

# USING ONTOLOGIES TO DESIGN COMPETENCY-BASED E-LEARNING APPLICATIONS

Maria Bagiampou<sup>1</sup> and Achilles Kameas<sup>2</sup>

<sup>1</sup>*Faculty of Mathematics, University of Patras, Patras, Greece*

<sup>2</sup>*Educational Content, Methodology and Technology Laboratory, Hellenic Open University, Patras, Greece*  
*mpagiampous@gmail.com, kameas@eap.gr*

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**Abstract:** Lately, the approaches based on the concept of Competency are widely used in the field of Education as well as in the field of Human Resources Development. Competency Modeling is considered to be essential for any kind of Pedagogical Design within the area of e-Learning applications, adding to them several new possibilities. One of the most popular representations of competencies and learning goals (which are considered a kind of competency) is that of ontologies. This kind of representation allows processing by machines and their incorporation in e-learning applications. The present paper contains the presentation of an ontology-based model for the description of the learners' competencies, created through the combination and the extension of three existing ones. The ontology that we describe, was created as part of an experimental e-learning application for the description and management of competencies, learning goals and learning material about a specific field of knowledge.

## 1 INTRODUCTION

The concept of Competency is considered to be very important for any instructional process, as the selection of the learning methodologies, activities, paths, material, etc., to be used throughout the process, is based on the current and the target competencies of the learners. According to Komis (Komis B., 2009) the concept of competency is defined as the extensive set of knowledge, skills and attitudes, that someone possesses and uses according to the circumstances, in order to face certain situations and carry out successfully certain activities. Lately, the approaches based on the concept of competency are widely used in the field of Education as well as in the field of Human Resources Development. This is reflected in practically every instructional process, concerning either conventional, or e-learning practices. For example the new curricula design is becoming focused on the competencies to be acquired by the learners through the learning process rather than on the topics to be taught. According to researchers like Schmidt & Kunzmann (2007), Paquette (2007), Sicilia (2005), Knight et. al. (2006), etc., competency modelling is considered essential for any kind of pedagogical design within the area of e-learning applications. The incorporation of the

element of Competency in e-learning systems, allows them to support learning goals' sharing and re-use as well as linking competencies and learning goals to learning material (e.g. learning objects) and learning topics and manage the one with connection to the other, as mentioned in Van Assche (2007), Schmidt & Kunzmann (2007), etc. Another possibility is that of providing personalized services through keeping track of the current competencies of the learners, as part of their profile (Paquette, 2007; GrandBastien & Huyinh Kim Bang, 2008; Sicilia, 2005; etc.).

## 2 USING ONTOLOGIES TO DESCRIBE COMPETENCIES AND LEARNING GOALS

An ontology is a formal specification of a field of knowledge (Gruber, 1993). It provides the basic concepts of the field described, their relationships, and the terminology used to refer to the concepts and relationships. That is, an ontology provides both vocabularies and cognitive schemas (concerning a certain field of knowledge), which can be used as a common framework for communication between people, systems and organizations, facilitating the

sharing, interoperability and resource reuse (Uschold & Gruninger, 1996).

Ontologies are used as the main form of representation for modeling competencies and learning objectives, enabling their inclusion in e-learning applications and facilitating their efficient and adequate management (searching, matching, analysis). According to Sicilia (2005), ontologies outweigh other forms of representation of knowledge, both in terms of detailed description of a field of knowledge, as well as in relation to the management of the resulting descriptions, by intelligent software systems.

In this paper we describe an ontology concerning competencies and learning objects, which was created as part of an experimental e-learning application for the description and management of competencies, learning goals and learning material about the cognitive field of Object-Oriented Analysis. The key issue was to be able to use the ontology to express the widest possible range of learning objectives and competencies of the learners, in a form easily processable by machines.

