# An Ontology Model for Building, Classifying and Using Learning Outcomes

Aikaterini Kalou[1], Georgia Solomou[1], Christos Pierrakeas[1,2], Achilles Kameas[1]

[1]Educational Content, Methodology and Technology Laboratory (e-CoMeT Lab)
Hellenic Open University (HOU)
Patras, Greece

[2]Dept. of Computer Science in Administration and Economy
Technological Educational Institute (TEI) of Patras
Patras, Greece

{kalou, solomou, pierrakeas, kameas}@eap.gr



***Abstract*—Learning outcomes are statements that should accompany any type of educational material intended for lifelong learning. These statements deliver important information, which works as an indicator for students in the process of learning. However, in order for this information to be further utilizable within the context of intelligent e-learning applications, a more fine-grained definition and structure should be adopted. Having these in mind, we initially assign a strict and rather technical definition for the notion of learning outcomes, which is fully aligned, though, with their educational purpose. We then propose an ontological model for their representation and classification, which fully adheres to this definition. Our ultimate goal is to provide the mean for exploiting all aspects of knowledge implied by such statements within intelligent applications. To bear out this possibility, we apply our model to a selected piece of educational material provided by the Hellenic Open University.**

***Keywords-Lifelong Learning; Learning Outcomes; Bloom Taxonomy; Ontologies***

## I. Introduction

A very important task when designing a course, and especially one that is offered as part of a lifelong learning program, where students study in isolation, is the provision for well-defined learning outcomes, clear in their meaning and structure. Learning outcomes enable educators to clarify educational intentions, to identify and sequence content, to decide on most appropriate teaching media, to select the most appropriate activities, to decide on suitable ways of assessing learning and to evaluate the effects and effectiveness of educational materials. On the other hand, well-constructed learning outcomes help learners know the exact concepts to be absorbed and enable them to evaluate their progress themselves. What is more, learners are encouraged to continue their effort and achieve bigger involvement and better performance in the educational process [14].

All this amount of information, if carefully elaborated within the context of an intelligent system, could be transformed into useful knowledge. This knowledge can be further combined and exploited by inference mechanisms, and thus lead to the deployment of significantly advanced services, able to suggest alternative paths in learning. However, for real lifecourses, issues related to knowledge representation and management appear.

Ontologies have long been used for managing and representing knowledge. In the field of education alone, they appear as a well-known technique, adopted by many e-learning specific applications. As an example, some categories of educational ontologies that have been emerged are *domain knowledge ontologies*, *teaching strategy ontologies*, *learner model ontologies*, *ontologies for competence modeling* [4].

This paper is organized as follows: in section II we specify the structural elements of learning outcomes and present some taxonomic systems for their classification. In section III we describe an ontological schema for modeling learning outcomes. Section IV presents a case study, where these ontologies are applied for representing learning outcomes in the context of a real course. Conclusions and future work follow, in section V.

## II. Defining and Writing Learning Outcomes

A short survey of the literature on the term *learning outcomes* comes up with a great number of definitions that differ significantly to each other. According to the good working definition, proposed within the Bologna project [10] and in the context of European Qualifications Framework [5], learning outcomes are statements of *"what a learner is expected to know, understand and be able to demonstrate after completion of a learning process (a lecture, a module or an entire program), which are defined in terms of knowledge, skills and competence*".

As referred to practical guides of many educational organizations, a well-defined and effective learning outcome should be SMART. The acronym SMART sets a group of criteria [15]. According to these criteria a learning outcome should be ***S****pecific*, ***M****easurable*, ***A****ttainable*, ***R****elevant* and ***T****ime-bound*. During the learning design process, though, SMART criteria should not be used as a guide for developing learning outcomes, but rather as a checklist to ensure that produced learning outcomes are consistent to these principles.

A commonly known framework for developing learning outcomes is the "ABCD model", proposed by the educational theorist R. Mager [13]. According to this strategy, a well-written learning outcome is structured of four main components: (i) ***a****udience*, (ii) ***b****ehavior*, (iii)

***c**ondition* and (iv) ***d**egree*. The *audience* component specifies the intended group of people who should learn by the process. *Behavior* should be expressed by an action verb, indicating the learner's observable behavior. The *condition* part determines the context of actual conditions under which the behavior is to be expressed. It may include tools, materials, procedures aid, etc. Finally, *degree* (also known as *standard* or *criterion*) describes the required level of quality for the observed behavior. It can be described in terms of accuracy, productivity level, time, and degree of excellence.

