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Pedagogically-Driven Ontology Network for Conceptualizing the e-Learning Assessment Domain

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ABSTRACT

The use of ontologies as tools to guide the generation, organization and personalization of e-learning content, including e-assessment, has drawn attention of the researchers because ontologies can represent the knowledge of a given domain and researchers use the ontology to reason about it. Although the use of these semantic technologies tends to enhance technology-based educational processes, the lack of validation to improve the quality of learning in their use makes the educator feel reluctant to use them. This paper presents progress in the development of an ontology network, called AONet, that conceptualizes the e-assessment domain with the aim of supporting the semi-automatic generation of assessment, taking into account not only technical aspects but also pedagogical ones.

Keywords

Ontology, Ontology network, e-Learning, e-Assessment

Introduction

It is well known that e-learning has become a popular and growing business, thus, the number of courses available on Internet is growing rapidly. Among factors affecting e-learning success, proper feedback mechanisms are integral. As Dewey (1963) argues, learning is fundamentally social in nature. Thurmond, Wambach, Connors and Frey (2002) state that diversity in assessment and perception of interaction with others influences e-learning satisfaction considerably. The use of different evaluation methods in an e-learning system causes learners to establish a connection between themselves and their instructors, which in turn helps to ensure that their learning efforts are properly assessed (Sun Tsai, Finger, Chen, & Yeh, 2008). There are a variety of instruments for assessment; however, in an e-learning system, only a few of them are generally used, with the most popular being objective instruments such as multiple and simple choice.

In the area of e-assessment, there are two problems to overcome. First, e-assessment must be accepted by educators. A tool to support devising and creating valid and reliable assessments, from a pedagogical perspective, is needed. This means that we must define a mechanism to validate whether the assessment covers all of the learning objectives of a course and satisfies certain pedagogical principles such as those proposed by Bolivar (2011). E-learning systems must allow educators create diagnostic, summative, and formative assessment, along with self-assessment, co-assessment, and hetero-assessment.

In the e-learning context, ontologies, and web semantic technologies are widely used with different purposes. Chang and Chen (2009) propose a tool for peer assessment to satisfy the requirements of cooperative learning in an e-learning environment. Gladun, Rogushina, García-Sanchez, Martínez-Béjar, and Fernández-Breis (2009) propose a domain ontology to assess learners' skills. In this case, the domain ontology is not only the learning instrument but also a means for testing and teaching. Also, in research literature, different approaches that define ontology as a structure to guide the automated design of assessment can be found in (Castellanos-Nieves, Fernández-Breis, Valencia-García, Martínez-Béjar, & Iniesta-Moreno, 2011; Simperl, Mochol, Burger & Popov, 2010). However, most of these approaches are based on individual ontologies that only model a part of the assessment domain, considering only the structural aspects of the assessments. For example, Castellanos-Nieves et al. (2011) defined an ontology for supporting open-question generation, whereas Simperl, et al. (2010) model only true-or-false-type questions. Related to assessment in an e-learning environment, Frutos-Morales, Sanchez-Vera, Castellanos-Nieves, Esteban-Gil, Cruz-Corona, Prendes- Espinosa, and Fernandez-Breis (2010) propose the use of semantic web technologies to generate semantic feedback in the TL process. Despite the efforts made in this sense, much work remains, especially when considering the pedagogical aspect of the e-learning environment.

Farrús and Costa-Jussà (2013) propose the generation of assessments on demand, where assessment is composed only of open questions, the authors do not specify the ontologies used in that process. In Rupere, Chaka, Zanamwe and Mavhemwa (2013), authors propose the use of language ontology in web system, which lets assesses student knowledge through short open questions. In Elsayed, Eldahshan, and Tawfeek (2013), authors propose to assess learners with multiple-choice questions and open questions related to the area of mathematics that require a variable number of steps to reach the solution using emantic systems. Fernández-Breis Frutos-Morales, Gil, Castellanos-Nieves, Valencia-García, García-Sánchez, and Sánchez-Vera (2011) incorporate semantic interpretations of the mapping between domain ontology and ontology that supports the overall structure of the assessments. Jia, Wang, Ran, Yang, Liao, and Chiu (2011) focus on the particular issues of learning in work environments, learning that is constructed on practical tasks and work situations. The developed ontology assists in facilitating and directing learning activities of employees to achieve individual and organizational needs. Chen, Lee, and Tsai (2011) propose the use of a personalized learning that incorporates an evaluation scheme that generates knowledge questions and correct answers using an ontology in order to assess the level of competence of vendors with respect to knowledge about mobile phones. In her master thesis, Romero and Leone (2007a, 2007b) defined an ontology that emphasizes the design and management of learning material to evaluate the e-learning process in distributed environments. However, this ontology is strongly associated with a specific e-learning platform and may not be reused. Alsubait, Parsia, and Sattler (2012) show the design of an algorithm for generating questions automatically. This algorithm considers only multiple-choice questions, without specifying ontologies on which it is based. Radenković, Krdžavac, and Devedžić (2009), used a descriptive logic reasoner for assessment. This reasoner is focused on the answers and solutions proposed by the students and the intelligent analysis of them.

Scoreanzi and Romero (2014) conducted a comprehensive bibliographic review on the use of semantic web technologies on the e-assessment domain. It proposes a conceptual model, which gives a started point for stakeholders on e-learning projects to know the progress on this subject.

The main objective of this paper is to show the AONET ontology network and discuss in detail the ontologies that conceptualize the assessment domain. To this end, this paper is organized as follows. First the main concepts around semantic web technologies are introduced. Following, the AONET ontology network is presented, and the ontologies of the assessment domain are discussed in depth. Next, the evaluation of the ontologies is presented. In the next section, the use and limitations of the ontologies are discussed. Finally, Section 5 summarizes and concludes this work.

Background technologies

The aim of this section is to present the main concepts around semantic web technologies necessary to understand the AONET ontology network.

The concept of "ontology" seems to enjoy as many definitions as attempts to define it. In the course of this paper, we adopt the definition given by Maedche (2002): "An ontology is a 6-tuple consisting of concepts, relations, hierarchy, a function that relates concepts non-taxonomically, a set of axioms, and a set of rules."

Formally: O: = {C,R,H,rel,A,DR} where:

- Two disjointed sets, C (concepts that represents classes) and R (binary relations among concepts).
- H⊆CxC is the concept hierarchy or taxonomy. So, H(C1, C2) means C2 subsumes C1 if and only if C1 is a subclass of C2 or if every instance (individual) of C1 is also an instance of C2 (Guarino & Welty, 2004).
- rel→CxC relates the concepts non-taxonomically.
- A: set of axioms that are logical sentences which are always true, and express the properties of model paradigm, expressed in an appropriate logical language.
- DR a set of derivation rules that model rules about the domain of discourse, expressed in an appropriate logical language. Every DR is a Horn-like clause with the structure of $p_1(x_1) \wedge ... \wedge p_n(x_n) \rightarrow q(y)$

Ontologies can be lightweight or heavyweight (Gómez-Pérez, Fernandez López, & Corcho, 2004). The former describes concepts and relationships that hold among them. The latter add axioms and derivation rules to the former. Thus, every heavyweight ontology has a lightweight version.

The main component of a heavyweight ontology is the set of derivation rules. The ontology web language (OWL) (W3C, 2012) is the standard for implementing an ontology. We must combine OWL with other representation formalism in order to generate rules. One of the integration approaches is the semantic web rule language (SWRL), which provides the ability to express Horn-like rules in terms of OWL concepts. With the aim of extracting information from OWL ontologies, a query language is needed. The most powerful language is SQWRL, which is based on the SWRL rule language and uses SWRL's strong semantic foundation as its formal underpinning (Allocca D'aquin & Motta, 2009).

An ontology network is a set of ontologies related together via a variety of different relationships such as mapping, modularization, version, and dependency. The elements of this set are called networked ontologies (Allocca et al., 2009).

