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Knowledge Representation in Support of Adaptable eLearning Services for All

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Abstract

In general, formal knowledge representation enables computers characterize relevant information related to determined process elements and actors in a domain for specific advanced reasoning. In the eLearning domain, several mechanisms of knowledge representation have been proposed, such as standards, technological specifications and ontologies. Both ontologies and specifications play an important role in eLearning systems because they offer an explicit conceptualisation allowing key concepts and terms relevant to a given domain to be identified and defined in a structure able to facilitate reasoning, use and exchange knowledge between the components and users of its systems and by that, to contribute to the increase of its computational intelligence. In this paper we introduce the importance of the knowledge representation mechanisms to support the generation of adaptable eLearning services for all.

Keywords: Knowledge Representation; Ontologies; eLearning; Diversity

1. Introduction

The development and use of knowledge representation mechanisms in learning has increased in the pursuit of generation intelligent and adaptable eLearning services to provide accessibility for all.

An ontology is an explicit specification of a conceptualisation [1] that refers to the shared understanding of some domain interest, which may be used as a unifying framework to facilitate knowledge sharing. Ontologies

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allow key concepts and terms relevant to a given domain to be identified and defined in a structure able to express the knowledge of a domain or a segment of the reality/world. Its recognised capacity to represent knowledge, to facilitate reasoning, use and exchange knowledge between systems or users contributes to increase the computational intelligence of its system. Thus, ontologies can be used to support knowledge management and to provide some intelligence to eLearning systems.

In this paper, authors present some users modelling specifications to identify learners' needs in relation to disabilities. In addition, two approaches to provide accessible learning scenarios are introduced. Then ontologies and a short guideline to develop them in eLearning are described. Afterwards, an example of using technological specifications in accessibility and adaptation for all in higher education and, an example of ontologies applicability to support adaptable eLearning related services are demonstrated. At the end, conclusions are presented emphasizing the use of a hybrid knowledge representation approach in supporting solutions and services for the diversity in an actual and active research project.

2. User Modelling for accessibility in eLearning

From a technological perspective, disability is not an identifying characteristic of the learner but rather a failure of the learning environment to meet the learner's needs. Disability is a mismatch between the learner's requirements and the education offered. Inclusion, then, is a learning environment that will transform appropriately to create the optimal education environment for the individual learner [2].

Virtual higher education should be an accessible service for all and it must consider the specific needs of each student, adapting the processes in order to cover their necessities. This idea born in line with the global, regional and local policy actions, whose seek an education that answers to immediate social demands that are focused on the objective of having a greater number of students receiving education during more time, counting with an attractive educational offer with a recognized higher level of quality, equity and inclusion, and involving the great majority of institutions and sectors of society.

The accessibility compliance approach aims to take accessibility guidelines into account when creating learning resources. According to [3] accessibility is a set of properties that are built into the product, service or system from the outset, enabling people within the widest range of abilities and circumstances as is commercially practical to access and use it. According to this approach, the accessibility of a learning object implies its availability in at least one accessible format or modality satisfying both user needs and preferences (including functional abilities), and user context (including device capabilities and environmental conditions). The W3C WAI guidelines on web accessibility provide a set of rules for accessibility, directed at web authors, web authoring tool developers, and user agent developers. These guidelines follow the "design for all" philosophy. They make web browsing easier for people with disabilities, in particular for users of common assistive technologies like screen readers, mouse or keyboard emulators. Other guidelines should be used as a complement to W3C WAI guidelines for ensuring accessibility of the different media learning objects may be composed of, i.e. text (including science notations), images, audio, video, animations, etc. [4]. Furthermore, accessibility guidelines for creating reusable packages of learning contents, such as SCORM or ePub3, should be observed if applicable. Providers of the first approach try to create a single resource that is accessible to everyone. Often to guarantee accessibility, developers ensure that the web content meets some accessibility guidelines as W3C WAI Web Content Accessibility Guidelines. However this approach has some difficulties if we consider the main providers of learning scenarios are teachers, which frequently don't have time or enough knowledge to support the creation of accessible learning resources. Actually, according to [5] most of the learning objects available in global learning objects repositories don't meet accessibilities guidelines. Additionally, teachers who are not from the area of computer often feel frustrated because the results of their work creating accessible learning objects not justify the effort required. Hence, teachers should be provided with suitable training and tools that support them in the process of authoring accessible learning materials.

