Ontologies and metadata for E-Learning environments in Ecological and Environmental science

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Abstract: - Ecological and environmental science has remained a discipline in which e-Learning has not been widely utilized, possibly due to the complexity and heterogeneity of the e-Learning content available. Traditionally the Learning Objects for ecological and environmental science consist of Web pages, unstructured documents, numerical data files and numerical data in databases. Using metadata attached to Learning Objects and different kinds of data enhances the use of heterogeneous materials. Metadata may be characterized as information about the data required to understand not only the data itself but also its context, quality and structure, as well as to make the data accessible and retrievable. This paper reviews research on metadata, ontologies and markup languages for e-Learning and describes the e-Learning content for ecological and environmental science. The paper describes two common metadata specifications, i.e. the Learning Object Metadata and the Dublin Core as well as two potential markup languages for ecological and environmental e-Learning, i.e. the Ecological Metadata Language and the Geography Markup Language. Metadata provides means to organize the major topics of e-Learning courses and for visualize the semantic connections between concepts. It is possible to extend and reuse metadata specifications by utilizing ontologies and ontology languages (e.g. Web Ontology Language). A semantic e-Learning environment for ecological and environmental science gives a student a possibility to build mental structures and learn in a constructive, self directed and activity oriented way.

Keywords: - e-Learning, markup languages, environmental data, Learning Object, metadata, ontology

1 Introduction

Requirements for enhanced quality and effectiveness on teaching have made the e-Learning a commodity for academia. In ecological and environmental science there are many specific requirements, such as the need to bind teaching to real environmental data and geospatial information.

Ecological and environmental data consist of raw data such as numerical measurements made in the field, their derivatives. Data collected in databases enable the binding of distance as well as classroom teaching to real world and its phenomena. Provided with means to search and connect the data and its context for e-Learning makes databases and efficient tool.

Research on structured documents and metadata has provided new solutions for interoperability, reusability and durability for resources available on the Internet. World Wide Web Consortium (W3C) has produced specifications, techniques and languages in that field. All this is aimed to find a ‘lingua franca’ to be used with e-Learning and other resources on the Internet. Extensible Markup Language (XML) provides the commonly utilized syntax and means for marking up the content as well as metadata and ontologies describing it for the resources on the Internet. It is a contemporary meta-language on which different markup and metadata languages have been built.

This paper reviews metadata standards, ontologies and markup languages potentially usable for ecological and environmental science e-Learning environments and examines possibilities to build semantic learning environments using concepts of both pedagogy and ecological and environmental science.

Further this paper reviews the concepts of metadata, semantics, and ontologies and describes the LOM and DC metadata standards. After that we describe the e-Learning resources, data and metadata for ecological and environmental science. Finally we describe potential markup languages and ontologies for e-Learning on the domain.

2 E-Learning

E-Learning is education via the Internet, network, or standalone computer. It is a form of network-enabled transfer of skills and knowledge. E-Learning applications and processes include Web-based learning, computer-based learning, virtual classrooms and digital collaboration. Content is delivered via the Internet, intranet/extranet, audio or video tape, satellite TV, CD-ROM, etc. E-Learning supplies novel presentation methods and distributed access to a wide variety of data. It can also reach students under widely variable circumstances [1] and hence facilitates the development towards the information society. E-Learning bridges the gap in time and space between teachers and students.

Resources of e-Learning include both hardware and software. In order to reach the maximum flexibility and the highest efficiency of e-Learning, it has been proposed to organize learning contents as independent Learning Objects which can be dynamically combined to construct personalized learning programs [2].

IEEE defines Learning Object as any entity, digital or non-digital, which can be used, re-used or referenced in technologically supported learning [3]. Examples of Learning Objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organizations, or events referenced during technology supported learning. Polsani [4] criticizes this definition as too broad and impractical because non-digital objects are included. He thinks a conceptual definition of Learning Object should lay out principles of learning and reusability, two basic intentions of the Learning Objects. A digital object or media can be a Learning Object only when it is a part of some form (for example a course) and it establishes a relationship between the user and stored information. The reusability of Learning Objects is achieved by differentiating object and its use. Polsani [4] defines a Learning Object as “an independent and self-standing unit of learning content that is predisposed to reuse in multiple instructional contexts”. The formal composition of a Learning Object is the arrangement of elements, which could be for example text, image, video, animation etc. In this article we refer to Learning Object as any digital resource that can be reused to support learning.

There are a multitude of online-platforms available which provide basis for e-Learning. According to they deal with wide range of digital media types, offer content management, course and user management and technical possibilities for interaction, communication and collaboration. At University of Dortmund in Germany they have built an e-Learning course of health-education [5], which uses on Hyperwave [6]. Other platforms used are for example Moodle [7].

3 Metadata for Learning Objects

There are multiple connotations about the concept of metadata. Gilliland-Swetland [8] defines metadata as “the sum total of what one can say about any information object at any level of aggregation”. Haase [9] states that metadata is any data which conveys knowledge about an item without requiring examination of the item itself. Anido [10] defines metadata simply as information about information.

Metadata record consists of structured information about the resource it describes. It is structured in a manner that facilitates the management, discovery and retrieval of those resources [11]. They offer description of the content, quality, condition, authorship, and any other characteristics of some objects or data.

Educational metadata extend the scope of description that can be included in a metadata record with information that has particular educational relevance. Metadata are used in networked object and knowledge sharing systems [12] facilitating the use of distributed and heterogeneous repositories.

