Ontological Web Portal for Educational Ontologies

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Abstract. In spite of the fact that the field of applying ontological research in education is fairly young it is already quite broad and fuzzy. The set of technologies used and developed there have roots in a variety of diverse areas of information and pedagogical sciences. To facilitate the process of scientific and scholastic search the domain needs to be structured.

This paper presents two main results: an ontological overview of the *Ontologies for Education* field and an initial report on the development of an ontology-driven web portal providing a single network place, where researchers, students, and practitioners can find information about available research projects and successful practices in this field.

Introduction

Among the variety of modern trends in educational technology development the application of ontological research is probably one of the most fashioned and rapidly evolving. After the first dedicated workshop in 1999 [1] seven more workshops [2, 3, 4, 5, 6, 7, 8] and three special journal issues [9, 10, 11] have been brought out. This does not include numerous papers in related conferences, journals, and books. In spite of the fact that the filed is fairly young it is already quite broad and fuzzy. The set of technologies applied and developed there have roots in a variety of diverse areas of information and pedagogical sciences. To facilitate the process of scientific and scholastic search and the research in this area we decided to collect and classify the available information in the field and to use it for building the *Ontologies for Education (O4E)* Web Portal.

A number of papers have been devoted to the analysis of the field providing overviews of its different aspects. Mizoguchi and Bourdeau in their seminal work [12] enlisted a number of challenges that have not been met yet by the AI-ED technologies and proposed a roadmap of how the application of ontological engineering could assist in dealing with those challenges. Similar work is done in [13, 14, 15], as well as in [16] for the more specific domain of Web-based Intelligent Systems. Several overviews of existing tools or created domain ontologies have been also performed. Examples of the former are the overview and comparison of ontology engineering environments [17], and the analysis of semantic annotation tools for learning material made in [18]. An example from the latter group is the overview of ontologies in the domain of engineering design [19].

This paper however intends neither to give a broader overview of ontology-based solutions to existing problems in e-Learning nor to evaluate the developed artifacts. It rather attempts to provide a general *snapshot* of the state-of-the-art research in the filed of applying and developing ontologies for education. It also proposes building of a single web place, where relevant research projects and successful practices are classified and annotated. We consider that such an effort is well-timed, since there is already a critical but not yet excessive mass of information, so it is still possible to handle it. Pretty soon the situation will be much more unfavourable; note that in 2004 alone three special journal issues related to the Educational Semantic Web have been published! [9, 10, 11]. We believe that building of even modest ontology and using it to index the more important available resources (publications, events, projects, groups, etc.) would be of great benefit to the *O4E* community. We further believe that the *O4E* Portal will make it possible for the interested part of the *O4E* community to collaborate on extending and refining the ontology and keeping the resources current. The reported here work is the first step in this direction.

The following discussion is divided into three parts focused on the development process of the *O4E* ontology, the ontology itself, and the *O4E* Web Portal.

1. The *O4E* Ontology Development

Our first goal was to collect and structure the available information related to the use of ontologies in the field of education. When the question for classifying and representing the collected information arose, it was natural to think about building of an ontology.

It is often the case in computer science that the technological developments appear before the theoretical ones. *Ontology engineering* is not an exception of this pattern. Several related standards, languages, and powerful tools have been already developed [20]. However, the (e-learning) ontology designers and practitioners still face major problems and lack of support to develop even simple ontologies. We mean not *syntactic* but *semantic* problems. What ontology designers currently miss are some theory-backed *practical* techniques for manual ontology development. Recent findings in knowledge engineering along with the first results in the educational ontological research [12] can help in tackling this “bottleneck” problem. We tried to use those findings when eliciting, structuring and designing the *O4E* ontology.

In our project, as in many other ontology-based applications, we have to deal with two types of knowledge - *subject domain* and *structure*, which leads to two types of ontologies. A *domain ontology* represents the basic concepts of the domain under consideration along with their interrelations and basic properties. A *structure ontology* defines the logical structure of the content. It is generally subjective and depends greatly on the goals of the ontology application. It typically represents hierarchical and navigational relationships. While a domain ontology can be used as a mechanism for establishing a shared understanding of a specific domain, a structure ontology enforces a disciplined approach to authoring, which is especially important in collaborative and distributed authoring.

The process, named in all methodologies just “create ontology”, is a time- and mind-consuming iterative procedure of *categorization* or *laddering*, together with *disintegratio*n or *detailing*. It is a totally informal analytical design, and output structures are rather subjective and sometimes awkward. The collective work gave us the opportunity to merge personal viewpoints into a common framework.