However, it is true that in some cases producing accessible learning contents (e.g. audio description of video, accessible science notation for blind users) requires the participation of specialized professionals who support authors.

There is the accessible learning experience approach, which are built through learning experiences that match the needs of the individual learner. This approach require the definition of two different process, the user modelling process and the adaptation process in order to obtain as a result a learning environment or experience more flexible which recognises the specific differences among learners achieving an approach able to adapt to the learning experience or environment to the student particularities. It matches the needs of the learner with the education delivered by transforming the presentation of the resource, adapting the method of navigating or interacting with the resource, supplementing the resource with learner scaffolds or alternative representations of material, re-aggregating the resource or replacing the resource with an equivalent alternative. This approach also supports cumulative authoring of learning material so that many educators can pool approaches to achieving a specific learning outcome for a diverse set of learners [6].

User's needs could be identified in a virtual learning environment basically through a user modelling process. The user modelling process defines and maintains up-to-date user models [8]. There is different categorization for user models. Brusilovsky and Millan basically define two types, feature-based models and stereotype models. The first one models changeable features of users, whereas the second defines groups of users that share specifics characteristics. Bull et al. [8] define the models as inspectable, editable or negotiable according with the capacity of the user to modify the model. According with the capacity of representation [9] user models, they could be classified in raw data models, Visual models and Decision support models. A raw data model are 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.

User modelling approaches also have several categorizations. Graf et al. [7] classify the user modelling techniques as dynamics and statics. 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, while the static user modelling detect the student model in a specific time (t) and only there. Brusilovsky and Millan [8] introduce Test based user model, Overlay model and Uncertainty-Based User Modelling. Test models permit to construct statics user models often 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 management the user model. Baker et al. [10] classify user modelling approaches as Super fidelity, High fidelity and Low fidelity according with the successful probability to infer a model with an adequate precision.

User modelling process takes place through the development of different sub modelling process, qualitative modelling, quantitative modelling and the evaluation modelling. Qualitative modelling identifies the features to be modelled and their characterization. Quantitative modelling permit to define how this features could be modelled using a determined scale. On the other hand the evaluation verifies the validity of the model. User model representation is one of the most interesting issues recently investigated, some of the standards generates as solutions are: PnP [11], LIP [12], among others.

3. Ontologies for Knowledge Representation in eLearning

Gruber stated in 1993 one of the most well-known description about what ontology is: "An ontology is a formal, explicit specification of a shared conceptualization" [13]. The term is borrowed from philosophy, where ontology is a systematic account of Existence [13]. Where, a 'conceptualisation' refers to an abstract model of some phenomenon in the world, which identifies the relevant concepts of that phenomenon. 'Explicit' means that the type of concepts used and the constraints on their use are explicitly defined. And, 'Formal' refers to the fact that the ontology should be machine understandable. And finally, 'Shared' reflects the notion that ontology captures consensual knowledge that is not restricted to the knowledge view of some individual, but reflects a more general view shared and accepted by a group.

In education, widespread appliance of such a shared instructional vocabulary offers advantages for teachers and learners. A more accurate search for learning resources, made possible by the explicit instructional function, leads to better reuse and less duplication, hence faster authoring of curriculums. By seeking instructionally appropriated learning material, learners can bridge knowledge gaps more efficiently [14].

