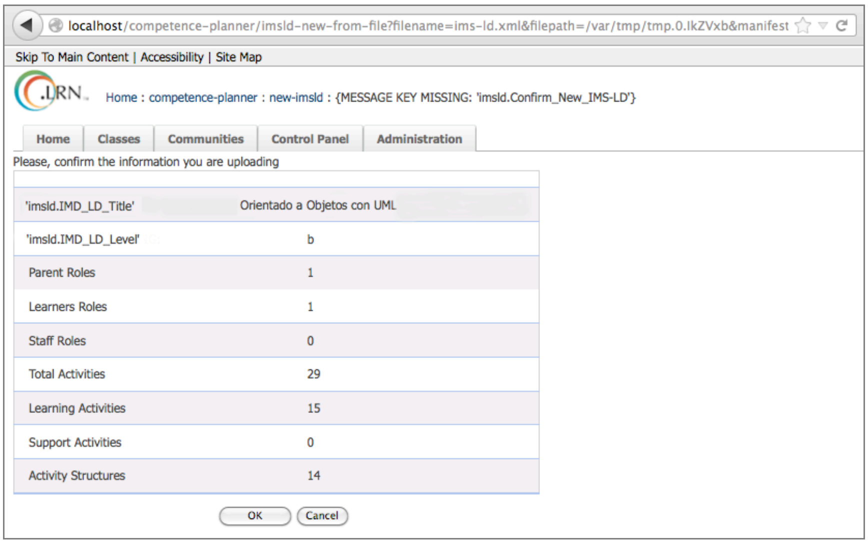


Figure 53. Manifest has been read upon dotLRN

Following the process, when the teacher clicks over ok botton in Figure 53, the system proceeds to UoL in the learning platform. Figure 54 shows the view of the IMS UoL without members enrolled. The user could add member to the UoL clicking in the Manage Members bottom in Figure 54.

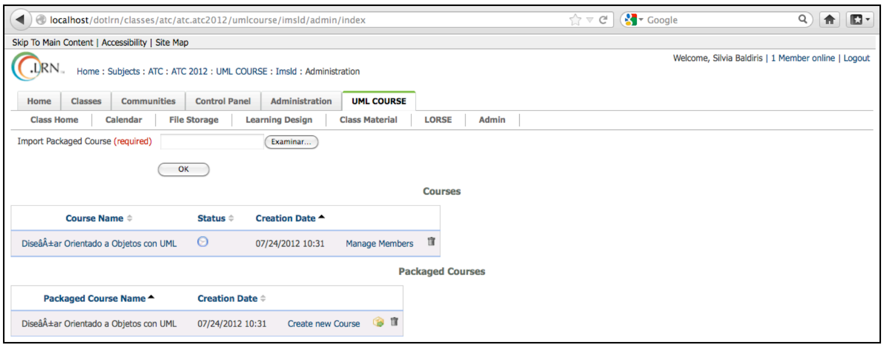


Figure 54. IMS – LD uploaded

All learning objects considered in the generation process have been referenced in the generated UoL. Figure 55 shows the Question and test interoperability files have been identified and uploaded automatically. This type of learning objects are special because the neccesary link to the assessment package upon dotLRN was implemented in order to achieve that they could be displayed correctly.

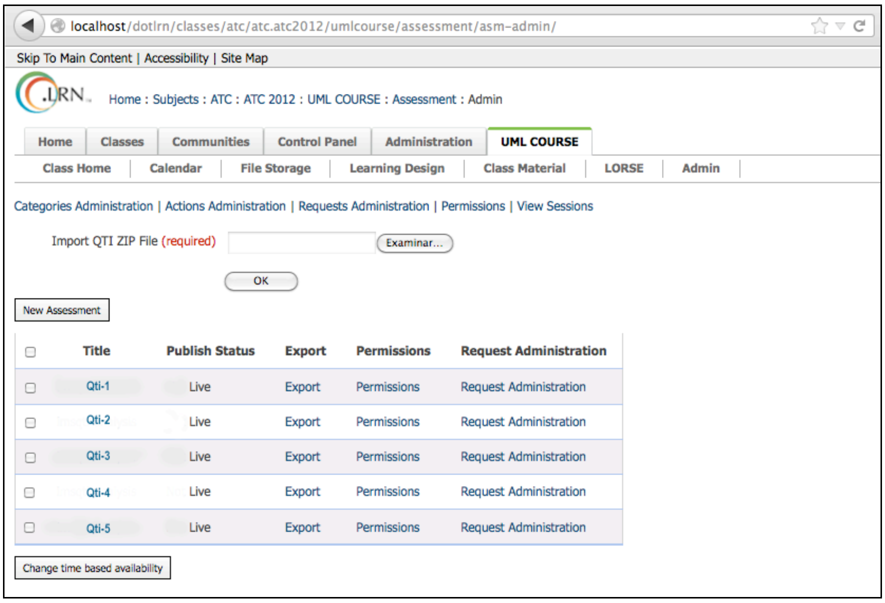


Figure 55. Qtis uploaded over dotLRN

Figure 56 shows an IMS UoL for the Learner role in dotLRN. When the student desires to begin the study about this UoL she needs to access this interface.

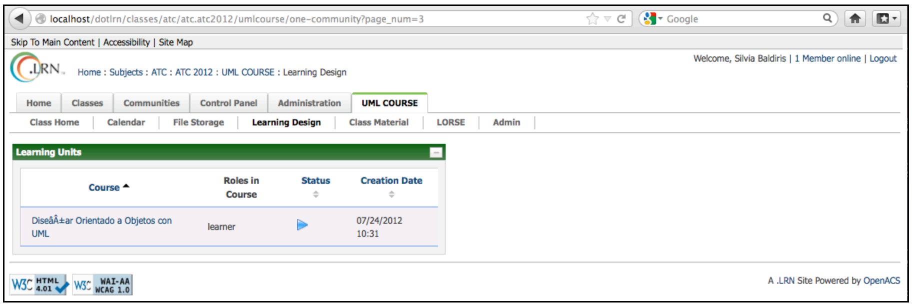


Figure 56. UoL for the Learner role in dotLRN

Figure 57 shows an IMS UoL for the Learner rol in dotLRN. Names are used to facilitate the explanations. Figure shows three sides. Left- Top side show the generated Activity structures. ls-1-as is the generated activity structure for a student with the learning style 1. ls-2-as is not suited for this student. ls-1-as consists of different activities associated to the competence levels. As the student involved in this example haven't had any previous experience in the topic his level of competence is *initial*. The ls-1-inicial activity structure is presented to him in this side.

The left lower side shows the created enviroment for this user. In this side the learning objects has been ordered according to the user's learning style.

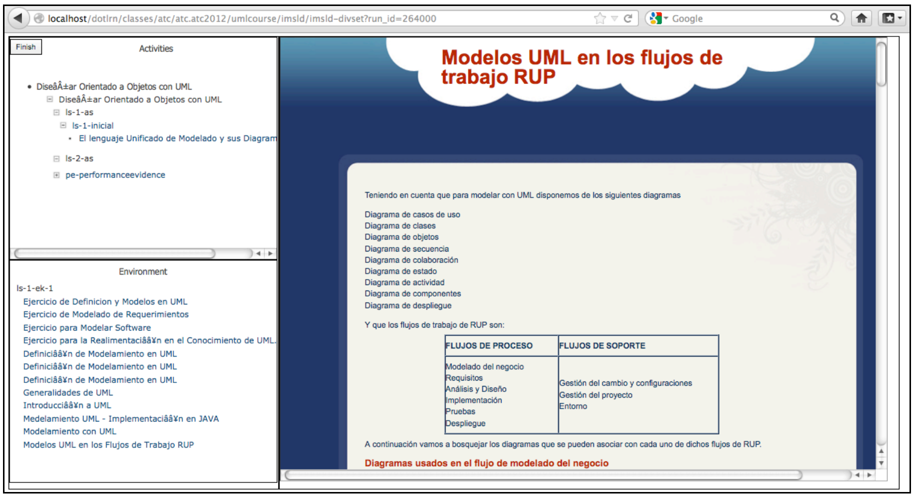


Figure 57. UoL for the student role in dotLRN

pe-performanceevidence activity structure in Figure 57 consists of the different assessment activities associated to each level of competence. Figure 58 shows dotLRN view of the assessment package used to develop test-based assessment. As mentioned before if available the tests are uploaded automatically in the UoL when they are available in the learning object repository.

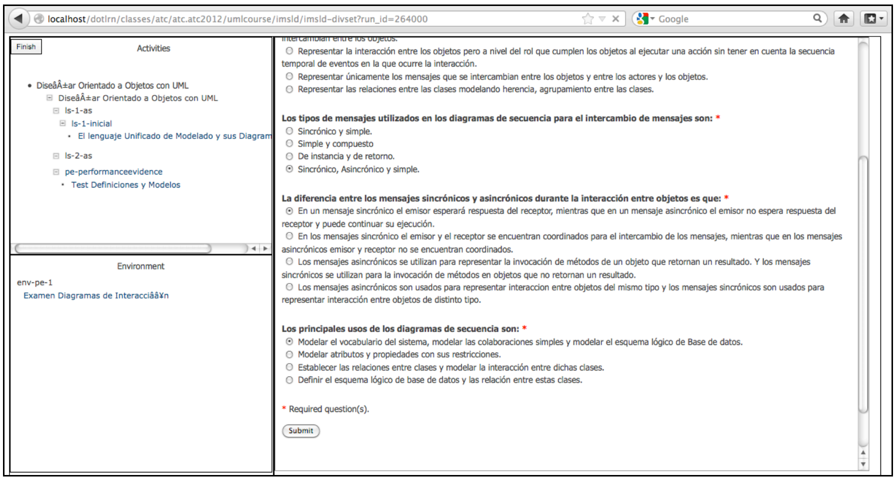


Figure 58. Test based Assessment upon dotLRN

Figure 59 shows the view of the UoL after the first test has been answered successfully.

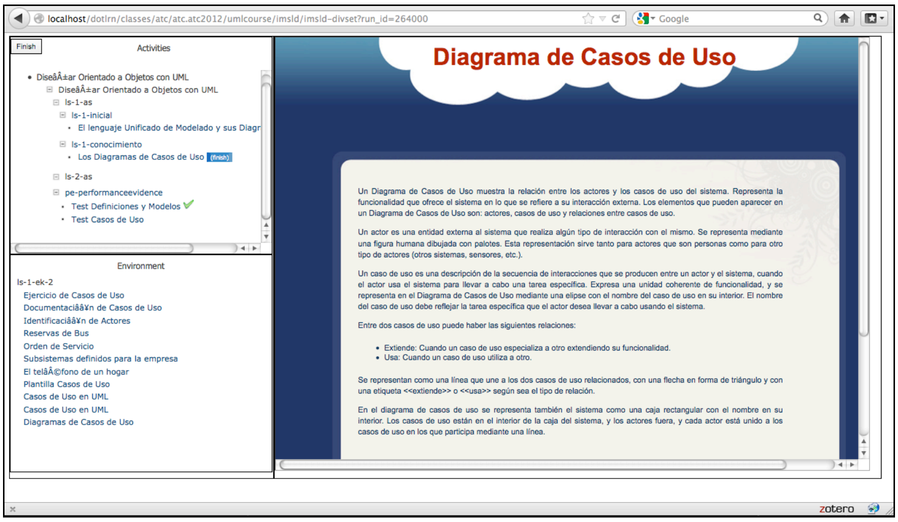


Figure 59. View of the UoL after test successful presentation

As possible to observe the other test according to the assessment sequence is shown in Figure 59. It is also possible to observe in Figure 59 the update sequence based on the defined competence knowledge.

5.4. EVALUATION

5.4.1 General Description

The main purpose of this evaluation process is to validate the learning design generation processes, verifying that the process supports teachers in the difficult task of designing adapted learning designs adjusted to user competences and learning styles.

The layers involved in this evaluation are *the adaptation decision making laye*r and the *User satisfaction layer*. Layers include the evaluation scenario of the different learning designs based on competences and on the user's learning style considering the teachers's point of view and the system performance as a good indicator of the solution success.

The principal actor in this evaluation is the teacher, who evaluates the proposed approach through the analysis of three dimensions:

- The learning-teaching process specification (Competence definition, metadata specification and the link between both)
- The learning design generation process, and
- The available adaptations in the learning design generation process to address the selected user's features

To develop this evaluation, we considered two different analyses focused on teachers and a third analysis focused in the system performance:

- A qualitative interpretative analysis was designed in order to capture teachers' opinions about our approach. This type of research permits us further progress in the comprehension of the teachers' behaviour as well as their intention and attitude, in particular, when they design a course using technologies. The created scenarios allowed us to deepen in the knowledge about the expectative, fears, uncertainties and barriers of the teachers when they use new technologies and methodologies, showing different opportunities to improve our solution.
- A quantitative analysis based on a Gap Model instrument [105] data analysis that was used to verify the teachers' satisfaction with our solution.