One of the guidelines with regard to the *structure ontology* relates to the clarity and *mapability* of the structure. Taking into account that our ontology is to be used not only as a knowledge component of an information system but also as a *mind tool* for manual information search and navigation, we tried to follow the principle of good shape (or beauty), which is not

new in basic scientific abstraction and modeling (e.g. physics, chemistry, etc.). The most substantial impulse to it was given by the German psychologist Max Wertheimer. His criteria of good *Gestalt* (image or pattern) [21] we partially transfer to ontological design:

- Law of Pragnanz (the law of good shape): the organization of any structure in the nature or cognition will be as good as the prevailing conditions allow. 'Good' here means regular, complete, balanced, and/or symmetrical.
- Law of Parsimony: the simplest example is the best (the Ockham's razor principle); entities should not be multiplied unnecessarily.

In case of building ontological hierarchies we have to keep in mind that a well-balanced hierarchy is much more comprehensible. We enlist below some tips that we consider useful in formulating the idea of "harmony" in a hierarchical structure:

- Concepts of one level should be linked to their parent concept by one type of relationships, for example, "is-a", "has-part", etc. This means that concepts of one layer should have similar nature and level of granularity.
- The ontological tree should be balanced, that is, the depth of the paths in the tree should be more or less equal (±2 nodes). This will insure that the general layout is symmetrical. Asymmetry might indicate that the shorter branches are less investigated or the longer ones are too detailed.
- Cross-links should be avoided as much as possible.

When building a structure ontology to be used for information visualization and browsing, it is important to pay special attention to clarity. Minimizing the number of displayed concepts is the best tip according to the Law of Parsimony. The maximal number of branches and the number of levels may follow Miller's "magical number" (7±2), which is related to the human capacity for processing information [22].

The "beautification" bias is a methodological approach that can help finding points (nodes) of "growth", "weak" branches, inconsistencies, and excessiveness. But, in fact, specific domain knowledge features may be of higher priority than structure ontology design principles.

2. The *O4E* Ontology

Figure 1 shows the result of our efforts in developing the *O4E* domain ontology. In fact we started with the development of a *partonomy*, using only the "part-whole" relationship type. We plan to consider later the use of other suitable relationships.

The top-level meta-concepts of the domain ontology divide the whole field according to the role ontologies play in the research. When an ontology is considered as an object (the result of an activity) the research is focused on the theoretical and/or practical issues of the ontological engineering that are specific to the educational context. Ontologies might also serve as a technology, facilitating the solution of some educational problems, such as interoperability of knowledge-based systems and components, or assessment of structural knowledge. In this section we summarize the important issues in those two fields. Note that we haven't included references here; they have been included in the developed *O4E*-based topic map (see Section 3.).