In order to address this issue several authors suggest that ontologies can be used to describe Learning Objects (LO) content, thus providing LO with a new dimension of reusability – content reusability. Ontologies for e-learning are different in the following aspects: content – what the learning material is about, context – in which form a topic is presented, and structure – as learning material does not appear in isolation [15].

Valuable information can be gained by mining metadata of educational resources. However, if the mined data is annotated using IEEE Learning Objects and Metadata standard (LOM), then significant pedagogical information is missing. While LOM and SCORM provide a framework for the representation and processing of the metadata, they fall short in including the needed semantic density for more specific pedagogical tracking. Using a pedagogical ontology will provide a higher level of decision support analysis and mining, based in qualitative issues like: the pedagogic methodologies used the collaborative degree of activities or the understanding expressed in the assessments. [16]

3.1. An eLearning Ontology building Example

An ontology can be used to represent a learning (explicit) knowledge base, facilitating the categorization of its elements and subsequently reasoning over it. To reach this purpose it is needed to understand how to organise learning related knowledge and transform it in appropriate and appellative learning objects. In addition, such related knowledge should be organised to assure learning objects handling. Thus, the build of an ontology to represent learning is an appropriate goal.

As a sequence of these ideas, authors identified a methodology to help on the development of an eLearning ontology. Such methodology is MENTOR, a methodology to support the development of a common reference ontology for a group of organisations sharing the same business domain [17]. This methodology has a light version focused on the building of ontologies from scratch. It is composed by two phases: one for the lexicon settlement and the second for the ontology building. In the following it is presented a small example of its use. It starts by the definition of some basic terminology gathering and its definitions attribution (glossary building) through its representation in a thesaurus structure and finally its consequent ontology building.

The concepts chosen to be presented here are directly related to elementary eLearning elements or objects and structure, and represent the starting point to the lexicon definition of the ontology.

A *leaning object* is any group of materials that is structured in a meaningful way and is tied to an education objective. In the creation of a learning object, the author should consider how it relates to other existing learning objects and other educational materials available in the platform [21].

A *learning course* is an ordered process or succession of a number of lectures dealing with a subject. It is conceived in a way that meets the specific desires and expectations of a determined target audience. A learning course is divided into several modules, according to the topics that are addressed. A learning module is a small piece of a learning course, essentially a lecture, with a very clear objective. Several modules of the same topic area can be grouped together to form a learning course as illustrated in Fig. 1 (a). A *Learning Programme* is a significant long-term learning activity which comprises a set of learning courses and/or learning modules Fig. 1 (b) [22]. It’s a construct conceived for learning in specific skills focusing on a given target audience and using a selected delivery approach. Reference learning programmes are those that are designed for reference target audiences (especially relevant within a given learning environment) and that serve as orientation for targeted learning execution [22].

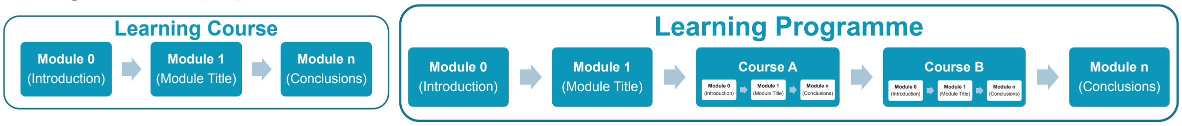

Fig. 1. (a) Learning Course; (b) Learning Programme

A *learning curriculum* is the set of related instructional elements and content offers in a given field of study [23]. It's designed to establish the underpinning that is to be used to frame down learning course elements. There could be several learning curriculum areas, and each usually has at least one course defined with its direct contents of such area (Fig. 2 (a)). Nevertheless there are some learning topics that are used by other areas, so it is usual to find courses that exist in several learning curriculums. Such relations give some complexity to the classification of these learning elements [24].

