When the Domain of the Ontology is Education

J. Bourdeau, R. Mizoguchi**, Y.Hayashi**, V. Psyche*, R. Nkambou****
**TELUQ-UQAM, 100 Sherbrooke W., Montréal, QC, Canada H2X 3P2*
*** ISIR, Osaka University, 8-1 Mihogaoka, Ibaraki, Osaka, 567-0047 Japan*
****UQAM, Dép. d'informatique, CP 8888, Centre-ville, Montréal, QC, Canada H3C 3P8*
E-mail: bourdeau, psyche@licef.teluq.uqam.ca ; mizoguchi, hayashi@ei.sanken.osaka-u.ac.jp : nkambou@uqam.ca

Abstract

In the field of Technology-Enhanced Learning, a domain ontology usually means an ontology of the domain to be learned by the students. This paper describes an ontology named OMNIBUS, where the domain of the ontology is education, with a description of its framework and its main concepts. It then briefly describes a software called SMARTIES that can use this ontology and CIAO, a software that provides services to authors of IMS-LD scenarios. Future work includes the merging of these software applications as well as improvement of the ontology and consensus-building for its contents.

1. Introduction

In the field of Technology-Enhanced Learning, domain ontology usually means ontology of the domain to be learned by the students [1], [2], [3], [4], [5] such as optics or lexicology. The raison d'être of these domain ontologies is mainly for learning environments to take advantage of the technologies of the Semantic Web in meaningful ways and to provide the vocabularies required by learning objects repositories and their meta-data. Ontological modeling is also used for the modeling of a system as in the case of LORNET's TELOS system [6].

This paper describes an ontology named OMNIBUS, where the domain of the ontology is education, with a description of its framework and its main concepts. It then briefly describes a software called SMARTIES that can use this ontology and CIAO, a software that provides services to designers or authors of IMS-LD scenarios. Future work includes the merging of these software applications as well as improvement of the ontology and consensus-building for its contents.

2. The OMNIBUS Ontology

This section introduces the OMNIBUS ontology, namely its origin, structure, main components, how it has been elaborated and how it is still a work in progress.

The term "ontology" is often used to refer to ontologies of very different nature, from vocabularies for the Web2 technologies to "heavyweight" ontologies, which are philosophically oriented and provide a conceptualization of the existence of things [7], [8]. The OMNIBUS ontology is of the second type and consists of a major effort to conceptualize the world of education based on the philosophy of existence.

2.1. Why an ontology of education

The history of this ontology goes back to a vision article [9]. They claimed that an ontological modeling framework would have the potential to encapsulate educational knowledge in a declarative way and could then be exploited by Authors or software agents to support theory-aware instructional/learning design and the design of learning environments. By "Theory-aware", we mean the capability of a system to support the activities of users based on the understanding of theories relevant to the task being performed.

Nkambou et al. [10] discussed the benefits for an Author of accessing theoretical knowledge and the required functionalities of a theory-aware ITS Authoring environment. According to them, these benefits are to: 1) make decisions (macro, micro) after reflection and reasoning, 2) explain their design decisions, 3) check consistency of design decisions, (intra-theory or inter-theories), 4) produce 'scrutable' learning environments, and 5) have heuristic knowledge well grounded in theoretical knowledge. The required functionalities are that authors can ask

the system: 1) what theories apply best to a learning situation or goal, 2) to show examples, 3) for advice on whether this element of a theory can be combined to an element from another theory, 4) what is the risk associated to doing so, 5) if there is a preferable solution, etc.

Some authoring tools such as CREAM-tools [10], or CTAT [11] possess this 'theory-awareness' but are 'monotheoretical'. Therefore, they are restricted to one perspective, as well as limited by this theory: ACT-R in the case of CMU, and Gagné in the case of Cream-tools. They do not reflect the variety of existing theories and models, do not allow for design decisions that would take advantage of this 'biodiversity', and do not provide what can be called the "common principles" [12]. Because these theories exist and because an ontology of a domain reflects what is existing in this domain, they can become part of this ontology similarly to other more concrete existing things. Some instructional design methodologies such as MISA [13] integrate several theories and models into a unified framework, but without the 'awareness' of the respective origin of the principles. Therefore, they do not allow the designer to reflect on the fundamental vision of Learning, Instruction and Instructional Design upon which these principles are built. Wiley has called for "connecting learning objects to instructional design theory" [14] and proposed a taxonomy of learning object types that could be instrumental for accomplishing this vision.