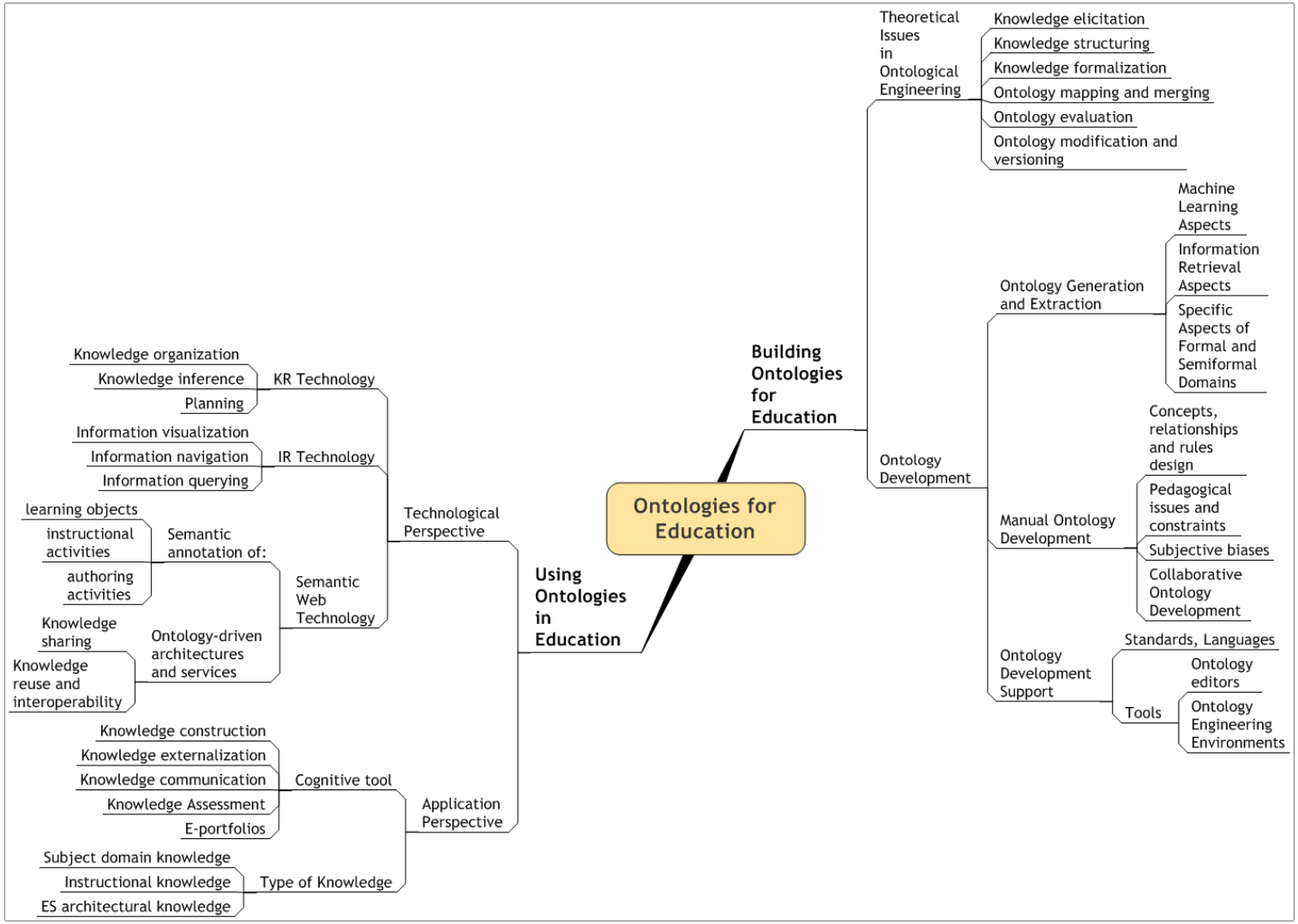

Figure 1. State-of-the-Art Ontology of Ontological Technologies for Education

2.1 Building Ontologies for Education

When analyzing resources focused on different tasks of educational ontology development we identified two naturally separated areas of research. While some papers mostly study the theoretical issues of ontology engineering, another large set of resources is about practical aspects of ontology development. Three large groups could be identified inside the latter part:

- Automatic and semi-automatic ontology generation and extraction using different kinds of sources and different technologies.
- Manual ontology development, where the research is focused on problems either related to the ontology engineering process or specific to educational technology.
- Research on using different standards and languages for ontology implementation, including attempts of binding Semantic Web and educational (e.g. LOM or SCORM) standards or reporting case studies on implementing general-purpose ontological formalisms in educational settings.

2.2 Using Ontologies in Education

This field combines diverse research on different kinds of educational applications of ontologies. We tried to look on this branch from two perspectives depending on what kind of technology is implemented and what role an ontology plays within a project. Speaking about the technological perspective, we defined three main areas, two of which (knowledge representation and information retrieval) are kind of "technological donors" for the ontological research, while the third one (Semantic Web) benefits from it the most.

As to the application perspective, ontologies have been considered for a long time only as a technical artifact acting as a knowledge base component. The field of education is one of the first, where understanding of an ontology as a cognitive tool came around. In many respects it was due to the wide spread of the constructivist paradigm of learning and the broad use of such knowledge technologies as concept maps, mind maps and others for learning purposes.

3. The *O4E* Web Portal

Our second goal was to create a web place not only for publishing the created ontology but also to serve as a point of access to the relevant online information.

The initial idea was to design a website containing a graphical representation of the developed taxonomy along with an index page linking all resource web pages we have found. Figure 2 shows a screenshot of the website.

After creating the first version of the website we felt that we should further represent the ontology in an *exchangeable*, *shareable* and *interoperable* format, so that it can be easily moved, updated, merged, etc., which is *a must* for its further development and survival. We chose to represent it as a Topic Map (TM) [23], since this Semantic Web technology is very appropriate for formalization of lightweight ontologies and for structuring and representing ontology-based web information. For its development we used TM4L, which is briefly described in the following section.