An ontology network differs from a set of interconnected individual ontologies in the relations among ontologies since in an ontology network, the meta-relationships among the networked ontologies are explicitly expressed (Gómez-Pérez, et al., 2004). The DOOR (descriptive ontology of ontology relations) ontology defines general relations between ontologies such as *includedIn*, *equivalentTo*, *similarTo*, and *versioning* using ontological primitives and rules (O'Connor & Das, 2009). In this paper, the following relationships are used:

isTheSchemaFor
keeps the link between a model and its metamodel.

usesSymbolsOf
This relationship happens when an ontology, O, involves individuals belonging to another ontology, Q, in such a way that ontology Q defines some properties that take value in individuals that are classified by classes of ontology O.

cross-ontologySubsumption
This relationship exists between a class belonging to an ontology and its superclass belonging to another ontology.

relatedTo
This relationship exists between two classes belonging to different ontologies.

This work was implemented through the NeOn (http://www.neon-project.org) toolkit and complemented by the NeOn methodology, which is a scenario-based methodology that supports the collaborative aspects of ontology development and reuse (Vitturini, Benedetti, & Señas, 2011).

The main advantage of using an ontology network is the conceptualization of a given domain in a modular way. The networked ontology is small enough to be understandable by anybody and its maintenance is easy. In addition, several ontology designers could work on different networked ontologies concurrently.

The AOnet ontology network development

In order to design the AOnet, the NeOn methodology in conjunction with the methodology proposed by Corcho, Gomez-Pérez & Fernandez-Lopez (2003) was followed. AONet consists of five ontologies that conceptualize three different domains: course topic domain, educational resources, and assessment. Figure 1 shows the AONet ontology network.

The *Educational Resource Specification Ontology* conceptualizes the educational resources used by the educator in the TL process. Some standards emerge to overcome the formalization of educational resources, which are constantly evolving. In most cases, the use of a learning object (LO) definition and its description by LOM (Learning Technology Standards Committee, 2002) is the common denominator. It is possible to optimize the educational resource development process. This ontology is related to Course Domain Specification ontology through the *relatedTo* relationship. It identifies the connection between educational resources and concepts belonging to the specific domain. That is to say, an educational resource is developed in order to achieve different concepts, relations and definitions about a domain topic. A LO metadata instance describes relevant characteristics of an educational resource, with the aims of facilitating the search, acquisition, interchange, and evaluation of a resource by educators, learners, and software systems. We add *LOnto ontology* to the network built (Romero & Godoy, 2010), which conceptualizes the semantic definition of LO based on LOM IEEE 1484.12.1 standard (Learning Technology Standards Committee, 2002). Then, the Educational Resource Specification ontology is related with LOnto through the *isTheSchemaFor* relationship.

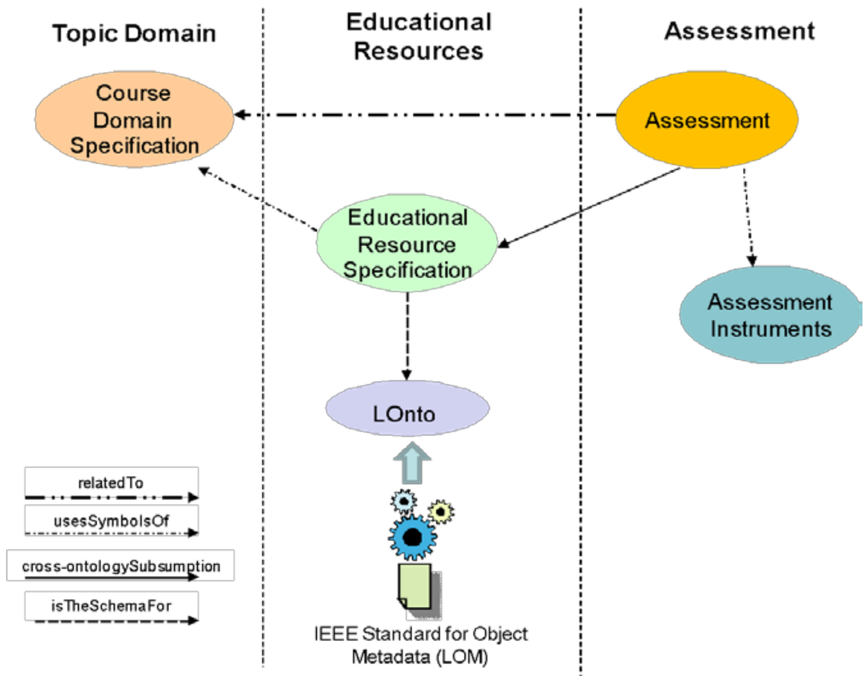


Figure 1. AONet ontology network

Assessments are part of the educational resources involved in the TL process when the educator wants to evaluate the knowledge and skills acquired by learners. In this context, the ontology network has the Assessment ontology, which is related with Educational Resource Specification ontology through the *cross-ontologySubsumption* relationship. In the same way, this ontology is related with Educational Domain Specification ontology through the *relatedTo* relationship. These relations indicate that an assessment is used to evaluate the results of the TL process about the knowledge domain.

There are different instruments to evaluate learning processes, which are modeled by the *Assessment Instrument* ontology. These instruments are used by educators to create an assessment. For instance, an instrument is a true-or-false question, a conceptual map, an exercise, an essay activity, etc. Using such instruments, the *Assessment* ontology has the *usesSymbolsOf* relationship with the *Assessment Instrument* ontology.

The next sub-sections describe in detail the core ontologies that conceptualize the assessment domain: Assessment Ontology and Assessment Instruments Ontology. In order to develop these ontologies, we followed Scenario 1 from the NEON methodology, since this scenario refers to the development of ontologies from scratch. In this scenario, ontology developers should first specify the requirements that the ontology should fulfill, by means of the ontology requirements specification activity. Then, the ontology developers assigned to the ontology project should carry out: (1) the ontology conceptualization activity, in which knowledge is organized and structured into meaningful models at the knowledge level; (2) the ontology formalization activity, in which the conceptual model is transformed into a semi-computable model; and (3) the ontology implementation activity, in which a computable model (implemented in an ontology language) is generated.

Assessment ontology

The requirements specification of the assessment ontology

This ontology models the structure of an assessment in a TL process and considers the e-learning domain. From a didactics point of view, assessment is necessary to evaluate the learning process and, thus, is also of relevance to the e-learning situation. However, assessment can be considered difficult within a distance learning environment. The assessment can be considered as an element that provides information to guide and enhance the TL process.

With the aim of defining the requirements of the Assessment Ontology, a set of competency questions (CQs) were defined. CQs consist of a set of questions and answers presented in natural language so that the ontology can answer them correctly (Noy & Hafner, 1997). In order to specify the CQs, we identified intended users and domain experts. In this case, three intended users and two domain experts were involved in the CQs definition. The middle-out technique was followed to define the CQs. That is, first, the intended users and domain experts suggested a set of CQs. From this set, complex CQs were decomposed into simple CQs, and simple CQs were organized into complex CQs. During the overall process, we received input from the domain experts and the end users. They used the following criteria for validating the competency questions:

- Correctness. Domain experts checked the correctness of each competency question, verifying that its formulation and answers were correct.
- Consistent. Domain experts also verified that the competency questions did not have any possible inconsistency.

Following, a set of the CQs that the Assessment Ontology has to answer is shown.

Given an assessment, who is the author?
Given an assessment, in which moment does it takes effect?
Given an assessment, who is being assessed?
Given an assessment, who is the evaluator?
Given an assessment, which activities are part of it?
Given an assessment, which rubric has been defined?
Given an activity, which reactives are part of it?
What are the formative assessments?
What are the diagnostic assessments?
Given an author, which diagnostic assessments did he develop?
Given a student, which self-assessments did he answer?
What is the role of an agent involved in a given hetero-assessment?

The assessment ontology conceptualization

An Assessment is composed of one or more activities (exercises that assess a particular domain topic). Each activity is composed of one or more reactives (an item that uses an instrument).

There is a moment in the TL process when the assessment takes effect (Arredondo, 2002). If the assessment is early in the process, it is known as a diagnostic assessment. Teachers can use this kind of assessment to become acquainted the background knowledge of student.

A formative assessment is performed during the TL process. Its goal is to give feedback to learners and educators about how well learners understand specific content.

A summative assessment occurs at the end of the process. Its goal is a judgment: to derive a grade, qualification, or accreditation.

Agents (an educator, learner, author, or management) are involved in the assessment-playing roles. These agents can play different roles such as: assessed or assessor.