When writing learning outcomes, it is a good practice to classify them into different skill levels, according to a *learning outcome taxonomy*. The various levels in a learning outcome taxonomy indicate the different degree to which the underlying skill or knowledge has been attained. Illustrative examples of such taxonomies are *Bloom's* [2] and the *Revised Bloom's Taxonomy* [11], as well as *SOLO* [1], *Gagne's* [7] and the *Fink's Taxonomy* [6].

Nevertheless, the Bloom's Revised Taxonomy seems to be the most widely applied. As in its original form, the revised version consists of three domains: the *Cognitive*, *Affective*, and *Psychomotor* domain, where each of them is further divided into knowledge levels by order of difficulty. The Cognitive domain is composed of six successive levels: *Remember*, *Understand*, *Apply*, *Analyze*, *Evaluate* and *Create*.

Learning outcomes that concern sentiments, attitudes and values fall into the affective domain. The affective domain includes concepts such as *Receiving* ideas, *Responding* to ideas, *Valuing* ideas, *Organization* of ideas, and *Characterization* by value set. On the other hand, the psychomotor domain is related to the physical skills and/or the performance of motor tasks according to a standard of accuracy, rapidity, or smoothness. For the analysis of this specific domain, three different approaches have been proposed ([3], [9] and [17]). In the context of our work, the Simpson's approach described in [17] has been adopted, since it is more detailed. According to this approach, learning outcomes are classified in the following levels: *Perception*, *Set*, *Guided Response*, *Mechanism*, *Complex Response*, *Adaptation* and *Origination*.

Another important aspect of learning outcomes is their sequencing. With this term, we denote the arrangement of learning outcomes into a logical teaching sequence. In [12], the following seven sequencing methods are proposed: *job performance order*, *chronological order*, *critical sequence*, *simple to complex order*, *comparative sequence*, *relationships between objectives* and *part to whole*. The educator may use only one method or a combination of them.

## III. EDUCATIONAL ONTOLOGIES

In this section, we describe deployed ontologies, as well as rules that come to augment the extraction ability of knowledge. We first give an overview of the schema that encodes the structure of learning outcomes. Afterwards, we give a synopsis of the one modeling the revised Bloom Taxonomy. The coupling of these ontological models leads to the *Combined* ontology, suitable for representing the structure and sequence of learning outcomes.

In order to build the ontologies, we followed a widely-adopted methodology, proposed in [16]. As far as their typical representation is concerned, we adopted the most recent version of the Web Ontology Language which is a W3C standard, namely OWL 2. More specifically, our ontologies fall into the OWL 2 RL profile, a quite expressive sublanguage of OWL 2 able to accommodate rule-based technologies.