Learning Object Metadata (LOM, IEEE 1484.12.1) standard supports the use of Learning Objects and fosters platform interoperability. The LOM describes the hierarchy of data elements and it is defined by utilizing XML and XML Schema schemas. Each LOM element contains a hierarchy of subelements. For example the <educational> element includes the <learningresourcetype> element, which denotes the specific type of Learning Object (e.g. Exercise, Simulation, Diagram etc.). In addition to the name, size (the number of values allowed) and values, also the value range and data types of elements may be defined. The data type indicates one of the six allowed data types.

The beginning of LOM document could look like as follows:

```
<lom>
<general>
<identifier>
<catalog>URI</catalog>
<entry>http://www.jyu.fi/documents/1234</entry>
</identifier>
<title>Kasviplanktonopas</title>
<language>fi</language>
…
</general>
…
</lom>
```

An other metadata standard which can be used for Learning Objects is the educational version of the Dublin Core (DC) Metadata standard, It has an element of “Audience”[13], [14] may be utilized. The “Audience” element has “Mediator” and “Audience Education Level” refinements. DC element “Relation” has a new element-refinement “Conforms To”, which may refer to an established standard to which the resource conforms (Table 1).

The DC educational version elements can be utilized as follows:

```
<dc:audience>Masters program
students</dc:audience>
<dcterms:mediator>Professor</dcterms:mediator>.
<dcterms:educationLevel>Secondary
science</dcterms:educationLevel>
<dc:relation>Laboratory instructions</dc:relation>
<dcterms:conformsTo>SFS
3021</dcterms:conformsTo>
```

The elements of DC and LOM specifications are not directly comparable. Whereas DC uses 15 elements plus additional ones for e-Learning the LOM metadata is grouped into 10 categories (Table 1). However the both standards define element “Rights” on the main level. While LOM defines “Educational” as a main category the DC uses elements related to education as extensions.

Table 1. Comparison of Learning Object Metadata (LOM) and Dublin Core (DC) as Learning Object (LO) metadata languages. DC educational version elements and definers are marked with *

LOM		**DC**	
Element categories	**Descrip-Tion**	**Element/ Definer**	**Descrip-Tion**
Lom	Root element	Title	Resource name
General	Describes the LO as a whole	Creator	Responsible for making the resource.
Lifecycle	History and current state of the LO	Subject	The topic of the resource.
Meta-metadata	Describes the metadata itself	Description	Abstract, a table of contents etc.
Technical	Technical requirements and characteristics of the LO	Publisher	Responsible for making the resource available.
Educational	Describes educational and pedagogic characteristics of the LO	Contributor	Responsible for making contributions to the resource.
Rights	Rights and conditions of use for the LO	Date	Time associated with an event in the lifecycle of the resource.
Relation	Relationships between the LOs	Type	The nature or genre of the resource.
Annotation	Provides comments on the educational use of the LO	Format	The file format, physical medium, or dimensions of the resource.
Classification	LO in relation to a particular classification system	Identifier	An unambiguous reference to the resource.
		Source	The resource from which the described

			resource is derived.
		Language	A language of the resource.
		Relation	A related resource.
		Definer: conformsTo*	A reference to an established standard to which the resource conforms.
		Coverage	Topic, applicability of the resource, or the jurisdiction under which the resource is relevant.
		Rights	Rights held in and over the resource.
		Audience*	For whom the resource is intended or useful.
		Definer: mediator*	Mediates access to the resource and for whom the resource is intended or useful.
		Definer: :educationLevel*	Audience education level

4 Semantics of Learning Objects

Mao et al. [1] argue that LOM and DC focus only on the minimal set of elements and that their simple structure can not help students to learn complex information and relationships among topics. To complete a learning task, students do not only require an understanding of what the learning materials talk about, but also the semantic connections and relationships between these materials. Brooks et al. [15] state that by creating domain, educational, and learner characteristic ontologies, content can be dynamically linked to those competencies that are observed in a running e-Learning system.

IMS Learning Resource Meta-data Specification utilizes the LOM metadata specification and offers two additional mechanisms for adding semantics to LOM elements: 1) LOM element or value may be mapped to a more precisely defined element or term in a related schema or element set or 2) the meaning of the LOM element or value can be defined through a reference to the best and most common practices in the LOM community or by using the definitions provided the Oxford English Dictionary [3].

Sheth et al. [16] organize metadata into three types of semantics: 1) implicit semantics, which appear in unstructured text that has loosely defined and less formal structure, 2) formal semantics, which appear when the data representation takes a more rigid form and 3) powerful semantics, which imply the combination of simple syntactic structures to represent the meaning of complex ones.

Al-Khalifa and Davis[11] classify the representation of metadata in e-Learning applications into three categories: 1) standard metadata applications, which use the IEEE-LOM standard or a variation of it so that the standard only provides hierarchical structure for metadata specifications, 2) semi-semantic metadata applications that use the IEEE-LOM standard with an extended semantic component and 3) semantic metadata applications that rely on domain ontologies to define the metadata. An example of an application using semantic metadata is the metadata project of Advanced Research in Intelligent Educational Systems, Canada [15]. One of their approaches is to use WordNet [17] as a closed ontology from which learners and teachers select metadata vocabulary.

A controlled vocabulary is a set of unambiguous terms explicitly stated to be used in a specific domain [15]. Explicit conceptual relation occurs when there is at least one explicit class or entity representing a concept and related terms. The conceptualization is the product of a mental abstraction which may be presented as classification or aggregation [18].

Ontology is an explicit specification of a conceptualization. It is a shared vocabulary with a specification of its intended meaning [19]. The Semantic Web is a universe of metadata and ontologies expressed in machine readable format along with software tools, which allow the understanding of semantic relations among heterogeneous and distributed resources on the Web [20].