Depending on the roles that each agent assumes in a particular assessment, the assessment can be classified into Self-assessment, Hetero-assessment, and Co-assessment.

Self-assessment is the assessment in which a learner evaluates his/her own progress in the learning process. In this case, the learner assumes both roles: assessed and evaluator.

Hetero-assessment is a kind of assessment where the agents involved are educator and learner, and the educator assesses a learner. This is a classical approach and is traditionally presented in the TL process, where educator plays the role of evaluator and the learner plays the role of assessed.

Co-assessment is peer assessment. It can be done between learners or between educators playing both roles.
Figure 2 shows the ontology model. It is considered a good practice that the rules and style of lexical encoding for naming elements be homogeneous within the ontology. All concepts were defined in singular, and the name of a class was defined using the upper camel case style, while the name of a relationship was defined using the lower camel case style.

The main concept of the Assessment Ontology is the class Assessment. This is a prerequisite for achieving educational quality. Regarding assessment composition, the *isComposedBy* relation set an Assessment is composed of Activities, which in turn have one or more Reactives.

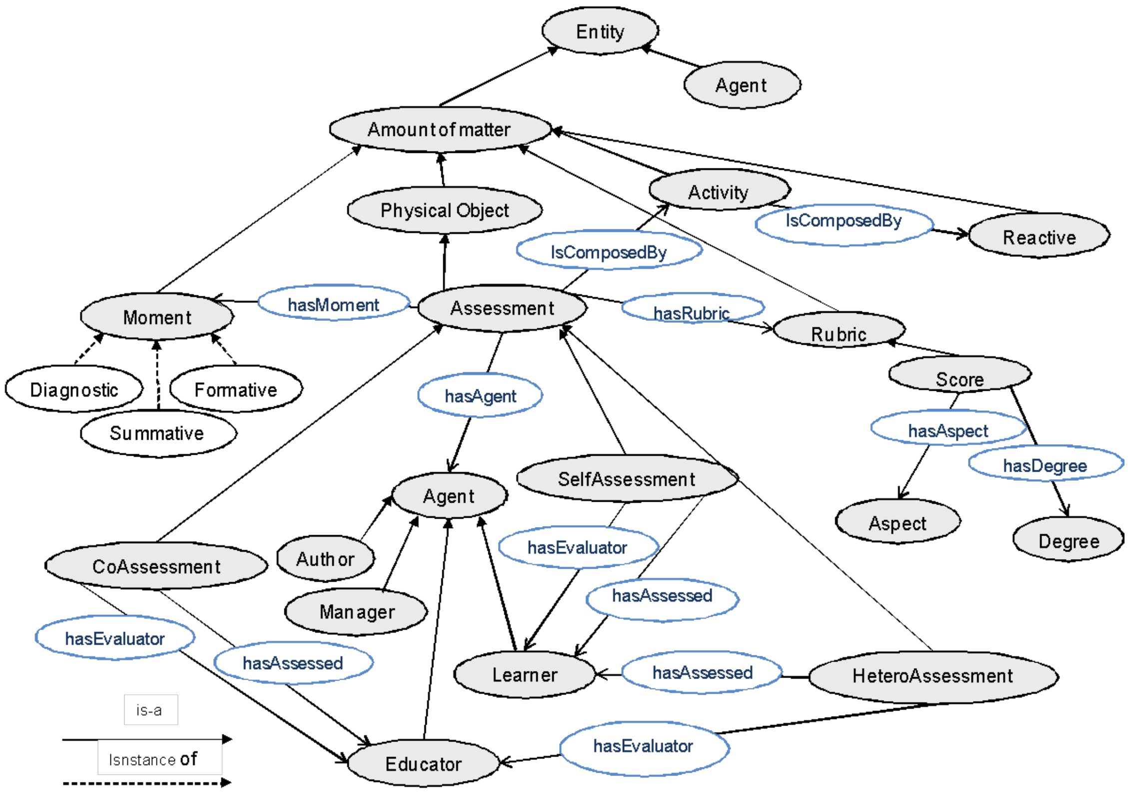


Figure 2. Assessment ontology

The Moment class has three instances, Diagnostic, Summative, and Formative, which represent the classification of an assessment according to the moment in which it takes effect. Three Assessment subclasses are defined: SelfAssessment, HeteroAssessment, and CoAssessment. The Agent class represents the actors involved in the assessment process. Four subclasses have also been defined: Author, Learner, Educator, and Management.

The hasEvaluator and hasAssessed relations restrict the agents involved in each type of assessment. Subsequently, hasEvaluator and hasAssessed relations link SelfAssessment with Learner classes. In the same way, the hasEvaluator relates HeteroAssessment with Professor and hasAssessed relates HeteroAssessment with Learner classes. Also, the CoAssessment class has four relations instead of two. One pair of hasEvaluator and hasAssessed relations relates CoAssessment with Educator classes meaning that the assessment takes effect between peer educators. The other pair of relations relates CoAssessment with Learner classes, meaning that the assessment takes effect between peer learners.

The assessment ontology formalization

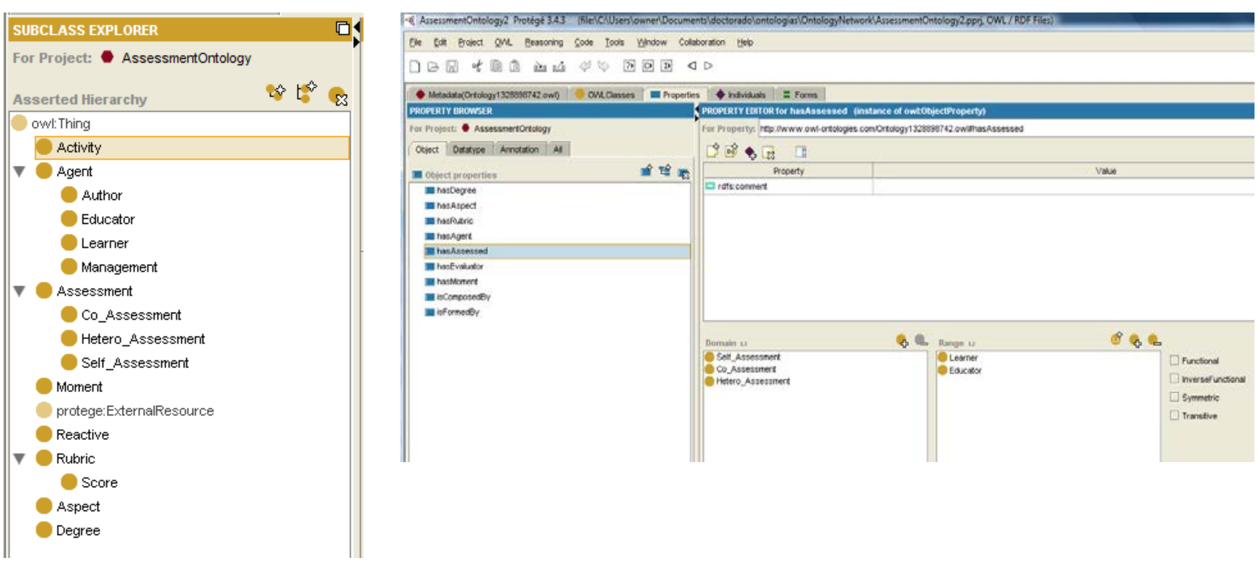
Before implementing the ontology, we formalized axioms to restrict the way in which relations can be performed because the definition of relations alone is not enough to define type of assessment according to the agents involved. For instance, CoAssessment can be seen as both HeteroAssessment and SelfAssessment because nothing restricts the definition of the relationships. Table 1 shows the axioms defined to restrict different types of agents involved in SelfAssessment**,** HeteroAssessment, and CoAssessment. These axioms have been written in first-order logic.