A *dynamic learning curriculum* is a curriculum, which its associated learning courses are modularized in the sense to be able to pick up a module from them if appropriate, to a specific learning programme. Fig. 1 (b) illustrates this example. The Module 1 could come from a course where all the other modules are not appropriate to be present on this specific learning programme example. By this modularization it's enabled a dynamic curriculum. The dynamic learning curriculum is therefore flexible, learner-centric and competency-based. This conceptual framework holds instructional elements (modules and materials) by focusing on atomic competences and skills within established domains [25].

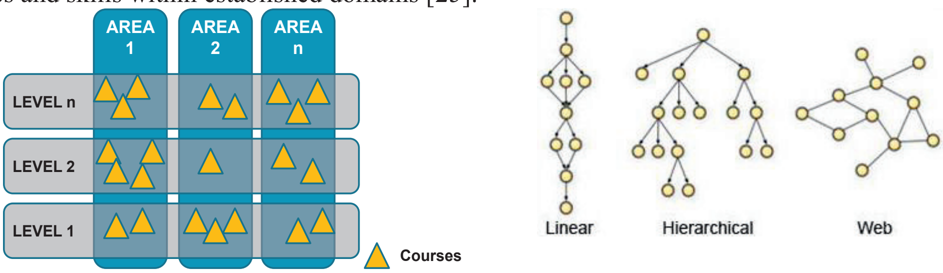

Fig. 2. (a) Learning Curriculum; (b) Types of learning contents structures

The main difference between a learning curriculum and a learning programme is that a learning programme is designed to develop specific skills, and the learning curriculum embraces all the fields of area of study. It is usual to find several learning programmes within a particular learning curriculum. There are various ways to organize and deliver the learning content, depending on the subject matter and the trainer preference. Fig. 2 (b) presents some structures types, which learning lessons (courses or programmes) can follow.

Metadata is the information about an object, be it physical or digital. As the number of learning objects grows exponentially and the needs for learning expand equally dramatically, the lack of information or metadata about objects' places a critical and fundamental constraint on the ability to discover, manage, and use objects [19]. Thus, Metadata has a main role to the search engines within the learning platforms to locate and identify the Learning Objects. It can aggregate specific information like learning areas, levels, keywords or target audience.

Specifications and standards in e-learning enable different independent assets of learning to coexist for effective and better learning outcomes and also support properties like [20]: 1) Interoperability, making it possible to work with other Learning Objects and with Learning Management Systems; 2) Reusability, allowing others the use of the objects created, even in different ways that firstly the object was designed for; 3) Accessibility, adding the information needed for quick and easy discovery so it can be found by other developer; and 4) Durability, by using the latest metadata standards so the lifespan long [21]. Many organizations like IMS, IEEE, ARIADNE, ADL, and AICC are making standards in the field of e-learning and most of the standards made by them are becoming the de facto standards in e-learning [20]. These standards have been defined to structure learning by also providing metadata to represent its objects (e.g. multimedia content, instructional content, learning objectives, instructional software, learner profiles, etc.).