- A performance analysis permits us to observe the efficiency of our proposal comparing the time needed for teachers with different profiles for constructing basic learning designs and the necessary time used by the system.

5.4.2 Sample Description

This research was developed with 22 teachers from University of Girona from different areas of knowledge as pedagogy, economy, law, psychology, tourism, and administration science. These teachers impart different courses in the university, some of them supported by a virtual learning environment (Moodle).

The criteria to select the sample was the convenience [114] referred to a case selection based in the easiest access to teachers considering their context conditions or random coincidences.

In our case, we considered specific teachers with available time in the university. We ensured that these people were involved in different faculties in order to promote different points of view in the sample.

Figure 60 shows general data about the sample involved in our study. The main features of the sample are as follow:

- The range of teachers' age is comprised between 30 and 65 years old.
- The sample counts with a similar proportion of male and female.
- All the teachers do not need special access to technology.

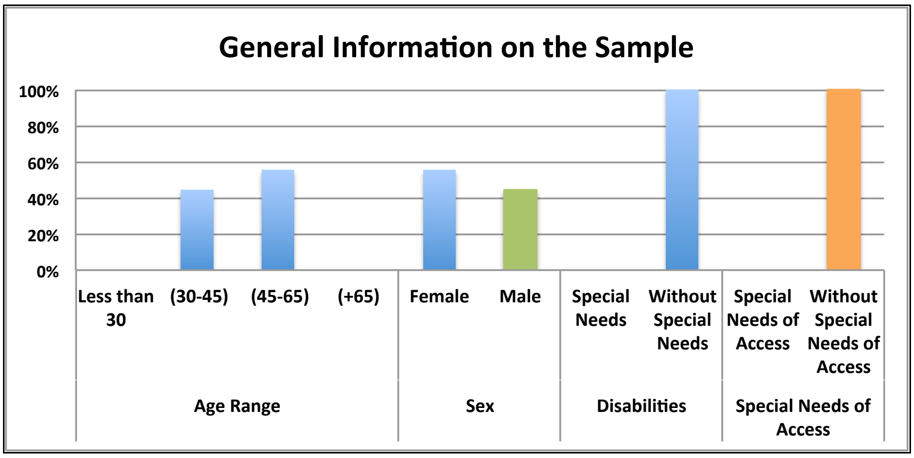


Figure 60. General Information on the sample

According to Figure 61 and with respect to the use of information technologies, teachers involved in our study declared to be experts and have average experience in the use of computers and Internet as a tool in their teaching tasks. They have more than 3 years using Internet and they spent between six and fifteen or more hours using Internet a week.

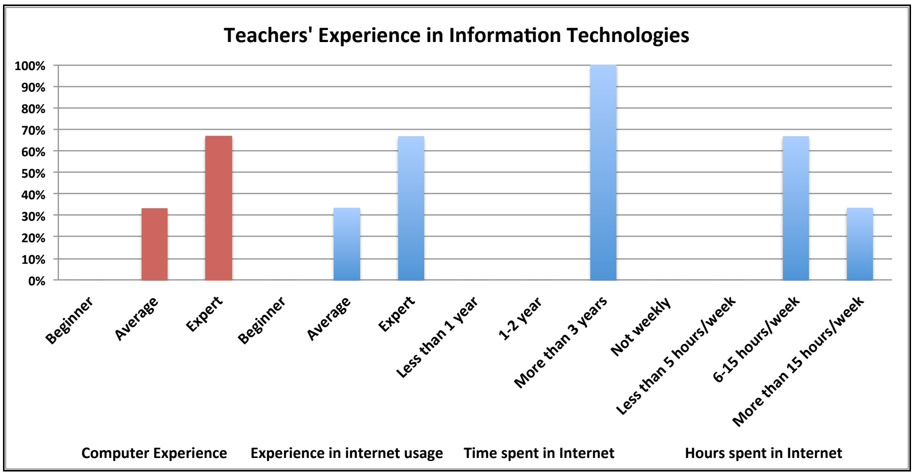


Figure 61. Teachers Experience in Information Technologies

As presented in Figure 62, all teachers in the study have more than 12 years teaching in the University of Girona. 55% have a teaching degree. The most common learning platforms used by the teachers are Moodle [126] and La Meva UdG [127]. They also use ACME [128], which is an author tool for developing learning objects from University of Girona. 55% of the teachers declare to have developed learning resources to support their teaching process.

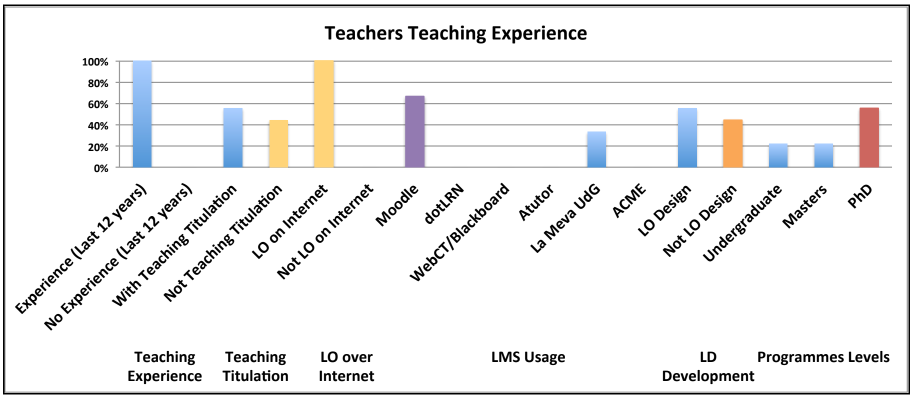


Figure 62. Teachers General Teaching Experience

Figure 63 shows that teachers have experience in different degree programmes as undergraduate, masters and PhD programmes. Teachers have more experience in traditional programmes and blended learning; less experience is observed in integral virtual courses.

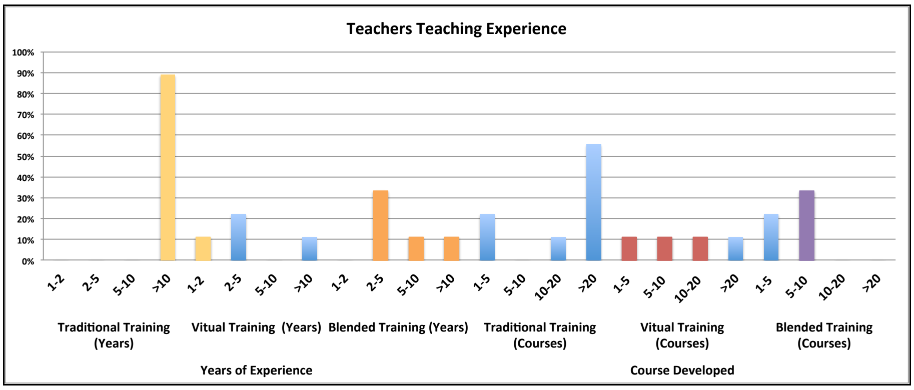


Figure 63. Teachers Teaching Experience on degree courses

5.4.3 Qualitative Analysis

5.4.3.1 Description

For the qualitative analysis design we considered the development of a longitudinal qualitative study [129], where the main strategy was the case studies.

Case studies permit us to concentrate in a particular situation. In our case, in the learning design process, to obtain as a final product a better understanding of potential opportunities to improve our approach, as well as to support teachers in a better way in the difficult task of designing courses.

The following process for developing the descriptive study was divided in four parts in order to evaluate the three proposed dimensions:

1. Introduction.

The purpose of this part is to contextualize the teachers in the purpose of the study. In this part, some elements are introduced: the session objective, the concept of learning design and learning objects, a general description of IMS Learning Design specification using prepared slides and the Recourse Author tool description, which was used to manually generate the IMS learning design.

2. Analysis of the proposed learning-teaching process specification.

The purpose of this part is to present teachers the defined learning-teaching process specification and to use these guidelines to manually construct a specific and previously prepared learning design. The steps followed in this part are:

- The competence model is presented to the teachers and the elements of this model are discussed. Then, the competence of the testing course, prepared using the model, is presented to the teachers. The teachers analyse the competence of the course according to the proposed model and express their point of view.
- The teacher defines a metadata for some learning objects in the learning platform specifying the necessary labels according to the IMS-MD model; we emphasize in the specification of *Classification Label* and *Learning object type*.
- The teacher manually designs the proposed learning design of the course using a particular authoring tool. Based on the study presented in [8], we selected Recourse as the author tool in this step. After completing the design development, a space of discussion was proposed for teachers to express their point of view about it.

3. Analysis of the learning design generation process.

In this part of our study the main purpose was to present the teachers the semi-automatic learning design generation process with the purpose to capture their opinion about for comparing it with the manual design process.

- Teachers were introduced to the learning management system used, as well as each element of the framework implemented.
- The teachers call Designer in order to generate the learning design of the course.
- Course is displayed into the learning management system and after the teachers verify that everything is developed according to the learning-teaching process specification, they are motivated to modify some elements of the course. Modifications permit to reaffirm the idea of a semi-automatic process instead of a totally automated process.
- After the generation process, a discussion was proposed to teachers in order to capture their opinions about the generation process.

4. The analysis of the available adaptations in the generation process.

Having developed the generation process with teachers, the implementation of the generated adaptation process based on competences and learning style was analysed jointly.

- The Activity Structures to address the different learning designs were described to teachers.
- The teachers prove the sequence based on Competences Levels. The teachers present the different tests and verify the sequence of different levels.

- A Discussion was proposed for teachers to capture their opinions about the adaptation process to offer a personalization process to users.

This process was developed in sessions with the teachers during three hours. These sessions were recorded. During the sessions, the teacher was free to ask any question, to say any comments about the process and to do any additional thing.

5.4.3.2 Results of the qualitative analysis

In this section the results of our study are presented. First, we have selected the most important cases to describe the results of applying our methodology. The analisys of these cases permit us to introduce the most relevant conclusions of our study.

Psychology Faculty Case

General Description

The Psychology Teacher is a professor of University of Gerona from the Psychology faculty. He is a professional in the personality, assessment of behaviour and psychological treatment.

His age is in the 45-65 range, without disabilities and access limitations to technology. He declares that he is an expert in the Computer and Internet use, browsing more than 15 hours a week. However, he declares that he hasn't developed learning objects.

He uses email, forums, chats, blogs, social and professional networks, text processors, spreadsheets, and video and photo editors for his personal use. He uses some of these tools in his professional context.

The teaching activity of the professor is 20 years, with a university teaching degree. He has experience in different courses modalities, faces modality courses and blended learning. He has also worked with different kind of programmes, more than 20 courses of undergraduate and postgraduate, Masters, PhD programmes.

He has used Moodle and La Meva UdG learning platforms to support learning and teaching process.

The teacher identifies some advantages in the use of learning platforms such as:

- The dynamic, participative, interactive characteristics and the easy access to the information for students and teachers.
- Ecologic and economic, for instance, no photocopies are necessary.
- The students could freely select learning objects according to their interest and also self-manage their time.

- The teacher was able control the student behaviour in a better way.
- The possibility of developing learning activities online.
- The possibility of developing a student track.
- Reusing learning objects and using open source learning objects is possible.
- The facility of using different sources of information and document types.
- Minimal technical experience is required from the teachers.

The teacher also identifies some difficulties in the use of learning platforms such as the incompatibility among browsers, which difficult the use of some solutions and limitations in supporting group activities, in particular, in the personalization of this process.

The analysis of the Psychology Faculty Case

At the beginning of the process, the teacher seems to be very interested on the elements introduced by the researcher. He conceives the learning design process as a complex process and expresses his expectations for the proposed solution.

During the analysis of the competence definition, the teacher expresses his agreement with the representation of the learning process purpose through competences and also to divide the competence into the simplest objectives according to Bloom.

The exercise over Recourse for the learning design generation in a manual way takes *one hour and a half.* At the end of this part, the teacher was enabled to upload his unit of learning in dotLRN. This activity motivates many questions about different elements in the tools, which were solved at the same time.

The teacher acknowledged how the information of the competence specification facilitates the development of the unit of learning in a manual way.

He discovers the IMS LD specification elements in Recourse and the utility of the different elements in the specifications, as well as the learning objects roles in the LD.

The teacher understood the importance of the IMS manifest document as well as the container of the course structure and the base for the course interoperability. He also understood the manifest validation process as a mechanism to guarantee the sharing of learning designs.

Some conclusions of the Teacher according to the manual process of design are:

- The teacher newly emphasizes in the complexity of the design process and in the required time to develop the design according to the proposed process. He suggests that the task could be justified for the future reuse of the generated learning design.