When EML was released, it included a component called 'theories' together with an invitation to develop this component, but this has not been carried out to our knowledge [15]. The first proposal to link EML and IMS-LD with a theory-aware environment was developed in collaboration with the team of LORNET's Theme 2 and presented at AIED'05 and I2LOR'06 [16], [17]. In summary, parts of our work have been presented at the following conferences: AIED"05, EC-TEL'06, ITS'04, ICCE'06, SWEL-AIED'07, and the ontology has been made available on a Web site with access to the Hozo editor (http://edont.qee.jp/omnibus/doku.php).

2.2. A framework for an Ontology of Education

The main challenge in building this ontology was to develop a framework that would allow the declarative modeling not only of concrete phenomena (such as 'talk' or 'write') but also of theoretical knowledge about the phenomena related to learning, instruction, and instructional design. Moreover, both had to be consistent with and directly connected to an upper level ontology. Constructing this framework has required deep reflections and numerous discussions. Transforming the knowledge about education from an epistemological perspective to an ontological one has been and still is a major research effort.

Preliminary results were presented at ITS'2002 [18], as a nested structure whereby the 'learning' is at the core, the 'instruction' is around it, and the 'instructional design' surrounds the 'instruction.'

The modeling of the world of learning was conducted by characterizing the concrete and abstract processes and objects that constitute the learning phenomenon, as well as its context. The modeling in the Hozo editor follows the philosophy that is built in this tool, namely with the basic concept of "role". The same modeling was applied to the worlds of instruction and instructional design and resulted in the upper level concepts illustrated in Fig. 1.

Theories and models required a unifying framework that could represent their common ground as well as the variations that they offer in understanding and explaining the processes of learning, instruction and instructional design. Previous efforts to provide a unified framework from an epistemological perspective [19], [20], [21] were analyzed and a complete re-conceptualization was performed from an ontological perspective.

The main results are described in the following sections. Only the few main "Wholeness" concepts are described below: *Learning*, *Learning mechanism*, *I_L event*, and *Way-knowledge*. We introduced "wholeness concept", on the basis of the observations that most of the things are composed of parts and that those parts are connected by a specific relation to form the whole. The "wholeness concept" is a conceptualization of the whole. For example, the "brothers" concept is a wholeness one. Theoretically, every thing that is a composite of parts can be conceptualized as a wholeness concept and a wholeness concept possesses properties of its part concepts".

(Throughout the text, the names of the concepts extracted from OMNIBUS are in italics). The specification of the theories and models is described in 2.6. The 'Relation concepts' are of two kinds: 1) basic relations such as "*before*" and "*after*" and 2) "*Way-Knowledge*" concepts, which are introduced in 2.5.

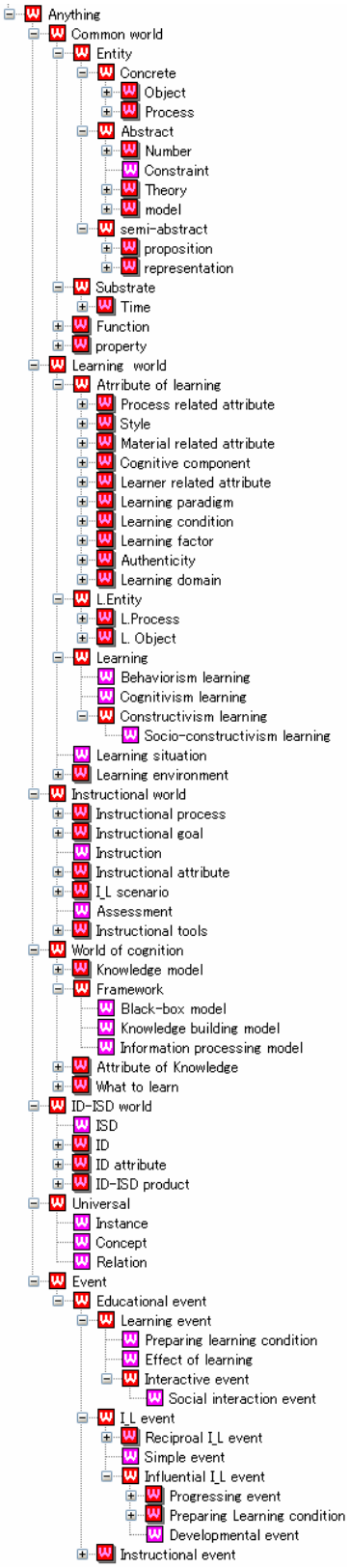

Fig. 1. Upper level concepts

2.3. Learning and Learning Mechanism

The first concept to be specified is the concept of *Learning*, which was done in the most possible primitive way to reflect its pure existence and to be theory-neutral. In OMNIBUS, *Learning* is defined as a process that produces a change of state (Fig. 2) whereby an agent, whose role is to learn, changes its state from has-not-learned (before) to has-learned (after).

