Ontology-Based Approach to Build Intelligent E-learning systems

D. Mouromtsev[1], V. Gorovoy[2]

[1]Dcomputer Science Department, St. Petersburg State University of Information Technologies, Mechanics and Optics, Saint-Petersburg, Russia

[2]Graduate School of Management, Saint-Petersburg State University, Saint-Petersburg, Russia

Abstract - *Today e-learning systems become more and more social and have tendency to include web 2.0 software. A number of online tools and resources give a new adaptive and integrated environment for educational purposes. The Long Tail Learning phenomenon promotes a better motivation and involves students in learning. But all these benefits miss a component of the concept knowledge about a studied domain which is usually provided by a teacher. Meanwhile, ontological engineering is a very effective methodology to create, keep up-to-date, review and structure teaching courses and materials. The combination of the ontology-based approach and the new web 2.0 technologies suggests that students engage in an active learning process where such skills as collaboration, creative and analytical thinking, communication and socialization are developed more effectively. The first results of applying the described technology prove a wide perspective of the use of this technology as a part of e-learning systems.*

Keywords: ontological engineering, educational technologies, e-learning, wiki

1 Introduction

This article describes a new approach to build web-based educational systems relying on ideas from Education 2.0, ontological engineering and active learning methodology. The authors give the analysis of the last tendencies in the electronic learning (or e-learning) as a type of Technology Supported Education/Learning (TSL) and focus their attention on the web technology as a basis for e-learning. E-learning is naturally suited for distance learning and flexible learning. The term e-Learning 2.0 or Education 2.0 [1, 2] is used to refer to new ways of thinking about e-learning inspired by the emergence of Web 2.0 [3]. From the e-learning 2.0 perspective, conventional e-learning systems are based on instructional packets that are delivered to students using Internet technologies. In the traditional approach the role of the student consists in learning from the readings and preparing assignments being evaluated by the teacher. Nowadays e-learning becomes more and more social and includes web 2.0 software, such as blogs, wikis, podcasts

and virtual worlds (like Second Life). The last phenomenon has also been referred to as Long Tail Learning [4].

The second basic idea is that ontological engineering provides a very effective methodology to create, keep up-to-date, review and structure teaching courses and materials. In the context of computer and information sciences, ontology defines a set of representational primitives used to model a domain of knowledge or discourse [5]. It also refers to the knowledge engineering methodology. So applying the ontological engineering to a teaching process can increase the effectiveness of learning.

The last background thought is the use of active learning methods. An efficient instructional strategy that mixes guidance with active learning is "Learning by teaching" (LdL) [6]. This strategy allows students to teach the new content to each other, which is obviously nothing other then collaboration, pure and simple.

The union of the above mentioned approaches gives a new web-based learning technology. This technology allows solving such problems as a variety of teaching materials, a fuzziness of the structure of the studied area, the lack of relationship between parts of teaching courses. These problems are critical for newly created courses and, of course, for many existing ones. The other application of the suggested technology is checking students' knowledge by creating ontology-based reports. In many cases this approach may be more effective then traditional tests as often tests are not the best way to review a students' knowledge.

2 Ontological Engineering as a core of E-Learning system

Ontologies are widely used for e-learning tasks. One the best mind maps describing ontologies for education is suggested in [7]. From the application perspective ontologies are used as a cognitive tool for such tasks as knowledge construction, knowledge externalization, knowledge communication and knowledge assessment. The author's goal is to provide an instrument which will help to solve all these tasks in education. It's a tool both for the student and the