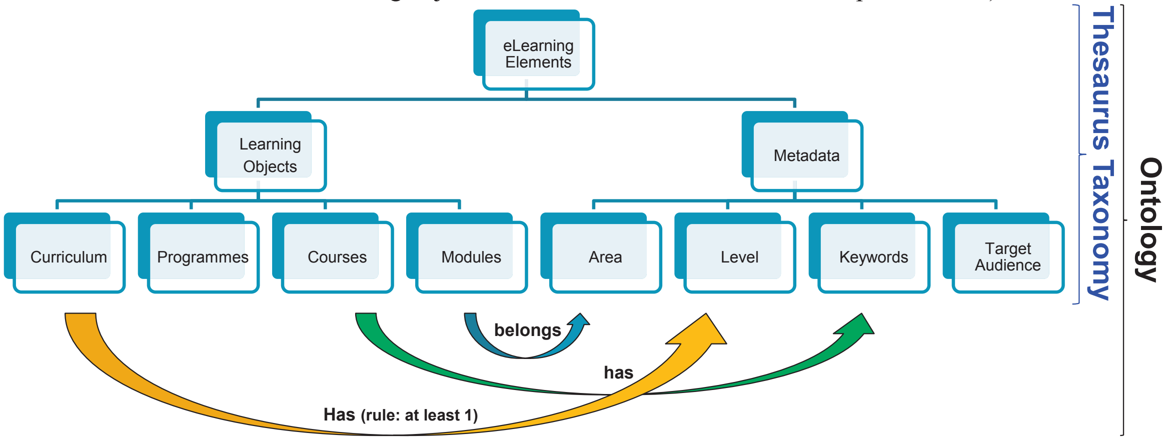

Fig. 3. (a) A subset of an eLearning Thesaurus and Ontology

From the previous concepts and definition (glossary), it is possible to develop a thesaurus, which taxonomy is represented in the upper part of Fig. 3. Such thesaurus contributed to the building of an ontology as defined by Sarraipa et al. in [17], which is also presented by the overall Fig. 3. A "Curriculum" is a "Learning Object" that "has" at least one "level". The "level" is a "metadata" of an "eLearning element". Despite being appropriate and useful, the subset of the eLearning ontology represented in Fig. 3 does not present relations to any standards elements (e.g. PnP). Authors are presently involved in a project (called ALTER-NATIVA presented in conclusions section) which is addressing the inclusion of such standards in eLearning ontologies to facilitate the integration and interoperability of eLearning components & users, and specially to provide intelligence to services in the support for eLearning adaptable services to enable accessibility to the learners.

4. ELearning Demonstration Scenarios

4.1. A2UN@ Project

The project A2UN@ "Accessibility and Adaptation for ALL in Higher Education", is funded by the Spanish Ministry of Science and Innovation. It began on January 2009 and will last for 3 years. The project involves the National University of Distance Education (UNED) and the University of Girona (UdG).

Its main goal is to build a general ICT framework to support the development of the Long Life Learning (LLL) services required to attend the accessibility and adaptation needs for ALL in HE. To this end, the project has been structured through a series of work packages, including following areas: (1) standards supporting IT accessibility to learning objects and services, (2) user modelling and dynamic support, (3) adaptive and re-usable learning services and workflows, and (4) device modelling, adaptive user interfaces and negotiation strategies. Thus, the goal of this project is to detect, extend, interrelate, integrate and exploit as much as possible all these areas upon which a general, flexible, open, standard-based framework can be defined to support the development of the LLL paradigm.

In this context, important advances have been done in different user modelling process proposed achieving validated process to infer users competences, learning styles, attention deficit and hyperactivity disorder (ADHD) symptoms, reading and writing difficulties as well as the user context detection.

One of the most relevant contribution of A2UN@ is Designer which aim at alleviating the workload for teachers of creating adaptive courses by reducing the complexity involved in authoring standardized and adaptive learning designs adjusted to their students' characteristics (competences and learning styles), which are inferred through a dynamic user modelling approach. In order to support interoperability of the user modelling and adaptation, an intensive usage of learning specifications and standards is done. Fig. 4 shows the general elements as well as an outline of different technologies and standards linked to A2UN@ proposed framework. The main elements are described as follows