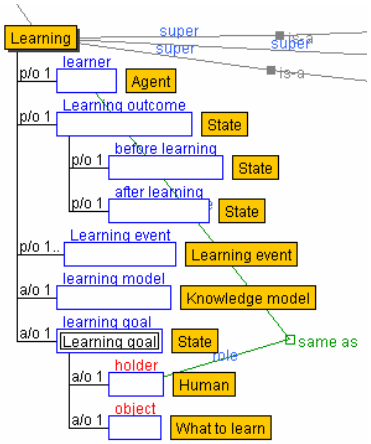

Fig. 2. The Wholeness concept of *Learning*

Building upon this definition of *Learning*, a *Learning Theory* provides an explanation of how this change can occur through a *Learning mechanism*, as will be presented in 2.6.

2. 4. The concept of an *I_L event*

Learning and instruction can be viewed as two separate processes, but in order to represent the interaction between the two, they were integrated into one entity. For this reason, a *Learning event* has been specified as an action performed by an agent; this agent is a human, and his/her goal is to change the state of the learner from "has-not learned" to "has-learned". An *Instructional event* has been specified as an action with an agent which is a human and a goal which is to support the learner in reaching his/her goal, by either influencing, stimulating or scaffolding the learning process. An *I_L event* has been specified as a pair of Instructional and Learning events, composed of an action with two agents, learner and instructor. They interact and share the same goal: to produce a change of state in the learner (Fig.3).

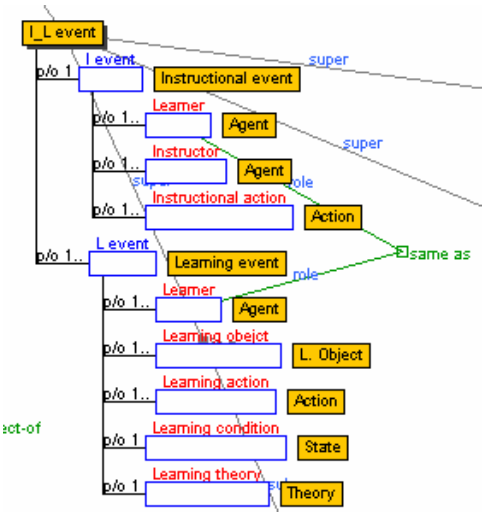

Fig. 3. The Wholeness concept of an *I-L_event*

An *I_L event* is a type of *Event*, and several types of *I_L events* have been identified in this ontology: simple, reciprocal, and influential. A *Reciprocal event* can be of the dialog type (*Tell-Listen*) or an assignment. An *Influential event* can be to remind, raise motivation, or gain attention. This specification allows the description of the relation between instruction and learning in a learning/instruction process.

2. 5. The concept of *Way-Knowledge*

Another essential concept is the Relation concept of *Way-Knowledge*, which relates directly to instructional design. Authors have to make design decisions, either for building learning scenarios or for constructing learning or tutoring environments. The OMNIBUS ontology characterizes the fine-grain level of knowledge needed to support a 'theory-aware' decision making process. This concept of *Way-Knowledge*, is composed of an *I_L event* as a macro level event and of *I_L events* as micro level events such as *Inform* or *Give feedback* (Fig. 4). *Micro events* are considered as decomposition of the *Macro events*, and the decomposition relation itself corresponds to educational strategies extracted from well-known theories such as Gagné's, Merrill's or Keller's, or from models such as Dick and Carey's, to name a few.