- He highlights the necessity of sharing learning objects and designs among universities, which is not a reality until now, as a mechanism to reduce the time to generate new courses.
- The teacher also emphasizes in the importance of guaranteeing the stability of authoring tools because errors produce uncertainties in the teacher and many times this uncertainties are not overcome.

Finishing the manual process, the semi-automatic process is introduced. The teacher creates the competence using the competence package and he uploads the metadata of the resource associating them to the competence. The teacher calls Designer and he automatically generates the IMS learning design.

Some conclusions about the semi-automatic process are:

- The teacher indicates that the semi-automatic design process is fantastic. He gives a positive value to the possibility of future modification of the design.
- He considers the adaptive learning process as a positive contribution to the learning management system.
- He suggests improving the appearance of the learning design player because he indicates that the player could be difficult to understand for the student.
- The teacher indicates that he feels that the universities need to use approaches like Designer to ease the teacher task of course design, at least in the University of Girona.
- The teacher suggests simplifying maximally the process in order to facilitate the use for the teachers and also to improve the usability of the solution. He indicates the solution should specify a simple sequencing process that should be intuitive for teachers. The usability of the solution reduces the frustration of the teachers facing the technologies.

Polytechnic School Case

General Description

The Polytechnic School Teacher is a professor of the University of Girona from the Department of Computer Architecture and Technology. He has a PhD in the doctorate programme of information technology.

His age is in the 45-65 range, without disabilities and access limitation to technology. He declares that he is an expert in the Computer and Internet use, browsing more than 15 hours a week.

He uses forums and professional networks for learning and tools such as email, text processor, spreadsheets, for both personal and work context and video and photo editor as a hobby.

The teaching activity of the professor is over 10 years, with a university teaching degree. He has taught in more than 5 courses in face-to face or blended learning modality.

He also declares he has developed learning objects using ACME, an author tool for developing mathematics and algorithmic exercises created by him. He has used Moodle and La Meva UdG as learning platforms to support learning and teaching process.

The teacher identifies some advantages in the use of learning platforms such as:

In Moodle:

- To be an open source solution facilitates the updating and growth of new solutions.
- Because of the use of Moodle in a university as a learning platform, the students usually feel more comfortable with this environment where they can freely select learning objects according to their interest and also self-manage their time.
- The standardization work over Moodle has been interesting.

In ACME:

- Possibilities for personalization.
- Modular application.
- No trivial problem solution.
- Wide typology of Learning Activities.
- Integration with other learning platforms.

The teacher also identifies some difficulties in the use of learning platforms:

In Moodle:

- Complex process of assessment.
- Reduced typology of Learning Activities.
- In his opinion, unfriendly.

In ACME:

- Little standardization.

The analysis of the Polytechnic School Case

The teacher expresses the importance of defining the learning purpose in terms of competences, specially in the European space of higher education. He also expresses to know the Bloom's taxonomy as a good solution from the technical point of view for representing learning objectives. In this case, remember that Professor has a PhD in information technology and he has developed learning solutions over learning platforms.

The manually learning design generation took half an hour. The necessary time to develop LD with some people with technical experience was much lower than the one needed with some people with only pedagogical experience.

After the manually generation was finished, the teacher expresses the difficulty for the teachers to develop this task, because it was a time consuming task and maybe it could be difficult for teachers to understand the IMS LD standard, which is important for developing the process.

The conversation with the professor was easier to carry because of his previous knowledge about metadata, manifest, and the different technical issues associated to our solution.

At the beginning of the explanation about the semiautomatic learning design, the teacher was really interested when we were analysing the different tools used in the generation, as well as the technical issues such as the algorithms used to generate the suitable plan.

Some conclusions about the semiautomatic learning design were:

- He was really impressed with the difference between the necessary time to generate manually an IMS learning design and the one using Designer.
- He highlights the adaptation process as a mechanism to facilitate the task of the teacher for monitoring the student behaviour in the system.
- He also highlights the possibility to perform changes in the IMS learning design after its generation because of the flexibility given to teachers for changing the design at any given time.
- The professor emphasizes that one of the most important issues for teachers at the moment is the necessity to have author tools which permit reusing previous work developed by other teachers around the world. He asks: why is it necessary to do things that others have already done, maybe things which people have dedicated a considerable amount of time as the case of distribute learning objects? In this context, a tool as Designer is interesting for teachers.
- The teacher mentions that he likes the proposed competence definition because he thinks that dividing the competence into sub goals is a good option

for conceiving and monitoring the competence acquisition process. He mentions that in his experience, the student's learn in a sequential way, and if the learning process assesses student behaviour sequentially, then the student process is facilitated.

Pedagogy Faculty Case

General Description

The Pedagogy Faculty Teacher is a professor from University of Girona from the Education and Psychology Faculty. He is a professional in Natural Sciences and Mathematics (for primary school), Therapeutic Pedagogy (for secondary school) and Educational Technology (for Superior Education).

His age is in the 45-65 range, without disabilities and access limitation to technology. He declares that he is an expert in the Computer and Internet use, browsing more than 15 hours a week.

He uses email (Thunderbird, Outlook, web mail), forums (Moodle), chats (Facebook, Skype), blogs (Blogger, WordPress), social (Facebook, Twitter) and professional networks, text processors (MSWord, OpenOffice), spreadsheets (MSWord, OpenOffice), and video and photo editors (Gimp, FireWorks, Pinnacle Studio, WMM, JayCut), as well as tools such as JClic, Flash, Dreamweaver, Joomla for his personal use and for learning indifferently.

The teaching activity of the professor is over 10 years in face-to-face and virtual programmes. He has a diplomat in Teaching and a degree in Pedagogy from University of Girona.

The teacher also declares that he has developed learning objects using Dreamweaver, Nvu, and JClic over Moodle. He has experience in more than 20 courses with different modalities in undergraduate and postgraduate, Masters, PhD programmes. He has used Moodle and La Meva UdG learning platforms to support learning and teaching process.

The teacher identifies some advantages in the use of learning platforms such as:

- Learning platforms are a common virtual space for all the actors in the learning process.
- Learning content updating process is easier than in the traditional process.
- Learning platforms increase the possibility of collaboration among the actors of the learning process.
- E-learning eliminates space and time dependencies.
- Adaptation in Learning platforms improves the dynamism of virtual courses.

- Learning platforms facilitates individualized treatment for students.
- Learning platforms increase the possibility to share learning content and activities.

The teacher also identifies some difficulties in the use of learning platforms:

- The lack of student focus and commitment.
- The lack of human contact.
- Some students are not comfortable with virtual learning environments.
- The excessive generalization of the learning content compromizes the learning process.
- Poor student technical competence could be a problem for accessing learning.
- Adaptation is not easy to achieve in virtual learning environment because adaptation is really an expensive process.

The analysis of the Pedagogy Faculty Case

Some conclusions about the semiautomatic learning design were:

- Our approach eases the difficult task of design for teachers reducing the necessary time to create and standardized learning design.
- The teacher generally tries to deliver students a unique learning object with a particular pedagogical and didactical intention influenced by the teacher style, but maybe this learning object does not address the learning preference for all the students in the virtual environment. In this context, using different types of learning objects is a good solution and also provides adaptation based on the learning object type according to the students learning styles.
- However, the professor suggests considering the excessive standardization of the learning processes because each professor have his/her particular style of design.
- Learning object type is an important element for addressing the kind of learning the teacher needs to stimulate in the student. Knowing which elements in the learning process match with the different learning to be achieved is very important.
- The professor also analyses the necessity of remembering to stimulate the relation between students and teachers, because an excessive process of automation, in particular, in E-learning could be dangerous in his concept.

- The teacher emphasizes the necessity of guaranteeing the quality of the learning objects, which is an important issue in the learning object economy because it is one of the most relevant issues to guarantee the learning design quality. The process for selecting a learning object should be contextualized to the teachers and students necessities.
- An unavoidable task for the teacher is to refine the design generated and to verify that this design covers the necessities of the student in an adequate way. In this way the "semi" automatic proposed process is promising.
- Usability tests are important in order to capture the satisfaction of the teachers in action.

The previous description cases permit us to understand the process followed in the qualitative analysis and the nature of the results. In the following sections we present a joint vision of some selected cases which describe other interesting results and additional conclusions provided by these teachers.

Economic and Business Science, Tourism and Organization Faculty

Economic and Business Science General Description

The Economic and Business Science teacher is a professor from the University of Girona from the Economic and Business Science faculty. She is a professional in Financial Economics and Accounting. The Teacher is in the 30-45 age range, without disabilities and access limitation to technology. He declares that she is an expert in the Computer and Internet use, browsing more than 15 hours a week.

The teacher uses wikis, blogs, professional networks, text processors, spreadsheets for learning and work, as well as tools such as email, social networks and video and photo editor for personal issues.

The teaching activity of the professor is more than 10 years old in masters and undergraduate programmes, without degree in pedagogical issues. He has taught in more than 2 courses in face-to face modality.

He also declares that he hasn't developed learning objects, and she doesn't use any learning platforms.

Tourism General Description

Tourism teacher is a professor from University of Girona from the Tourism faculty. She is a professional in Social Communication.

The teacher has an age in the 45-65 range, without disabilities and access limitation to technology. She declares that she is an expert in the Computer and Internet use, browsing more than 15 hours a week.

She uses forums, wikis, blogs, social and professional networks, text processors and spreadsheets for learning, as well as email, chat and video and photo editors for her personal use. She uses some of these tools in her professional context, in particular email, chat and forums.

Teaching activity of the teacher is over than 10 years, with a Master in didactic and multimedia materials design from Universitat Oberta de Catalunya.

The professor has experience in more than 20 face-to-face courses, more than 10 courses in blended learning modality and more than 5 virtual courses. She has participated as a teacher in undergraduate, postgraduate and masters programmes.

She also declares that she has developed learning objects using ACME platform and Moodle.

The teacher has used Moodle and La Meva UdG learning platforms to support learning and teaching processes.

Organization General Description

Organization teacher is a professor of University of Girona from the Department of organization, management and product design. He is a professional in Companies organization.

He has an age in the 30-45 range, without disabilities and access limitation to technology. He declares that he is a user with medium experience in the Computer and Internet use, browsing more than 15 hours a week.

He uses email, forums, social networks, text processors, spreadsheets and video and photo editors for his personal use and for learning indifferently.

Teaching activity of Teacher is over 10 years in face-to-face and over 5 years in virtual programmes, without degree in pedagogical programmes.

Teacher also declares he has not developed learning objects before and he has experience in more than 20 courses in face-to-face programmes and more than 10 in virtual programmes. He has used Moodle and La Meva UdG learning platform to support learning and teaching processes.

Teacher identifies the possibility to have asynchronous communication as the main advantages of learning platforms. However, he feels that the lack of personal, face-to-face, communication process could be the main problem of this kind of systems.

The analysis Economic and Business Science, Tourism and Organization Faculty

In general, the teachers consider a good idea to specify learning purposes in terms of competences to be achieved.

The teachers were very interested in the generation process as a mechanism to ease the design task of the teachers and to reduce the necessary time to create learning designs. This process permits to perform the design task more efficiently, effectively and agile.

The teachers consider the adaptation process as an added value in the learning context which facilitates the process of addressing user features making the educative offer more flexible.

The teachers think the reuse of learning objects is a possibility to improve virtual learning process for uniting the efforts of teachers from different universities.

The teachers indicate the possibility to develop tests of the solution in a bigger scale and they were really interested in this issue.

5.4.4 A quantitative analysis based on Service Quality Gap Model

5.4.4.1 Description

A Gap Model of service quality [105] is focused on the perceived quality of the learning design generation process by teachers. The perceived quality results from a comparison of expectations of the users with their perception of offered service performance.

The Gap models consider that all users have an expectative about the service quality of the offered service. The difference between the expectative and the perception is called Gap, in which reside the opportunity to improve the service.

We considered a Gap Model as a part of the layered evaluation in our study, considering the exploratory research [130], which supports the notion that service quality is an overall evaluation similar to attitude. The Gap Model captures the attitude of the teachers towards our development, which is the most important objective in this part of our study.

In order to carry out the gap model we have developed a particular instrument (the used survey could be found in appendix c) to measure the user perception in each of the previously defined dimensions (see section 5.4.1).

The survey consists of three parts:

- The first part consists of questions related to characterization data of the teacher: name, age, relation with technology, expertise in learning object creation and other relevant information. This information was summarized in section 5.4.2.

- The second part consists of eleven questions distributed in three proposed dimensions in order to obtain the feedback of the teacher about their perception over three complementary processes:
  - *Learning and teaching processes specification analysis* capture teacher's opinion about how the competence is defined and how the learning object metadata are specified (SQ1-SQ2-SQ3).
  - *Semi-automatic learning design generation process analysis* establishes the gap according to the teachers' opinion on the learning design generation process with respect to a manually learning design generation (GQ1-GQ2-GQ3-GQ4).
  - *Adaptation process analysis* captures the perception of the teacher about the utility of the adaptation process based on competences and learning styles of the students (AQ1, AQ2, AQ3, AQ4).