Table 1. Axioms to restrict agents involve in assessment

Description	First-order logic
A co-assessment takes effect between peer educators or between peer learners.	$\Im \models (\forall x,y,z(CoAssessment(x) \wedge hasEvaluator(x,y) \wedge hasAssessed(x,z)) \Rightarrow ((Educator(y) \wedge Educator(z)) \vee (Learner(y) \wedge Learner(z))))$
A hetero-assessment has an educator as the evaluator and a learner assessed.	$\Im \models (\forall x,y,z(HeteroAssessment(x) \wedge hasEvaluator(x,y) \wedge hasAssessed(x,z)) \Rightarrow (Educator(y) \wedge Learner(z)))$
A self-assessment has a learner which is both evaluator and assessed.	$\Im \models (\forall x,y(SelfAssessment(x) \wedge hasEvaluator(x,y) \wedge hasAssessed(x,y)) \Rightarrow Learner(y))$
An assessment always has an author.	$\Im \models (\forall x\ Assessment(x) \Rightarrow \exists y\ (hasAgent(x,y) \wedge Author(y)))$

The assessment ontology implementation

Assessment ontology has been implemented in Protégé ontology editor. Figure 3(a) shows the ontology hierarchy and Figure 3(b) shows the hasAssessed relation properties.



(a) (b)

Figure 3. Assessment ontology implementation

Assessment instruments ontology

The requirements specification of the assessment instruments ontology

The Assessment Instrument ontology models different instruments that could be used for implementing an assessment. An assessment instrument is the physical support that is used to collect the information about the expected learning of students.

The Assessment Instrument ontology has to be able to answer the following competency questions:

Given an assessment, which activities use multiple-choice instrument?
Given an assessment, which activities use simple-choice instrument?
Given an assessment, which activities use completion instrument?
Given a simple-choice instrument, which is the true option?
Given a simple-choice instrument, which are the distractors?
Which is the answer of a given correspondence instrument?
Which are the single instruments of a portfolio?
What is the organization of a portfolio?
Which instruments can be used for an assessment?
What are the types of essay?
What is the scope of a restricted essay?
How is a restricted essay organized?
Which citations have a restricted essay?
Which are the mechanics of a restricted essay?

The assessment ontology instruments conceptualization

Class Instrument is the main concept in this ontology. It is related to the Reactive concept from Assessment ontology through the uses relation, which in term is an instance of usesSymbolsOf meta-relationship. There are two types of instruments: FormalInstrument and SemiformalInstrument, representing formal and semiformal techniques, respectively. For semiformalInstrument, we have considered two types: SimpleInstrument**,** such as Exercise, ConceptualMap, and Essay, and CompositeInstrument, such as Portfolio, which consists of a collection of SimpleInstrument elements that help record learning processes and students' progress. Figure 4 shows the relationships among concepts previously defined.

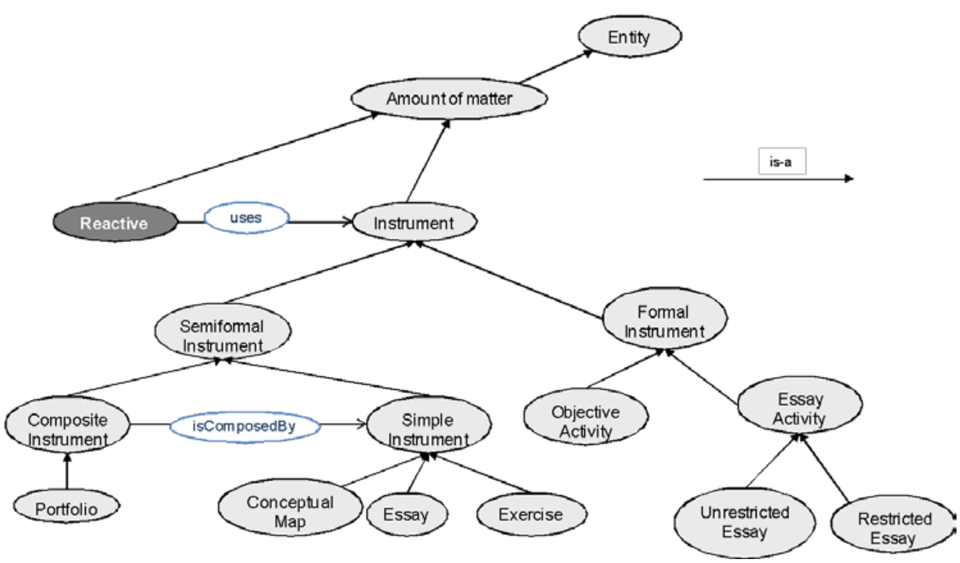


Figure 4. Assessment Instrument Ontology

As FormalInstrument**,** we consider two classifications: ObjectiveActivity, where students have to identify the correct answer and EssayActivity, where learners have to elaborate the answer in writing. ObjectiveActivity is one of the most used activities by professors because it eliminates the subjectivity in the rating, even when it has an additional complexity to develop it.

ObjectiveActivity has three sub-concepts: Choice, Correspondence**,** and Completion. Choice has Option associated. The concept Option is specialized into two sub-concepts: Distractor and TrueOption. Distractors are items that are not correct, and TrueOption is the correct item. The concept Choice is specialized as: SimpleChoice (contains only one correct option), and MultipleChoice (which can have more than one correct option). In both cases, Option can only have a true/false answer associated. Finally the concept Answer can be of different types: TrueFalse, Numeric, Text, and Relation. Figure 5 shows the definition of Objective activity as part of Assessment instrument ontology.

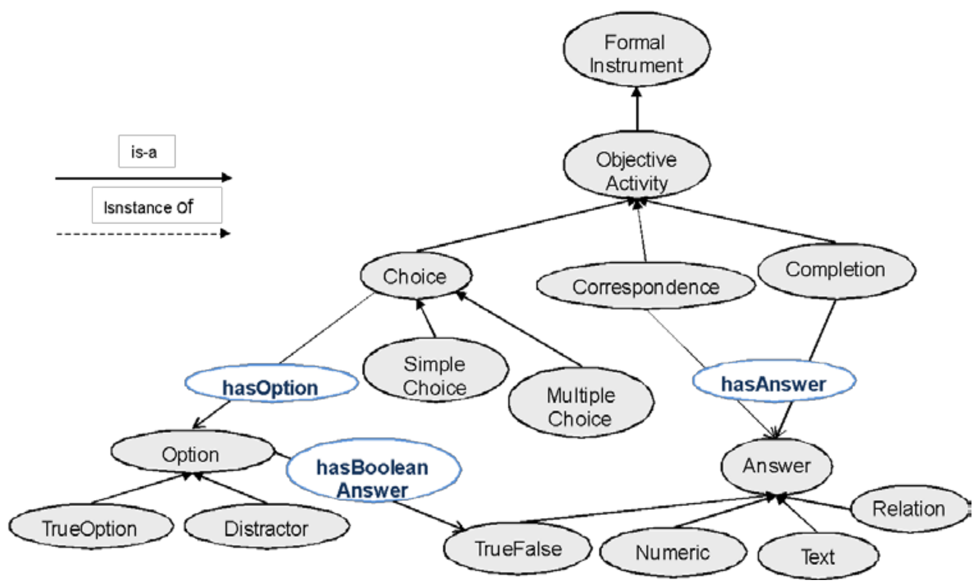


Figure 5. Objective activity instrument description

According to Diaz and Barriga (2008), there are some pedagogical recommendations when a choice instrument is used. If educators follow these guides, we can say that the instrument is valid in a pedagogical sense. In this work, we used these recommendations to define rules to express the restrictions in the generation of valid instruments.

From a pedagogical perspective, there should always be a right option. As well, these types of activities should not include options such as “none of the above” or “all of the above.” In general, items should be relevant to the context being assessed in a clear and simple way and preferably written in the affirmative mode. The distractors should appear as attractive as possible to the uninformed student. These pedagogical recommendations can be defined as:

- A simple-choice instrument should have at least four options.
- A simple-choice instrument should have only one true option.
- A multiple-choice instrument should have more than one true option.
- A multiple-choice instrument should have at least four options.
- A multiple-choice instrument cannot have options such as “all of the above” or “none of the above.”