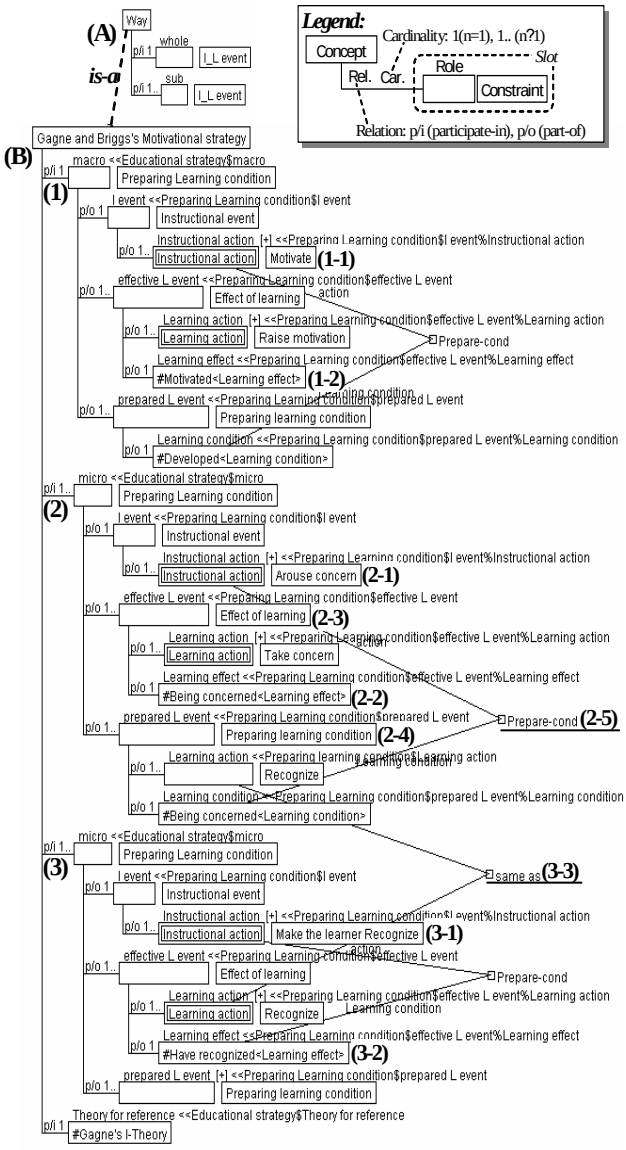

Fig. 4. The Wholeness concept of *Way-Knowledge*

This Relation concept is directly exploited by SMARTIES as will be presented in section 3.

2. 6. Theories and Models

This section introduces the concepts of *Theory*, *Learning theory*, *Theory of instruction*, and *Theory of instructional design*, as they are defined in OMNIBUS.

A *Theory* is a proposition that offers a hypothesis to explain a phenomenon (*of what*), with evidence of any kind and of any strength. It has a creator, a date of creation, and can have other properties such as methodologies, taxonomies, topics and principles (Fig. 5).

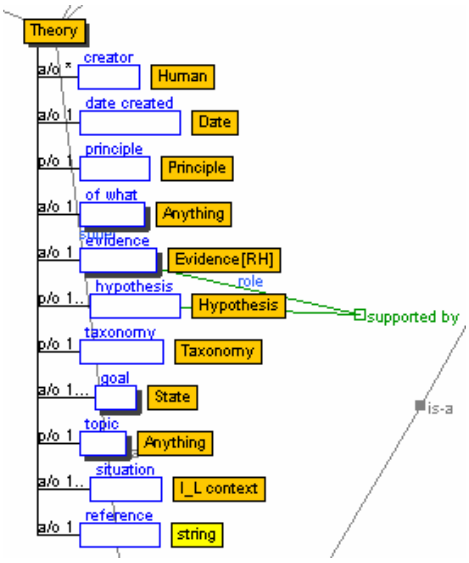

Fig. 5. The Wholeness concept of *Theory*

A *Learning theory* inherits all the features of a *Theory* and offers a hypothesis to explain the learning phenomenon, hereafter called *Learning mechanism* (Fig. 6). It has a creator, a date of creation, and can have other slots such as a 'type of learner' (child, adult) and topic (math or language learning).

Since no learning theory from the neurosciences is available yet, all learning theories originate from speculation, observation, and experimentation. They all tentatively provide an explanation of what the learning mechanism constitutes. Because they rely upon a theory of knowledge, they relate to a paradigm and are usually classified under these paradigms. Greeno et al. [21] propose such a classification and formulate the learning mechanism that is hypothetized for each paradigm. In the case of behaviorism, the mechanism is association. Cognitivist theories share the information processing mechanism. Constructivist theories see interaction as the learning mechanism. Socio-constructivist theories have social interaction. Our framework uses these classes and the characterization by *Learning mechanism* to represent theories.

Each learning theory inherits from the concept of *Learning theory* and is characterized either by a specialization of the learning mechanism or by any other feature. For example, Piaget's constructivist theory 'Genetic Epistemology' has two specific learning mechanisms, accommodation and assimilation. These explain cognitive development in early childhood.