Table 47 shows a section of the survey that permits us to understand its structure. We have defined a number of questions to evaluate each dimension. The teachers must evaluate each question in a [1..10] scale using two criteria, the importance and the satisfaction. The importance criterion is referred to the relevance or value of the analysed process for the evaluator, this criterion is a measure of the user expectations. The satisfaction criterion is referred to user perception or the grade of agreements with the offered service performance. The [1..10] scale should be divided into categories as described in Table 48.

Table 47. Service Quality Survey Structure

DIMENSIONS	IMPORTANCE						SATISFACTION					
LEARNING AND TEACHING PROCESSES SPECIFICATION (SQ1-SQ2-SQ3)												
SQ1. The competence specification to be achieved for students as well as the elements considered in its definition represent for you a learning purpose?	0	1	2	3	…	10	0	1	2	3	…	10
SEMI-AUTOMATIC LEARNING DESIGN GENERATION PROCESS (GQ1-GQ2-GQ3-GQ4)												
GQ1. Semi-automatic learning process facilitates the learning design process upon a learning management system?	0	1	2	3	4	10	0	1	2	3	4	10
ADAPTATION PROCESS (AQ1-AQ2-AQ3-AQ4)												
AQ1. The adaptation mechanism helps students in their learning process orienting their advance in the process.	0	1	2	…	4	10	0	1	2	3	4	10

Table 48. [1..10] scale for assess importance and satisfaction

WITHOUT IMPORTANCE OR UNSATISFIED	LOW IMPORTANCE AND LOW SATISFACTION			IMPORTANT OR SATISFIED				VERY IMPORTANT OR VERY SATISFIED		
0	1	2	3	4	5	6	7	8	9	10

All question are presented in the appendix c.

- The third part allows us to capture the opinion of the user about the importance of each proposed dimension. Teachers provide us a percentage [1 … 100] to measure the importance of each analysed dimension.

5.4.4.2 Analysis of the Gap Model Results

After the interview phase, we proceeded to analyse the results of our study. Table 49 shows the condensed results for each dimension considering the response provided by the 22 teachers from University of Girona. Figure 64 shows a data graphical point.

Table 49. Condensed analysis of teacher satisfaction

CONSOLIDATED	IMPORTANCE	SATISFACTION	GAP
Learning and teaching processes specification (SQ1-SQ2-SQ3)	8,9444	8,3333	0,6111
Semi-automatic learning design generation process (GQ1-GQ2-GQ3-GQ4)	8,5625	8,0208	0,5416
Adaptation process (AQ1-AQ2-AQ3-AQ4)	8,6458	8,2083	0,4375
TOTAL	8,71	8,18	0.53

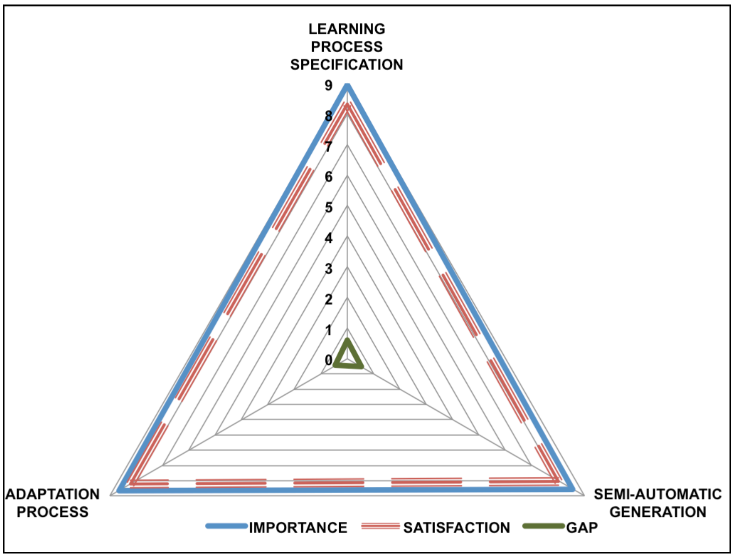


Figure 64. Condensed analysis of teachers' satisfaction

As presented in the importance column from Table 49, consolidated data show that the specification of the learning process, a semi-automatic generation process, and to provide adaptations in a virtual learning environment are very important processes to be considered for teachers when they design virtual courses.

As well, consolidated data show that teachers were very satisfied with the solutions provided for addressing each of the processes involved in the study. This means that the provided solution adds value to their teaching-practice, confirming the data obtained from the qualitative analysis.

In general, teachers have qualified with a high score the importance and satisfaction in each dimension. The difference between importance and satisfaction (gap) for the proposed solution is 0.53, which we consider minimum according to the scale. This means that the proposed solution seems to meet the expectations of the surveyed teachers.

In order to give more details about the results of some of the questions in the survey, where the gap was bigger than others, and also to provide explanations about results, we introduce Table 50, Table 51 and Table 52 as well as their associated graphical representations (see Figure 65, Figure 66, and Figure 67).

Table 50. Service Quality Study Results for Learning and Teaching Process Specification

LEARNING AND TEACHING PROCESSES SPECIFICATION (SQ1-SQ2-SQ3)			
	IMPORTANCE	**SATISFACTION**	**GAP**
CONSOLIDATED	**8,9444**	**8,3333**	**0,6111**
SQ1	9,4166	8,4166	1
SQ2	8,6666	8,25	0,4166
SQ3	8,75	8,3333	0,4166

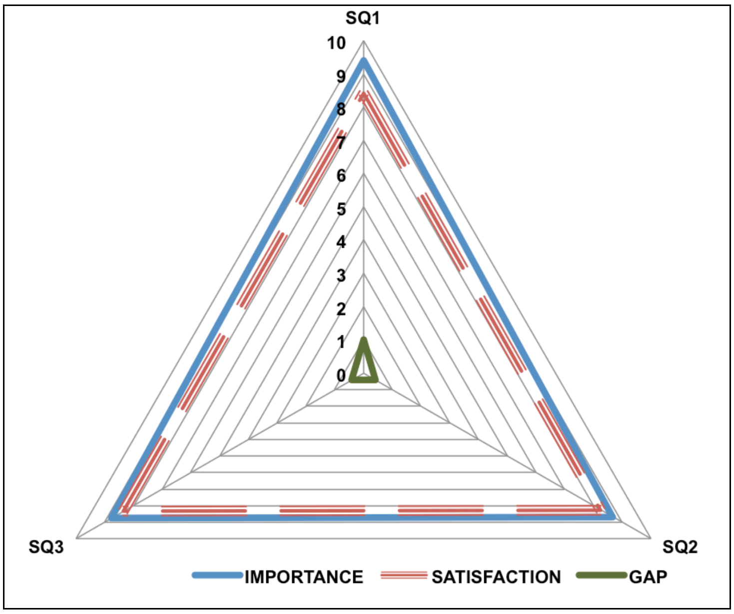


Figure 65. Detailed analysis of teachers' satisfaction for Learning and Teaching Process Specification

Table 51. Service Quality Study Results for Semi-Automatic Generation

SEMI-AUTOMATIC LEARNING DESIGN GENERATION PROCESS (GQ1-GQ2-GQ3-GQ4)			
	IMPORTANCE	SATISFACTION	GAP
CONSOLIDATED	8,5625	8,0208	0,5416
GQ1	8,5	8	0,5
GQ2	8,75	8,3333	0,4166
GQ3	8,4166	7,8333	0,5833
GQ4	8,5833	7,9166	0,6666

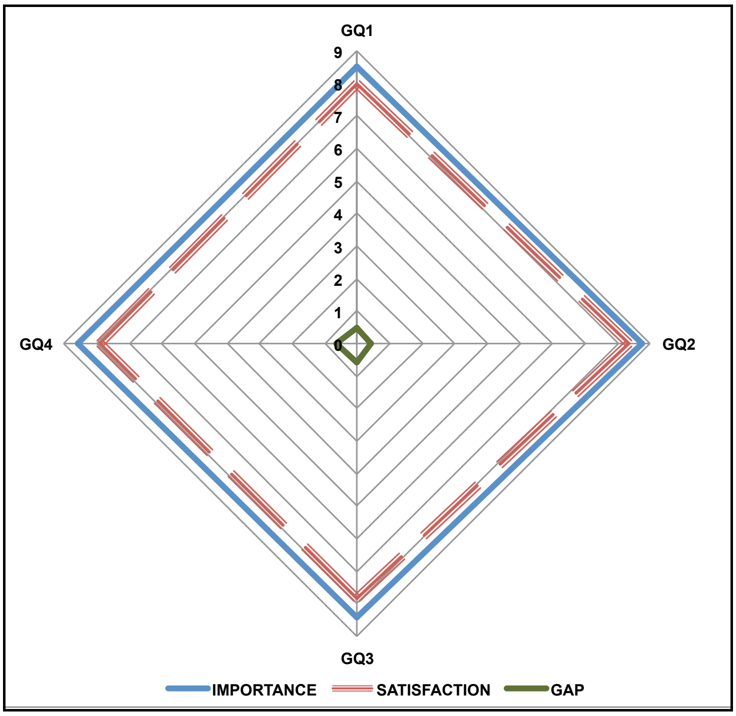


Figure 66. Detailed analysis of teachers' satisfaction for Semi-Automatic Generation

Table 52. Service Quality Study Results for Adaptatioin Process

ADAPTATION PROCESS (AQ1-AQ2-AQ3)			
	IMPORTANCE	SATISFACTION	GAP
CONSOLIDATED	8,6458	8,2083	0,4375
AQ1	8,9166	8,5833	0,3333
AQ2	8,4166	8,1666	0,25
AQ3	8,75	8,0833	0,6666
AQ4	8,5	8	0,5

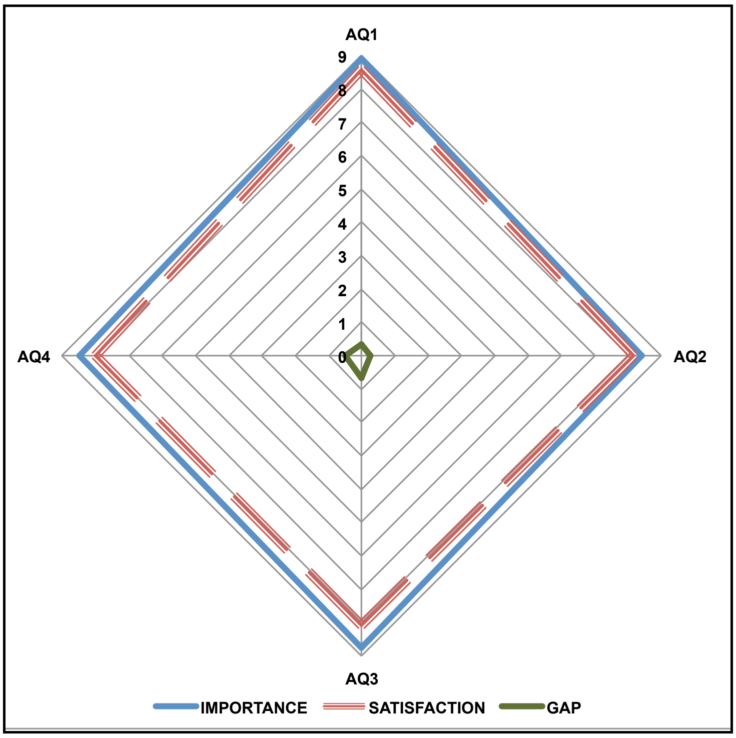


Figure 67. Detailed analysis of teachers' satisfaction for Adaptatioin Process

The most relevant difference between the importance and satisfaction of the teachers is presented in question SQ1 which as mentioned before, ask the teachers their opinion about the proposed competence definition as could be observed in Table 50. Although the satisfaction score is still high, the importance score indicates that adding more flexibility in the definition of the learning purpose is necessary. This is a normal situation because defining objectives, goals, achievements, among others, can be performed in many different ways.

About this issue, the use of IMS reusable definition of competence and learning objectives permits us to add the necessary flexibility in the definition of learning purpose.

Although the scores are still high, the differences between the importance and satisfaction in GQ1-GQ2-GQ3-GQ4 observed in Table 51 refer to improvement opportunities in the generation process. In particular, teachers insisted on having more diversity of didactic approaches to support learning design generation process. To address these issues could increase the perception about the benefits of using Designer.

On the other hand, the close relationship between the importance and satisfaction of teachers for the proposed adaptation process based on competences and learning styles which could be observed in the consolidated results for the last set of questions, AQ1- AQ2- AQ3- AQ4 was really surprising (see Table 52). We think that this is due to the teachers' positive attitude towards the learning design adaptation process because they recognize, as they mentioned in the qualitative study, that this process is a very difficult task for them at the course design time.