Among the current knowledge management techniques, ontologies play a greater role than ever [21]. Current research on ontologies has shown that they facilitate the retrieval, interaction and management of resources (e.g. [22] or [13]). Ontologies allow teachers to organize major topics of the course. They also provide students opportunities to interact with Web-based courses and other educational systems and also support semantic information access to materials relevant to certain topics [1].

Tane et al. [23] presented a methodology and implementation of an ontology-based Courseware Watchdog, which supports users in finding and organizing distributed e-Learning resources by offering a common framework for the retrieval and organization of courseware material. They propose that the simple structure of LOM or Dublin Core prohibits their use for modeling more complex knowledge, whereas ontology languages are not only able to integrate LOM and Dublin Core metadata, but also allow the standards to be extended by non-standard metadata elements.

Mao et al. [1] discuss about an approach that relies on an ontology-based digital library. They provide a system with three modules: Material Classification Module, Content Organization Module and Semantic Information Access Module. The Material Classification Module automatically classifies e-Learning resources to one or more concepts in the ontology. After that the resources are associated with the ontology by indexing and querying the material by a generic search engine using the concepts of the ontology. In the result set, resources having a ranking value greater than a minimum threshold will be assigned to the queried concept. The Content Organization Module is for teachers to create courses. They make course description files where they give the concepts which are needed in the course. The Semantic Information Access Module helps students to navigate or search the course topics. Ontology structures domain concepts so that students achieve more accurate or comprehensive results.

5 Ecological and environmental learning resources and metadata

It has been pointed out that the ecological and environmental science academic community still does not embrace the opportunities offered by the Internet technologies and that the strategy of developing e-Learning environments unfortunately falls far outside the mainstream of its university education. [24]. Currently, there are many academic e-Learning systems of which most influential ones are developed commercially [1].

5.1 E-Learning resources

Traditionally the digital learning resources for ecological and environmental science are Web pages, unstructured documents, numerical data files and numerical data in databases. The Web pages have both static XHTML-pages with hypertext and interactive elements, implemented by some programming language (e.g. With Java, In Silico biology E-learning Environment, [25]).

An example of a traditional learning environment at University level is Web-based e-Learning courses of "Biomedical Materials" (Xianoying et al. 2005). They have developed a teaching system for the course including construction of a multimedia courseware and Web-based e-Learning courses. The static material is text together with multimedia material like pictures, tables, illustrations, GIF animations, PowerPoint slides and Flash movies. Metadata is provided in the beginning of each paragraph (syllabus, emphases, key questions, learning target). They have not used XML-based structured documents at all and the metadata is presented as text on HTML-pages.

5.2 Examples of using Metadata for e-Learning

Ecological or environmental metadata may provide multiple levels of support for e-Learning, it may 1) support data discovery, 2) facilitate acquisition, comprehension and utilization of data by humans, and 3) enable automated data discovery, ingestion, processing and analysis [6]. The last of these levels require comprehensive and structured metadata.

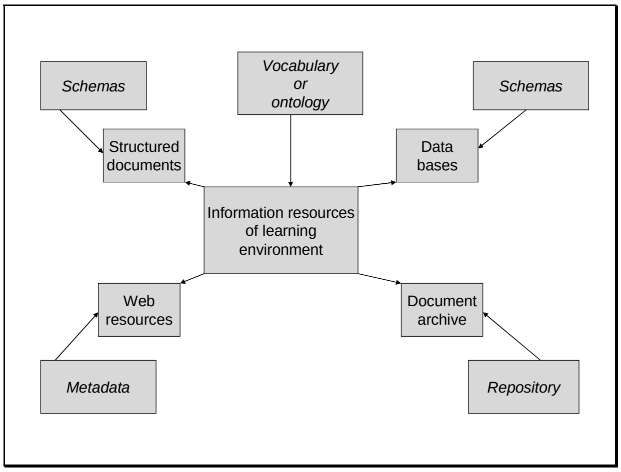

Figure 1. The resources of a learning environment and related metadata (italic) connected to them

E-Learning metadata may be attached to a repository of a document archive, schemas for databases and structured documents, metadata for Web resources and a vocabulary or ontology for the domain or discipline (Fig. 1).

Following example illustrates the use of PowerPoint slides, multimedia files and a conceptual schema, defining the connections between the concepts (Fig. 2). The slides and multimedia files are Learning Objects while the conceptual schema diagram on the left side of the screen provides a vocabulary and helps students to realize to connections between concepts and choose the path through the slides.