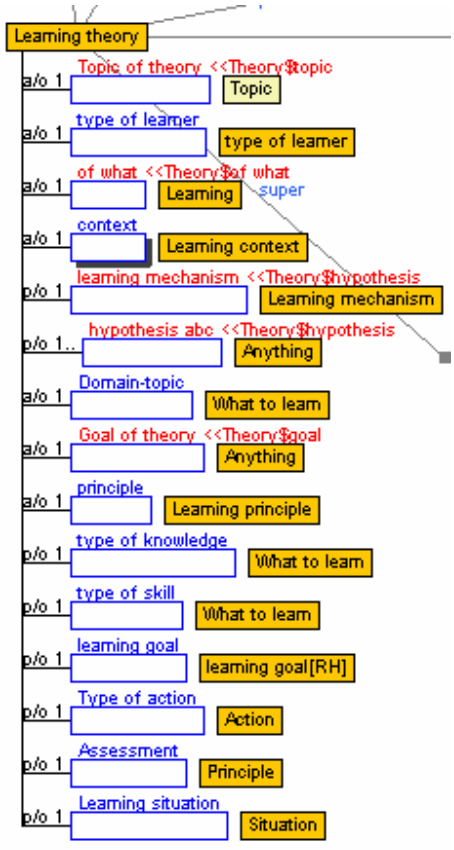

Fig. 6. The Wholeness concept of *Learning theory*

A *Model* does not provide a hypothesis about a phenomenon, but can be based on existing theories, and therefore eclectic. Examples are Dick and Carey's model of instructional design, or Joyce and Weil's models of teaching. A *Model* is composed of selected components that represent the target object (Fig. 7).

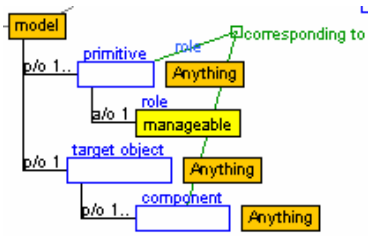

Fig. 7. The Wholeness concept of *Model*

A *Model* can also be derived from one specific theory, or emerge from practice, without trying to bring up a new hypothesis to explain learning or motivation or another basic phenomenon in education.

2.7. The Ontology of One Thousand and One Concepts

An ontology aims at specifying and structuring the main concepts that constitute a world or a domain. In the case of learning, instruction, and instructional design, the challenge was to capture the essential concepts and link them to an upper level ontology. An ontology also needs to be usable for the purpose for which it has been created. Therefore, a trade-off between essential concepts to be represented, and necessary concepts for using the ontology had to be found.

One difficulty that aroused during the analysis was the potential confusion with the names of the OMNIBUS concepts. Names such as learning, motivation and assessment have been in use both in the scientific and the everyday worlds, with numerous and sometimes very different meanings. As a result, it is recommended to look at the content of the concept, i.e. its ontological specification, rather than its name, in order to grasp its real meaning in OMNIBUS. From the beginning, original concepts such as *I_L event* or *Way-Knowledge* have been cleared by their specification.

OMNIBUS has 1001 concepts, but it is real, neither an Arabian tale nor a Japanese one!

2.8. A Work in Progress

OMNIBUS is an ambitious project which has reached a good level of maturity but still requires additional work in several aspects. Although the ontology is already 'scrutable' and inspectable by the scientific community through open access on the Web site, a systematic collection of feedback is yet to be organized and supported. This process is under preparation and the feedback from the SWEL, AIED, Kaleidoscope, and LORNET communities is being requested. Ontological engineering is a flexible process which knows how to include changes and additions. Moreover, the ontology needs to integrate a larger number of theories, since only a few have been included to date.

3. SMARTIES, an Authoring Software using OMNIBUS

The first expected user of OMNIBUS is an instructional designer creating a learning scenario, i.e. in the role of an Author. Therefore, a proof of concept had to be conducted in order to demonstrate the relevance and the usability of the ontology in this situation.

For that purpose, an Authoring software named SMARTIES has been developed with the capability of designing IMS-LD scenarios by using the theory-aware features of OMNIBUS [22]. The basic functionalities of SMARTIES are to read from the ontology and to support the scenario building through a process called 'I_L event decomposition' [23].

3. 1. Read from OMNIBUS

The first functionality of SMARTIES is to read from OMNIBUS, its wholeness concepts with their properties, and the relation concepts that link them. Basically, this is how the application becomes 'theory-aware'.

3.2. I_L event decomposition

Using the declarative knowledge from OMNIBUS, SMARTIES proceeds to a fine-grain analysis called 'I_L event decomposition" (Fig.8).

