SEMANTIC LEARNING INTERVENTIONS USING WEB SERVICES TECHNOLOGY

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ABSTRACT

In science learning, cognitive concepts that are distinguished for the complexity of their structure and operation can be understood by using successful metaphors. Conventional instruction is ineffective in dealing with misconceptions. We propose a semantic learning interventions management system that utilizes web services technology. The proposed system aims to be an integrated educational solution that offers interoperable, web service-based, cross-platform learning services. It extends the available educational logic and content by publishing and consuming educational web services. Additionally, the combination of Web Services and Semantic Web offers sophisticated capabilities including automated discovery, composition, invocation, and monitoring.

KEY WORDS
Semantic web, web services, teaching/learning metaphors

1. Introduction

A variety of computer applications have been developed and used in teaching e.g. computer-based laboratories [1], multimedia [2], simulations [3], exploratory environments [4] and intelligent tutors [5]. In addition, computer graphics applications have been used in Informatics Engineering courses [6] .

When the students cope with a difficult cognitive concept, they are confused trying to visualize its operation, as well as to understand the interrelations of its conceptual units. This happens because students do not have clear sense of the complicated cognitive concept. In scientific cogitations, metaphors and terms constitute useful tools in teaching [7]. In teaching, successful metaphors can be used in order the students to create analogies with their prior knowledge and construct their

conceptual forms. Conceptual metaphor is the mechanism by which abstract concepts are understood and reasoned about in terms of physically-based concepts [8]. A metaphor is used to communicate the characteristics of a difficult-to-conceptualise concept, which is the *target*, in terms of another, more accessible and familiar concept in the addressee's prior knowledge, the *source*.

In science learning, cognitive concepts that are distinguished for the complexity of their structure and operation can be understood by using successful metaphors. Teaching interventions are very useful because: a) they offer opportunities to the students to express their ideas and b) give the ability to the teacher to connect what the students understand to the new conceptual units of a cognitive concept that are taught. In learning and teaching, the following issues must be considered: a) the investigation of students' thought; b) the interpretation of their alternative perceptions for a cognitive concept; and c) the development of conceptual tools and successful teaching interventions for the students.

Conventional instruction is ineffective in dealing with misconceptions. For example, students' alternative conceptions for a complex cognitive concept are considered to be not easily affected by traditional instructional methods. In curriculum courses, transforming ideas and correcting defects of students' knowledge is beyond the reach of traditional teaching approaches, as they tend to ignore the possibility that the students' perception is different than that of the teacher [9].

Tobin and Tippins (p. 728) [10] have suggested "metaphors appeal as ways of beginning conversations about teaching and learning science and making it easier to be reflective in and in practice" and "teaching and learning described in terms of metaphors which can then be foci for analyses". Thomas and McRobbie [11] investigated the effect of an intervention using the metaphor "learning is constructing" on students'

metacognition and learning processes. Research on science education has often focused on the study of alternative conceptions and mental representations that students employ before and after instruction. The main aim of an alternative constructive teaching approach is the development of such conditions that would facilitate students' active involvement in learning and functional understanding of curriculum courses. Among the important issues is the study of the effects of computer tools that aim to facilitate students' active involvement in teaching and learning.

2. Motivation

Most metaphors (used in teaching interventions) are not computer-based and their management is a time-overloaded process. Besides, the development of effective web-based interventions that are flexible, problem-based, non-linear, incorporate multimedia and are adaptive to learner characteristics, will involve a large number of disciplines, in an expensive and extremely time consuming manner.

Management environments for semantic web teaching interventions or metaphors have not been developed yet. The Semantic Web is envisioned as an extension of the current Web, where in addition to being human-readable using WWW browsers, documents are annotated with meta-information. This meta-information defines what the information (document) is about in a way, which is machine processable. The Semantic Web sits on top of the Web as an integrating fabric. Such an environment forms a platform for information brokers, search engines, and "intelligent agents". The combination of Web Services and Semantic Web creates the next generation of Web Services; i.e. the Semantic Web Services with far more sophisticated capabilities including automated discovery, composition, invocation and monitoring [12].