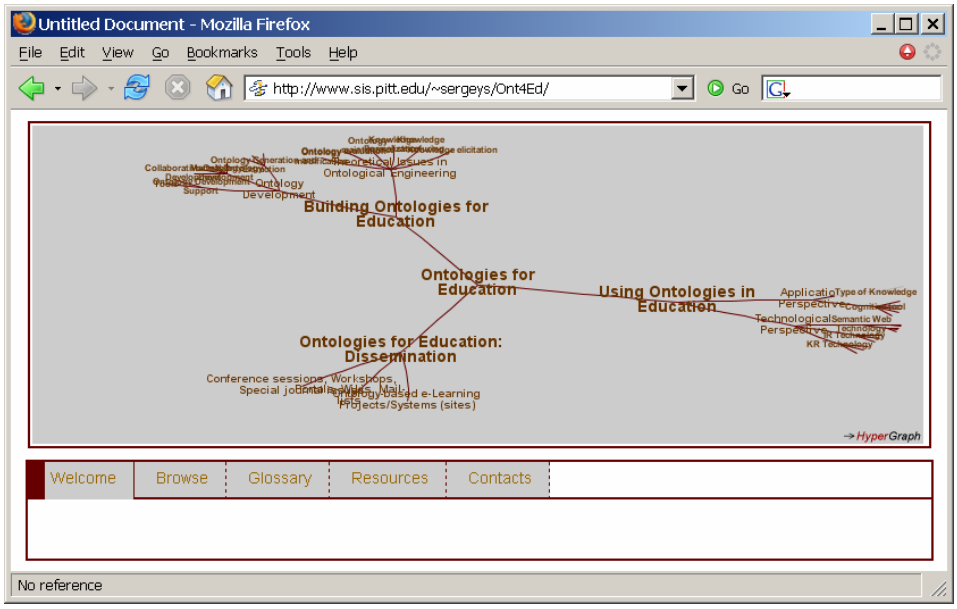

Figure 2. Graphical representation of the developed ontology.

3.1 Creating the Ontology with TM4L

TM4L (Topic Maps for e-Learning) is an environment providing support for creating and using ontology-aware topic maps-based repositories of online (learning) materials [24]. It consists of two tools: a TM Editor and a TM Viewer, both standalone applications. In addition, a client-server topic map navigator (the TM4L Browser) is currently under development. The topic maps created with the TM4L Editor (see Fig. 3) are fully compliant with the XML Topic Maps (XTM) standard and thus interchangeable and interoperable with any standard TM tools (can be browsed with any standard TM browser/viewer). The Editor supports also the TM fundamental feature of easy and effective merging and interrelating of existing information resources while maintaining their meaningful structure. This allows for flexibility and expediency in re-using and extending existing repositories.

The main objects that the TM4L Editor manipulates are topics, representing subjects (e.g. domain concepts), relationships, resources, and scopes (views) [26]. We have currently chosen to use the following types of resources: Research Papers, Special Journal Issues, Books, Projects, Software, Conferences, Workshops, Mail Lists/Wikis, Research Labs and Working Groups, and People. We presume that each resource has a unique URI (e.g. the online paper's URI, the project, conference or person's webpage, etc.) and use these as *subject identifiers* for the resources. This allows merging deferent versions of the *O4E* topic map correctly.

An additional advantage of using the TM4L Editor and Viewer is that they are free standalone personal tools for creating and browsing educational topic maps, so any interested person can download them [25], along with the current version of the XTM representation of the *O4E* ontology for their own use. This would allow personal (individual) collection of information resources and augmentation of the topic map. If a person doesn't change the ontology (i.e. only adds resources and uses the already defined relationship types) and uses the agreed subject indicators, he or she can later contribute the result of their work to the *O4E* community. For that purpose they need to send their XTM file to the *O4E* Portal administrator for merging with the main *O4E* topic map. As we already mentioned, the TM4L Editor supports topic maps merging.