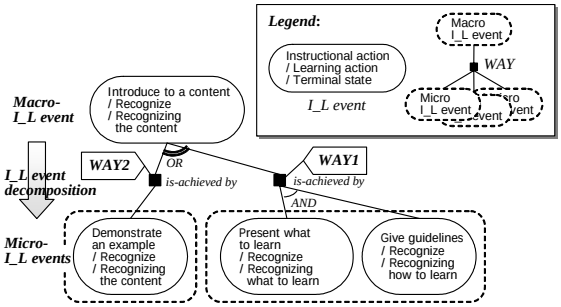

Fig. 8. An example of an I_L event decomposition

This decomposition is a structure of *I_L events* which aim at achieving a change of state in the learner. An upper (macro) *I_L event* is connected with the lower (micro) ones through the change of a learner state. Fig. 7 illustrates an example of an *I_L event* decomposition. The macro *I_L event* consists of introducing a content to be recognized by the learner. There are two WAYs to achieve this: WAY1 is based on Gagné and Briggs's theory, and consists of presenting what to learn and of giving guidance. The other is based on Collins's theory which has no guidance since it is discovery-based. These two WAYs have the same goal but achieve it through different strategies. The relation is described by an OR relation between WAY1 and WAY2.

Using SMARTIES, the result of this Authoring process is a scenario than can be exported to an IMS-LD editor, such as RELOAD.

SMARTIES has been implemented as a Java application. In order to access the OMNIBUS ontology, SMARTIES uses the Hozo API.

4. CIAO, an Assistant to IMS-LD Authors

CIAO was developed as an Assistant to Authors of IMS-LD scenarios, to provide them with 'theory-aware' services [16], [17] and [24]. The four functionalities of CIAO are briefly presented below, followed by an insight into an integration of CIAO with OMNIBUS and SMARTIES.

4. 1. CIAO's Four Functionalities

CIAO's role in an Authoring system is to provide services to an Author as suggested by [10] and [15]. In spite of the fact that EML provides a model called "Theories of learning and instruction" which refers to "The instructional theories, principles and models as described in the literature" [15], EML has a very limited connection to theories. The model contains only four concepts which are, in fact, the three classes of educational paradigms (Behaviorism, Rationalism, and Pragmatism-Socio-historicism) and a class named "eclectic".

Our vision of an Author's need for a strong representation of theories is introduced in the form of a Use Case in UML (Fig 9). An Author can access this representation using CIAO, and these services are supported through the binding of instructional/learning scenarios to theories.

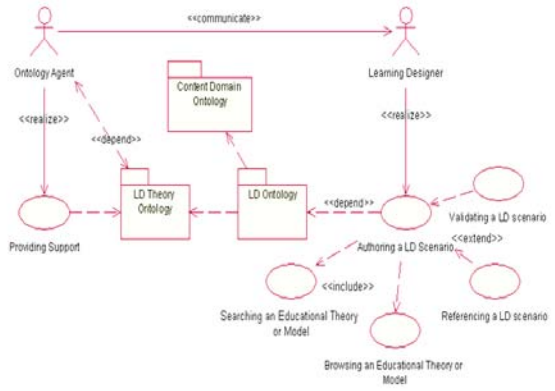

Fig. 9. Use Case of CIAO

CIAO's four functionalities are: "Explore, Search, Analysis, and Export." The "Explore" service allows users (depending on their competencies) to explore the ontology using four different options ("Class Description, Class Hierarchy, Ontology Documentation and Ontology Repository") in order to find out information about classes and instances. With the "Search" service, they can query the ontology to find out a piece of theoretical knowledge using either a predefined, parameter-based, or SeQRL request. SeQRL is an SQL-based language which works with ontologies in RDF(S). CIAO can analyze a learning scenario in the IMS-LD format and perform either a syntactic or a semantic analysis using analysis rules in JAVA. With the syntactic analysis, the users can check if their scenarios are consistent according to the ISM-LD standard. With the semantic analysis, they can check what educational theories and paradigms would say about their scenarios. Finally, it is possible to extract the classes or the instances of the ontology exploited by CIAO, in different formats, e.g. RDF/XML, N-triples, etc. [24].

CIAO has been implemented using SESAME, an open source JAVA platform, to store and request for information in the RDF and RDFS formats. Also, some plug-ins from JENA (HP Labs Semantic Web Research) and Protégé-OWL (Stanford University) APIs have been integrated inside CIAO in the Sesame Architecture, in order to exploit the full potential of the ontology. These plug-ins are *Sesame-Jena Adapter* and *Protégé RDF(s)-DB Backend*.

