Student Modelling based on Ontologies

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Abstract— In this paper I show how ontologies support the student modelling through the semantic definition of concepts that depict a student. The aim is to outline the framework for building ontologies as knowledge repositories. The advantages stemmed from the design and the use of ontologies are quite valuable, such as: the formal representation of knowledge based on axioms; the inferences outcome from inheritance relations; the easy-readable ontology’s code for humans and machines; and the provision of federative services for ontology management through agents. Hence, as a result of the experiment that was fulfilled in a Web based education system (WBES), I found out that ontologies provide a solid and reliability support for depicting attributes that concern to an individual, who is represented by a student model (SM).

Keywords— Student modelling, student model, ontologies, Web based education systems

I. INTRODUCTION

Student modelling is the process by which Web based education systems (WBES) acquire information about a user [1]. This process is a life-cycle integrated by tasks as the following: knowledge elicitation about the student, construction, maintenance, and exploitation of the knowledge repository [2]. As a result, a mental model composed by attributes and preferences of the student is set in a module called student model (SM). Such SM also includes an engine devoted to carry out inferences about the behaviour and the learning of the student. The SM is needed for achieving a personalized interaction between a WBES and any student [3], because without it a WBES lacks of elements for distinguishing one user from others.

The development of a mental model that characterizes an individual is a complex task that is target of multidisciplinary research composed by sciences such as: psychology, philosophy, sociology, and neurology. The perspectives that are taken into account for describing an individual depend of the specific goal of study. Thus, in WBES such points of view are called domains, and they are devoted to state the knowledge acquired by the student, the cognitive skills of the individual, the learning preferences of the student, and many more characteristics about the person. Thereby, a SM is a set of domains oriented to outcome a personal profile of the individual. Also, a domain encompasses a set of concepts that characterizes such point of study about the individual. Any concept is outlined as a property, which contains an attribute and a value. The attribute represents the term that labels the concept, whereas the value brings out a kind of measure for such term according to the semantics of the concept, e.g. the “intelligence quotient” (IQ) is a term to depict a concept about the cognitive potential of an individual, whereas the value “quite high” could be appropriate for the IQ of a smart human being.

However, the personal profile requires of a suitable semantic definition that gives away the meaning of the terms that a SM contains. Therefore, in this work the ontologies are proposed as the appropriate paradigm to set the semantics of the knowledge about the student. Hence, according to the Foundation for Intelligent Physical Agents (FIPA) [4], ontology is: “A philosophical term to refer a particular system of categories accounting for a certain vision of the world.” The ontology does not depend on a particular language; thus, it is always the same. However, from the artificial intelligence’s point of view, the ontology reveals: “An engineering artefact constituted by a vocabulary to describe a certain reality, plus a set of explicit assumptions regarding the intended meaning of the vocabulary words.”

Wherefore, in this approach the meaning of the attributes and the characteristics of the values, which depict the concepts of the domains, are stated by ontologies. Thereby, the organization of this paper is as follows: In section two, a formal model for the SM and the ontologies is outlined with the purpose of setting the formal baseline of the approach. Afterwards in section three, the content and the structure of the SM are set. Next in section four, it is shown how to encode such knowledge into ontologies and how it is available through specialized agents. In addition, in section five the trial and its outcomes are described. Finally, in the conclusions section, a discussion of the approach is stated and the future work is claimed.

II. FORMAL MODEL

In this section the formal model for the SM and the ontologies is described. The first one is based on formulae of the calculus prepositional, where the beliefs that a SM holds about the student are stated as prepositions. As regards to the ontology’s theoretical fundament, a distinction between two key terms, conceptualization and ontology, is pointed out.