### 3 OUR ONTOLOGY

Before we construct our ontology we sought for existing ones. We identified three ontology-based models: those of Sicilia (2005), Paquette (2007) and Van Assche (2007). Each of the approaches offer a different and complementary view on the concept of competency or the concept of learning objective. Given the value of each model, we decided to not adopt only one of them, but to combine and extend them, in order to meet our goal, for a generic competency that produces easy to process descriptions of competencies and learning goals. In the following section we describe the basic concepts (classes) of our competency ontology -lack of space prohibits a detailed analysis- and then we summarize its features and abilities.

#### 3.1 Basic Concepts

The basic concept of our ontology is **Competency**, defined as the ability to apply some Generic skill in a Knowledge Entity (particular subject matter) under some Conditions. For example, "Be able to describe (generic skill) the functional requirements of a particular system (knowledge entity) using use case diagrams (condition)". The definition of competency is based on that of Paquette. It differs in that it does not use the term performance, but the term condition

that is more generic and can refer both to the performance, as well as to other restrictions, mentioned below.

The **General Skill** refers to some *knowledge, skill* or *attitude* and is expressed by means of an active verb. The class Generic Skill is analysed in three subclasses: the *Affective Domain Generic Skill* (referring to *attitudes*), *Cognitive Domain Generic Skill* (referring to *knowledge*) and *Psychomotor Domain Generic Skill* (referring to *skills*). In our work, we only analyzed further the generic skills for the Cognitive Domain. The analysis was based on the widely accepted and widely used Bloom's taxonomy of learning objectives of the Cognitive Domain (Bloom, 1956).

The **Knowledge Entity** /Entities, to which some Generic Skill is applied, comes from some domain ontology, in our case from an ontology about Use Case Diagrams, an element of the UML software notation.

The **Condition** in our competency ontology refers to any restrictions in relation to the occurrence of a competency. In particular it can concern: a) **Numerical restrictions** in relation to the knowledge entity involved. *E.g. To cite two uses of the Use Case Diagrams.* b) **Performance restrictions** (concerning the complexity, frequency, autonomy, scope and context), in which the competency occurs. *E.g. Describe any system's environment of as a set of actors (scope: total).* c) **Restrictions concerning other competencies.** *E.g. To describe the functional requirements of a specific system using use case diagrams.*

#### 3.2 Features and Capabilities

The features and capabilities of our ontology, concerning the description of competencies and learning goals, can be summarized in the following: a) Competency and learning goals description using independent components, b) Use of established taxonomies and controlled vocabularies to define components, c) Analysis of the generic skill in cognitive domain generic skill, affective domain generic skill and psychomotor domain generic skill d) Ability to define competencies with two generic skills, using independent components, e) Connect competencies and learning goals to knowledge entities, f) Integration of numerical restrictions in the description of learning goals, g) Use other competencies or learning goals as a condition/restriction of some competency or learning goal, h) Difficulty level assignment/calculation for each general skill and competency, i) Ability to

define prerequisite competencies/learning goals for some competency/learning goal.

Features c), d), g) and g) are **new features** that we added, attempting to formulate a more complete and more generic competency ontology (compared to these proposed by Sicilia, Van Assche and Paquette). The feature *analysis of the generic skill in cognitive domain generic skill, affective domain generic skill and psychomotor domain generic skill* combined with the possibility to automatically connect competencies with knowledge, skills or attitudes according to their generic skill, gives us the opportunity to search for competencies and learning goals that refer to some knowledge, skill or attitude. See for example the query “competencies that refer to some knowledge about the topic Use Case”, answered in figure 1.

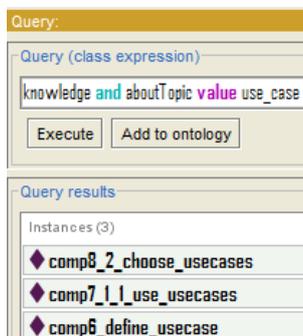


Figure 1: The results of the query “Competencies that refer to some knowledge about the topic Use Case”.