A targeted validation was done for CIAO in the form of an evaluation by expert inspection. The results indicate a good convergence of views of experts consulted: experts estimate that CIAO lacks usability in its graphical interface. However, experts are mostly in agreement that the services provided by CIAO and an ontology, are useful and adaptable (flexible, interoperable). Notably, there is a total convergence of opinion on the fact that the services of exploration, the research by predefined queries and the learning scenario analysis, as well as the use of an ontology are very useful.

However, CIAO has some limitations: it is not a proactive system, it is not yet connected with an Authoring system, and the analysis rules used for analyzing educational scenarios are not inside the ontology, except one in SWRL. All of the other ones are outside the ontology and in JAVA. The following section discusses the integration of CIAO with SMARTIES.

4. 2. Towards an Integration of CIAO with OMNIBUS and SMARTIES

As OMNIBUS, SMARTIES and CIAO share the same large goal and are complementary to one another, an integration framework was considered and is illustrated in Fig. 10.

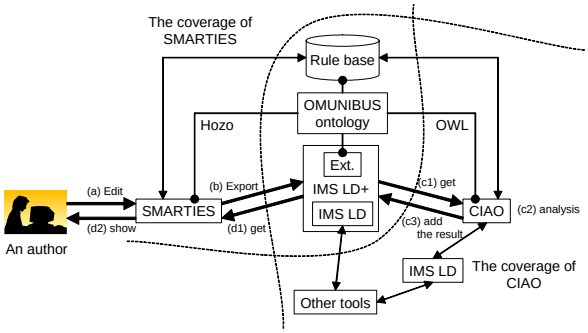

Fig. 10. Integration of CIAO-OMNIBUS-SMARTIES

SMARTIES is an Authoring tool that provides an Authoring interface to the users and intelligent support for Authoring; the scenarios authored using SMARTIES contain their design rationale with theoretical justification based on the OMNIBUS ontology and are exported together with this information into the IMS-LD format. These IMS LD scenarios can then be analyzed by CIAO, which can report the results to SMARTIES and its user. In addition to this, CIAO will analyze any IMS LD scenarios based on OMNIBUS ontology and annotate theoretical information to them. The results can be edited using SMARTIES.

5. Conclusion and Future Work

The work presented in this paper is work in progress. OMNIBUS needs to integrate more theories and models for Learning, Instruction, and Instructional Design. It also needs to be improved and complemented, and in that respect the contribution from the SWEL, AIED, Kaleidoscope and LORNET communities are being requested. The consensus-building process in ontological engineering has been discussed in various circles, but it still remains an open question. We simply expose the results of our work to the scientific community and request feedback.

Future developments include: 1) the evolution of SMARTIES with an explanation generation functionality whereby SMARTIES can explain the selection of *Way-Knowledge* based on criteria from the theories or models, 2) the integration of CIAO with TELOS, and 3) the integration of SMARTIES with CIAO. Our team is also considering the integration of the OMNIBUS ontology with an existing ontology of collaborative learning, CHOCOLATO [25].

References

[1] Desmoulins C., and Granbastien M., " Une ingénierie des EIAH fondée sur des ontologies", *Environnements informatiques pour l'apprentissage humain*, Grandbastien M. and Labat J-M. (Eds.), Hermes sciences, Paris, 2006, pp. 161-179.

[2] Devedzic V., "Education and the Semantic Web", *International Journal of Artificial Intelligence in Education*, Vol. 14, 2, 2004 , pp.165 – 191.

[3] Devedzic V., *Education and the Semantic Web*, Springer Verlag, Berlin, 2006, 353 p..

[4] Gasevic, D. and Hatala, M., "Ontology mappings to improve learning resource search", *British Journal of Educational Technology*, Special issue: The Semantic Web for E-learning, Vol.37, No.3, 2006, pp.375-389.

[5] Crampes, M. and Bourdeau, J., Editorial du numéro spécial *Ontologies pour les EIAH*, Revue Sciences et Technologies de l'Information et de la Communication pour l'Éducation et la Formation (STICEF), 2004, vol. 11, pp. 223-246, http://sticef.org.

[6] Magnan, F., and Paquette, G., "Telos: An ontology driven e-learning OS", in S.Weibelzahl and A. Cristea, Eds, Dublin. Proc. Of Workshop, Fourth International Conference on Adaptative Hypermedia and Adaptive Web-Based Systems, 2006.