A. Student Model Baseline

The baseline of this SM approach is based upon the formal model given by Self [5]. In such model, the concepts that represent the SM are considered beliefs (B) that the system (s) owns about the student (U). The beliefs are stated by prepositions (p) that can be true or false. Wherefore, for any domain oriented to characterize the student, as the cognitive (C), the system owns a set of prepositions (Bsp)
that it believes that is true about the student, such as: \(Cs(U)\),

\[Cs(U) = \{ p | Bsp(U) \cap p \in C \}. \tag{1}\]

\[SM = Cs(U) \cup Ps(U) \cup Ls(U) \cup Ks(U) \cup Ts(U). \tag{2}\]

B. Ontology Formal Model

Due to the philosophical meaning for ontologies is different of the one that the artificial intelligence sets, it is necessary to preserve such former definition. Therefore, in this paper the term conceptualization is used to hold the philosophical semantics, whereas the ontology term is concerned to the perspective of the artificial intelligence. Such terms are formally stated as follows according to the definitions given by FIPA [4].

1) Conceptualization Formal Definition: The term conceptualization concerns with the formal structure of reality as perceived and organized by a subject independently of the occurrence of a situation and the language used to describe it. The conceptualization sets meaning about conceptual relations in a domain of representation independently of a state of affairs. Conceptual relations are stated on a domain space by the structure \(<D, W>_\rangle\), where \(D\) is a “domain” and \(W\) is the set of all states of affairs of such domain, called “set of possible worlds”. For example, in the puzzle domain: \(D\) is the set of blocks, and \(W\) is the set of all spatial arrangements of such blocks.

Given a domain space \(<D, W>_\rangle\), it is established a “conceptual relation” \(p\) of arity \(n\) on \(<D, W>_\rangle\) as a function \(p^n: W \rightarrow (\exists D)^n\) from \(W\) into the set of all \(n\)-ary relations on \(D\). For a conceptual relation \(p\), the set \(Ep = \{ p(w) | w \in W \}\) owns the “extensions” (\(E\)) of \(p\). Thus, a conceptualization \(C\) for \(D\) is stated as a tuple: \(C=<D, W, R>\), where \(R\) is a “set of conceptual relations” on \(<D, W>_\rangle\).

Based on \(C\), for each world \(w \in W\), the corresponding world “structure” \((S)\) is stated as: \(S_c=<D, R_e, R_c>\), where \(R_e = \{ p(w) | p \in R \}\) is the “set of extensions”, relative to \(w\), of elements of \(R\) (\(R\)). Hence, all the intended world structures of \(C\) is the set \(SC = \{ S_c | w \in W \}\).

Also, a “logical language” \(L\), with “vocabulary” \(V\), it is stated as a “model” \(M\) for \(L\) by means of the world structure: \(M=<S, I>_\rangle\), where \(S=<D, R>_\rangle\), is a world structure and \(I: V \rightarrow D \cup R\) is an “interpretation function”, which assigns elements of \(D\) to constant symbols of \(V\), and elements of \(R\) to predicate symbols of \(V\). Thus, a model fixes a particular extensional interpretation of the language.

What is more, an “intentional interpretation” is set by the structure \(<C, \zeta>_\rangle\), where \(C=<D, W, R>_\rangle\) is a conceptualization, and \(\zeta: V \rightarrow D \cup R\) is a “function” that assigns elements of \(D\) to constant symbols of \(V\), and elements of \(R\) to predicate symbols of \(V\). This kind of interpretation is called an “ontological commitment” \(K\) for \(L\). Thus, if \(K = <C, \zeta>_\rangle\) is an ontological commitment for a language \(L\), then it claims that \(L\) commits to \(C\) by means of \(K\), while \(C\) is the underlying conceptualization of \(K\).

Also, given a language \(L\), with vocabulary \(V\), and an ontological commitment \(K\) for \(L\); a model \(M\) will be compatible with \(K\) if \(M\) meets three constraints: 1) \(S \in S\); 2) for each constant \(c\), \(I(c) = \zeta(c)\); 3) for each predicate symbol \(p\), \(I\) maps such a predicate into an admissible extension of \(\zeta(p)\), i.e. there is a conceptual relation \(p\) and a world \(w\) such that: \(\zeta(p) = p^w\) \(\zeta(w) = I(p)\). As a result, the set \(IS(L)\) of all models of \(L\), that are compatible with \(K\), become the set of “intended models” of \(L\) according to \(K\).