Also, the feature that concerns the support of numerical restrictions as an independent component of the description of a competency, allows a more complete description that remains easy to process (figure 4).

Finally, the integration of other competencies as a condition/ restriction in some competency enables us to define competencies with two generic skills (the one depending from the other). For example, using our ontology, it is possible to describe the learning goal "To be able to describe the functional requirements of a software system using uses cases", by considering the part *using use cases* as a condition competency of the main competency that is “to be able to describe the functional requirement of a software system”. The condition competency is then also analysed in components (generic skill, knowledge entity, condition). The description of a competency like the above is not possible using the existing proposals, so, concerning this particular possibility, our ontology supports the formulation of machine processable descriptions of a wider range of competencies and learning goals.

## 4 EXPERIMENTAL USE AND EVALUATION OF OUR COMPETENCY ONTOLOGY

In order to evaluate our competency ontology we used it to describe a set of learning goals, concerning a certain field of knowledge and proposed by a group of experts. Below we can see some indicative examples of these descriptions:

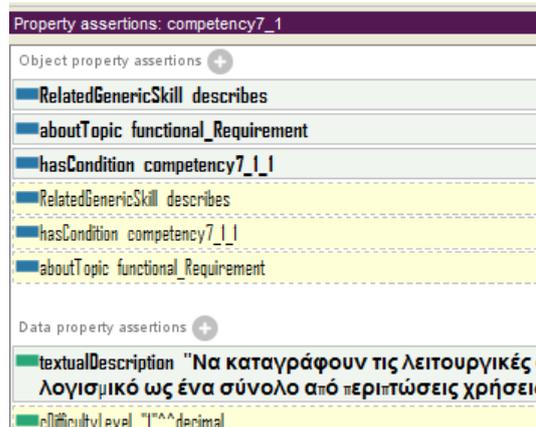


Figure 2: Description of the competency with textual description "To describe the functional requirement of a software system using uses cases". The part *using use cases* of the textual description is considered as a condition competency of the main competency that is “to describe the functional requirement of a software system”. We can see that the competency is assigned the difficulty level 1 (according to its general skill difficulty level).

The ontology allowed the description of **all** the learning goals proposed by the experts. It also allowed the description of some learning goals that were not possible to describe using the existing proposals, such as learning goals with condition another learning goal or learning goals with quantity restrictions. Also, as we can see in figures 2, 3 and 4, practically every parameter of a competency’s textual description can be described using some small independent component.

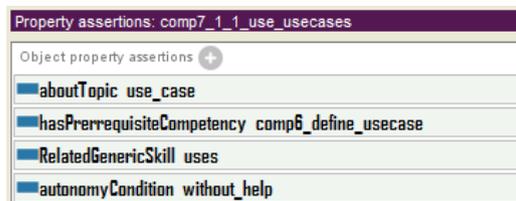


Figure 3: Description of the competency with textual description "To be able to use use cases”. As we can see there is a condition concerning the expected autonomy in the performance of the learner.

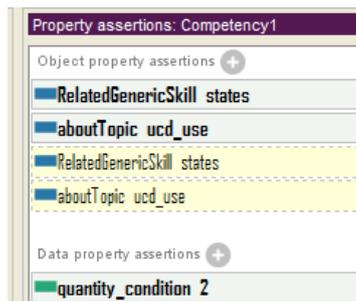


Figure 4: Description of the competency with textual description “To name two uses of the Use Case Diagrams”. We can see how the quantity restriction (two use cases) is integrated as an independent component in the competency description.

## 5 CONCLUSIONS AND FUTURE WORK

The results of the experimental use, allow us to assume that our competency ontology adds new possibilities to existing proposals and can be used to generate a wide range of competencies and learning objectives, that are easy to process by computer systems. In the near future we intent to further improve our ontology (e.g. by further analysing the generic skills of the cognitive and affective domain and use a more sophisticated way of calculating the difficulty level of a complex competency). Finally, we plan to use our ontology as part learning systems that support courses in Higher Education.

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