5.4.4.3 Analysis of the teachers opinion importance of each dimension

Results presented in Figure 68 show that teachers consider the three analysed dimension highly important. This reaffirms the results presented in the second part of our study. The result was calculated as an average of the percentage provided by the sample of teachers.

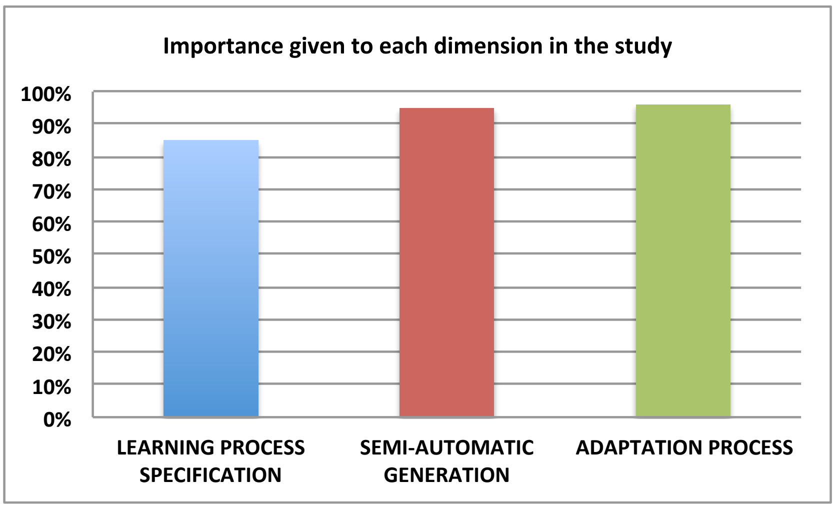


Figure 68. Perception about the importance of each dimension involved in the study

5.4.5 System Performance Analysis

One of the traditional measures of automatic generation processes has been the performance of the systems according to the time of generation. We consider that providing a vision of this performance is important and this is the main objective of this section. However, we also provide a comparison between the Designer performance and the Human Designer performance.

5.4.5.1 *Performance of Designer*

The performance analysis developed for Designer considers the course presented in chapter 3.2.2.2. Competence definitions, as well as metadata files, for 80 learning objects were used in order to test the generator. The Designer service using the mentioned inputs generates an IMS- Learning Design which was imported to the selected learning platform. Table 53 shows the results of execution. Data includes generation time as well as import time.

Table 53. Designer performance

NUMBER OF LO	SECONDS
20	1,305
30	2,94
40	3,498
60	24,626
80	26,233

5.4.5.2 *Comparing Designer Performance Vs Human Designer performance*

With the purpose of comparing the performance of Designer with a similar process developed by humans we developed an extra testing scenario. We asked teachers to finish a partially constructed learning design. Their contribution was only to link the same number of learning object considered in the testing of Designer performance analysis (20, 30, 40, 60, 80). The used authoring tool was the same used in the qualitative study, *Recourse.* Results of this analysis are shown in Table 54. Figure 69 shows the average time spent by the teachers in a graphical point of view.

Table 54. Manual Load of Learning Objects into a learning design Time (sec)

NUMBER OF LEARNING OBJECT	20	30	40	60	80
GROUPA	104	166	215	320	432,5
GROUPB	134,66	203	259,33	379,33	500,33
GROUPC	193	241,66	332,33	517,66	677,66

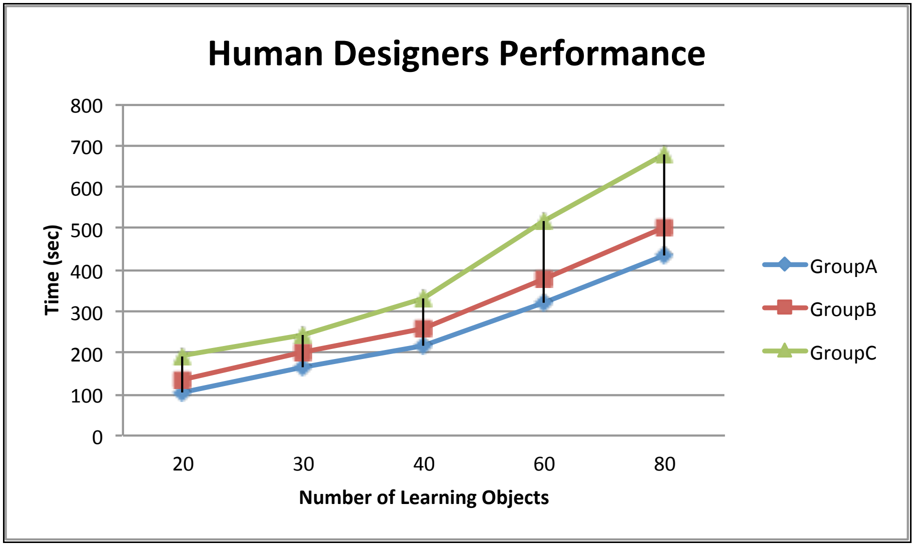


Figure 69. Manual Load of Learning Objects into a learning design

Groups presented in the Table 54 were not established a priori, but from the results of the times used in the process. 3 groups were defined and for each case, the time average for importing 20, 30, 40, 60 and 80 learning objects was calculated in seconds.

Obtained results of this analysis are shown in Figure 70.

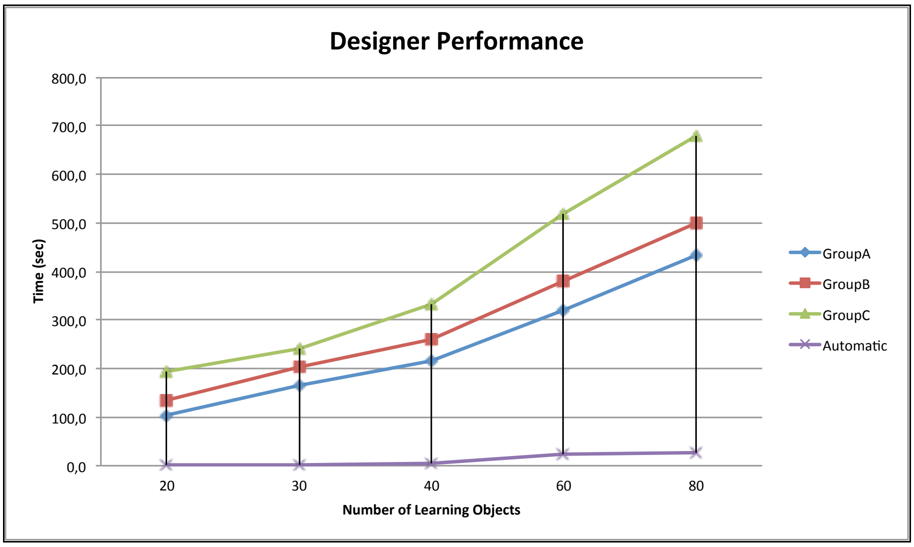


Figure 70. Comparing Designer Performance Vs Human Designer performance

Results of the study show the Human Designer performance times are bigger in two orders of magnitude with respect to Performance of Designer. However, after increasing the number of the objects, the slope does not grow significantly in the Performance of Designer, while the manual generation growth is appreciable. Additionally, from the qualitative point of view, the experiment allowed some other known perceptions of the teachers involved in the sample:

- Tiredness and lack of motivation grew with the number of objects.
- Errors in the selection of learning objects associated with the competences set.
- Opinion of loss of time in this process.

In general, the study allowed reaffirming the necessity of semi automatic learning design generation.

5.5. CONCLUSIONS OF THE CHAPTER

Developing adaptive and standardized courses is very time-consuming for teachers. In this chapter, we introduced an approach for reducing teachers' workload for generating standardized and adaptive learning designs. A framework for learning design generation was described and, in particular, Designer: Semi–Automatic Standardized Learning Design Generator was introduced and evaluated.

Our evaluation showed that the participating teachers found our approach useful, specially for the possibility to easily create an IMS-LD and also for the possibility of providing learning paths adapted to the students' learning styles and competences. However, they also complained that the production of learning resources and virtual activities and its semantic relations through metadata requires an initial extra effort, but they also agreed that in subsequent opportunities, this effort decreases as the possibility of reutilization grows.

We consider the results from this study as valuable because (1) these teachers cover a broad spectrum of participants since they were from different fields and with different levels of experience in online learning, and (2) the results of the gap analysis clearly showed that all participants perceived our developments as important and satisfied their expectations. These positive results encourage further studies with a larger sample group.

Future work will also be oriented to take into account other students' characteristics such as special needs, and teachers' preferences about pedagogical methodologies for learning design generation, as well as the use of other techniques for the learning design generation.

6. CONTEXTUALIZED LEARNING OBJECTS SERCHING AND POSITIONING PROCESS

This chapter introduces our solution for improving our learning design generation process presented in chapter 5. Distributed learning objects are adding into the generated learning design according to their relevance to address the competence to be achieved by the students. Our solution stimulates the learning object reuse through accessing distributed learning objects repositories (DLOR) as sources of LO with diverse granularity, which are elements in the generated learning design.

Intelligent retrieval process consists of two differentiated parts, the Distributed Learning Objects Metadata Searching Process and the Micro-Context based Positioning Process.

Distributed Learning Objects Metadata Searching was conceived as a mechanism to promote a reuse-oriented approach. This process is supported by agent technologies and its main purpose is looking for external LO, not developed by the teachers, which could be used for our solution as inputs in the learning design generation process.

Micro-Context based Positioning Process proposes the analysis of the learning objects' metadata and the current Micro-Context (in the LOR it live) considering disambiguation techniques in order to establish the LO relevance for a specific micro-context in a learning design and thus helps in placing the object in its correct context.

The rest of the chapter is structured as follows. In section 6.1. the Distributed Learning Objects Metadata Searching Process is introduced. Section 6.2. describes the Micro-Context based Positioning Process. Section 6.3. shows evaluation results and finally in the section 6.4. some conclusions and remarked future works are introduced.

6.1. LORSER: META-SEARCHER OF LEARNING OBJECTS OVER DISTRIBUTED LEARNING REPOSITORIES BASED ON INTELLIGENT AGENTS

In order to address the Distributed Learning Objects Metadata Searching Process, we have developed a learning object repositories searcher (LORSE), which stands for Distributed Learning Objects Metadata Searcher, as a mechanism to promote a reuse-oriented approach.

LORSE multi-agent system [87] has been modelled as an independent set of JADE intelligent agents that collaborate to support the users in the LO searching process.

LORSE consists of two different types of agents: the Directory Facilitator Agent and the Specific Searcher Agents. The main purpose of this multi-agent platform presented in Figure 71 is to deliver to the most suitable LO according to the parameters provided by the user in a specific query.

The Directory Facilitator Agent maintains a directory of tuples, where each of them relates one specific searching service over a LOR with one specific agent called Specific Searcher Agent. Each Specific Searcher Agent develops the task of registering a new service into the Directory Facilitator Agent and of processing the services requested. When an external process needs to request a particular service in the platform, the external process must communicate with the Directory Facilitator Agent to request the identifier of the agent in charge of a specific service. Specific Searcher Agents implement particular web clients through behaviours for requesting search services over particulars repositories. LORSE has grown from [87] where we introduce an example of application with three repositories (Merlot, Conexions and UdG), now LORSE count with nine repositories including six additional services: DalSpace [131], Deep Blue [132], DLESE [133], ARIADNE [134], SMETE [135] and GATEWAY [136]. Current LORSE architecture is shown in Figure 71.

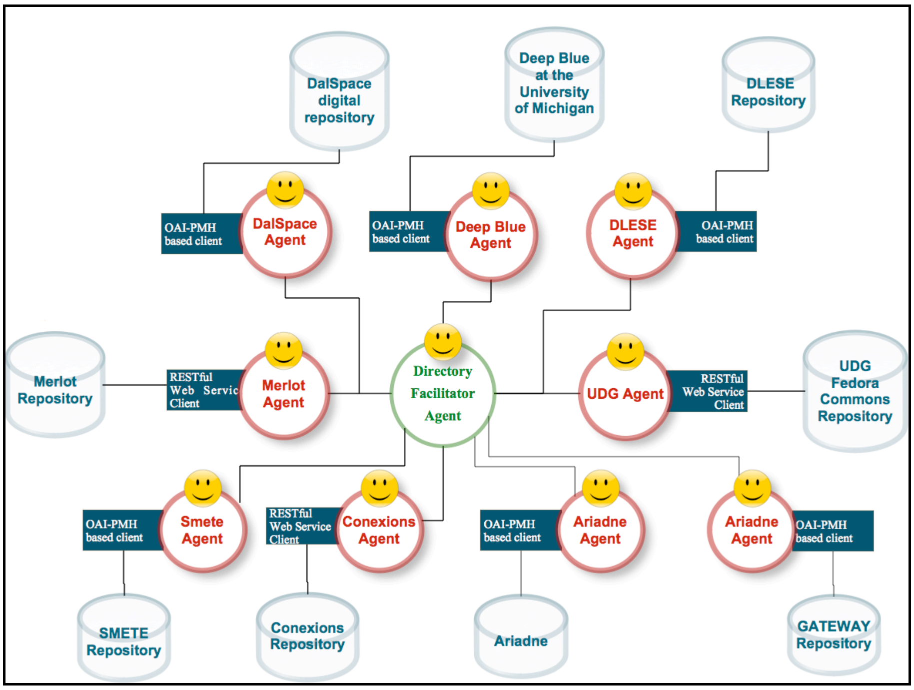


Figure 71. LORSE Multi-Agent Platform

When the Merlot Agent (Specific Searcher Agent in charge to the integration of Merlot Repository) is born, the Merlot searching service is registered to the Directory Facilitator Agent in order to allow other agents or processes to locate and send requests to this agent. The Merlot agent is activated when a request for searching is sent to it. Merlot agent counts with a particular behaviour, which is a client of the RESTful web service, offered by Merlot repository. When a request is sent to the agent and according to the terms and conditions of the query, the agent performs a connection with the service, sending the parameters. The same behaviour gets the response, which is an XML document (metadata).