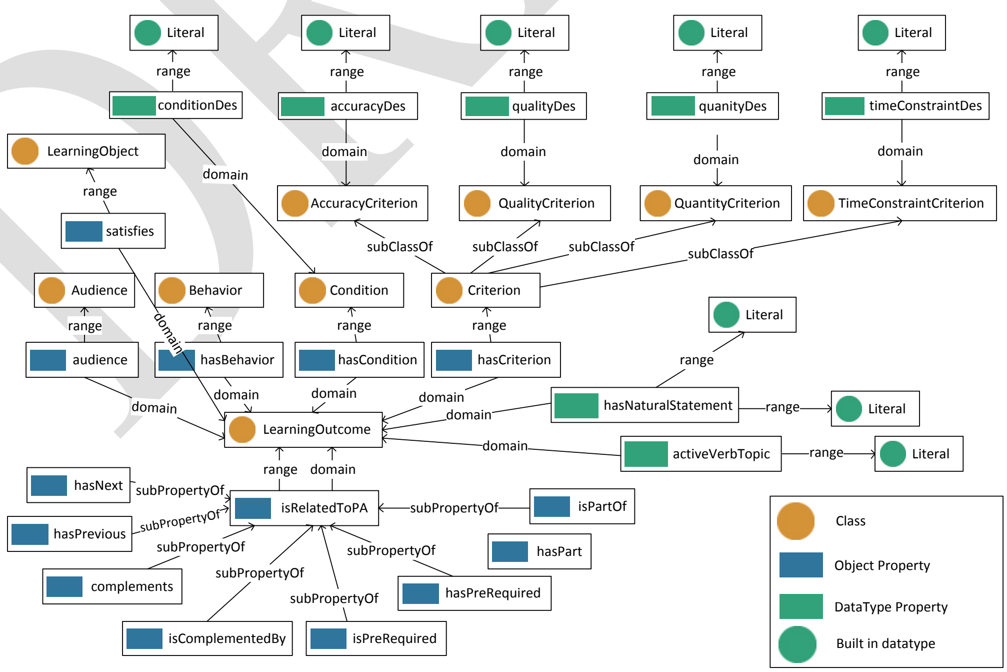


Figure 1. The Learning Outcome ontology

### A. Learning Outcomes as Ontology

In the *LearningOutcome* ontology, the structure of a learning outcome is captured, according to the ABCD model. A learning outcome is represented by the *LearningOutcome* class, whereas its four structural elements are modeled by the *Audience*, *Behavior*, *Condition* and *Criterion* (expresses the *degree* component) classes respectively (see Fig. 1). Especially, for *Criterion*, a set of four sub-classes has been defined (*AccuracyCriterion*, *QualityCriterion*, *QuantityCriterion* and *TimeConstraint-Criterion*) so as to express the various aspects of the degree component. Learning outcomes are bound to one or more learning objects. Besides, learning objects are self-contained units of educational content that serve exactly this purpose, namely the mastering of learning outcomes [17]. To represent the notion of a learning object, a concept with the name *LearningObject* is provided.

Each class representing a structural element of a learning outcome is associated with a natural language description. This description is captured by literal datatype properties in the *LearningOutcome* ontology, like *accuracyDes*, *conditionDes*, *qualityDes*, *quantityDes* and *timeConstraintDes*. All declared datatype properties are depicted in Fig. 1.

On the other hand, relationships between instances are modeled as object properties. In this context, a learning outcome is an aggregation of relationships that link an instance of the class *LearningOutcome* to instances of the class *Audience*, *Behavior*, *Condition* and *Criterion*.

Furthermore, object properties are used for expressing sequencing methods for learning outcomes. Dependency relationships are expressed by a pair of inverse properties, namely *hasPreRequired* and *isPreRequired*. In addition, pair wise inverse properties *complements* and *isComplementedBy* are set to describe supportive correlations. The sequencing of learning outcomes in terms of time, relative importance or increasing difficulty is expressed by the transitive properties *hasNext* and *hasPrevious*. Note, also, that all aforementioned properties are irreflexive, meaning that no instance can be related to itself via any of them. Finally, the "part to whole" sequencing method is given by the transitive and pair wise inverse properties *hasPart* and *isPartOf*.

### B. The Bloom Taxonomy as Ontology

The proposed ontology schema for expressing the classification of learning outcomes follows the revised Bloom Taxonomy. Hence, consideration for all its three domains (i.e., cognitive, affective and psychomotor) is taken.

Our design process has resulted in the core ontology *BloomTaxonomy*. All main classes, as well as their sub-classes are illustrated in Fig 2. As shown in this figure, each class takes its name after the particular domain of Bloom Taxonomy that actually represents and lies under the super-

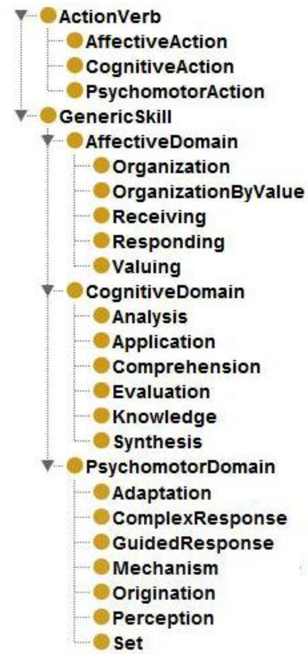


Figure 2. Bloom ontology – the hierarchy of its classes

class *GenericSkill*. The levels of knowledge to which each domain is further analysed, are in turn expressed as subclasses of the domain's specific class.