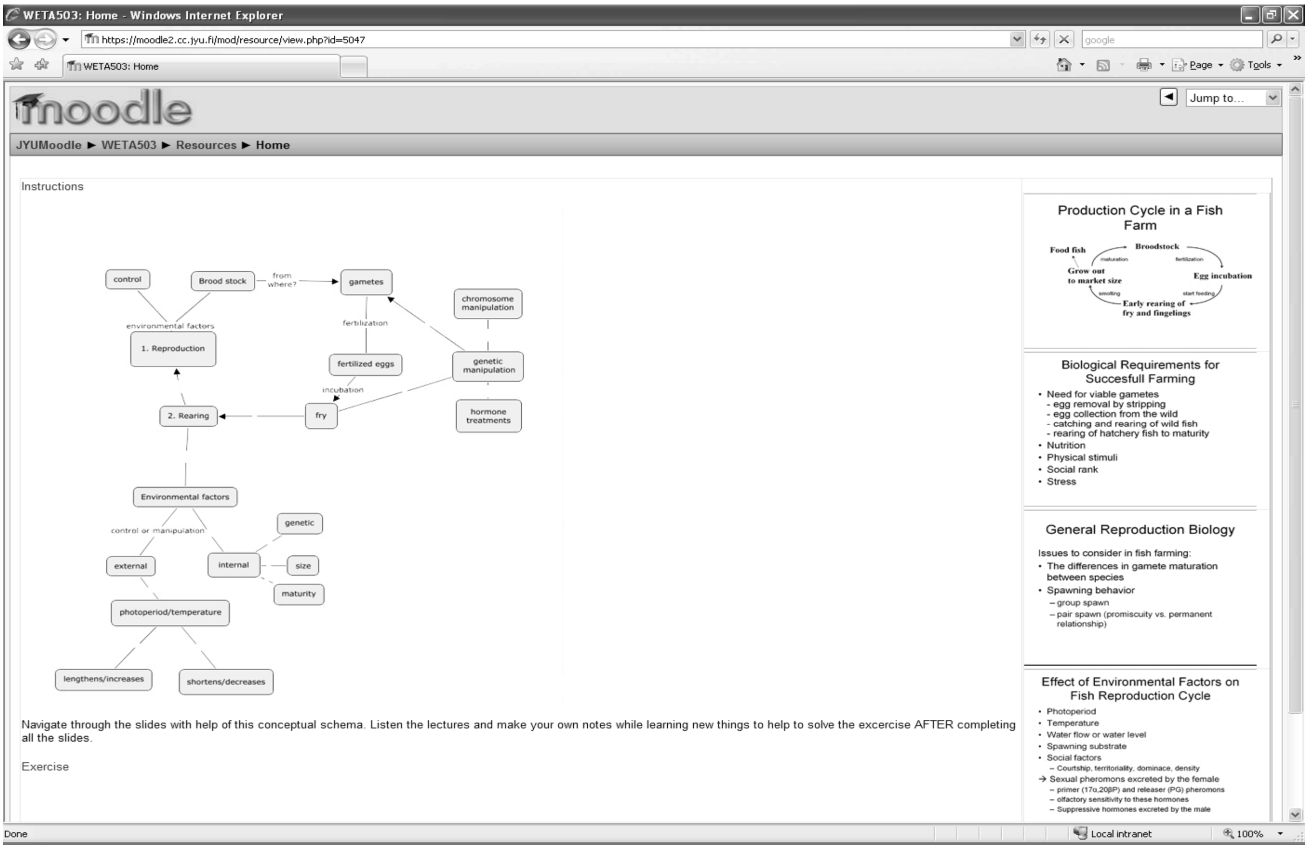

Figure 2. User interface for e-Learning environment with conceptual schema and links to multimedia files

Environmental and ecological research data consists of raw data and different kind of summaries made of it. The data can be geospatial, i.e. related to a geographical location. Numeric or encoded observations in tables can be seen as raw data. Interpreting the data requires understanding of the types of variables, measurement units, potential biases in the measurements, sampling methodology and so on, i.e., the metadata. The data can be searched by the metadata connected to the measurements: the unit and the geographical location (Fig. 3).

Environmental metadata may be seen as information about the data and the information required tounderstand it including data set contents, context, quality, structure, and accessibility [26]. Both data and metadata can be stored in local databases or they can be Web resources.

5.3 Metadata Development – Related Work

The examples on the previous chapter describe the use of metadata related to different kind of resources from slides to databases. And thus there is need for more consistent and broad metadata for connecting different resources and e-Learning contexts.

There are several environmental and ecological metadata specifications and many ongoing projects to produce widely accepted metadata and markup languages for environmental data. Long Term Ecological Research (LTER) Network is creating LTER sites for Europe [27]. ALTER-Net [28] is developing the capacity for research and monitoring of the sites. The goal of the ALTER-Net WP I6 issue is the creation of a framework for sharing data, information and software tools amongst the ALTER-Net partners in support of biodiversity research, policy and public understanding of science [29]. Very few of the partner institutes of ALTER-Net currently offer their data online. This is partly due to the lack of standards and unawareness of the functionality provided by the network technologies and participating communities within the networks.

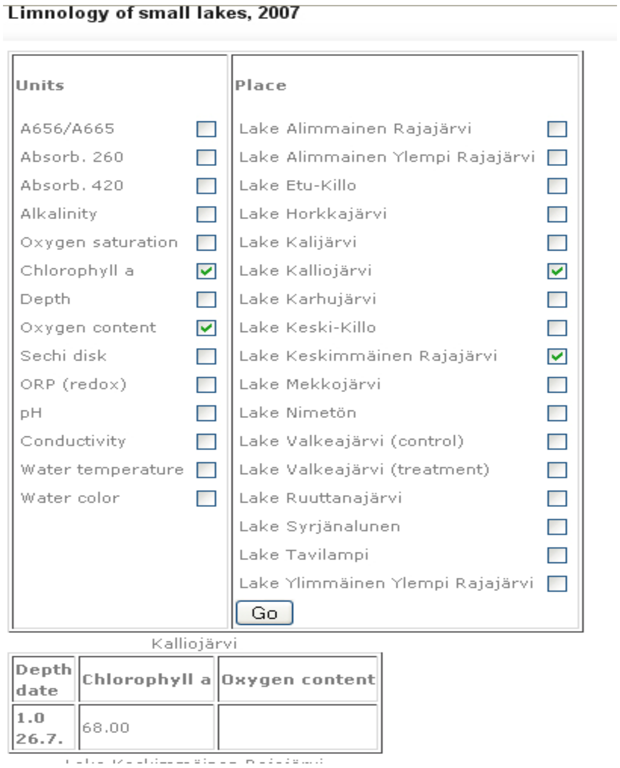

Figure 3. Metadata about database used for retrieving data from a course database

6 Markup Languages for Ecological and Environmental Science

In the beginning of this century Arndt et al. [30] developed the Environmental Markup Language in Germany. However it never became widely adopted in academic world and the research of this topic slowed down [31].