The implementation of Connexions and UDG Agent is similar to the Merlot agent, they have behaviours designed to interact with the RESTful web service offered by this applications.

For the integration of DalSpace digital repository, Deep Blue Repository at the University of Michigan and DLESE Repository, ARIADNE, SMETE and GATEWAY into the multi-agent platform, we have created an intelligent agent for each of them with a indexer behaviour, which using the OAI-PMH harvester protocol indexes the categories (catalogues) and records into each category (resource) of each particular repository. Each resource metadata is stored in a database as a tree. In this way the information is available for searching.

Figure 72 shows a view of the multi-agent system implementation over Jade.

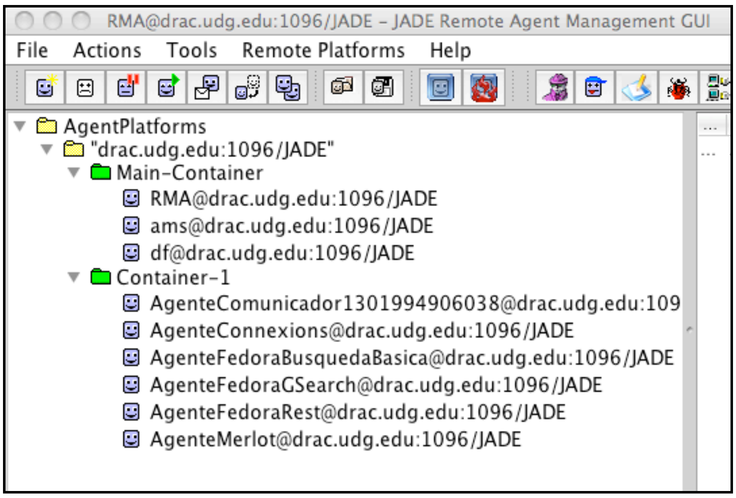


Figure 72. JADE View of the LORSE Multi-Agent Platform

In order to test LORSE with real users, we have integrated our proposed platform upon OpenACS/.LRN learning environment. For the integration process it was necessary to implement the LORSE Client package in this platform as a web service client upon dotLRN in order to send requests to the LORSE Multi-agent Platform and process its responses. This package offers an interface to users that provides functionalities in order to search over several repositories in a transparent way. Therefore, when teachers use the learning environment they are able to search LO from those repositories to enhance the activities designed in the platform without necessity of leaving to the learning environment.

Figure 73 shows a view of the LORSE integration into OpenACS/.LRN learning environment.

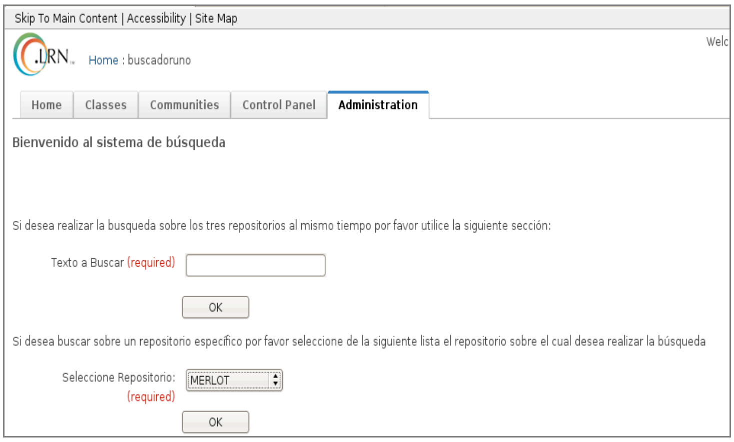


Figure 73. LORSE Integration upon OpenACS/.LRN

Figure 74 presents some results of searching over Connexions repository upon dotLRN.

Figure 74. Results retrieved by LORSE from Connexions repository

6.2. LOOK: MICRO-CONTEXT BASED POSITIONING PROCESS

6.2.1 Description

The main purpose in this section is to explain our approach to enrich our learning design generation process considering external and distributed LO, which are stored in LOR. To achieve this objective two different sources of information are available. The information prevenient from LOR, in particular, the catalogue or indexed mechanism of the LO and the LO metadata. And on the other hand, the information provided by the teacher in the competence definition is available. As mentioned before, the competence definition consists of four categories of information: *Competence General Information* which provides general data about the competence; *Competence Elements* which are smaller learning purposes and means more specific and concrete learning process outcomes; *Didactical Guidelines* and the *Competence Context* of application.

Competence Elements in turn describe the Essential Knowledge which the student should mobilize in a specific context to demonstrate the acquisition of the competence and the *Competence Evidence* as the mechanism to measure the level of achievement of each particular competence element.

This available information which is the available knowledge evidences are evaluated according to [137]. Schum's evidential reasoning approach explains how the evidence coming from different sources can be evaluated. In our case, the analysis of the evidence is related to its relevance, the relevance of the learning object for addressing what the teacher is looking for. It means relevance of the LO to motivate the achievement of the competence in students.

6.2.2 Learning objects relevance through the Micro-Context

The automatic disambiguation of word senses (WSD) has been an interest and concern since the earliest days of computer treatment of language in the 1950's and it involves the association of a given word in a text or discourse with a definition or meaning (sense) which is distinguishable from other meanings potentially attributable to that word [138].

All disambiguation work involves matching the context of the instance of the word to be disambiguated with either information from an external knowledge source (knowledge driven WSD), or information about the contexts of previously disambiguated instances of the word derived from corpora (data-driven or corpus-based WSD).

The assignment of words to senses is accomplished by reliance on two major sources of information:

- The context of the word to be disambiguated in the broad sense: this includes information contained within the text or discourse in which the word appears, together with extra-linguistic information about the text.
- External knowledge sources, including lexical, encyclopedic, etc. resources, as well as hand-devised knowledge sources, which provide useful data to associate words with senses.

Most disambiguation works use the local context of a word occurrence as a primary information source for WSD. Local or “micro” context is generally considered to be some small window of words surrounding a word occurrence in a text or discourse, from a few words of context to the entire sentence in which the target word appears.

We are going to consider the micro-context of a learning object as a part of the curricular structure where the learning object should live (learning design to be generated). Let us present the following example.

Consider the following curricular structure shown in Table 55 belonging to a course of Unified Modelling Language (UML), generated based in the competence definition provide by a teacher.

Table 55. Part of a Curricular Structure of UML Course

Unified Modelling Language
• Introduction to UML
o *Concept*
o *Diagrams*
o *Relation of UML with the Unified Process of Development*
• The models
o Use cases diagrams
o *Actors*
o *Use Case*
o *Relations*
o *Class diagrams*
o *Sequence diagrams*
o *Activity diagrams*

We need to place the LO, which can be obtained as the results of a preliminary search based in the mechanism provided by the LORs, or according to the metrics described in Table 6, in the structure from Table 55. In this manner, we developed the analysis of two different micro-contexts, the micro-context of the LO in the repository structure (catalogue) where the LO is placed, and the micro-context of the LO in the curricular structure, where the LO will be placed. Comparing this possible micro-context, a decision regarding the best location of the learning object in the learning design can be performed.

The first step is to define the micro-context of each learning object (LO) to be placed and also the possible micro-context in the curricular structure.

The micro-context where a LO is placed in a LOR catalogue is given by equation 2.

$$loMicroContext(LO,C) = SuperCategories(LO,C) U SubCategories(LO,C)$$

Equation 2. LO micro-context

In Equation 2, LO is the learning object and C is the catalogue in the LOR. loMicroContext defines the LO Micro-Context into a particular LOR catalogue.

Table 56 shows the loMicroContext of one LO, “Introduction to OMG's Unified Modelling Language”.

Table 56. Introduction to OMG's UML

Science and Technology
• Computer Science
    o Programming Languages
        o **LO Introduction to OMG's Unified Modelling Language**

cuMicroContext defines the possible micro-context in the Curricular Structure (CS) provided by the teacher. These possible micro-contexts are given by Equation 3.

$$csMicroContext = \sum_{1}^{N} cuMicroContext(\text{leaves})$$

Equation 3. Curricular structure micro-context

The number of leaves in the CS defines the possible micro-context in the curricular structure. Three of nine possible micro-contexts (cursive in Table 55) in the CS are shown in Table 57.

Table 57. Possible micro-context in the UML Course

FIRST POSSIBLE MICRO-CONTEXT IN THE LEARNING DESIGN
• Unified Modelling Language o Introduction to UML o Concept
SECOND POSSIBLE MICRO-CONTEXT IN THE LEARNING DESIGN
• Unified Modelling Language o The models o Use cases diagrams ▪ Actors
THIRD POSSIBLE MICRO-CONTEXT IN THE LEARNING DESIGN
• Unified Modelling Language o The models o Class diagrams

Now, the second step is to calculate the similarity between the different CS Micro-Context and the LO Micro-Context in order to place the LO in the structure. For this step, we propose to use different existing metrics to calculate the similarity between the TF-IDF (Term Frequency, Inverse Document Frequency) inferred vectors through the analysed Micro-Context (CS and LO). We use similarity measures that have been extensively validated in information retrieval, in particular, Dice coefficient and Cosine Distance [139].

Dice coefficient compares the similarity between two vectors (Q and D) from 0 to 1, where 1 indicate identical vectors and 0 orthogonal vectors. Equation 4 shows Dice coefficient.

$$s = \frac{2|Q \cap D|}{|Q| + |D|}$$

Equation 4. Dice coefficient

Cosine Distance varies between -1 and 1, where −1 means exactly opposite, to 1 means exactly the same and 0 usually indicates independence, and in-between values indicate intermediate similarity or dissimilarity. Equation 5 presents Cosine Distance. θ represents the angle between Q&D.

$$s = \frac{Q.D}{|Q||D|} = \cos(\theta)$$,where θ is the angle between Q & D

Equation 5. Cosine Distance

Based on the results of the algorithms for metrics implementation, the LO will be placed in the most similar Micro-Context in the CS with respect to the Micro-Context of the LO in the repository structure (catalogue).

6.3. EVALUATION

6.3.1 Description of the evaluation process

After implementing our solutions for searching and locating LO, an evaluation of our developments has been conducted. As mentioned before, main issue of this chapter is to introduce our solution for looking learning objects in distributed learning object repositories as well as their positioning process in the most promising micro-contexts of the future generated learning design.

In section 3.2.2.1 we introduce the layered evaluation for adaptive hypermedia systems as a good approach to completely validate the elements of this kind of systems. We consider the use of a layered evaluation process to measure the results in our development because the most important associated decision process (locate a learning object in a learning design structure) support an adaptive mechanism (Adaptive Learning Design Generation Process based on students and teachers preferences). According to the adaptive system evaluation theory different layers have been considered in our study in order to test all the elements of the adaptive system [102], [140], [141]. In this part of our research, we consider the following set of evaluations layers:

- The decision making evaluation layer, where the question to be answered is: are the decisions about where the learning objects should be located valid and meaningful for teachers?
- User satisfaction evaluation layer, where the question to be answered is: is the proposed solution adequated to the teacher's expectation?

6.3.2 Testing Course, Object Oriented Design with UML

Object Oriented Design with UML is a course offered by the University of Girona in the formal educational process. The course pretends to stimulate the student the achievement of the following competence in students: "The student will be able to design object oriented software using the unified modelling language (UML). The student will identify the most adequate diagrams to support the specification of each step in the object oriented development process"

For this competence, five different competence elements and their associated competence knowledge were defined:

First Competence Element: Student defines Unified Modelling Language and identifies its main associated diagrams. Competence Knowledge: Unified Modelling Language and its Diagrams.