II. Ontology Formal Definition: The ontology is a set of logical axioms designed to account for the intended meaning of a vocabulary. An ontology is formally depicted as follows: given a language \(L\) with an ontological commitment \(K\), an ontology \(O\) for \(L\) is: a set of axioms stated in such way that, the set of its models approximates as best as possible to the set of intended models of \(L\) according to \(K\).

However, an ontology \(O\) specifies a conceptualization \(C\) in an indirect way due to: it only approximates a set of intended models, and these models weakly characterize a conceptualization. Thus, an ontology \(O\) for a language \(L\) approximates a conceptualization \(C\) if there is an ontological commitment \(K = <C, \zeta>_\rangle\) such that the intended models of \(L\), according to \(K\), are included in the models of \(O\).

This means: a language \(L\) commits to a conceptualization \(C\) by an ontological commitment \(K = <C, \zeta>_\rangle\). As a result, a set of models \(M\) is stemmed from the language \(L\), but the ontology \(O\) is just an approximation of the set of models \(M\). In spite this, the ontology \(O\) is able to depict the set \(IS(L)\), which corresponds to the set of intended models of \(L\) according to \(K\).

III. STUDENT MODEL DESCRIPTION

In this section the content and the structure of the SM are outlined. The content embraces four items to depict the stimulus, the student, the knowledge to be acquired, and the Cognitive Map (CM). As regards the structure, this subject brings out three kinds of repositories to represent knowledge.

A. Content

With the aim to enhance the learning of the students, in [6] I developed a SM based on a CM, which represents and estimates the causal influence that a teaching experience produces on the students. This proactive student centred approach encompasses four types of domains oriented to set: teaching experiences, a student profile, the knowledge acquired by the student, and the elements of a CM.

1) Teaching-Experience Profile: As regards the teaching experience, each lecture is tailored according to specific learning philosophies as objectivism and constructivism. Whereas, content is mainly authored through video or sound

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1 In section II.B symbols denoting structures and sets of sets appear in boldface.
items for stimulating visual or auditory senses respectively [7]. Therefore, four options are outcome for each lecture in order to deliver the most suitable one for a given student based on her/his personal profile. Hence, every option is characterized by a teaching experience profile. This profile encompasses attributes stemmed from the subject to be taught and the content domains, whose purpose is the following.

a) Subject. It depicts the nature of the lecture to be taught through qualitative measures about the level of: abstraction, complexity, practice, and technical issues.

b) Content. In this domain qualitative levels of dynamic and static content are estimated. Also, it is acknowledged the degree of application of objectivism and constructivism philosophies. What is more, it is measured the level of linguistic and no linguistic content, and the use of sound, image and video items into the Web pages.

2) Individual Profile: The description of the individual profile of the student is composed by three domains: learning preferences, cognitive, and personality. The evaluation of each domain for a given student is fulfilled by means of psychological tests. Each test contains criteria and quantitative procedures for computing the level of presence of every attribute that characterize the student. As a result, each quantitative value is attached to its respective qualitative scale in order to identify a level of intensity. The nature of the three domains is the following:

a) Learning Preferences. Based on the “Multiple Intelligence” work achieved by Gardner [8], eight kinds of learning styles are considered as: intrapersonal, verbal, logic, visual, auditory, interpersonal, corporal, and naturalistic.

b) Cognitive Skills. By the application of a cognitive test, some mental capabilities of the individual are estimated, such as: short time memory, visual skills, causal reasoning, verbal proficiency, mathematical reasoning, and IQ [9].

c) Personality. A psychology test is applied for estimating the intensity of forty five attributes of the personality of the student, such as: addictions, adaptability, depression, insecurity, maturity, psychosis, sociability, and health issues [10].