In the context of this ontological schema, the only property we have defined is called *requires*. This property denotes that mastering a skill level -belonging to a certain domain- implies and imposes mastering of all other levels that are positioned lower in the learning outcome hierarchy.

Action verbs convey the learning outcome's behavior and they are represented as instances of *BloomTaxonomy*. More specifically, they are organized under three classes (*AffectiveAction*, *CognitiveAction* and *PsychomotorAction)*, each one expressing specific kind of action for a learning outcome. For example, the verb '*change*', which can be used for expressing either cognitive or psychomotor skills, is assigned to both *Adaptation* and *Application* level.

### C. The Combined Ontological Model

The *Combined* ontological schema results from merging the two ontologies (*LearningOutcome* and *BloomTaxonomy*). So, neither new classes nor additional datatype properties have been defined in it. The main objective of the *Combined* ontology is to assign learning outcomes to the various knowledge domains and levels of the Bloom Taxonomy. However, it makes provision for the following relationships, which are modeled as object properties: *subject*, which correlates a learning outcome or a condition component with a knowledge subject, *hasBehavior*, which bounds a learning outcome to an action verb of the Bloom Taxonomy, and *hasBloomLevel*, which reveals the level of Bloom Taxonomy that a learning outcome belongs to.

Nevertheless, several characteristics and correlations between learning outcomes can be only elaborated by restriction rules and by exploiting existing reasoning mechanisms. As a consequence, the *Combined* ontology schema includes two types of rules, all expressed in the Semantic Web Rule Language (SWRL). Examples of these rules are given in Table I.

With the first type (rule #1) the reasoner checks a learning outcome's behavior (i.e., its main verb) and infers the Bloom taxonomy level it belongs to. With the second type (rule #2) reasoner checks if two learning outcomes have the same knowledge subject, and if so, it finds other learning outcomes that come previous or next to it in the sequencing of Bloom Taxonomy.

TABLE I. RULES IN THE COMBINED ONTOLOGY

| *#* | *Rule* |
|---|---|
| **1** | IF (*y* ***is-a*** *Knowledge*) AND (*x* ***is-a*** *LearningOuctome*) AND (*x* ***hasBehavior*** *y*) → *x* **hasBloomLevel Knowledge** |
| **2** | IF (*x* ***is-a*** *LearningOuctome*) AND (*y* ***is-a*** *LearningOuctome*) AND (*x* ***hasBloomLevel*** *b1*) AND (*x* ***subject*** *s1*) AND (*b1* ***hasLevel*** *l1*) AND (*y* ***hasBloomLevel*** *b2*) AND (*y* ***subject*** *s1*)AND (*b2* ***hasLevel*** *l1*) AND (*l2* ***greaterThan*** *l1*) AND (*s1* ***sameAs*** *s2*) → **x hasNext y** |

## IV. CASE STUDY: MODELING LEARNING OUTCOMES FOR THE TOPIC OF JAVA

Hellenic Open University (HOU) is specialized in distance and lifelong learning. Therefore, all of its educational material has been designed according to lifelong learning principles, meaning that is directly associated with learning outcomes. The Java programming language is taught within the course module of "Software Engineering" which is offered as part of the HOU's study course in Informatics. All Java related material has been directly correlated to learning outcomes, but with one quick look it is easy to realize that for these statements neither the ABCD model, nor the Bloom taxonomy have been used.

Therefore, we chose this material in order to apply our ontological model and re-construct the already defined learning outcomes. Our goal is to produce more fine-grained statements, suitable for use within intelligent e-learning applications that could aid students in learning Java.

We were focused on the subject domain of Java operators, arrays and control flow statements. Initially, we had to re-formulate already written learning outcomes and re-construct them following the ABCD model. However, it was often the case when we had to build additional statements so as to express missing learning outcomes about concepts, for which no provision had been made. The selection of the right behavior (i.e., verb) proved to be a notably difficult task, given that its implying action affects the classification of produced learning outcomes among the various levels of knowledge in the Bloom Taxonomy.

This step was realized in collaboration with the coordinator and tutors of the Java course, who are both experts in the knowledge domain of Java, and in distance education principles. The output of this step was 32 statements expressing learning outcomes for the selected subject referring to operators, arrays and control flow statements. In Table II we present some example learning outcomes, in their resulting ABCD form.