teacher. But it's not only about ontologies, it's also about collaboration.
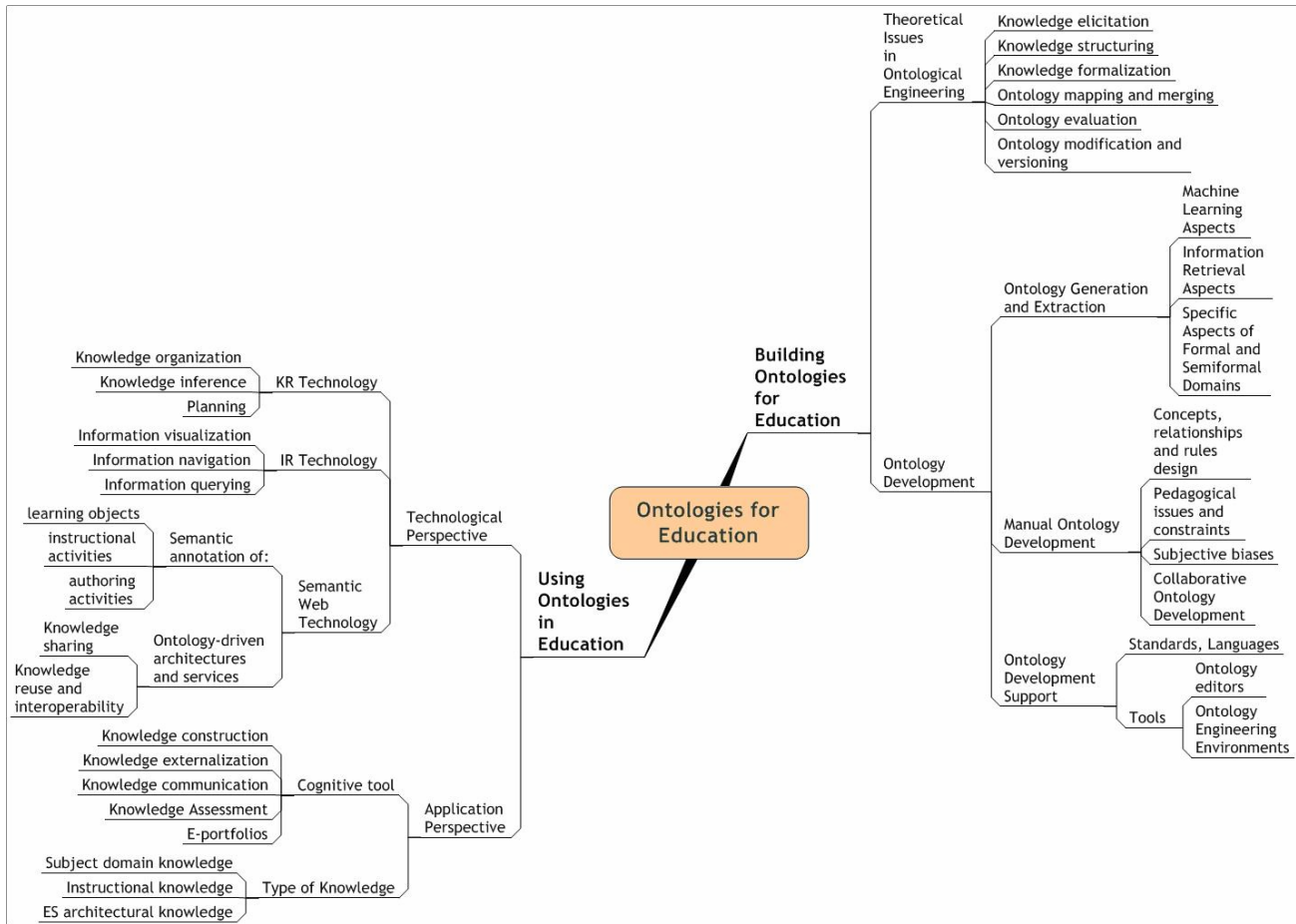
Fig. 1: Ontology of Ontological Technologies for Education
from [D. Dicheva, S. Sosnovsky, T. Gavrilova, P. Brusilovsky, Ontological Web Portal for Educational Ontologies]

As it is correctly stated in [8] it is impossible to find an e-learning information system, where metadata are not a core component. The schemas known to have a major impact on the design of current e-learning systems are IEEE LOM, IMS, SCORM, DCMI-Ed, and different application profiles related to them, which are created to describe the properties of learning objects. A limitation of these standardized metadata models is to be focused primarily on descriptive and administrative metadata to describe learning objects' properties. As a result, they do not help sufficiently to organize, describe and retrieve learning memories (where learning resources are produced within the working process), richer contextual metainformation is needed.

Ontological engineering is closely related to knowledge engineering which is a core of any courseware work [9]. In [10] is shown that ontologies are useful structuring tools. They help to organise axis along which every student can mentally mark his vision in the information hyper-space of domain knowledge. Ontologies also provide a meta-level of knowledge representation to join deferent kind of subject's knowledge as a set of ontologies.

Educational ontology design process includes five simple practical steps [11]:

1. *Glossary development*: The first step should be devoted to gathering all the information relevant to the described domain. The main goal of this step is selecting and verbalizing all the essential objects and concepts in the domain.

2. *Laddering*: Having all the essential objects and concepts of the domain in hand, the next step is to define the main levels of abstraction. Consequently, the high level hierarchies among the concepts should be revealed and the hierarchy should be represented visually on the defined levels.