Table 2. Pedagogical rules for simple and multiple choice in first-order logic

Description	First-order logic
Simple choice	
1. A simple-choice instrument should have at least four options.	$\Im \models (\forall x,y,z,w,r(SimpleChoices(x) \wedge hasOption(x,y) \wedge hasOption(x,z) \wedge hasOption(x,w) \wedge hasOption(x,r)) \Rightarrow (y \neq z \neq w \neq r \wedge z \neq w \neq r \wedge w \neq r))$
2. A simple-choice instrument should have only one true option.	$\Im \models (\forall x,y,z(SimpleChoices(x) \wedge hasOption(x,y) \wedge hasOption(x,z)) \Rightarrow (TrueOptions(x) \wedge \neg TrueOptions(z)))$

Multiple choice	
3. A multiple-choice instrument should have more than one true option.	ℑ|=(∀x,y,z(MultipleChoices(x)∧hasOption(x,y)∧hasOption(x,z)∧ TrueOptions(y)∧TrueOptions(z)) ⇒ y≠z)
4. A multiple-choice instrument should have more than four options.	ℑ|=(∀x,y,z,w,r(MultipleChoices(x)∧(hasOption(x,y)∧hasOption(x,z)∧hasOption(x,w)) ∧hasOption(x,r)) ⇒(y≠z≠w≠r ∧z≠w≠r ∧w≠r))
5. A multiple-choice instrument cannot include an option such as "all of above" or "none of above."	ℑ|=(∀x,y,z,w(MultipleChoices(x)∧hasOption(x,y)∧hasAttribute(y,z)∧value(z,w)) ⇒ (w ≠ "all of the above" ∧ w≠ "none of the above"))

Table 2 shows the pedagogical rules that have been taken into account. The first column describes the rule in a colloquial language. The second column shows the fist-order logic description of such rules. For simplicity, in the second column we use a reified concept such as SimpleChoices and MultipleChoices, depicting the sets of simple-choice and multiple-choice elements, respectively.

The EssayActivity is divided into two sub-concepts: RestrictedEssay and UnrestrictedEssay. Restricted essay is a written learning exercise that has a predefined topic and scope (Attali, Lewis & Steier, 2013; Birkenhauer, 2008). All students completing a restricted essay write about the same thing, in the same way, and in accordance with specific instructions and parameters (Landauer, Laham & Foltz, 2003). A rubric is provided to learners so that they can adapt their writing to the restrictions required for the essay (Cooper & Gargan, 2009). The essay must have relevant content, logical organization, and sound written mechanics (i.e., correct spelling, grammar, and punctuation) (Shermis, Mzumara, Olson, & Harrington, 2001). Assessment is conducted in accordance with the rubric (Cooper & Gargan, 2009; Read, Francis, & Robson, 2005). Citation of sources in a specific format (e.g., APA) may or may not be required (Birkenhauer, 2008). Figure 6 shows the description of RestrictedEssay as part of the Assessment Instrument ontology.

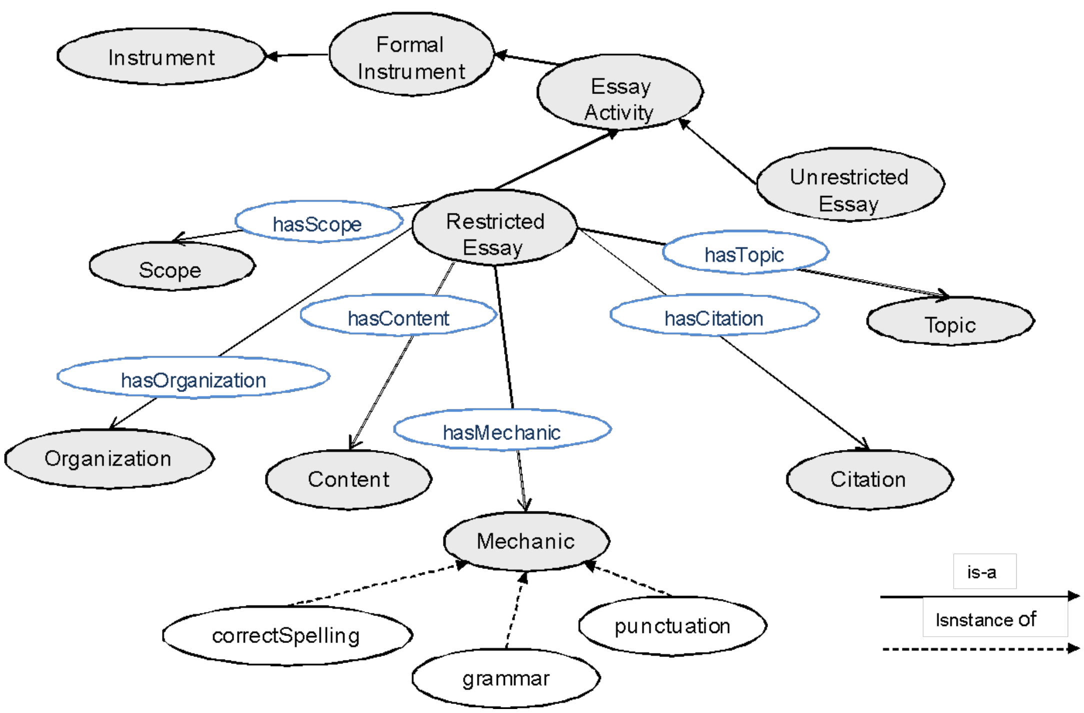


Figure 6. Restricted essay activity

In this context, integrity axioms were defined in order to set the condition that a restricted essay must meet. Table 3 shows these axioms.

Table 3. Integrity axioms for RestrictedEssay

Description	First-Order Logic
A restricted essay must have a topic.	ℑ|= (∀x RestrictedEssay(x)⇒ (∃y Topic(y)∧hasTopic(x,y)))
A restricted essay must have a scopes.	ℑ|= (∀x RestrictedEssay(x)⇒ (∃y Scope(y)∧hasScope(x,y)))
A restricted essay must have mechanics.	ℑ|=(∀x RestrictedEssay(x)⇒(∃y Mechanic(y)∧hasMechanic(x,y)))
A restricted essay is disjoint with unrestricted essay.	ℑ|=(∀x,y(RestrictedEssay(x) ∧ UnrestrictedEssay(y)) ⇒ x ≠ y)
A restricted essay must have organization.	ℑ|=(∀x RestrictedEssay(x)⇒(∃yOrganization(y)∧hasOrganization(x,y)))
A restricted essay must have a content.	ℑ|= ∀x RestrictedEssay(x)⇒(∃y Content(y)∧hasContent(x,y))
A restricted essay must have citations.	ℑ|= ∀x RestrictedEssay(x)⇒(∃y Citation(y)∧hasCitation(x,y))

An unrestricted essay is a written learning activity that may or may not have a predefined topic and scope (Birkenhauer, 2008; McNamara, Crossley, & McCarthy, 2010). Students completing an unrestricted essay may write about similar topics or different ones; however, the objective of the assigned essay must be the same for all learners (Read et al., 2005). Student essays must conform to instructions and parameters; however, these may be intentionally ambiguous or loosely defined in order to encourage discovery or creativity on the part of the learner (Landauer et al., 2003; McNamara et al., 2010). A rubric may be provided to learners so that they can more clearly understand expectations for the essay (Cooper & Gargan, 2009; Shermis, Mzumara, Olson, & Harrington, 2001). The essay must have relevant content, logical organization, and sound written mechanics (i.e., correct spelling, grammar, and punctuation) (Shermis, Shneyderman, & Attali, 2008). Assessment is conducted in accordance with articulated expectations, and, if a rubric is provided, assessment conforms to the rubric (Attali et al., 2013; Shermis et al., 2001). Citation of sources in a specific format (e.g., APA) may or may not be required (Birkenhauer, 2008).

A portfolio (see Figure 7) is a collection of a learner's evidence of learning in a course or curriculum. A portfolio may contain artifacts created by the learner, solutions to problems solved by the learner, reflections on artifacts or solutions, written descriptions of artifacts or solutions, and reflections on previous feedback from peers or instructors (Chang, Liang, & Chen, 2013; Van der Schaaf, Baartman, & Prins, 2012). A portfolio must have content and organization (Vance et al., 2013). A portfolio's definition, content, and organization may be proscribed or learner designed (Van der Schaaf et al., 2012; Vance et al., 2013). A portfolio is assessed in accordance with the requirements set forth by the instructor (Vance et al., 2013).