3) Knowledge Domain Profile: The Bloom’s taxonomy [11] is used to estimate the knowledge domain that a student holds as background and later on as the acquired from the teaching experience delivered by a WBES. Such taxonomy sets six proficiency levels that in progressively order are: 1) knowledge; 2) understanding; 3) application; 4) analysis; 5) synthesis; 6) evaluation. Each level gives away that the individual masters some competences.

For instance, the level one “knowledge” revels that the student is able to define a concept; the level two “understanding” demands the explanation of such concept; whereas the level three “application” inquires to use the concept in another situation; the level three “analysis” claims to identify the main elements of the concept; while the level five “synthesis” commands to integrate the concept with others of the same kind; and the level six “evaluation” challenges the person to set the principles of the concept. However, with the purpose to reveal the lack of knowledge for a given concept, the Bloom’s taxonomy is enhanced by means of a tier called “ignorance”, which is located as the zero level, before the former six tiers.

The evaluation of the knowledge domain is stemmed from a set of key concepts about the teaching domain. Hence, a quiz of progressive complexity is applied to the student in order to identify the appropriate level that the student actually masters. Hence, the value assigned to each key concept of the knowledge domain corresponds to one of the seven levels of the “enhanced Bloom’s taxonomy”. Thus, it is said, that if a student gets the level $n$ for a key concept, where $n > 0$ and $n < 7$, this means that he/she also masters the previously $n-1$ levels; otherwise she/he holds level 0.

4) Cognitive Maps Profile: A CM is a mental model that sets as people think and structures a subject of study from a causal view [12]. The CM depicts the beliefs of a person by concepts, relations, and inferences. Thus, a CM is the result of a mental task called cognitive mapping. During this process the person represents the objects or phenomena of the issue to be analyzed as concepts. Next, the causal influence that a cause concept exerts on an effect concept is set as a causal relationship. Afterwards, causal inferences are carried out to predict behaviour and outcomes.

The CM is sketched as a digraph of cause-effect relations among concepts. Also, a CM draws causal conclusions based upon incomplete and inductive reasoning. The knowledge induced depicts the variation about the state of activation of the concept in the context and traces the dynamic behaviour of the evolution of concepts’ states along the time.

In this approach, a rule base fuzzy CM version is used. The formal model of such version of CM is fully stated in [6, 12], but a resume is pointed out as follows:

The state of a concept is evaluated from two views: level and variation. The level is the intensity of activation that a concept owns in a given point of time. The variation is the change that occurs in the state of the concept after a while. The level and the variation of the concept’s state are instantiated by qualitative values that are members of a domain of discourse, e.g. high, low, increases, and decreases.

Each causal relation states that: if the level or the variation of a cause concept’s state corresponds to a specific qualitative value, then as a consequence a variation value is attached to the effect concept’s state, e.g. if visual content of the lecture is low then decreases much the visual learning preference of the student. Hence, a causal relationship between couples of concepts is fully set by a rule base. In such rule base there is just one rule for each value from the domain of discourse attached to the cause concept.

The causal behaviour and outcomes are stemmed from a simulation process. During an iterative process, a variation value is computed for each cause concept through a fuzzy carry operation. This operation computes the causal influence that occurs on a effect concept by the accumulation of variations oriented to increase and decreases the state of the concept, e.g. given two consequence values: increases much and decreases quite low, the final value could be: increases.
B. Structure

The structure of the SM based on ontologies is composed by three kinds of repositories: meta-definition, instances and temporal. The nature and the characteristics of the three repositories are outlined as follows:

1) Meta-definition: This repository states the concepts and the causal relations by means of three elements: classes, properties, and objects. A class identifies a given concept that is member of one of the four domains: teaching experience, individual, knowledge, and CM. A property characterizes one attribute that describes a given class by means of a specific value. An object is an instantiation of an entity of a given class, where specific values are attached to properties of such class.

2) Instances: The instances repository embraces the objects that characterize a student, the knowledge acquired by her/him, and an option of lecture. Therefore, the learning preferences, the cognitive skills, and the personality attributes of a student are stated in a specific instance repository. Moreover, her/his background and acquired knowledge about the teaching domain are depicted in another instance repository. Also, every option of lecture is outlined by means of a specific teaching experience profile, where the attributes of the subject and the content are instantiated.