3. *Disintegration*: the main goal of this step is breaking high level concepts, built in the previous step, into a set of detailed ones where it is needed. This could be done via a top-down strategy trying to break the high level concept from the root of previously built hierarchy.

4.   *Categorization*: At this stage, detailed concepts are revealed in a structured hierarchy and the main goal at this stage is generalization via bottom-up structuring strategy. This could be done by associating similar concepts to create meta-concepts from leaves of the aforementioned hierarchy.

5.   *Refinement*: The final step is devoted to updating the visual structure by excluding the excessiveness, synonymy, and contradictions. As mentioned before, the main goal of the final step is try to create a beautiful ontology. We believe what makes ontology beautiful is harmony.

3   Ontological Engineering as a core of E-Learning system

The project is named "OntolingeWiki" after two stems: ontological engineering and wiki. It provides web-representation of the educational ontology and supports annotation of it with the help of wiki pages. This technology can give the model of teaching processes which help both the teacher and the students to provide knowledge and check it. The result of student's work in "OntolingeWiki" can be a very important part of his or her E-portfolio, which becomes very popular among students, teachers and employers.

The "OntolingeWiki" educational model is an adaptation of a traditional active learning approach. Students can work individually or in groups, but a team-work is preferred. The whole learning process is divided to four stages:

•   **Domain research**: Students are introduced into the teaching problem. They find and study possible ways to solve a task and organize teams to perform the work.

•   **Knowledge engineering**: This stage requires to deep into the domain problem. Such qualities as communication and socialization are very important at this stage.

•   **Design of the Domain ontology**: Students use acquired knowledge to create an ontology describing the solution of the task. It is very important that the ontology represents individual understanding of the student. It can be easily checked and corrected by the teacher.

•   **Content development**: The final stage of the educational process includes practical steps of making solution. Students develop their skills, practice in collaboration work.

According to suggested stages of learning results of the students' work represent a complex description and solution of the teaching task. These results may be a good base for the next generation of students who will study the same problem. So the educational work will remind a pyramid building and this idea is the main benefit of this model. It is also important that this methodology is self-directed by nature.
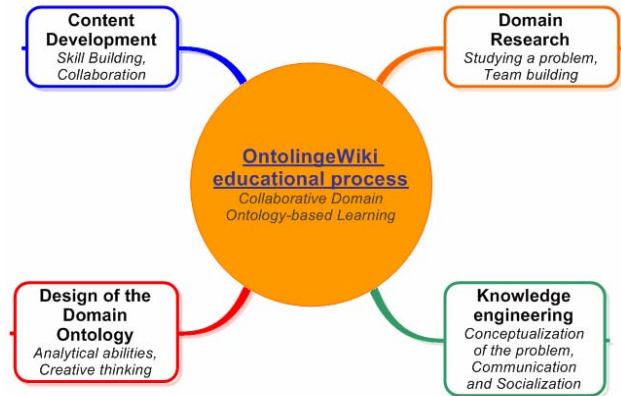

Fig. 2: The model of "OntolingeWiki" educational process

4   The technology description

Ontology can be a tremendous cognitive tool, but it should be provided with an appropriate representation to become such a tool. We propose that a good visualization based on hypergraph technology is a good solution for ontology representation, because it has several advantages: one can see all concepts and the scale of ontology, concepts within one's focus are shown bigger than those at the periphery, the navigation is simple and intuitive.

Good ontology with good visualization can become a great tool for education if the last has a feature of annotating ontology concepts with some content. Wiki technology suits for such kind of tasks and it also provides wonderful environment for collaboration which is very important in educational tasks.

Summarizing points mentioned above the next components were united in the core of "OntolingeWiki" technology:

•   OWL-parser to process ontologies,

•   Hypergraph visualization interactive module for ontology navigation,

•   Wiki as a content management system an collaboration environment,

•   Web-application environment to manage the process and provide necessary services.

"EduOntoWiki" [12, 13] was one of the first projects taking advantage of both ontology as a tool for structuring knowledge and wiki as a great environment for collaboration. "OntolingeWiki" project was partially inspired by "EduOntoWiki" and it has several distinctive features:

1. The authors think that visualization of ontology is very important from a cognitive point of view, that's why hypergraph was preferred to the standard tree representation used in "EduOntoWiki".