6.1 Ecological Metadata Language (EML)

The third example (Fig. 4) contents ecological data about measured amounts of individuals of some species, metadata about the measurements (location, date, sample size) and about the data package as a whole.

EML has been designed and developed by the ecological community to support data discovery, access, integration, and synthesis [33]. It is based on prior work done by the Ecological Society of America and associated efforts [26]. EML is implemented as a series of XML document types that can be used in a modular and extensible manner to document ecological data. Each EML module is designed to describe one logical part of the total metadata that should be included with any ecological dataset. EML was designed with many standards in mind. Those include Dublin Core, the Content Standard for Digital Geospatial Metadata (CSDGM from the US geological Survey's Federal Geographic Data Committee (FGDC)), the Biological Profile of the CSDGM (from the National Biological Information Infrastructure), the International Standards Organization's Geographic Information Standard (ISO 19115), the ISO 8601 Date and Time Standard, the OpenGIS Consortiums's Geography Markup Language (GML), the Scientific, Technical, and Medical Markup Language (STMML), and the Extensible Scientific Interchange Language (XSIL). EML is implemented in XML with schemas expressed as XML Schema schemas.

The EML module is a wrapper container that allows the inclusion of any metadata content in a single EML document. In EML, the definition of a resource comes from the Dublin Core metadata so that the top-level structure of EML has been designed to be compatible with the Dublin Core syntax. In EML, the definition of a "Data Package" is the combination of both the data and metadata for a resource. The metadata encoded by EML provides a formal description of what is inside a data set. For example, all metadata files contain the name of the person who collected the data, where data were collected, the types of sampled organisms or systems, a description of the structure of the data set, the meaning of abbreviated variable names, the units of measurement, searchable key words, etc. In addition Ellison et al. [33] proposed that the current structure of EML would be expanded to allow for a specification of the computational methods or statistical models used to derive data sets from raw data.

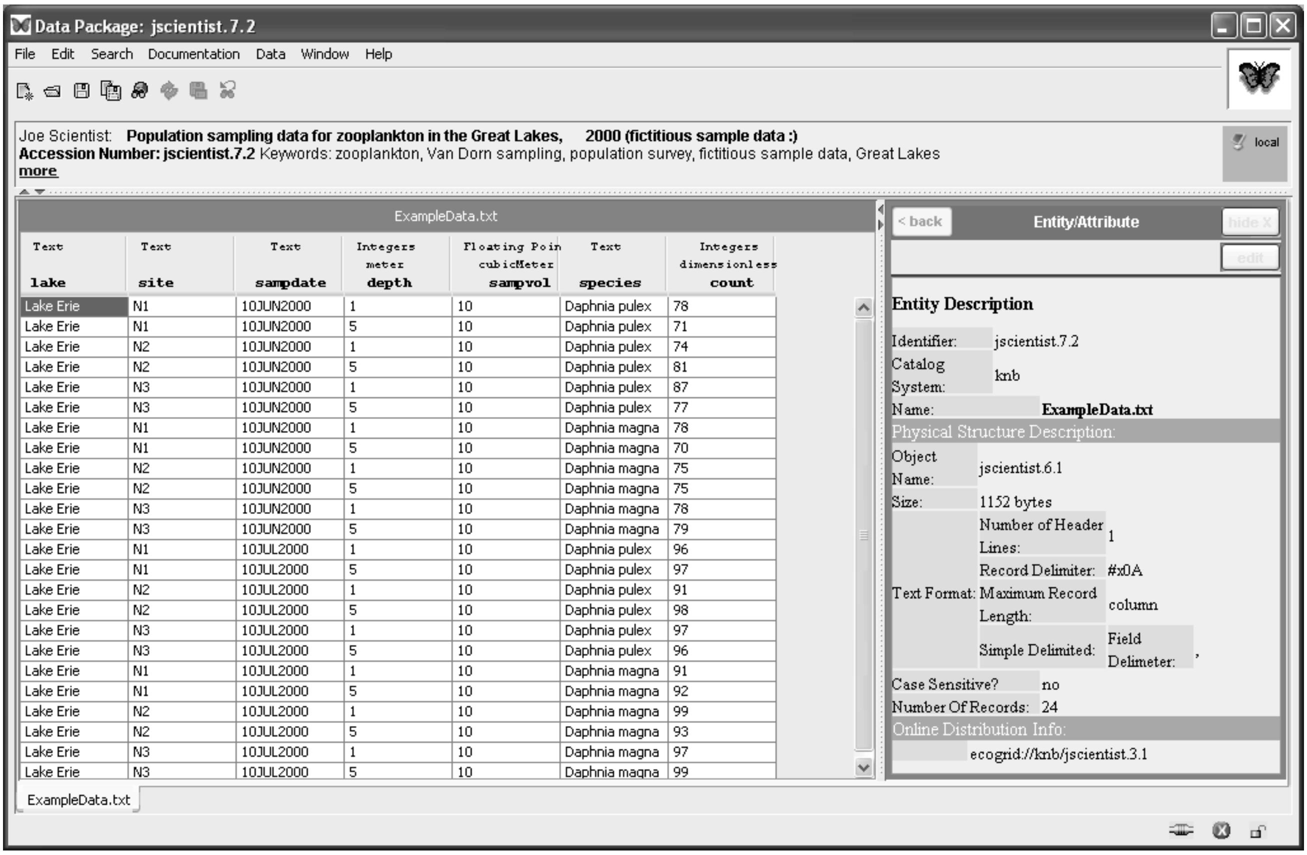

Figure 4. View to ecological species (water flea) data with metadata connected to individual measurements and to the data package as whole using Morpho 1.6.1. [32].