3) Temporal: This repository encompasses CM items, such as: concepts, causal relations, fuzzy rule bases, domain of discourse attached to concepts, qualitative values for the concepts’ states, and their corresponding fuzzy sets. Some of these items are updated during simulation as a result of the fuzzy-causal inference. For instance, at each cycle a new concept’s state is computed for every effect concept. The assessment of the causal behaviour for a given concept is stemmed from the value that instantiates its state in each iteration. Also, at the end of the simulation, the final value attached to the concept’s state means the causal outcome.

IV. ONTOLOGY DEPLOYMENT

The deployment of the ontology is achieved through two stages: implementation and administration. The first one carries out the design and the development of the ontology, whereas the second stage is devoted to manage the ontology in a distribute environment.

A. Implementation

The design and the construction of the ontology follow the guidelines for building ontologies set by FIPA [4]. This method aims to accomplish a basic ontology’s prototype. Afterwards, successive versions of the ontology are outcome. So in this approach the first version of the Meta-definition ontology is built by means of the Protégé tool [13]. As a result, a repository of code written in Web Ontology Language (OWL) is delivered. According to the structure, elements, and syntax of OWL classes, properties and objects are encoded in the ontology’s file. For instance, in Fig. 1 a OWL code sample appears to show how to declare the class “concept”, the property “description”, and the object “cognitive skill short time memory” through lines 10-20, 47, and 50-60 respectively. What is more, in line 18 a hierarchical relation between the concept and the _id classes is stated by means of the element “rdfs:subClassOf”. Thereby, the concept class inherits the properties attached to the super class _id. Thus, this ontology is based on the object-oriented paradigm.

```xml
01 <!-- Namespaces references -->
02 <rdf:RDF xmlns:rss="/purl.org/rss/1.0/"
03 xmlns="http://a.com/ontology#"
04 xmlns:owl="http://www.w3.org/2002/07/owl#" >
05 <!-- Class declaration: concept -->
06 <owl:Class rdf:ID="#concept" xmlns:rdf="rdf"
07 xmlns:owl="owl">
08 <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xmlns:rdfs="rdfs">concept: it is a way of thinking</rdfs:comment>
09 <rdfs:subClassOf xmlns:rdfs="rdfs">concept</rdfs>
10 <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xmlns:rdfs="rdfs">concept: it is a way of thinking</rdfs:comment>
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26 <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xmlns:rdfs="rdfs">concept: it is a way of thinking</rdfs:comment>
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35 <rdfs:subClassOf xmlns:rdfs="rdfs">concept</rdfs>
36 <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xmlns:rdfs="rdfs">concept: it is a way of thinking</rdfs:comment>
37 <rdfs:subClassOf xmlns:rdfs="rdfs">concept</rdfs>
38 <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xmlns:rdfs="rdfs">concept: it is a way of thinking</rdfs:comment>
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41 <rdfs:subClassOf xmlns:rdfs="rdfs">concept</rdfs>
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43 <rdfs:subClassOf xmlns:rdfs="rdfs">concept</rdfs>
44 <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xmlns:rdfs="rdfs">concept: it is a way of thinking</rdfs:comment>
45 <rdfs:subClassOf xmlns:rdfs="rdfs">concept</rdfs>
46 <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xmlns:rdfs="rdfs">concept: it is a way of thinking</rdfs:comment>
47 <rdfs:subClassOf xmlns:rdfs="rdfs">concept</rdfs>
48 <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xmlns:rdfs="rdfs">concept: it is a way of thinking</rdfs:comment>
49 <rdfs:subClassOf xmlns:rdfs="rdfs">concept</rdfs>
50 <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xmlns:rdfs="rdfs">concept: it is a way of thinking</rdfs:comment>
51 <rdfs:subClassOf xmlns:rdfs="rdfs">concept</rdfs>
52 <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xmlns:rdfs="rdfs">concept: it is a way of thinking</rdfs:comment>
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54 <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xmlns:rdfs="rdfs">concept: it is a way of thinking</rdfs:comment>
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56 <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xmlns:rdfs="rdfs">concept: it is a way of thinking</rdfs:comment>
57 <rdfs:subClassOf xmlns:rdfs="rdfs">concept</rdfs>
58 <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string" xmlns:rdfs="rdfs">concept: it is a way of thinking</rdfs:comment>
59 <rdfs:subClassOf xmlns:rdfs="rdfs">concept</rdfs>
60 </concept>
```