An important question (related to the educational semantic web) is how to represent an intervention in a formal, semantic way so that it can be interpreted and manipulated by computers as well as by humans. In general, this process is known as "Educational Modeling" [13]. The automated processing of web interventions requires that explicit machine-processable semantics are associated with web interventions as metadata, so that they can be interpreted and combined. In this way, we can exploit the web interventions services to their full potential. Introducing Semantics to web intervention services brings the following advantages:

1) An explicit notation of interventions can preserve and share knowledge about effective learning designs. It opens the possibility to build and share catalogues of effective learning and teaching patterns that can be communicated very precisely and can be adapted to other contexts, problems and content.

2) A semantic framework can help the intervention developers in the structuring and integration of the development work. It enables authors to reflect on their thinking and authoring and design support

agents and tools that can be created to help the developers to do their jobs more effectively and efficiently.

3) Semantically enriched web intervention services handle the interoperability at the technical level; that is, they make intervention web applications talk to each other independently of the hardware and software platform. But even if applications interoperate at the technical level, there is still a need for semantic interoperability. This kind of interoperability of web intervention services can be addressed at the semantic level through ontology mapping.

4) Semantics can be used for the discovery and composition of web intervention services. The main mechanism for service discovery is service registries. Semantics can be used for the discovery of web interventions service registries. However, web service registries themselves are also in need of discovery.

Since no two learners have the same learning pre-requisites, skills, aptitudes or motivations, adaptation to individual learner characteristics is highly desirable. However, such adaptation can only be done realistically, when the adaptation is wholly or at least partially automated. Otherwise, it inquires too much work for the learner and/or teacher. When the representation includes descriptions of the conditions for adaptation, this process of adaptation can be software supported.

Sharing and re-use (parts) of interventions is needed to make intervention development more efficient; however sharing is hard to do when the objects of the metaphors are not semantically represented. The intervention objects are hard to find, hard to integrate into new contexts and – for new Learning Management Systems that receive metaphor objects from another systems- hard to interpret and structure in the correct way. An explicit semantic representation can serve as a means to create more advanced and complex, but consistent learning designs than are possible without such a representation. This is a characteristic of any language with semantic that enables one to write, read, rewrite and share meaning (natural language, musical notation etc).

This paper describes a novel web learning system that manages semantic web teaching interventions and metaphors for cognitive concepts of curriculum courses.

The rest of the paper is organized as follows. In Section 3, an evaluation modeling for web metaphors is presented. In Section 4, the overview of the proposed system is outlined. Section 5 describes details of the web services-based architecture of the proposed environment. Finally, Section 6 discusses conclusions and future work.

3. Modeling Web metaphors

Students' access to Web poses tremendous challenges to teaching and learning. Web offers possibilities for the employment of new teaching methods in curriculum courses. In our framework, a teaching intervention is

based on a conceptual metaphor between a cognitive concept (*term*) and its *analogous*. Every term and its metaphors (*analogues*) contain multimedia data. Qualitative research has demonstrated that great potential exists for the utilization of multimedia to convey graphic information, video and interactive presentations about educational content. Multimedia offer increased modularity, which is a very important aspect for the development and maintenance of web teaching interventions. Hereafter, we introduce the notions of *Web term* and *analogous:*

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term_id ={creator_id, conceptual_unit$_1$, conceptual_unit$_2$, .., conceptual_unit$_n$)
analogous_id={creator_id, term_id, analogous_unit$_1$, analogous_unit$_2$, ..,analogous_unit$_n$}

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where *term_id* is a cognitive concept, *conceptual_unit$_n$* is a conceptual unit belonging to this term, and *analogous_id* is a metaphor of this term.