6.2 Geography Markup Language (GML)

The geographic information is the information that describes phenomena associated directly or indirectly with a location in respect to the Earth surface [34]. The geographic metadata describes the content, quality, condition and other characteristics of the data that allow to locate data and to understand them. The ISO-19115:2003 Geographic Information Metadata Standard is the most general standard available.

Geography Markup Language (GML) is an XML coding for the transport and storage of geographic information, including both the geometry and properties of geographic features. GML is defined by XML Schema language. It can be used both to represent or model geographic objects and to transfer them across the Internet. In this way it serves as the foundation for all geographic Web services. GML was intended to define geographic application languages and hence is applicable to any geographic domain including forestry, environmental sciences, geology and oceanography [35].

Geospatial applications are supported by databases or file systems that can handle spatial data types. Spatial data objects have spatial attributes, such as location, geometry and neighborhood properties. GML documents contain nested spatial data types, allowing various components of spatial data to be described. The GML specifications support both information storage and retrieval.

GML includes various kinds of XML schemas for describing features, geometries and topologies through a hierarchy of GML objects. The GML specification provides a series of schemas for describing geographic data in XML. The application schema applies relevant features and types needed for the specific domain in question [36].

Data marked with GML can be viewed with several software products. For example Snowflake [37] reads GML application schemas and show them as maps with selected themes (Figs. 5 - 6).

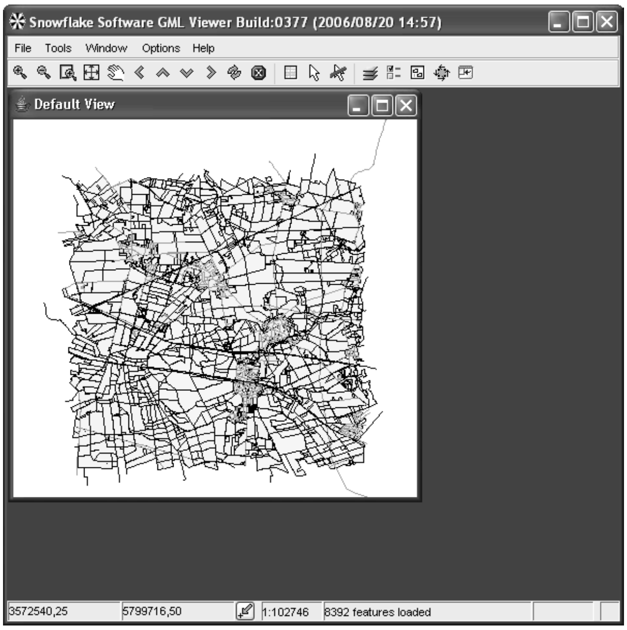

Figure 5. View from a data marked with GML using Snowflake.

Figure 6. Themes can be selected for the map view of Snowflake.

6.3 Towards Semantic E-Learning– Vocabulary and Ontology Development

Up to date generally no standards have been applied for environmental data resources, which can lead to problems in data exchange. It could also make it difficult to define a common ontology for the classification of data, which requires common concepts. Schentz et al. [38] have observed a strong interest in use of ontologies for data discovery as well as for harmonizing semantics for data transport. Most initiatives in this area are using OWL ontology language, which has the advantage of integrating services (OWL-S) into ontologies. This functionality would facilitate the integration of data with analysis and modeling tools.

In ALTER-Net the development of data sets for meta-information system with associated core ontology is the first step towards an eventual information framework [38]. After a thorough study of available technologies, Schleidt and Schentz [39] concluded that systems based only on XML and XML Schema schemas do not support semantics to the degree required. Relations between entries can not be fully annotated and there are no mechanisms for the extension of the schema. If an element must be extended, this is only possible by creating a new version of the entire schema. However, RDFS and OWL based systems cover most requirements, allowing the creation of ontologies in order to neatly structure and annotate the environmental data. Object oriented metadata structure has advantages of inheritance and it allows information of new individual classes to be communicated without having to transfer the entire schema. Also the relations of ontologies link data better to other data. As the American SEEK and US-LTER communities have started the development of ontologies for semantic annotation of ecological data, they strongly advised cooperation in this area.

A vocabulary of GEMET (GEneral Multilingual Environmental Thesaurus, [40]) has been developed as an indexing, retrieval and control tool for the European Topic Centre on Catalogue of Data Sources (ETC/CDS) and the European Environment Agency (EEA). It includes 22 different languages and it is divided to 40 different themes with 6562 terms. It defines a core of general terminology for the environment. Specific thesauri and descriptor systems (e.g. on Nature Conservation, on Wastes, on Energy, etc.) have been excluded and have been taken into account only for their structure and upper level terminology. The RDF-files of the thesaurus are downloadable.

Semantic Web for Earth and Environmental Terminology (SWEET) offers ontologies, which are written in the OWL ontology language [23]. The SWEET project provides a common semantic framework for various Earth science initiatives.