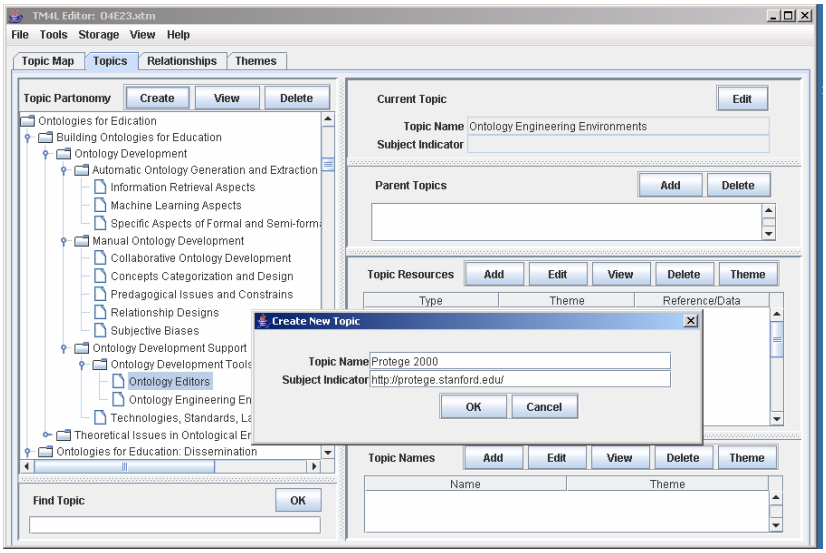

Figure 3. Creating the *O4E* ontology with the TM4L Editor.

3.2. Ontology Navigation

The TM4L Viewer offers three views: *Graph View*, *Text View* and *Tree View* (see Fig. 4). The user can browse the ontology by selecting an object (topic, relationship, relationship type or role) related to the currently displayed one. When navigating, the user can choose in which panel the information about the selected topic to be displayed. This allows browsing of different objects related to the current one without loosing the focus.

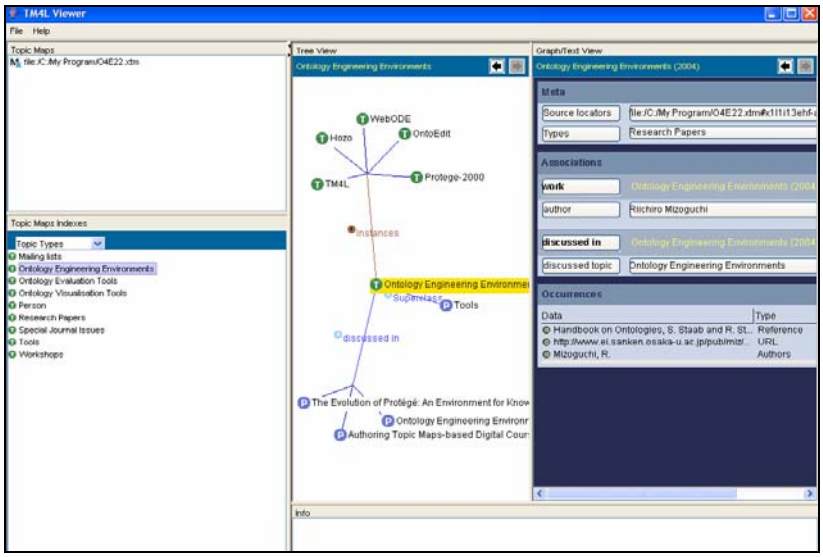

Figure 4. Browsing the *O4E* ontology in the TM4L Viewer.

When the user selects a particular resource type all instances of that type, for example, all workshops, special journal issues, etc. will be listed in the Tree view. By further selecting a particular resource, the user can see the topics (concepts) it is related to, as well as its content, or can follow the link in case it is an external resource.

4. Future Work and Discussion

We are convinced in the usefulness of the *O4E* Web Portal for the *O4E* community and plan to continue the project in several directions.

First, we need to refine further the designed partonomy. The preliminary results of web resource indexing show that some leaf concepts participate in a large number of recourses (that is, incorporate large amount of research), while other nodes could hardly be used for indexing of a single resource. Consequently, such "outlying" concepts need to be redesigned. Too 'rich' concepts (like *subject domain knowledge*) should be further divided into smaller ones, while some concepts lacking relevant projects might be combined with their neighbors.

We also plan to develop further the *O4E* Web Portal, focussing on the possibility of remote online editing of the ontology and resources.

Adding new resources to the *O4E* Web Portal is another direction of future work. Several more related workshops and conferences are being held this year and presumably more special journal issues are coming (we currently know about one [27]). As the number of resources grows, the problem of navigation throughout the portal will arise. To facilitate resource navigation the resources have to be carefully organised and structured. For example, a paper is a part of a workshop, and a person is a participant of some research group, etc. However, when the number of resources gets too large, only structuring would not help to avoid a navigational burden; then adaptive hypermedia technologies (like social navigation) might be applied.

We believe that the SW-EL@AE-ED'05 workshop participants will contribute to the development of the *O4E* Web Portal by providing feedback on the structure of the proposed ontology and by proposing the inclusion of new resources. We hope that the portal will take the role of a platform for collaborative community building of ontology-based repository of *O4E* resources.

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