Thereafter, we needed to model these natural language statements as instances of the *Combined* ontology. With the aid of Protégé, we created 32 instances of the *LearningOutcome* class, whereas building components were modeled accordingly. An example of such an instance is depicted in Fig. 3.

TABLE II. EXAMPLE LEARNING OUTCOMES FOR THE TOPIC OF JAVA

| ***ID*** | ***Learners will be able to:*** |
|---|---|
| LO_1 | ***quote*** *the* ***2*** *data types that Java language supports (Knowledge)* |
| LO_2 | ***explain*** *the difference between one-dimensional and multi-dimensional arrays (Comprehension)* |
| LO_3 | ***locate*** *the operators in a Java program (Comprehension)* |
| LO_4 | ***change*** *a variable's value by interchanging the operators' position and taking into account their priority (Application)* |
| LO_5 | ***combine*** *at least* ***3*** *different operators in order to construct arithmetic expressions that include decimal numbers (Synthesis)* |

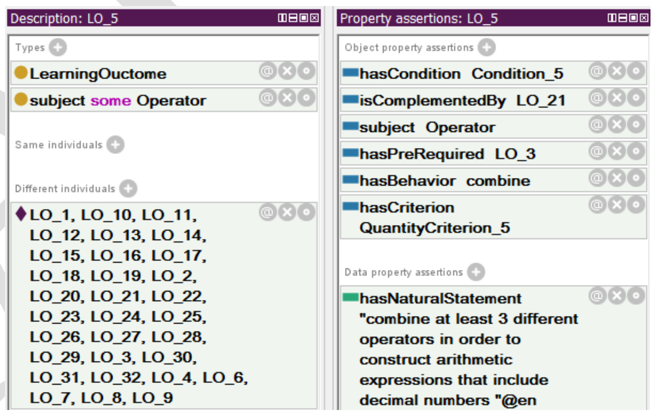


Figure 3. An example learning outcome in Protégé

To examine our model's capability to infer knowledge, we run some representative queries and evaluated them against the populated ontology. These queries are expressed in the Manchester OWL Syntax and tested through the DL query tab of Protégé. We demonstrated that apart from obtaining explicitly declared facts (concerning *knowledge subject*, *behavior*, *criterion* or *condition* of a learning outcome), based on this ontology we can request more complex things, like: 1) the level in the Bloom taxonomy a learning outcome belongs to, 2) its relative order in this taxonomy, and finally 3) a sequencing of learning outcomes in terms of inter-dependencies or supportive relationships.

Consider, for example, that we want to obtain all learning outcomes that belong to the *Application* level of the Bloom Taxonomy and refer to Java *operators*. This can be expressed using the first query of Table III. Let learning outcome with id LO_1 (Table II) be the result of the first query. We can additionally obtain learning outcomes regarding LO_1, but are ranked in lower (query #2) positions. Moreover, with query #3 we can retrieve learning outcomes that refer, for example, to Java operators and constitute a necessary requirement for learning outcome LO_5 (see Fig. 4). Finally, query #4 simply retrieves those statements that contain the verb *define* and refer to Java *arrays*.

Of course similar requests can be made for different domain subjects, different levels of knowledge and any kind of relationship modeled in the ontology as a property.

TABLE III. SOME EXAMPLE QUERIES IN MANCHESTER OWL SYNTAX

| # | *Query* |
|---|---|
| **1** | **subject** value **Operator** and **hasBloomLevel** value **Application** |
| **2** | **hasNext** value **LO_1** |
| **3** | **isPreRequired** value **LO_5** |
| **4** | **hasBehavior** value **define** and **subject** value **Array** |

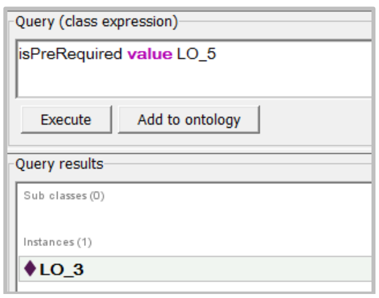


Figure 4. Results retrieved when evaluating query #4 of Table III

Semantic queries presented in section IV are actually examples of competency questions for our ontologies. Competency questions are a commonly used technique for evaluating such formalisms [8].