For example the beginning of a SWEET ontology, Bioshpere, looks like:

```
<?xml version="1.0" encoding="UTF-8" ?>
- <rdf:RDF
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-
syntax-ns#"
xmlns:owl="http://www.w3.org/2002/07/owl#"
xmlns:xsd="http://www.w3.org/2001/XMLSchema#
```

```
" xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
xmlns="http://sweet.jpl.nasa.gov/ontology/biosphere.owl#">
- <owl:Ontology rdf:about="">
  <owl:versionInfo>1.0</owl:versionInfo>
  </owl:Ontology>
  <owl:Class
rdf:about="http://www.w3.org/2002/07/owl#Thing" />
- <owl:Class rdf:ID="Vegetation">
  <rdfs:subClassOf rdf:resource="#Plant" />
  </owl:Class>
- <owl:Class rdf:ID="Lichen">
  <rdfs:subClassOf rdf:resource="#Plant" />
  </owl:Class>
- <owl:Class rdf:ID="Plant">
  <rdfs:subClassOf rdf:resource="#LivingThing" />
  </owl:Class>
- <owl:Class rdf:ID="Crop">
  <rdfs:subClassOf rdf:resource="#Plant" />
  </owl:Class>
-    <owl:Class rdf:ID="Leaf">
```

Protégé is a software product for editing OWL files [41]. A part of the Bioshpere ontology can be seen in an example from Protégé can (Fig. 8). With Protégé it is possible to add new classes (individuals) to the ontology and create new ontologies. In the example there have just added a new class named Cyanophyta to the class of Algae in Bioshpere ontology. This kind of taxonomy is very natural to biosphere. Ontology can be based on some common vocabulary like one used in Global Biodiversity Information Facility (GBIF, [42]).

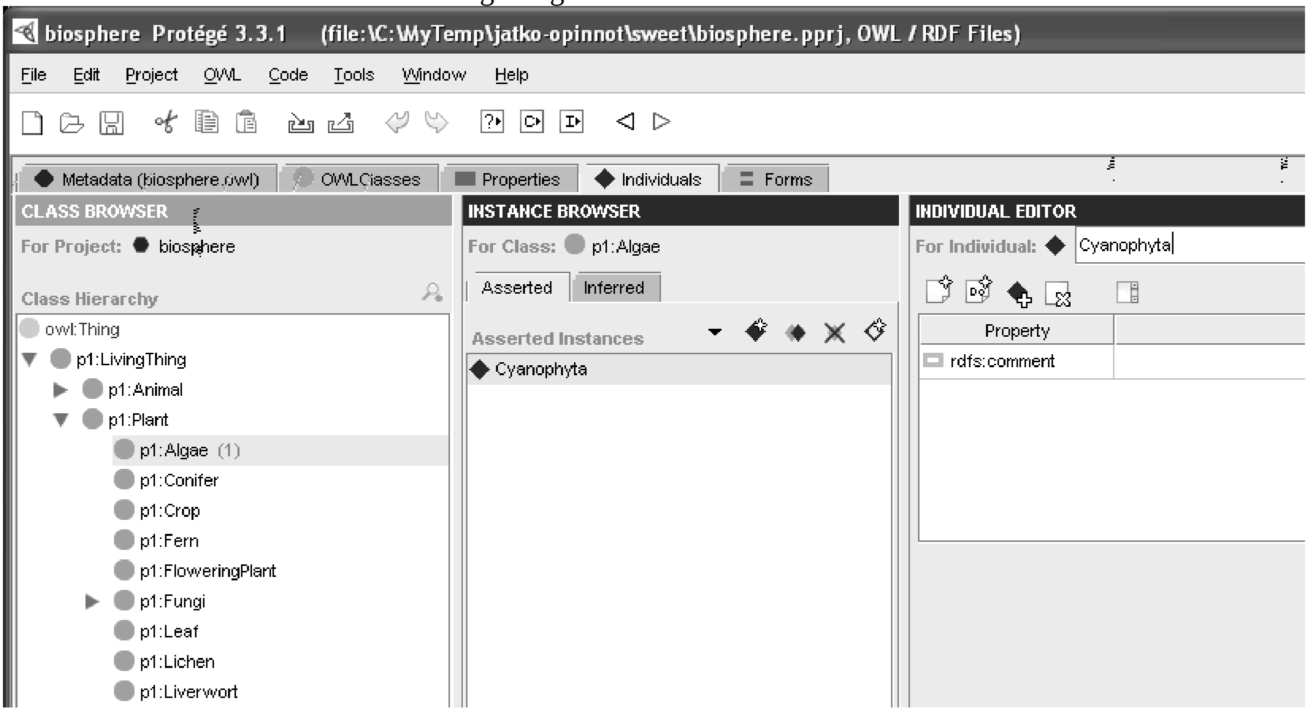

Figure 8. A part of a SWEET ontology (Bioshpere) viewed by Protégé

Bermudez and Piasecki [15] showed that it is possible to extend and reuse metadata specifications and vocabularies distributed by OWL ontology language, by utilizing the language’s flexibility to create restrictions on inherited properties. The domain specific ontologies can also be used to harvest entries from distributed resources on the Internet. Bermudez and Piasecki also developed a tool, Pangloss [43], that ties existing metadata descriptions and new metadata sets to form one comprehensive metadata realm.

7 Summary and conclusions

In ecological and environmental science the possibilities of e-Learning have still been only partly utilized. Interactivity with learning material and independence from time and place are unique for e-Learning. At the same time electronic material is free from fixed organization as pages that should be turned in order. Thus it can be freely organized in different ways for different purposes and even as tuned for different learners with different backgrounds and preferences.

A learner needs powerful means to orientate oneself on the information superhighway, similarly a teacher needs adequate tools to bring up the information available. Although LOM and DC facilitate the retrieval and use of learning materials, it has been pointed out that for understanding the semantic connections between Learning Objects semantic metadata is needed. It appends the metadata such as LOM or DC by providing explicit definitions of concepts and their semantic connections as well as the relationships between learning resources thus allowing teachers to organize and visualize major topics of the courses in respect to each other. For example in the course of Breeding and Farming Fish (Fig. 1) the conceptual schema, being connected to ontology, helps the teacher to organize the course material in respect to semantic connections between concepts irrespective the data system or file format. Semantic metadata based on domain ontologies also provides students with opportunities to interact with Web-based material and educational applications, and support semantic information access to resources relevant to topics students are interested in. Using ontology makes learning resources reusable and searchable for learning and research. It also allows the use of multiple kinds of Internet resources such as databases with metadata using the same vocabulary or learning objects from other learning environments.