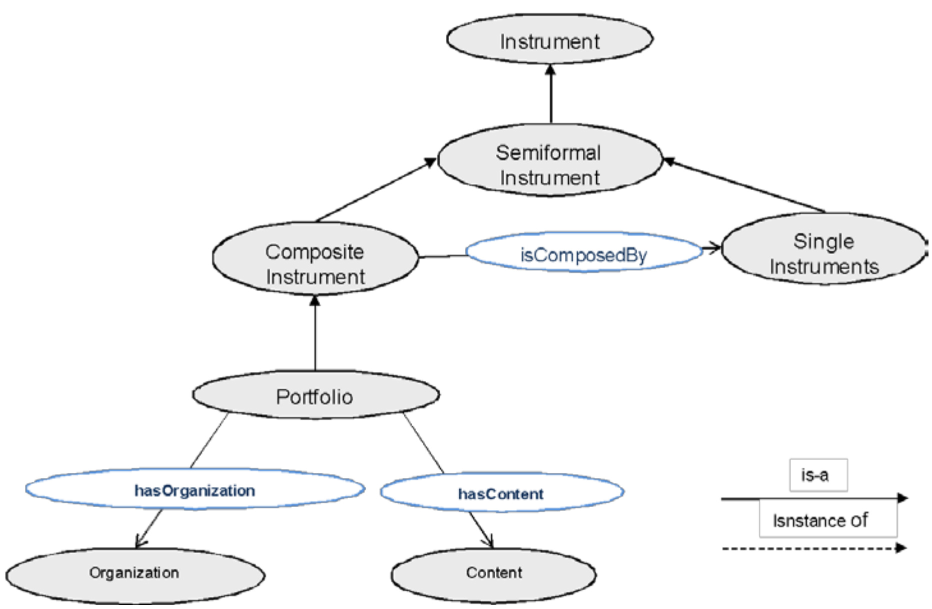


Figure 7. Semiformal instrument

The implementation of the assessment instruments ontology

We implemented the Assessment Instrument ontology in the Protégé ontology editor within the Assessment Ontology. Also, we implemented rules showed in Table 2 as derivation rules by using the SWRL and SQWRL languages. Beginning with simple choices, we implemented rules 1 and 2 as follows:

SimpleChoice(?sc)϶Option(?o) ϶ hasOption(?sc,?o)϶ sqwrl:makeSet(?os,?o)϶sqwrl:groupBy(?os,?sc)϶ sqwrl:size(?t,?os)϶sqwrl:greaterThanOrEqual(?t,4)® optionQuantityValid(?sc) (1)

SimpleChoice(?sc)϶distractor(?d)϶sqwrl:makeSet(?s1, ?d)϶ sqwrl:groupBy(?s1,?sc)϶ sqwrl:size(?t,?s1)϶sqwrl:equal(?t,1)® answerQuantityValid(?sc) (2)

Regarding multiple choice, we have three restrictions 3, 4, and 5 in Table 2 that are represented with sentences 3, 4, 5, and 6, respectively. Note that the restriction 5 was represented with two sentences, 5 and 6, for simplicity.

MultipleChoice(?mc) ϶ distractor(?d) ϶ sqwrl:makeSet(?s1, ?d) ϶ sqwrl:groupBy(?s1, ?mc) ϶ sqwrl:size(?t, ?s1) ϶ sqwrl:greaterThan(?t,1) ϶ answerQuantityValid(?mc) (3)

MultipleChoice(?mc) ϶ Option(?o) ϶ hasOption(?mc, ?o) ϶ sqwrl:makeSet(?os, ?o) ϶ sqwrl:groupBy(?os, ?mc) ϶ sqwrl:size(?t, ?os) ϶ sqwrl:greaterThan(?t,4) ® optionQuantityValid(?mc) (4)

MultipleChoice(?mc) ϶ hasOption(?mc, ?o) ϶ label(?o, ?l) ϶ sqwrl:normalizeSpace(?n,?l) ϶ sqwrl:stringEqualIgnoreCase(?n, “all of the above”) ® whithoutAll(?mc) (5)

multipleChoice(?mc) ϶ hasOption(?mc, ?o) ϶ lavel(?o, ?l) ϶ sqwrl:normalizeSpace(?n,?l) ϶ sqwrl:stringEqualIgnoreCase(?n, “none of the above”) ® withoutNon(?mc) (6)

Finally, if a simple choice meets the restriction (1) and (2) we can say that this simple choice is valid. This statement is represented with the following rule:

SimpleChoice(?sc) ϶optionQuantityValid(?sc) ϶ answerQuantityValid(?sc) ® validSimpleChoice(?sc) (7)

In the same way, if a multiple choice meets the restriction (3), (4), (5), and (6) is a valid multiple choices:

multipleChoice(?mc) ϶whithoutAll(?mc) ϶whithoutNon(?mc) ϶optionQuantityValid(?mc) ϶answerQuantityValid(?mc) ® validMultipleChoice(?mc) (8)

All the axioms were implemented as restrictions. Figure 8 shows the implementation of the axioms defined in Table 3.

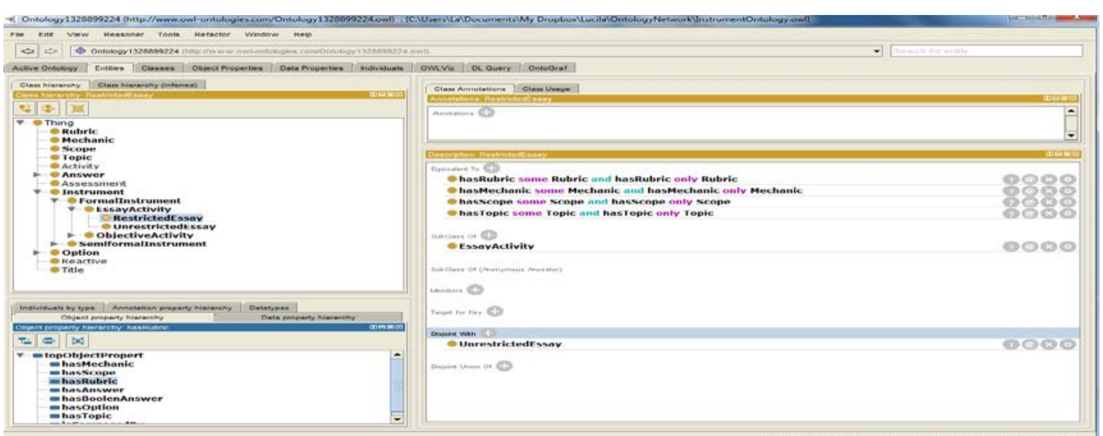


Figure 8. Axioms as restrictions in OWL2 language

Evaluation of the assessment and assessment instruments ontologies

To carry out the evaluation of the Assessment and Assessment Instrument ontologies, we considered two aspects. On the one hand, the model is an ontology so it is necessary evaluate the ontological characteristics to assess the quality of the ontology. On the other hand, ontologies have to be evaluated against a frame of reference to assess the correctness of them (Suárez de Figueroa Baonza, 2010).

Evaluating the quality of the ontologies

The evaluation of an ontology quality is a process to be carried out during the whole ontology building process. The goal of evaluation is to detect errors in modeling characteristics of the assessment domain; i.e., what it does not define or what it defines incorrectly.

With the aim of evaluating the Assessment and Assessment Instrument ontologies as an ontology itself, the inference engine Pellet was used because it is a consolidate tool that is mature in the task of verifying inconsistencies in ontologies. Besides, Pellet can be installed as a plugin in Protégé, is totally compatible with the OWL2 language. Using Pellet, we verified the consistence of the ontologies. Those inconsistencies could be related to the class disposition (classes in the same hierarchy and disjoint classes), the relationship among classes (range and domain), the type of attribute, or the application of rules in the ontology.

In addition, a tool, called OOPS! (OntOlogy Pitfall Scanner, http://oeg-lia3.dia.fi.upm.es/oops) was used to verify a catalogue of common pitfalls that could lead to modeling errors proposed by Poveda Villalon, Suárez-Figueroa & Goméz-Pérez (2010).