[7] Mizoguchi, R. and Bourdeau, J., "Le rôle de l'ingénierie ontologique dans le domaine des EIAH", No. spécial *Ontologies pour les EIAH*, Revue Sciences et Technologies de l'Information et de la Communication pour l'Éducation et la Formation (STICEF), 2004, vol. 11, pp. 231-246, http://sticef.org.

[8] Mizoguchi, R., Hayashi, Y. and Bourdeau, J. "Inside a Theory-Aware and Standards-Compliant Authoring System", Invited talk, SWEL'07 Workshop Proceedings, http://compsci.wssu.edu/iis/swel/SWEL07/swel07-aied07-papers.html

[9] Mizoguchi, R. and Bourdeau, J., "Using Ontological Engineering to Overcome Common AI-ED Problems", *International Journal of Artificial Intelligence in Education*, Vol.11, No.2, 2000, pp.107-121.

[10] Nkambou, R., Frasson, C., and Gauthier, G.: "CREAM-Tools: An Authoring Environment for Knowledge Engineering in Intelligent Tutoring Systems", In Murray, T., Blessing, S. and Ainsworth, S. (Eds): *Authoring Tools for Advanced Technology Learning Environments: Toward cost-effective adaptative, interactive, and intelligent educational software*, Kluwer Publ., 2003, pp. 93-138.

[11] Aleven, V., McLaren, B. M., Sewall, J., and Koedinger, K., "The Cognitive Tutor Authoring Tools (CTAT): Preliminary evaluation of efficiency gains", In M. Ikeda, K. D. Ashley, and T. W. Chan (Eds.), Proceedings of the 8th International Conference on Intelligent Tutoring Systems (ITS 2006), Springer Verlag, Berlin , pp. 61-70.

[12] Merrill, D., "First principles of instruction", *Journal of Educational Technology Research and Development*, 2002, Vol. 50, No. 3.

[13] Paquette, G. *Instructional Engineering in Networked Environments*, Pfeiffer, 2004, 250p.

[14] Wiley, D., "Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy", In *The Instructional Use of Learning Objects*, 2002.

[15] Koper, R., "Modeling Units of Study from a Pedagogical Perspective: the pedagogical meta-model behind EML", Open Universiteit Nederland, Heerlen, 2001, http://www.eml.ou.nl/introduction/articles.htm.

[16] Psyché, V., Bourdeau, J., Nkambou, R., and Mizoguchi, R., "Making Learning Design Standards Work with an Ontology of Educational Theories", in C.K. Looi et al. (Eds), *Artificial Intelligence in Education: Supporting Learning through Intelligent and Socially Informed Technology*, IOS Press, Amsterdam, 2005, pp. 539-546.

[17] Psyché V., "CIAO, an Assistant to IMS-LD Authors", I2LOR'2006, demo.

[18] Bourdeau, J. and Mizoguchi, R.: "Collaborative Ontological Engineering of Instructional Design Knowledge for an ITS", in Cerri, S., Gouardères, G. and Paraguaçu, F., *Intelligent Tutoring Systems*. Springer, Heidelberg: Lecture Notes in Computer Science, 2002, pp. 399-409.

[19] Reigeluth, C. M. (Ed.), *Instructional-design theories and models: An overview of their current status*. Hillsdale, New Jersey, Lawrence Erlbaum Associates, 1983.

[20] Ertmer, P. A., and Newby, T. J.: "Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective", *Performance Improvement Quarterly*, 6 (4), 1993, pp. 50-70.

[21] Greeno J. G., Collins A. M. and Resnick L. B. "Cognition and Learning", In *Handbook of Educational Psychology*, Berliner D. C. et Calfee R. C., (Eds.), New York: Macmillan, 1996, pp. 15-46.

[22] Hayashi, Y., Bourdeau, J. and Mizoguchi, R.: "Ontological Support for a Theory-Eclectic Approach to Instructional and Learning Design", Proc. of EC-TEL, Springer Verlag, Berlin, 2006.

[23] Hayashi, Y., Bourdeau, J. and Mizoguchi, R, "Ontological Modeling Approach to Blending Theories for Instructional and Learning Design", Proc. of the 14th International Conference on Computers in Education, 2006, pp. 37-44.

[24] Psyché V., « Rôle des ontologies en ingénierie des EIAH : cas d'un système d'assistance au design pédagogique », Montréal, Département d'Informatique, Université du Québec à Montréal, unpublished dissertation, 2007, 527 p.

[25] Isotani, S. and Mizoguchi, R., "An Integrated Framework for Fine-Grained Anlysis and Design of Group Learning", Proc. of the 14th International Conference on Computers in Education, 2006, pp. 193-200.