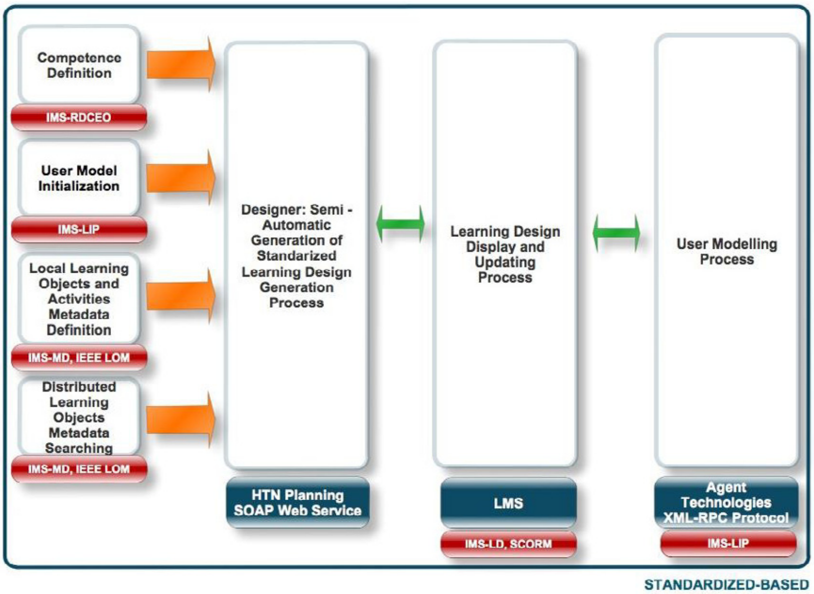

Fig. 4. A2UN@ Architecture

The *Competence Definition* permits to define appropriate performances that should be demonstrated by a person on a specific context. We consider two different types of competences: 1) generic (or transversal) competences and 2) specific competences [25]. Generic competences affect various fields and are transferable to a multitude of functions or training programs. They are focused on the "to be".

The competence definition consist of four categories of information: *Competence General Information* which provides general data about the competence; *Competence Elements* which are smaller learning purposes and refer to more specific and concrete learning process outcomes; *Didactical Guidelines* and the *Competence Context* of the respective application area. 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. Once a competence is defined, it can be exported to an interoperable xml file adjusted to the RDCEO [12] schema.

The User Model Initialization identifies and stores the initial state of the user model variables. Identifying user model variables (e.g., learning styles, etc.) could be done by the teacher through the explicit input of the variables' values, by the students through the application of specific psychometrics tools, or generated automatically based on behaviour data. The user model is stored in an interoperable xml file, in particular adjusted to the Learner Information Profile (LIP) Specification [12] schema.

The Local Learning Objects and Activity Metadata Definition are referred to the process of labelling learning objects develop by teachers (internal objects) with metadata. This process can be done manually by teachers themselves or supported automatically in the A2UN@ implementation.

Distributed Learning Objects Metadata Searching is a mechanism to promote a reuse-oriented approach. This mechanism is supported by agent technologies and its main purpose is to consider external learning objects, not developed by the teachers, which could be used as input in the learning designs generation process. We propose the analysis of the learning object 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 experience (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 can be displayed and updated later according to the performance and characteristics of the students, captured through the user modelling process. In order to support interoperability the generated learning design is adjusted to the IMS-LD [28] schema for level B of this specification. IMS-LD Level B allows concrete conditional path to generate the proposed adaptation rules.

The *Learning Design Display and Updating Process* is the process in charge for presenting and 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 according to the state of the corresponding user modelling variables.

The User Modelling Process aims at creating and maintaining an up-to-date user model. The adaptive learning 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. We consider two user characteristics, specific competences and learning styles.

For addressing the overall adaptation process we consider two perspectives: design time (when the course is created and composed in the LMS) and run time (when learners are learning in the course).

At the design time, the necessary information for the Designer (agent who generates the course) is developed and constructed. In particular, using different author tools, teachers define the competences, they define learning objects and services as well as their metadata. On the other hand, students are asked for applying some psychometric tools, in particular the Index of Learning Style by Felder and Soloman [29] in order to identify students' learning styles and store this information in the initial user model. This information is the input for the Designer for generating the adapted IMS-LD.

At the execution time, the generated learning design is displayed in the LMS and the user behaviour is monitoring. The analysis of user behaviours permits to redefine and update the users' user 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 characteristics (i.e. learning styles or competence levels), and (2) to update the input of the adaptation decision methods. Both of these updating processes are triggered based on execution parameters provided by teachers or the LMS administrator.