Evaluating the correctness of the ontologies

For evaluating individual ontologies, the most common evaluation approaches are (i) to compare the ontology to a gold standard ontology; (ii) to compare the ontology with a source of data about the domain to be covered (e.g., a set of documents); (iii) to evaluate the ontology verifying if it answers the defined competency questions; (iv) to have the ontology evaluated by human experts who assess how the ontology meets the requirements; and (v) to use the ontology in an application and evaluate the results (Suárez de Figueroa Baonza, 2010). To evaluate the correctness of the Assessment and Assessment ontologies, we used the last three approaches.

During the building process of the Assessment and Assessment Instrument ontologies, we evaluated them using the competency questions. In order to do that the evaluation, we take as example, the final exam of Artificial Intelligence course (Figure 9) (www.ai-class). This is a summative assessment. The first activity is about a search domain topic and has two reactives. The latter is about the machine learning domain topic and has one reactive.

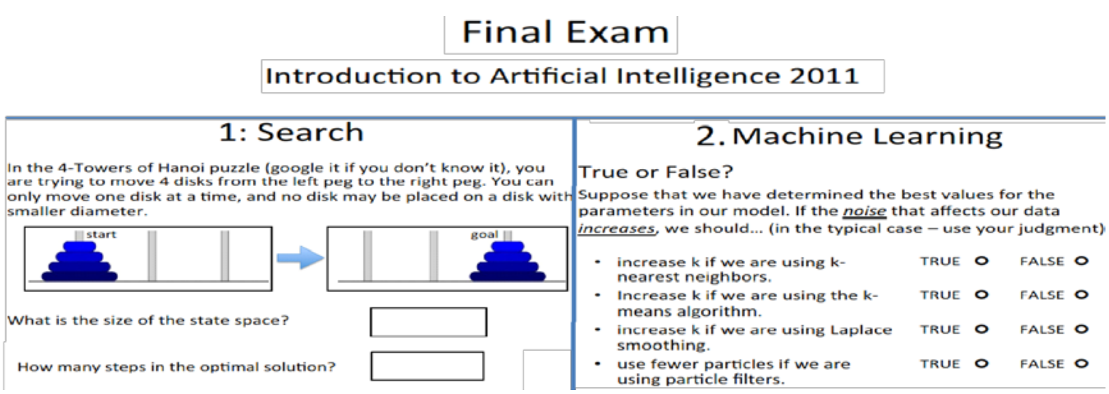


Figure 9. A final exam for the Artificial Intelligence domain

To populate the ontologies, we generated an instance of HeteroAssessment as shown in Figure 10. Also, the *ExamIntroductionToAI* instance has two activities as components: *MachingLearningActivity* and *SearchActivity*. The latter has two reactives associated: *SearchItem1* and *SearchItem2*. The instance of HeteroAssessment has a moment associated as well.

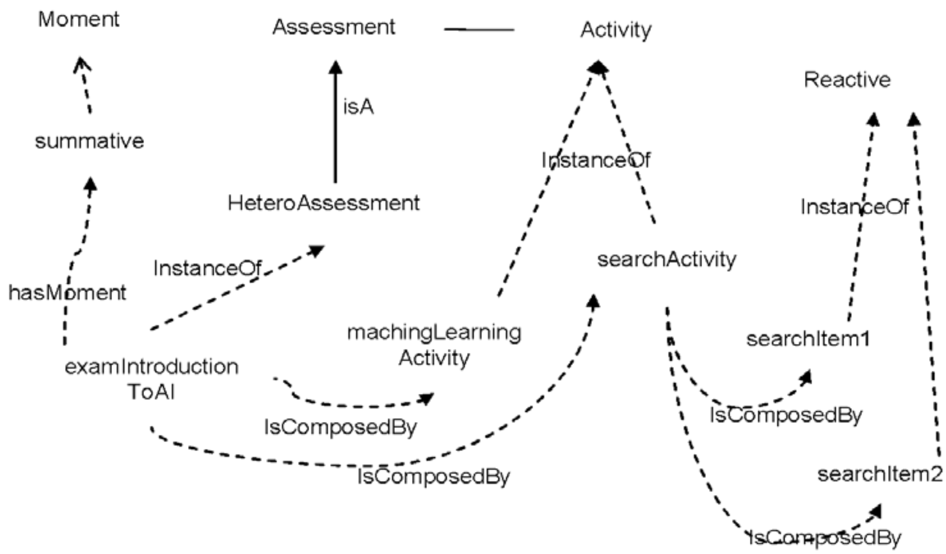


Figure 10. Population of the Assessment ontology

Following, Figure 11 shows the agents associated with the *ExamIntroductionToAI* instance. It is a HeteroAssessment,and it has associated two agents: first is an instance of *Learner*, which is associated through the link *hasAssessed*, and second is an instance of *Educator*, associated through the link *hasEvaluator.*

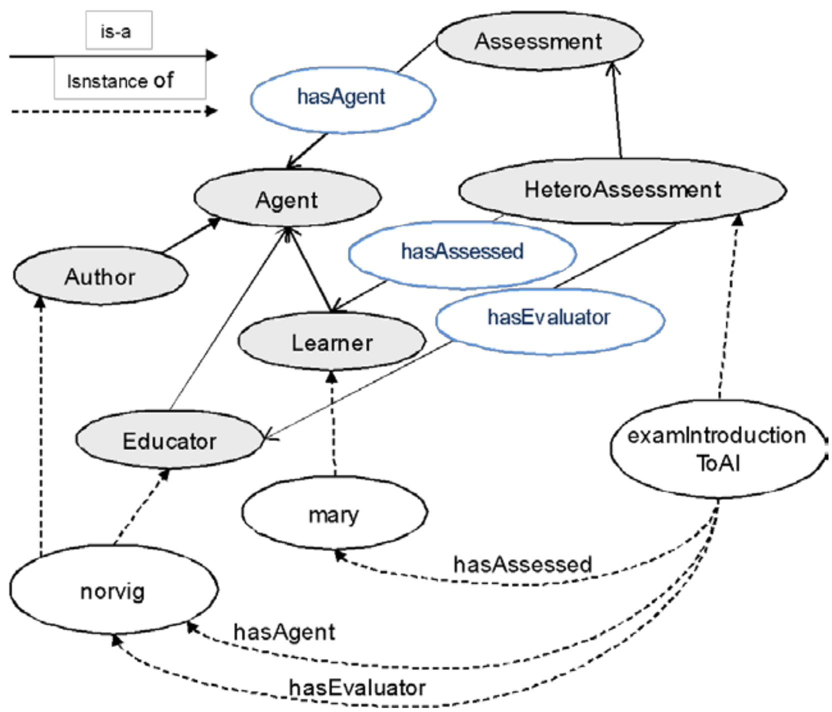


Figure 11. Agents join in the AI assessment

Next, the reactive *searchItem1* uses a completion instrument whose answer is *81*, an instance of Numeric (Figure 12).

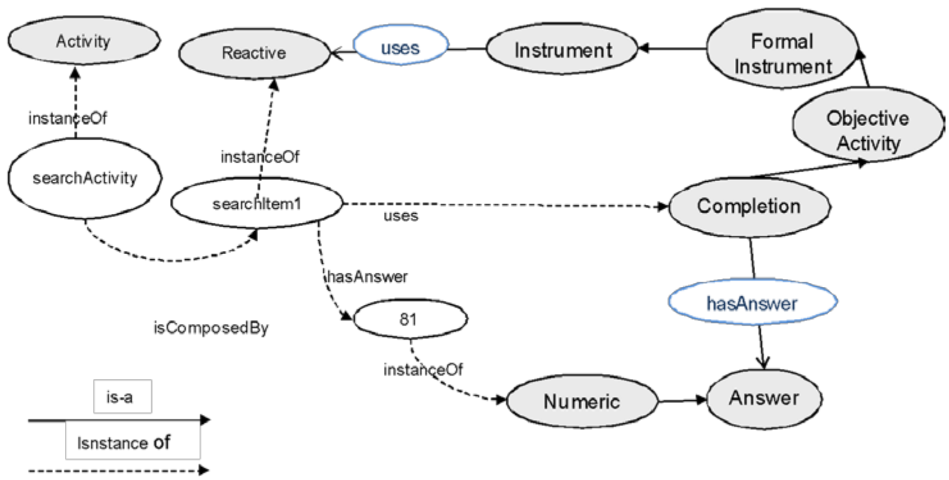


Figure 12. A completion instrument used in a reactive

The competency questions defined for these ontologies were implemented in SPARQL. An example of this implementation is shown in Table 4.