Second Competence Element: Student understands the concept of Use Case Diagrams and their associated concepts, such as actors, inclusion, extension, and generalization. Competence Knowledge: Use Case Diagrams.

Third Competence Element: Student understands the concept of Class Diagrams and design class diagrams considering users requirements. Competence Knowledge: Class Diagrams.

Fourth Competence Element: student understands the concept of interaction diagrams, in particular, sequence and collaboration diagrams. He/she expresses the dynamic view of the software using this kind of diagrams. Competence Knowledge: Interaction Diagrams: Sequence and Collaboration Diagrams.

Fifth Competence Element: student understands the concept of Activity Diagrams to construct activity flows. Competence Knowledge: Activity Diagrams.

For this course, 87 open learning objects were extracted to the course presented in section 3.2.2.2. These learning objects were located in an instance of the Fedora Commons Repository available at University of Girona. The set of learning objects to support the learning process covers diverse types of atomic resources with a specific pedagogical intention. There are these kinds of learning objects: exercise, simulations, diagrams, figures, graphs, indexes, slides, table, narrative texts, experiments, problem statements, lectures, questionnaires, exams and self- assessments. Furthermore, each learning object has one associated LOM metadata where the most relevant information about the learning object is defined through a labelling process.

6.3.3 The decision making evaluation layer

6.3.3.1 Description

The main purpose of this evaluation layer is to validate our process for positioning learning objects from different learning objects repositories in the curricular structure of a learning design.

According to the typologies from [142], [143] of the Learning Objects Repositories involved in our research and for the character of the previous obtained results, we have considered dividing the testing scenarios in two different environments, an uncontrolled and a controlled environment.

The uncontrolled environment consists of repositories with diverse level of labelling, where learning objects have different degrees of granularity. This environment permits us to verify the possibilities and limitations of our approach considering uncontrolled repositories over which labelled in the metadata is not defined or supervised.

The Controlled environment consists of repositories available at University of Girona where the labelling was previously defined considering the relevant information and the granularity of the learning objects was defined. This kind of environment permits us to verify more closely the precision of the proposed algorithms with a controlled set of learning objects and their metadata.

Both environments share the same testing course and, for this reason, the competence definition and the analysed micro-context associated to the competence were the same for both environments.

6.3.3.2 First scenario: an uncontrolled environment

Description and Methodology

This scenario shares the purpose of validating our proposal for positioning learning objects from different learning objects repositories in the curricular structure of a learning design.

Uncontrolled environment considers different learning objects repositories linked through the same interface provide by LORSE. Involved repositories are: ARIADNE, MERLOT, SMETE and GATEWAY. Learning objects in these repositories are labelled with LOM, others with Dublin Core, but in general, with a small set of information defined by the Market-Makers.

The process developed by the study in this environment was as follows:

- We looked for the catalogue provided for each defined repository.
- Different kinds of search were performed over the defined repositories using diverse search criteria. The criteria were defined considering the information provided for the metadata in each repository and the searching mechanism provided for each of them. Then, we select the ten most relevant LO for our study.
- Using the previous information, the LO micro-context (loMicroContext) in the repository was constructed in two different ways. The first one, as defined in section 6.2. . The second one also considered the LO metadata as a part of the LO micro-context. This was necessary because in many cases the LO micro-

context based on the LO catalogue was not significant for our study because the LO micro-context does not support the proposed similarity analysis.

- The next step was building the micro-context in the curricular structure (cuMicroContext). We defined six micro-contexts; five different micro-contexts according with to the five competence knowledges defined in the course competence, and a general course micro-context. This general course micro-context consists of the title, description and all the knowledge associated to the competence.
- Having all micro-context involved (loMicroContext and the cuMicroContext), we proceeded to compare them calculating the similarity measurements among the Micro-Contexts. We calculated the similarity between each learning object with respect to each curricular structure Micro-Contexts. Then, we consolidated an average similarity, grouping the learning objects according to the repository where the LO are placed.

Results and Conclusions

Table 58 shows the most relevant results of this study. The first column defines different criteria for searching in the considered learning objects repositories. The same criteria was considered to define the LO micro-contexts. Additional columns represent the results of the average similarity consolidation with respect to the general course micro-context.

Let us introduce an example. 0,2368 is the average of the similarity measure calculated among the ten learning objects retrieved using the metadata, in this case, Abbreviation of keywords from Merlot. For each learning object the similarity of its micro-context was calculated with respect to the general course micro-context mentioned before.

We do not show the analysis of the other partial curricular structure micro-contexts considering the competence knowledge because the similarity measures are very small and extremely close among them, which do not permit us to discriminate the most promising micro-context for a learning object.

One of the most important conclusions related to this study was that using the definition of the provided catalogue for uncontrolled repositories as a mechanism to define the learning object micro-context in a new learning design is very difficult. That could be verified by observing row six in Table 58. The reason is simple: the catalogue definition is too general for the LOOK process to place the learning objects into a micro-context defined by the competence. The Micro-context of the catalogue does not meet the Micro-context extracted through the competence definition.

Table 58. Analysis of General Competence Micro-Context and Learning Objects Micro-Context

SEARCH CRITERIA	MERLOT	ARIADNE	GATEWAY	SMETE
METADATA (ABBREVIATION OF A KEYWORD)	0,2368	0,2140	0,0092	0,2164
METADATA (ONE KEYWORD)	0,1915	0,2501	0,0518	0,1236
METADATA (KEYWORDS AND ABBREVIATION OF A KEYWORD)	0,1915	0,2737	0,0338	0,1236
METADATA + SHORT CATEGORIES	0,0986	NA	NA	NA
METADATA + CATEGORIES	0,1337	NA	NA	NA
CATEGORIES	0,0081	NA	NA	NA

This situation led us to redefine the Micro-Context of the learning object in equation 6.

$$loMicroContext(LO,C) = SuperCategories(LO,C) U SubCategories(LO,C) U Metadata$$

Equation 6. New LO Micro-Context

However, similarity measures between both Micro-Contexts do not show a strong relationship, although a manual analysis of the resources content shows a strong relationship for the educational process.

6.3.3.3 Second scenario: Controlled environment

Description and Methodology

As was mentioned before, in order to test our proposal in a controlled environment we have prepared a complete Course of Object Oriented Design with UML.

The main objective of this study was to analyse the capacity of our approach for locating adequately the learning objects into a specific course structure but with a set of learning objects labelled adequately.

The starting point is the "correct" classification developed by an expert teacher. This means that a teacher provided us with the information of how he/she puts the objects in the proposed curricular structure.

The process developed by the study in this environment was as follows:

- According to the information provided in the competence definition, a structure for the course was defined, as shown in Table 55.
- Teacher manually places the eighty-seven (87) available objects in the structure defined for the course. In this way, we have defined a point for comparing point.
- Five Micro-Contexts associated to the UML Course curricular structure (cuMicro-Context) were defined.
- The Micro-Contexts of each learning object (loMicro-Context) in the UML course were defined.
- Similarity measurements between each loMicro-Context and each cuMicro-Context were calculated. This means that for each LO available object in the course (87), its Micro-Context was compared to the five defined Micro-Context in the curricular structure.
- Grouping the LO according with the classification provided by the expert teacher, the similarity average for each curricular structure Micro-Context was calculated.
- Then, we compared the similarity for each set of learning objects for each curricular structure Micro-Context.

Results and Conclusions

Purpose of Table 59 and Table 60 is to present the LOOK precision to place the LOs in the best curricular structure micro-context. The obtained results come from calculating the average similarity for each set of learning objects previously placed by teachers in a particular csMicro-context. The results show the correspondence between the teacher's classification and the LOOK process classification and indicate that in general LOOK places the LOs in the best csMicro-Context according to teacher's opinion.

In Table 59 and Table 60, the rows show the identified csMicro-Contexts (Introduction, Activity Diagram, Class Diagram, Use Case Diagram and Interaction Diagram) and the columns represent the micro-context where the teacher classifies the set of learning objects previously. The values in the table indicate the average similarity between the Micro-context of each set of LO previously classified by the teachers and each csMicro-Context.

For example, considering the first column, we calculate the average similarity of the set of LO previously classified by teacher in Introduction Micro-Context and each csMicro-Context. In this way the similarities are: for the Introduction Micro-Context (0.2222), for the Activity diagram Micro-Context (0.1379), for the Class Diagram Micro-Context (0.1194), etc. We observe that the average similarity of the set of LO placed by the teacher in the Introduction Micro-Context coincides with the highest similarity calculated by LOOK in the Introduction csMicro-Context, 0.2222. In this way the decision taken by LOOK of placing these LO in the Introduction Micro-Context corresponds to the teacher manual decision of positioning these LOs in the Introduction Micro-Context.

Table 59. DICE Analysis Results

CURRICULAR STRUCTURE MICRO-CONTEXTS	ANALYSIS FOR THE SET OF LO PREVIOUSLY CLASSIFIED BY THE TEACHER IN EACH CURRICULAR STRUCTURE MICRO-CONTEXTS				
	INTRODUCTION	ACTIVITY DIAGRAM	CLASS DIAGRAM	USE CASE DIAGRAM	INTERACTION DIAGRAM
INTRODUCTION	0.2222	0.0350	0.0714	0.0833	0.12
ACTIVITY DIAGRAM	0.1379	0.4262	0.1	0.0769	0.1481
CLASS DIAGRAM	0.1194	0.0571	0.2898	0.1311	0.1587
USE CASE DIAGRAM	0.1481	0.0350	0.0357	0.4166	0.08
INTERACTION DIAGRAM	0.1666	0.0634	0.1935	0.1111	0.3214

Table 60. COSINE Analysis Results

CURRICULAR STRUCTURE MICRO-CONTEXTS	ANALYSIS FOR THE SET OF LO PREVIOUSLY CLASSIFIED BY THE TEACHER IN EACH CURRICULAR STRUCTURE MICRO-CONTEXTS				
	INTRODUCTION	ACTIVITY DIAGRAM	CLASS DIAGRAM	USE CASE DIAGRAM	INTERACTION DIAGRAM
INTRODUCTION	0.3292	0.1297	0.0564	0.1171	0.2240
ACTIVITY DIAGRAM	0.1428	0.5439	0.0734	0.1307	0.2138
CLASS DIAGRAM	0.1526	0.1657	0.3331	0.2221	0.2775
USE CASE DIAGRAM	0.1439	0.0992	0.0216	0.5379	0.1543
INTERACTION DIAGRAM	0.1683	0.2011	0.1616	0.1617	0.5452

In particular, Table 59 presents the results applying DICE similarity measure. DICE analysis generates a precision of 100%, which means the process has localized 100% of the set of learning objects in the adequate curricular structure Micro-Contexts. On the other hand COSINE analysis generates a precision of 100% with respect to the classification provided by the teacher as is shown in Table 60.

In general, results of the study presented in Table 59 and Table 60 show a strong correspondence between the classifications provided by the teacher and the possible classification based on the similarity measures provided by the algorithms.

Low values observed in Table 59 and Table 60 are predictable because of the character of the information available in the two different micro-contexts. Therefore some labels in the Competence definition as well as some labels in the LO metadata could contain irrelevant but comparable information, due to the purpose of each kind of information. Only the relevant words for both micro-contexts are actually important and the values shown in previous tables capture this relevance while ensuring the purpose of selecting the best object for each particular micro-context.

6.3.4 User satisfaction evaluation layer

6.3.4.1 Description and Methodology

Our main objective in this evaluation layer was to develop a qualitative study [129], which permit us to achieve a better understanding of potential opportunities for improving our approach and how to support this task in a better way. The used strategy was to develop case studies, which permit us to concentrate in a particular situation, in our case, the use of distributed learning objects for feeding learning designs.

The analysis was based on interviews with teachers, case studies in which the application of a Gap Model instrument for satisfaction evaluation was performed. The Gap Model permits us to capture the difference between the teachers' expectations and the satisfaction that they really obtain from the offered service as was mentioned in the section 3.2.2.1.

The Gap Model was applied in a particular instrument (a survey) to measure the user's satisfaction in four aspects of our proposal:

- The satisfaction with the searching process (SEQ1), i.e. the possibility to search over different distributed repositories in a unique environment.
- The usability of the tool developed upon dotLRN platform to integrate LORSE (SEQ2).
- The satisfaction with the results offered by the searching process (SEQ3).
- The satisfaction with the possible location of LO into a curricular structure available for testing (SEQ4).

All question are presented in the appendix c.

The process followed in our study was:

- Sessions with teachers from University of Girona were agreed.
- The main researcher introduces teachers in the learning objects repositories environment, showing them some of the most important ones.

- The main researcher introduces LORSE, its functionality and its integration into the dotLRN learning management system as a porlet.
- Teachers have the opportunity to develop some searches using the system.
- The LOOK process is described to teachers, who observe the possible learning objects to be included in the testing course.
- A session of discussions and brainstorming was proposed to the teacher in order to capture their opinions about our research. They were very motivated in this session.