4.2. CoSpaces Project

CoSpaces is an IP project funded by the EC under the IST Programme of the FP6, which overall objective is to develop organisational models and distributed technologies supporting innovative collaborative workspaces for individuals and project teams within distributed virtual manufacturing enterprises [30]. Training in

CoSpaces project aims exactly at providing knowledge and skills that allow key target groups within distributed manufacturing enterprises to understand collaborative practices and acquire the practical experience of collaborative design engineering methods, supported on meaningful case studies and demonstrators [24].

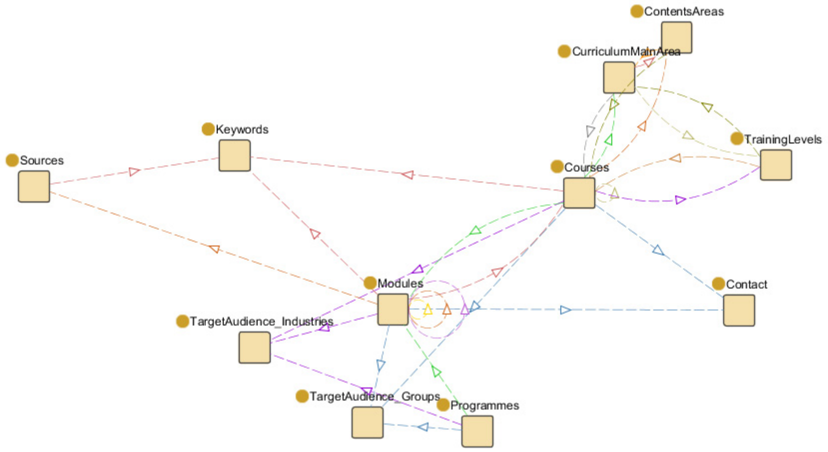

Fig. 5. Relationship structure of the Learning Ontology. Each colour represents a different property linking the concepts. Example: each Module has a set of Keywords, the property linking it is: hasKeywords

In addition, the same project envisaged to produce a service able to automatically orchestrate courses according to the user needs and profiles, in special consideration to academic people (from HE). The service generates adaptable courses with content originally developed for static courses. By having a training curriculum matrix and related data represented in an ontology, it is possible to reason over it and generates a training programme, which contents (courses / modules) are presented according to the user needs and following pre-determined pedagogical directives. Fig 5 presents an illustration of the eLearning model that has such training curriculum represented and which was built in Protégé. Protégé is a free, open source ontology editor and knowledge-base framework [31].