Figure 1. Example of ontology’s code written in OWL.
B. Administration

In order to federate the provision of specialized tasks for the ontology administration, such as query responses, update and maintenance, in this approach an ontology agent (OA) is built according to the specifications given by FIPA [4]. The details of the development of the OA are pointed out in [6]. However, in this section is given a brief description.

Due to the functionalities of a WBES are fulfilled through specialized agents that collaborate in a multi-agent system, the OA is designed as a middleware between the application agents and the ontology. So the OA is deployed by means of a Web Service in order to federate its support as a yellow pages advertisement. Wherefore, the OA reacts before the events that happen in a WBES. In addition, it catches messages that contain requests and queries that are sent by other agents. Afterwards, the OA decodes the message and interprets it according to its knowledge about the domain. Next, the OA achieves the tasks necessary to commit the requests. At the end, the OA encodes the outcome in a new message, and sends it to the requester agent.

V. Ontology Application

In this section it is show how the ontologies support the process for eliciting, representing, and managing knowledge. So an experiment is fulfilled to test the utility of a SM that is based on ontologies. Thus, the goal and the account of the trial are stated as follows:

A. Object of the Trial

With the purpose to increase the apprenticeship of the individuals when they receive lectures delivered by a WBES, I set a hypothesis: “The learning of the student is enhanced when the WBES takes into account the attributes of the student, the characteristics of the lectures and the prediction of the causal bias that the teaching experience produces on the acquisition of knowledge achieved by the student.”

In order to test such assumption, some main issues are considered, such as: how to elicit and represent the knowledge about the student and the teaching experiences? The first question is dealt through the carefully selection of formal models and the use of appropriate tools for measuring attributes of the student and the lectures. The second issue is met by the design of ontologies and the accurately content to be stated. These issues are already introduced earlier.

B. Trial Account

The trial is achieved through five sequential stages: 1) development of a WBES; 2) recruitment of volunteers; 3) psychological measurement; 4) teaching experiences provision; 5) statistical analysis of results.

1) Development of a WBES: During the construction of a WBES several tasks are accomplished, such as: the building of modules that this kind of system requires, the creation of the SM, the design of ontology repositories, the authoring of content about the teaching domain (in this trial the subject is related to the “Scientific Research Method”), and the development of four psychological tests to be applied on the Web.

2) Recruitment of Volunteers: In this stage a marketing campaign is carry out through the Internet. Thus, the trial is promoted among students and teachers at bachelor and graduate degrees. After two months, several hundreds of people submitted on-line their applications. As a result of the evaluation of the personal profile provided by applicants, 200 candidates from 26 states of Mexico country are accepted.

3) Psychological Measurement: With a universe of 200 volunteers, the psychological tests are applied to measure their learning preferences, cognitive skills, and personality. Also, a knowledge background test about the teaching domain is applied. This stage lasted two months, and at the end 50 subjects remained due to most of the participants progressively deserted.