## V. CONCLUSIONS AND FUTURE WORK

We presented here a method for modeling the notion of learning outcomes, as well as their classification, based on ontologies. Ontologies are considered a prominent technique for representing knowledge and gain ground in e-learning environments. After having reviewed the characteristics of a learning outcome, we opted for the ABCD model for their construction and the revised Bloom Taxonomy as for their classification. Such an ontological model for learning outcomes can significantly aid tutors and learners to the retrieval of useful knowledge.

In particular, the benefit for tutors is twofold: using the proposed model within the context of appropriately designed tools and applications, they would be able to build better structured and clearer in meaning learning outcomes. What is more, they could disseminate educational material through designated services in a more effective and personalized way. On the other hand, learners could better organize their study, given that they would have a more clear view about the expectations of a course and thus a practical guide in learning.

Our future work is focused in exactly providing both the tools and the methods for incorporating the proposed ontologies in intelligent applications, able to process and manage all aspects of knowledge existing in lifelong learning environments. What we finally intend to give in educational community, is advanced services for efficiently handling and disseminating educational material.

## ACKNOWLEDGEMENT

This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) (Funding Program: “HOU”).

## REFERENCES

[1] J. Biggs and K. Collis, “Evaluating the Quality of Learning: the SOLO taxonomy”, New York:Academic Press, 1982.

[2] B. Bloom, “Taxonomy of Educational Objectives”, New York: David McKay Company Inc., 1956-1964.

[3] R. Dave, “Psychomotor Levels”,. In Developing and Writing Behavioural Objectives, ed. Robert J. Armstrong. Tucson AZ: Educational Innovators Press, 1975.

[4] V. Devedžić, “The Setting for Semantic Web-based Education” in Semantic Web and Education, Springer New York, NY, 2006

[5] European Commission, The European Qualifications Framework for Lifelong Learning (EQF). Retrieved from http://ec.europa.eu/dgs/education_culture/publ/pdf/eqf/broch_en.pdf, 2008

[6] L. D. Fink, “Creating Significant learning Experiences: An Integrated Approach to Designing College Courses”, Jossey-Bass Publishers, San Francisco, CA, 295 p., 2003.

[7] R. M. Gagné and L. J. Briggs, “Principles of Instructional Design”, New York: Holt, Rinehart, and Winston, Inc., 2nd Edition, 1979.

[8] M. Grüninger and M. S. Fox, "Methodology for the design and evaluation of ontologies", In IJCAI95 Workshop on Basic Ontological Issues in Knowledge Sharing, 1995.

[9] A. Harrow, “A Taxonomy of Psychomotor Domain: A Guide for Developing Behavioral Objectives”, New York:David McKay, 1972.

[10] D. Kennedy, A. Hyland and N. Ryan, “Writing and using Learning Outcomes”, Bologna Handbook, Implementing Bologna in your Institution, C3.4-1, 1–30, 2006.

[11] D. Krathwohl and L. Anderson, “A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom’s Taxonomy of Educational Objectives”, New York: Longman, 2001.

[12] Learning Systems Institute, “Sequence Learning Objectives - How To. Task Based Curriculum Development Manual”, Retrieved from http://www.lpg.fsu.edu/charting/howtopdf/ht-obj5.pdf, 2011.

[13] R. Mager, “Preparing Instructional Objectives”, Belmont, California: Pitman Learning, 2nd Edition, 1984.

[14] A. Maher, "Learning Outcomes in Higher Education: Implications for Curriculum Design and Student Learning", Journal of Hospitality, Leisure, Sport and Tourism Education, 3(2), pp. 46-54, 2004.

[15] P J. Meyer, “What would you do if you knew you couldn’t fail? Creating S.M.A.R.T. Goals”, in Attitude Is Everything: If You Want to Succeed Above and Beyond. Meyer Resource Group, Incorporated, 2003.

[16] N. Noy and D. McGuiness, “Ontology Development 101: A Guide to Creating Your First Ontology”, Stanford Knowledge Systems Laboratory Technical Report KSL-01-05, 2001

[17] P. R. Polsani, “Use and Abuse of Reusable Learning Objects”, Journal of Digital Information, 3(4), 2003