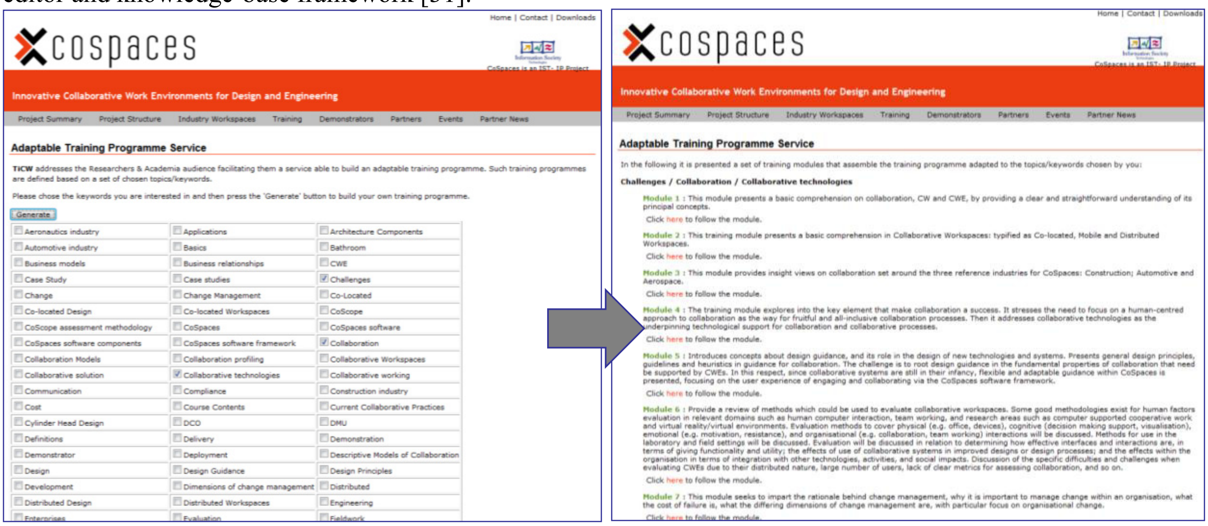

Fig. 6. Training orchestration example using the Adaptable Training Service

In such ontology (Fig. 5) each learning Module has several concepts associated, the Sources concept contains information about the sources referred in the Module, Contact includes the contact information of the author of a Module or Course and Keywords that contain a list of all relevant keywords needed for describing the contents of the Module. A Course, other than Contacts and Modules that contain the course also includes Keywords (that include Keywords inherited from its Modules) and belongs to a Curriculum Main Area that is divided by Content Areas and Learning Levels. Each Module and Course has a Target Audience Group and a Target Audience Industry, to be recommended accordingly to the profile of the learner. Finally, a pre-defined Programme is defined for a specific Target Audience Industry and Target Audience Group.

The mentioned service is available at http://gris-public.uninova.pt:8080/cospaces/ATPS_in.jsp (website accessed at March 2012). The service is available through a JSP page to the users, presenting a list of all the available training keywords. The user can select the ones that he/she could be interested in. After a submission, a training programme is prompted on the fly, adapted to the choice. A list of training modules is then presented. With such a list, the trainee could follow a training programme adapted to his/her interests. The Fig. 6 (left part) illustrates the first step: the user select a set of concepts. In this case, the concepts are: 'Challenges'; 'Collaboration', and 'Collaborative technologies'. After pressing the available button, a suggested training programme is displayed. It is composed by all the modules that contain the selected keywords and the recommended precedence's of them. On this sample, the trainee should start its learning process by a module that "*presents a basic comprehension on collaboration, CW and CWE (...)*" as shown in the first training module description of the list that resulted from such process (right part of Fig. 6).

5. Conclusions

The knowledge representation is one of the most important issues to be addressed when a solution for generating instructional designs is introduced. In this way there are different approaches to model such knowledge as ontologies and technological specifications. A2UN@ and CoSpaces projects implemented specifically the two mentioned different knowledge representation approaches. The authors concluded that both previous approaches are complementary. The first aggregates a standardised way to specify instructional information and the second presents the ability to enrich eLearning related services with computational intelligence. As a consequence to this analysis, authors defined a hybrid solution, which aggregates both mentioned approaches, as support of eLearning in the ALTER-NATIVA project. This project main goal is to define curricular guidelines with technological support for higher education in the areas of language, mathematics and science, to support people in context of diversity. Thus, our challenges in ALTER-NATIVA project imply a mixed solution considering elements of both approaches mentioned before, to provide the guidelines about how technology can assist teachers facilitating the difficult design task of adaptive learning scenarios for diversity context. To support teachers from different disciplines many of them from pedagogical careers with accessible tools that permit they the creation of accessible learning objects in an easy way. To specify and implement a dynamic user modelling approach, which support the generation of future adaptations and recommendations for teachers and learners. And, to provide teachers with an accessible learning object repository for the management of the learning objects including label and recommendation mechanism.

The main message to retain from this paper is that both ontologies and standards specifications use in knowledge representation for eLearning, will facilitate the intelligence increase of their related systems. Thus, all the specifications used in support for eLearning development, as example in the user modelling for accessibility will support the generation of advanced and adaptable eLearning services for all.

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