2. The standard full-scale wiki-engine "DokuWiki" is used instead of a self-developed one.

3. "OntolingeWiki" is a web-based service for submitting ontologies made by students and teachers and annotating them using wiki. This service doesn't support collaboration for ontologies' development accepting any ontology saved in OWL format. Collaboration on annotation stage is supported.

5 Methodology for creating diploma and course projects using OntolingeWiki

Standard approaches for developing diploma and course projects by students which suppose standard Word file as a result of the work lack the following important things:

• good structure of the course work or diploma is not leveraged by Word, so it usually depends only on the student's understanding of the importance of structuring his work. "OntolingeWiki" technology helps to solve this problem by putting step of ontology creation before developing of any content

• if the course work or diploma is created by several students, it is important to provide them good collaboration environment. Wiki environment is much better for collaboration than MS Word-like.

• result saved in a file is much less widespread than a project available in the intranet/internet. It is much easier to use the result in "OntolingeWiki" for future courses to teach students and provide them opportunity to enhance existing "OntolingeWiki" projects.

Team Role	Responsibility	Comments
Domain expert	Providing knowledge of the domain for knowledge engineers (usually using interview techniques)	Sometimes science tutor can held this role, sometimes real expert from the domain of research. It expert is not available knowledge can be taken from other sources.
Knowledge engineer	Knowledge acquisition from domain expert Ontology creation	This role requires good analytical and communication skills.
Content provider	Creating corresponding content for ontology concepts.	This role requires good knowledge of the domain concepts.

The following methodology was developed for creating diploma/course project in "Ontolinge Wiki" environment:
1. Students form team with the roles and responsibilities shown in table 1.
2. The process of ontology creation is iterative. Domain expert(s) and knowledge engineer(s) schedule regular meetings (once in a week or two) and through interview, review of already created part of ontology and mind mapping create new concepts and relations between them. We think that on this stage good visualization is very important from the cognitive point of view. Expert can see some relations which seem to spoil cognitive balance and clarity and correct them. It doesn't matter a lot whether special mind mapping tools such as MindMapper, FreeMind and others are used or only pencil and a list of paper are applied for creating mind maps.
3. During each iteration knowledge engineer(s) develop and improve ontology using one the many tools available on the market (Protege, TopBraidComposer, etc.). The only requirement to the ontology editor is its ability to save ontology in OWL format. The result ontology is uploaded on the server through the "OntolingeWiki" interface and becomes available for browsing.
4. Content providers attach actual content to new ontology concepts added by knowledge engineers and edit current content in "OntolingeWiki" by just selecting concept in ontology hypergraph or tree representation and creating a wiki-page using standard dokuwiki syntax. Fig. 3 shows how user interface looks like for content provider when no information is attached to the concept ("coherence" written in Russian at the given figure).
5. Steps 2–4 are repeated until the project is finished.

Fig. 3: Ontology concept without attached information

6 The practical application

The described ideas were implemented in the design of the ontology-based content management system for the virtual exposition of the optical technologies museum in Saint-Petersburg State University of Information Technologies, Mechanics and Optics. Many electronic teaching materials such as presentations, animations or java-applets were united in the virtual exposition which introduces a visitor with optics according to the chosen ontology model.

One of the web-pages of the created project, describing Hipparchus is shown on the figure 4.

Fig. 4: Ontology concept with attached content

The methodology shown in the previous section was successfully applied for creating the whole project of the Optics Knowledge Base. The project team consisted of one domain expert – the professor, two students with good analytical and communication skills and experience in ontology development played roles of knowledge engineers, two students from the faculty of physics with good knowledge in optics domain were content providers. Project took about 4 months and 10 iterations. DOLCE+Dn S Ultralite ontology (http://www.loa-cnr.it/ontologies/DUL.owl) created by Aldo Gangemi was used as an upper ontology at the beginning of the optics ontology creation.

Actually, optics domain is very difficult and there is no available well-structured optics encyclopedia in the internet, that's why this project can be very important not only for Saint-Petersburg citizens but for the whole world if it is localized and made available in the web.

7 Summary and future work

The first experience of applying the "OntolingeWiki" technology shows a great perspective to open up, share and reuse educational content and domain knowledge ontologies. Ontology-based conceptual modeling makes teaching process more comprehensive and flexible for an individual. Technology supported collaboration involves students into self-directed learning and develops creative and analytical thinking.

We plan to integrate in "OntolingeWiki" technology the whole spectrum of Web 2.0 tools and open Internet-access to our technology for a wide range of users.

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