4) Teaching Experiences Provision: First of all, some introductory lectures are provided to the population of 50 members. Afterwards, a sample of 18 subjects is randomly chose in order to achieve a standard error of 5%, which means that from 50 examples in 48 cases the prediction will be right. Later on, two sets of nine individuals are randomly organized, one called control, and the another experimental. Afterwards, ten key concepts, e. g., hypothesis, law, theory, are chose as the reference to compare the apprenticeship between the teams. So a pre-measure about the preliminary knowledge that the volunteers hold for the ten key concepts is applied. Next, the lectures about the key concepts are delivered through their respective teaching experience. Volunteers of the control team receive lectures that the WBES randomly delivers; whereas, members of the experimental team take the option of lecture that the WBES delivers according to the advice given by the SM. Such support takes into account the personal and the teaching experience profiles, and the outcomes of the CM. Finally, once the volunteer has taken her/his lecture, a post-measure test is applied for estimating the apprenticeship acquired by the participant regarding to such key concept.

5) Statistical Analysis of Results: As a first tasks the internal validation of the experiment is carried out based on a set of criteria as the following: the trial is blind, so none participant knows the nature of the experiment, neither the criteria used by the WBES for delivering lectures, nor her/his membership to any team. Also, volunteers do not meet each other during the trial. Based on such kind of constraints, a statistical analysis is accomplished. Firstly, the pre-measure and the post-measure regarding to the knowledge about the ten key concepts that a volunteer holds is stemmed from the number of level that corresponds to the enhanced Bloom’s taxonomy for each concept. So if the individual mastered the “understanding” level for the first key concept, she/he gains two points, but if the student has shown proficiency at the “synthesis” level for the second key concept, she/he gets five points. Hence, the total achieved for the ten key concepts is computed for each individual of the two teams as the preliminary knowledge. As a result, the control team scores 42 and 174 points as preliminary and final knowledge respectively; whereas the experimental team gets 38 at the beginning of the trial, and at the end it reaches 198, as it is show in Table I and Table II respectively.
TABLE I. DESCRIPTIVE STATISTICS ACHIEVED BY CONTROL TEAM

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pre-measure</th>
<th>Post-measure</th>
<th>Learning Differential Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Score</td>
<td>Score</td>
<td>Score</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
<td>31</td>
<td>27</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>29</td>
<td>26</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
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<td>32</td>
<td>16</td>
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<tr>
<td>7</td>
<td>3</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>22</td>
<td>19</td>
</tr>
<tr>
<td>C team</td>
<td>42</td>
<td>174</td>
<td>132</td>
</tr>
</tbody>
</table>

TABLE II. DESCRIPTIVE STATISTICS OF THE EXPERIMENTAL TEAM

<table>
<thead>
<tr>
<th>Subject</th>
<th>Pre-measure</th>
<th>Post-measure</th>
<th>Learning Differential Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Score</td>
<td>Score</td>
<td>Score</td>
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<td>4</td>
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<tr>
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<tr>
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<td>6</td>
<td>40</td>
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</tr>
<tr>
<td>7</td>
<td>3</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>15</td>
<td>13</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>E team</td>
<td>38</td>
<td>198</td>
<td>160</td>
</tr>
</tbody>
</table>

In addition, an analysis of variance is achieved to identify the tendency between pre-measures and post-measures. As a result the control team outcomes a low probability (P) of 0.1216 and the experimental team arrives to a P of 0.0059. Wherefore, the prediction for the control team lacks of significance, whereas the prediction for the experimental team is quite accurately, because the level of the probability is 994 for 1,000 cases.

CONCLUSIONS

The process for the acquisition, representation, and management of knowledge is quite complex. Moreover, the student modelling is a challenge, due to it implies to deal with subjective factors as the learning, the personality, preferences, and cognitive skills of people.

Wherefore, the selection, the development, and the application of methods, models, and processes oriented to carry out such tasks are the subject of deep research. For such reason, the contribution of this work is the proposal to use ontologies as confident knowledge repositories to depict the semantics of the SM. Given the trends to use ontologies in distribute environments like Internet; it is quite useful to encode them in languages such as OWL.

As the future work appears the design of psychological tools that are devoted to being applied on the Web. Due to the most psychological instruments are manually applied by the experimenter to the volunteer. Also, the automatic elicitation of knowledge about the individual should be enhanced by means of computational intelligence methods.

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