3.1. Metaphor's Performance'

The performance of a metaphor *analogous_id* is a vector $\vec{G}(ana\log ous\_id)$ given by the following Equation:

$\vec{G}(ana\log ous\_id)$ = {$G_{Investigation}$(analogous_id), $G_{Similarities}$(analogous_id), $G_{Differences}$(analogous_id)}
(Eq.1)

During the investigation of a student's thought, the student *j* relates the *n* conceptual units of the *term_id* with the *n* analogous units of the metaphor. For the student *j*, we have:

$$G_{j\,Investigation}(analogous\_id) = \sum_{i=1}^{n} c_i b_{ij}$$

(Eq.2)
where

n: the number of analogous or conceptual units
c_i: the coefficient weight for the *analogous_unit$_i$*, ($\sum_{i=1}^{n} c_i$ =1).

If all coefficients c_i are equals, then c_i=1/n.

B_j=$\sum_{i=1}^{n} b_{ij}$: the total number of successful relations made by student *j*. ($B_j \in [0, n]$)
If the student *j* relates successfully the *conceptual_unit$_i$*, then b_{ij}=1 (*succeed*), otherwise b_{ij}=0 (*failed*).

The first element of the vector is the investigation of all students' thought that is given by the following:

$$G_{Investigation}(analogous\_id)=\sum_{j=1}^{k} G_{jInvestigation}(\text{analogous\_id}) \Big/ k$$

(Eq. 3)
where

k: the number of all students
The second element of the vector is:

$$G_{Similarities}(analogous\_id)= \sum_{i=1}^{n} c_i s_i$$

(Eq.4)

where s_i is the number of similarities existing in *analogous_unit$_i$* with *conceptual_unit$_i$*

and $S=\sum_{i=1}^{n} s_i$ is the total number of presented similarities.
The third element of the vector is:

$$G_{Differences}(analogous\_id) = \sum_{i=1}^{n} c_i d_i$$

(Eq.5)

where d_i is the number of differences existing in *analogous_unit$_i$* with *conceptual_unit$_i$*

and $D= \sum_{i=1}^{n} d_i$ is the total number of differences.

In our framework, there are three contexts: *a) courses context, b) terms context* and *c) analogous context*. In this paper, we focus on Informatics courses: *Computer Fundamentals, Computer Networks, Data Structures, Operating Systems* etc. A course consists of a set of terms. A term consists of a set of conceptual units, and an analogous consists of a set of analogous units. Web concepts and metaphors help students to comprehend completely the substance of a cognitive concept.

4. Semantic interventions and the web service oriented management system

Web application development is a multi-facet activity involving different players with different skills and goals [14].

In distributed computing, current approaches are not sufficient to completely meet the needs for cross-platform application-to-application (A2A) integration. The present trend is moving away from tightly coupled monolithic systems towards systems of loosely coupled components. Following this trend, the proposed environment is a web-authoring environment that "consumes" web service-based teaching interventions for curriculum courses. This work provides a management environment to sciences' authors, in order to incorporate (into their own teaching procedures) educational data that exist in different remote content providers. Every teaching intervention is based on a proper metaphor for a term, while the term and its analogous (metaphors) are consisted of multimedia data.

The proposed system constitutes a management platform of multimedia educational content, which is compatible with the model IEEE P1484.1 [15] of the Learning Technology Standards Committee (LTSC) using web services interoperability attributes. The adoption of

this model provides high levels of portability and reusability of the educational content. Moreover, the proposed system takes advantage of web service technology in order to facilitate requirements for interaction and data exchange of educational content providers.

Web Services have been ubiquitously adopted because they are built upon open and platform independent standards such as XML [16], SOAP [17], WSDL [18], UDDI [19] and HTTP [20]. They have marked current web engineering methodologies and they have reached a high level of acceptance. In short, they are interoperable software components that can be used in application integration and component based application development.

Web Services use XML-based messaging to exchange data between the web service and the consumer. One of the core characteristics of a web service is the high degree of abstraction that exists between the implementation and consumption of a service. Web services allow applications and Internet-enabled devices to easily communicate with one another and combine their functionality to provide services to each other, independent of platform or language. Web services are characterized by SOAP messages (used to talk to a web service), WSDL files that describe a web service, and the UDDI used to find Web services. Conceptually, web services are very understandable. They eliminate many of the complexities that have been required, when there is a need for computer applications to interact with each other.