6.3.4.2 Results and Conclusions

The results presented in Figure 75 show a very close relationship between the importance perceived by the users referred to the evaluated issues and their satisfaction with the solution.

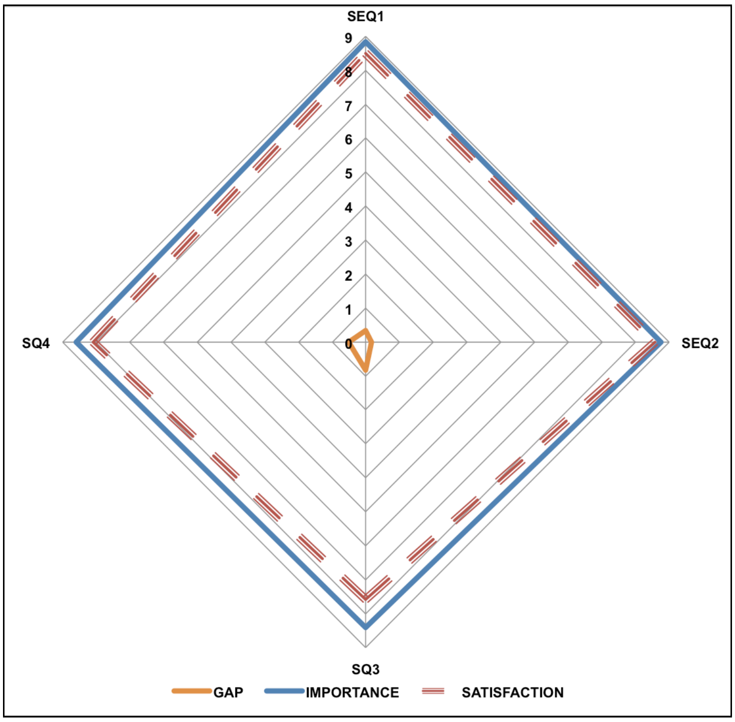


Figure 75. Results for the satisfaction evaluation layer

One of the most important parts of the descriptive analysis were the conclusions and opinions highlighted by the teachers, which could be summarized as follows:

- All Teachers think the reuse of learning objects is a possibility to facilitate the virtual learning process, because efforts from teachers of different universities might be united.
- All Teachers emphasize in the necessity of guaranteeing the quality of the selected learning objects to support learning design generation. For them, the quality is mainly referred to that both selected learning object should be contextualized to the teachers and students necessities, and LO must guarantee the learning design quality.
- According to the interviews from each teacher, we conclude that 60% of teachers consider a good practice for universities to include in their strategic plans the creation of spaces to update teachers about the resources available around the world and in their own universities, which could be used in the learning and teaching process. Teachers consider that many efforts developed by important institutions are not known in the academic context and, for this reason, their efforts may not be widely used by teachers. This is the case, for example, of the available and open learning objects repositories.

6.4. CONCLUSIONS OF THE CHAPTER

The main purpose of this chapter was to introduce our research for searching learning objects in distributed learning object repositories as well as their positioning process in the most promising micro-contexts of the future generated learning design. Our solution includes the definition of two differentiated process: the Distributed Learning Objects Metadata Searching Process (LORSE) and the Micro-Context based Positioning Process (LOOK), which were introduced in the document.

We have presented results in two evaluation layers, the decision making layer and the user satisfaction layer.

The decision making layer permits us to conclude that on one hand, to consider a searching process for the LO over controlled LOR for feeding learning designs is a promising option. Learning Objects selected and located into the learning design meet the teachers' opinion about a previous manual positioning process. In this process, the importance of the metadata labelling process and the competence definition has been demonstrated. On the other hand, the decision making process for including learning objects from uncontrolled learning objects repositories in semi-automatically generated learning designs is a difficult process. In fact, to achieve a good solution with these repositories, the objects metadata need to be refined. Metadata available in the involved repositories have limited information.

As a mechanism to obtain a closer vision of the teacher's satisfaction about our proposal, a User satisfaction evaluation layer was introduced. The results obtained with teachers from University of Girona permitted us to define some improvements from a user-centred design view. Although the results were promising and we obtained a high user satisfaction level, we also need to attend to some important elements:

- Some teachers suggest improving the appearance of the learning design player because they believe it could be difficult to manage for students.
- The teachers suggest simplifying both the LORSE and LOOK interfaces, in order to facilitate them the use of the interfaces and also to improve the usability of our solution.
- Results obtained in the descriptive analysis stimulate the development of evaluation scenarios when the main issues are testing the usability and accessibility of the proposed solution.

Part III

Summary of Contributions

7. CONCLUSIONS AND FUTURE WORKS

7.1. CONCLUSIONS

The objective of this thesis is to contribute to alleviate the workload of teachers on the creation of adaptive courses by reducing the complexity involved in authoring standardized and adaptive learning designs adjusted to their students' characteristics, in particular, learning style and competence levels. To that end, a new framework for a semi-automatic learning design generation was introduced. The framework consists of relevant process linked together to support teachers when they design adaptive courses in a LMS.

The main contributions of this work to the Tecnology Enhance Learning Community are summarized in the following paragraphs.

We contribute with a new solution to facilitate the difficult task for teachers when they construct personalized courses. Our solution called Designer is a new service based on HTN planning for a Semi–Automatic Standardized Learning Design Generation. Promising results were obtained in a layered evaluation developed with teacher from different knowledge domains. In general, teachers involved in the study confirmed the importance and relevance of the learning design generation process.

The second most important contribution of this dissertation is a new Dynamic User Modelling based on Learning Styles which was described and tested. Testing scenarios with university students was deployed. Results show a promising performance of the model for inferring the learning style over the time. An important issue addressed was the integration of the dynamic user modelling process with Designer upon the used LMS. The integration allows us to consider the change of the user learning style at the execution time in order to adapt the learning design offered to students.

Finally, the problem of contextualize learning objects into the semi-automatically generated learning designs which is one of the most important open issues in learning object economy was addressed. LORSE and LOOK, two innovative and interesting processes for searching and positioning learning objects in learning designs based on the micro-context analysis were introduced. Developed layered evaluation indicates that the process ease the teacher task when they design virtual courses, which permits them to include distributed learning objects in the learning design context.

7.2. FUTURE WORK

Our future research interest is focused on some of the different open issues identified as results of our research:

- Learning design generation future works are oriented to take into account other students' characteristics such as special needs, teachers' preferences about pedagogical methodologies on learning design generation as well as the use of other techniques for the learning design generation among them conditional planning algorithms.
- A good option to improve our solution of searching and positioning learning objects from uncontrolled learning objects repositories could be to develop a characterization of the learning objects repositories using ontologies. This will optimize the searching process to obtain more contextualized learning objects. Characterized learning objects repositories using ontologies permit us to add the necessary semantic that supports the selection of the repositories for a specifics designs process. In particular, as a result of the evaluation, the necessity of the following knowledge was identified: character and granularity of the LOR, technical details, main knowledge areas, e.g. math, languages, among others.
- Develop a Usability and Accessibility testing scenario in order to verify the facility of our solution to meet the access necessities of the users in detail.
- Machine learning techniques have been analysed and we have defined the Instance-base learning approach as a good approach for improving our adaptation decision method based on learning style. The learning task should be designed in order to redefine the data set used to infer the preferred order of the learning object types through adding a new instance in the data set based on the user's behaviours over the time. We are developing a test for new instance addition with different Instance-base learning algorithms among them several versions of IBK with several variations in the instance distance measures.

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A

Publications,

Projects,

Survey Form.

APPENDIX A

PUBLICATIONS

During my time as PhD student, I have generated the following related publications:

- S. Baldiris, S. Graf, R. Fabregat, and N. D. Duque Méndez, “Searching and Positioning of Contextualized Learning Objects,” The International Review of Research in Open and Distance Learning. Special Issue on Technology Enhanced Information Retrieval and Processing for Online Learning, 2012.
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APPENDIX B

PROJECTS

During my time as PhD student, I have collaborated in the following projects:

Supporting Trainers for an Inclusive Vocational Education and Training

Objective: This project's main objective is to offer to vocational education and training institutions an agreed and certified course for trainers and to provide them with a technical framework that let trainers design and develop accessible training content and courses for people with disabilities.

Funds: 281.655,96 €
Funding entity: Lifelong Learning Programme, Leonardo da Vinci Transfer of Innovation
Dates: 01/2013 – 12/2015

ARrELS - Augmented Reality in Adaptive Learning Management Systems for All

Objective: This project's main objective is to build a framework based on standards that address an active and situated learning through the use of emerging technologies such as augmented reality, mobile computing and open content in the context of an adaptive virtual learning process and personalized to the requirements and characteristics of users taking into account their functional diversity.

Funds: 19500 €
Funding entity: MICINN [TIN2011-23930]
Dates: 01/2012 - 12/2014

MIREIA, Content distribution through smart motors of recommendations adapted to social nestworks

Objective: This project's main objective is to build a framework for content recommendation based on the user profile which is inferred through the analysis of the user interactions in social networks.

Funds: 95978 €
Funding entity: MINECO [IPT-2011-2015-430000]
Dates: 05/2011 - 05/2013

ALTER-NATIVA, Referentes curriculares con incorporación tecnológica par alas facultades de educación en las áreas de lenguaje, matemáticas y ciencias, para attender poblaciones en contextos de diversidad.

Objective: This project's main objective is the creation of curricular guidelines with technological support for higher education institutions in the areas of language, mathematics and science, to attend people in the context of diversity.

Funds: 1.522.646,81€
Funding entity: European Commission, ALFA III Programme
Dates: 02/2011 - 04/2013

A2UN@: Accessibility and Adaptation for ALL in Higher Education

Objective: This project's main objective is to analyse the capability of developing a general ICT framework, which will be based on standards and user modelling, to support the development of the LLL (Life Long Learning) services required to attend the accessibility and adaptation needs for ALL in Higher Education, with special attention to the diversity of requirements of adult learners and those who have the so-called disabilities. To this end the project addresses interrelated scientific goals in the following areas: standards and metadata, user modelling, design for all, psychopedagogy, accessibility in user interfaces, assistive technology, machine learning, multi-agent systems and ubiquitous computing.

Funds: 36.900€
Funding entity: MICINN [TIN2008-06862-C04-02/TSI]
Dates: 01/01/2009 - 31/12/2011

Adaptation based on learning, modelling and planning for user-oriented complex tasks (ADAPTAPlan)

Objective: This project's main objective was to analyse the capability of automatically solving tasks that need the integration of planning, machine learning and interaction with different agents (human or software) to ubiquitously and dynamically adapt to the evolving needs of the context.

Funds: 46700€
Funding entity: MICINN [TIN2005-08945-C06-03]
Dates: 31/12/2005 - 12/2008

APPENDIX C

SURVEY FOR SUPPORTING GAP ANALYSIS IN THE USER'S SATISFACTION LAYER

LEARNING PROCESS SPECIFICATION	
SQ1	Competence specification to be achieved by the students as well as its associated competence elements represent that the educational purpose is?
SQ2	The learning object labeling process is adequated and it permits to specify in an easy and understandable way the relations between the learning objects and the competence.
SQ3	The generation of standardized learning designs, which could be interchangeable and shareable among teachers, stimulates the learning objects reuse and is helpful for the teachers and students in the learning process.
SEMI-AUTOMATIC GENERATION	
GQ1	The use of Designer helps you in the learning design process developed for you in the learning management system.
GQ2	Designer is easy and simple to use.
GQ3	Generated learning design quality covers your expectations.
GQ4	The Use Dificulty / Benefit relation of the learning design generation process is reasonable.
ADAPTATION PROCESS	
AQ1	The proposed adaptation mechanism based on the competences levels implemented over the learning management system helps the students to be focused and it orients their advances into the learning process.
AQ2	The proposed adaptation mechanism based on the student learning styles implemented over the learning management system addresses the students' preferences for the differente learning objects and activity types involved in the learning process.
AQ3	The proposed adaptation mechanism based on the competences levels implemented over the learning management system increases the students' satisfaction in the virtual environment.
AQ4	The proposed adaptation mechanism based on the students' learning styles implemented over the learning management system increases the students' satisfaction in the virtual environment.
DISTRIBUTED SEARCHING AND POSITIONING PROCESS	

SEQ1	Searching process over different learning objects repositories with the purpose to enrich the generated learning designs eases the teacher task of reuse efforts from other teachers in the world stimulating the reuse.
SEQ2	The proposed tool for searching over different learning objects repositories is easy and simple to use.
SQ3	Obtained results from the proposed searching process over different learning objects repositories are adequated according to the criteria that you provide to the system.
	The inclusion of learning objects into the generated learning design produced good results according to your opinion.