Table 4. Examples of the implementation of the competency questions in SPARQL

Competency question	SPARQL query
Given an assessment, who is the author?	PREFIX asse:<http://utn.frsf.edu.ar/assessment/> PREFIX ins:<http://utn.frsf.edu.ar/instrument> PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> . SELECT ?assessment ?agent WHERE { ?assessment asse:hasAgent ?agent AND ?agent rdf:typeOf asse:author }
Given an assessment, in which moment does it take effect?	PREFIX asse: <http://utn.frsf.edu.ar/assessment/> PREFIX ins: <http://utn.frsf.edu.ar/instrument> SELECT ?assessment ?moment WHERE { ?assessment asse:moment ?moment }
What are the formative assessments?	PREFIX asse:<http://utn.frsf.edu.ar/assessment/> PREFIX ins:<http://utn.frsf.edu.ar/instrument> SELECT ?assessment WHERE {?assessment asse:moment ?moment FILTER{regex(?moment, “formative") } }

We evaluated the CQs answers in conjunction with the experts in pedagogical aspects and the professor of the artificial intelligence course at the Universidad Tecnológica Nacional, Facultad Regional Santa Fe, who is an intended user.

After all the competency questions were evaluated, the Assessment and Assessment Instruments ontologies were used as informational source to develop a software tool called OFGA, which allows educators to generate an assessment and check its validity according to the pedagogical rules.

The tool was developed in Java language, using MySQL as DB engine and Apache JENA reasoner. Figure 13 shows the software tool architecture. The DAOs component is the access data layer and the ONTOLOGIES component gives support to the ontologies’ access. Both components provide services to the SERVICES component. View component is the user interface, and MODEL component is the conceptual model used by components in order to communicate with each other.

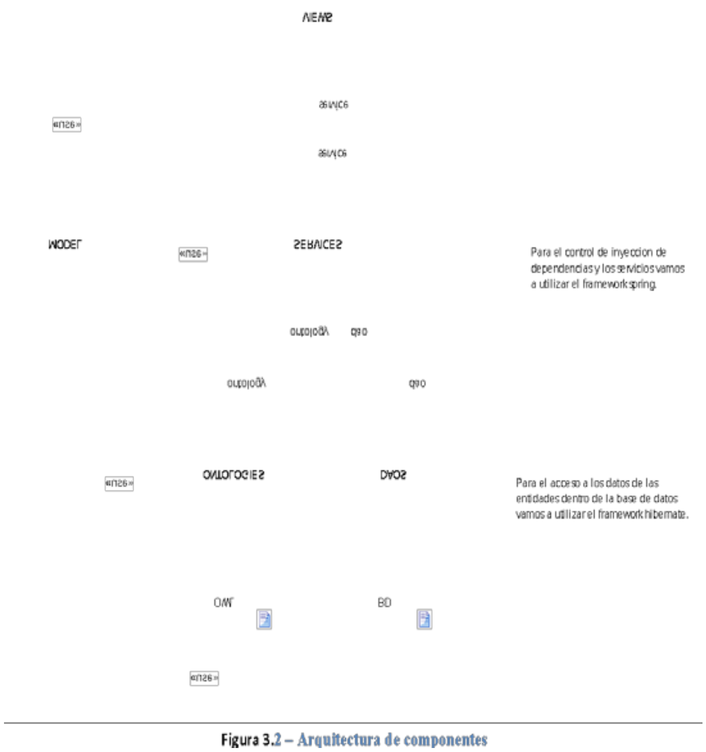
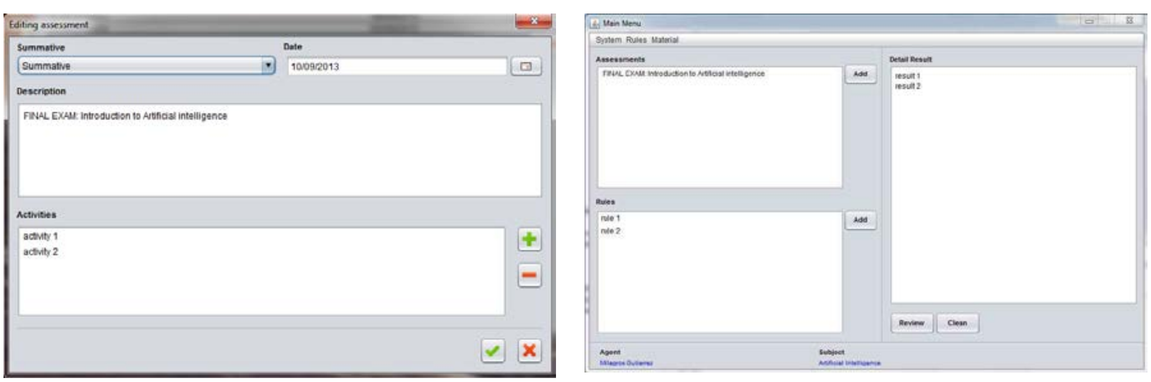


Figure 13. Software tool architecture

In this way, the ontology creation and manipulation is processed in main memory using only the necessary components in a way to avoid overload. The JENA inference engine allows the tool to derive knowledge using SWRL rules. The tool generates a RDF graph from ontology, which is used by the inference engine to make a reasoning. Then the persistent data are located in a database for future uses.

The main features of OFGA allow the user to generate a new assessment, add new activities, select instruments, validate assessment based on a set of selected rules, add new validations rules, and generate a pdf assessment document, among others. Figure 14(a) shows the assessment edition snapshot. Through this tool, the author can add activities to and erase them from the assessment. Figure 14(b) shows the assessment validation based on a set of selected rules. In this case, there is a set of rules defined, and the author can select which rules to apply to validate the assessment generated. Also, authors can write their own rules and decide whether an assessment meet these rules.



(a) (b)

Figure 14. Assessment generator Snapshot

The OFGA was used to validate the Assessment and Assessment Instrument from the intended user's perspective. While developing these ontologies, we carried out interviews with different experts in pedagogical aspects. To evaluate the ontologies with regard to usability, we invited five educators to use the software to model the evaluation that was used in their regular courses at the UTN, Facultad Regional Santa Fe, and Universidad Nacional del Litoral. We adopted the following criteria to select participants: all participants belonged to different disciplines; none of the participants had pedagogical training; and all participants had more than 10 years of experience teaching different courses. All participants evaluated the usefulness of the tool, and all of them discovered that most of their assessments did not follow the main pedagogical recommendations. In addition, from this experience we concluded that the Instrument Assessment ontology models most of the instruments types that are commonly used. However, more rules are necessary to evaluate the essay instrument.

Conclusion and future work

This work has shown progress in defining an ontology network whose purpose is to conceptualize the assessment domain in a TL process. The modularization that this network provides allows us to concentrate on a particular domain and incrementally build a more general model relating to different ontologies.

We presented concepts related to the assessment domain. Mainly, this work focused on describing the Assessment ontology that models the different classification and types of assessment in an educational context, as well as the different instruments used in assessment development.

Through the ontology network, it is possible to add a new ontology and relate it to an existing one. This work has presented the meta-relations found between three domain ontologies: topic domain, educational resource, and assessment domain ontologies. This development allows the appropriate description of resources to enhance their location and retrieval.

We present the integrity axiom and derivation rules (static and dynamic conditions) to meet two objectives: restrict the way in which an assessment can be developed and introduce pedagogical criteria. In the approach presented in this paper, the pedagogy and the technology are closely linked. In this sense, the ontologies are useful for assisting educators who do not have strong knowledge of pedagogical aspects.

Finally, we discussed an example of the ontology network population using an artificial intelligence assessment and showed snapshots of a tool to generate assessments using these ontologies. In the future, we intend to acquire additional validation assessments for a broad evaluation and refinement of the ontology.

We presented a tool that supports the development of assessment, and are working on improving the ontology network by adding new concepts and relations and new integrity and derivation rules. Additionally, we are developing tests using different types of assessments provided from different knowledge domains.

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