In this case, potential authors need an environment ready to deliver educational content in an autonomous way and 24x7x365 time frame availability, in order to support world wide education any time of the day effectively. On the other hand, it is resource-expensive to support separate dedicated machines for each necessary service of the proposed management environment, because this would complicate the users' data interaction and bring a network management overhead.

To confront the dilemmas posed by the described relationships, we propose a solution with the use of XML web services (see figure 1). We believe that in this way we have faced all of the previously named operational discomforts. The proposed web services architecture allows the participation of a numerous simple local systems, each one located in a different geographic region of the country. These servers can be low cost web servers and they will provide a lightweight access to the main services of the environment with the use of web services. Our solution is cost-effective, as it out-sources the different services through a simple web information server to the main web services providers. In this way, only the web service provider host will have to be a main-frame machine, while the user will have a quick and efficient interaction with a web information server close to its access position.

The included web services provide: a) informational only functions for the web surfers and b) complete educational content of metaphors-interventions for learners. These educational services allow full functionality the author and the learner, without direct access to a single central system but through transparent web services.

5. Functional specifications and architecture

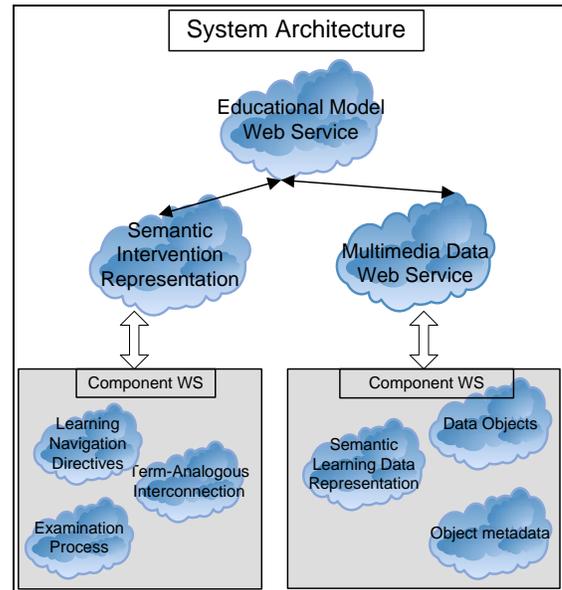The proposed architecture is depicted in Figure 1.

Figure 1: The proposed web services architecture

In this architecture, the system utilizes distinct web services available by potential different educational model, content or other multimedia data providers. Every author of learning interventions is able to use available educational models, semantically described interventions (terms and metaphors) and educational multimedia data, either stored locally in the system or available transparently through web services coming from different providers.

The proposed system aims to be an integrated educational solution that offers traditional learning services. Additionally, it extends the available educational logic and content by publishing and consuming educational web services.

Overall the system has different software components such as:

- The presentation and navigational layers that facilitate the educational model and logic.

- The adaptive profiling of the environment's users that supports personalization.

- The multimedia repository that is used in order to exploit the reusable educational objects.

- The generic data storage system that concludes the data layer.

Finally, additional operations are provided for administration and statistics.

In the web services perspective, the system includes three distinct operational choices for consumption or publishing.

5.1. Educational Model WS

This model provides access to different choices for the overall learning approach, such as course-driven, practice-driven or project-driven.

The course-driven approach focuses on supply. Theoretical concepts, skills and practicals are offered to students by means of elements of the curriculum programmed. This gives the students a firm foundation for tackling issues from professional practice.

The practice-driven approach is about looking for practical solutions to concrete problems, deriving directly from professional practice. It is at the core of projects and the extramural section of the training (work experience, dual system). Here, the student learns to work in a result-oriented way. Theory and skills are applied, and honed and deepened in practical situations.

Finally, the project-driven approach focuses on demand and responds to diversity of the individual student. The students' development towards the competencies for the course are monitored and supervised. The student is free to fill in the details of his/her own study modules (subject options, specialisation and final project/thesis) with appropriate learning routes, thereby placing individual accents on the body of competencies to be acquired.

Other educational models can be available by adopting web service technology interfaces.

5.2. Semantic Interventions WS

This web service includes the learning directives, the term and metaphor relationships and the examination – evaluation processes. All these operations are accessed through distinct nested web services to facilitate further interoperability and cross functionality. Each web service includes semantically designed descriptions.

To locate Web Services (based on the intervention capabilities they provide) a language is required to express these capabilities and the specification of a matching algorithm between service advertisements and service requests. The algorithm recognizes, when a request matches an advertisement. OWL-S [21] is adopted as service description language as it provides a semantic view of the WS which spans from the abstract description of the capabilities to the specification of the service interaction protocol, to the actual messages that it exchanges with other web services.

A semantic model for interventions was developed using literature research and expert group discussions, and the result was described with a formal modeling language: the UML [22]. The UML class diagrams can be translated to OWL Web Ontology Language, depending on the richness of the model. Our design was made according to the IMS Learning Design [23] that uses a semantic conceptual model of the teaching –learning process as its base.

- *Term – Analogous Relationship*

This WS publishes the conceptual units of the selected term in a randomized manner. In addition it provides the available relationships between the analogous and its terms that may be chosen for presentation to users. During the operation state, the system asks the student to relate the conceptual units of the term (e.g *computer*) to the units of the analogous (e.g. *factory*), in order to determine resemblances and differences between them. Units are presented as sets of educational objects using a multimedia content repository infrastructure. Each unit may comprise a series of multimedia objects such as video, images, sounds and naturally educational passages.

- *Intervention evaluation/ Course examination*

Through this WS, available evaluation procedures or test examinations are accessed. This WS receives details of the terms involved in a specific intervention and returns available evaluation and/ or examination processes either locally stored in the system or through remote WS providers. For example, a possible published evaluation of an intervention might be: *"How the factory would operate without the existence of its store rooms?"*. In the *term context*, this question is formulated as: *"How the computer would operate without the existence of its storage devices"*.

The evaluation of Web teaching interventions or metaphors is a new research topic and it is in infantile stage. Indubitably, the use of evaluation services for web teaching interventions and metaphors will involve better integration of evaluation, improved reliability, as well as saving of time from the side of instructors-evaluators.

5.3. Multimedia Web-compatible Content WS

Every learning object is composed by multimedia data. Nevertheless, to support an open architecture, each intervention and its learning objects derive from a multimedia content WS that they are attached to. To separate concerns semantic representation, metadata and data themselves are published through an independent component WS.

5.4. User Profiles

The system presents the resemblances and differences between the conceptual and analogous units. The presentation is based on the student's profile as it is recorded by his/her direct choices upon registration, as well as implicit observations of the multimedia objects that attract the student's attention. The profile is based on

the multi-layered user profile introduced in [24]. An overview of adaptive educational systems is given in [25].

6. Conclusions and Future Work

The overall aim of our research is to investigate the effects of web interventions to students' understanding of basic Informatics concepts. In this paper, a novel environment of semantically enriched web teaching interventions for curriculum courses is proposed. The new environment provides a powerful framework that integrates creation, management and evaluation of web interventions based on web services technology. The evaluation process of web interventions is based on a proposed model described in Section 3.

A semantic representation of interventions enables the educator to perform research into more effective and efficient learning designs. This can be done by comparing the experience with (parts of) learning designs structures in the context of real use. When the representation of the intervention does include a semantic, higher level description of the interactive processes that occur during the learning process, software agents can interpret these to support learners and staff in managing the workflow of activities in teaching and learning. These agents can also support the filtering of the appropriate resources to be used during the performance of an activity.

Future work will include investigation of Web interventions usage patterns by utilizing web log analysis [26]. Additionally further experimental study will be conducted on a pilot implementation of the system.

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