For example a student of the course Breeding and Farming of Fish (Fig. 1, Fig. 9) could have while exploring the conceptual schema access to different kind of resources (for example Web pages and databases) through an umbrella of a top ontology which connects the concepts to other ontologies and metadata. One could search and find relevant material and better understand the topic s/he is learning and the connections between concepts and materials. For example one can use “fry rearing” as a search phrase and find other Learning Objects (using semantic metadata connected to them), definitions of the concepts “fry” and “rearing” and concepts connected to them (using domain ontologies), spatial data about fry rearing in her/his area (using metadata connected to data about farming statistics) and so on. For environmental factors affecting rearing one could search for relevant data from databases (using metadata) and for knowledge of the different fish species reared from data repositories having metadata written for example in EML .

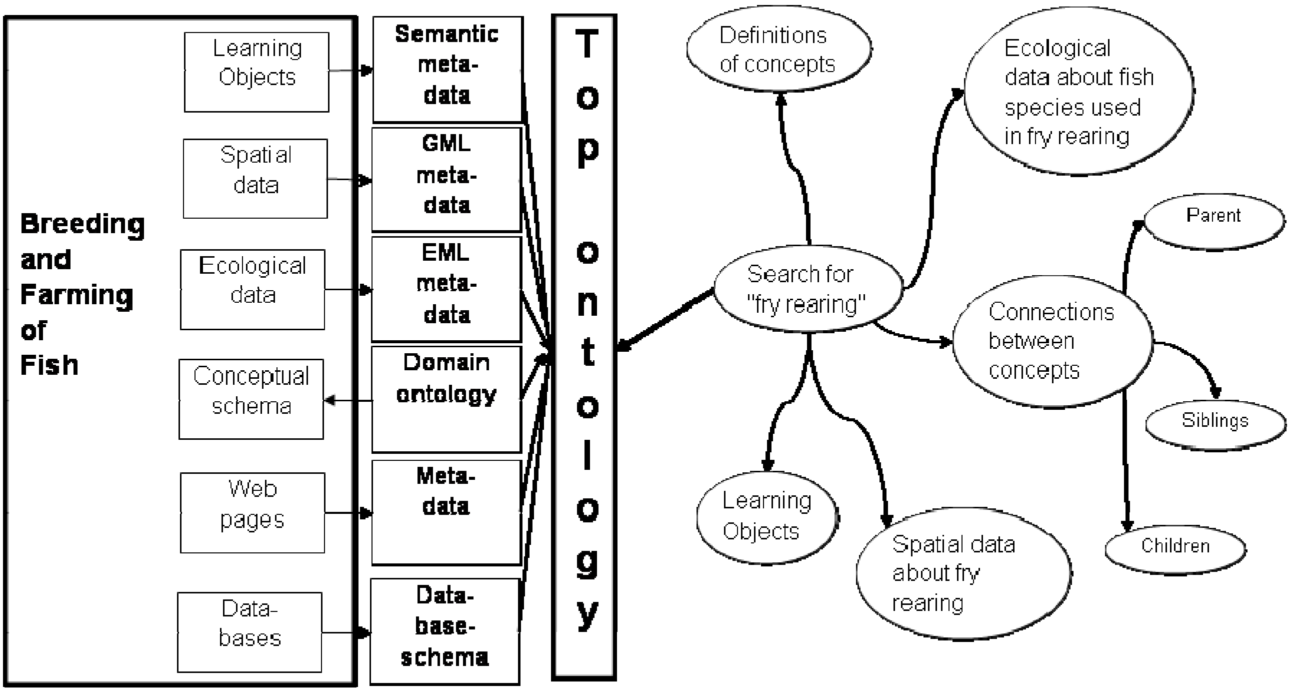

Figure 9. An example of a student searching for “fry rearing” using a top ontology for ecological and environmental science.

A student using semantic e-Learning environment has powerful tools to build mental structures of the topic. The underlying semantic structure can be used to connect the material to real world phenomena and data and the learning environment can offer tasks to be resolved. Such an e-Learning environment can support the constructive way of learning, task-orientation and self-directed activities [44]. Constructive way of learning gives more significance to the learning contexts as an alternative to the memorization and it helps to build knowledge, bringing activities closer to the real world. [45]

There is a need for a top ontology for e-Learning environments in ecological and environmental science. However connecting semantics to learning environments is a demanding task.

The Web Ontology Language (OWL) provides an object orientated approach for creating extensible ontologies. Such approach facilitates the creation of learning objects and environments with learning and domain specific, semantic metadata. For the discipline of ecological and environmental science EML, SEEK, US-LTER, GEMET and SWEET are a good basis for an ontology using the idea of reusing metadata specifications and vocabularies declared by OWL.

References:

[1] Mao M., Peng Y., He D., Ontology-Based Content Management and Access Framework for Supporting E-Learning Systems, *WI-IATW '06: Proceedings of the 2006 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology* , 2006.

[2] De Meo P., Garro A., Terracina G., Ursino D., Personalizing Learning Programs with X-Learn, an XML-Based, “user-Device” Adaptive Multi-Agent System, *Information Sciences* , Vol.177, No.8, 2007, pp. 1729-1770.

[3] IMS, *IMS Meta-Data Best Practice Guide for IEEE 1484.12.1-2002 Standard for Learning Object Metadata*, http://www.imsglobal.org/metadata/mdv1p3/imsmd_bestv1p3.html#1634949, 31.1.2008.

[4] Polsani P.R., Use and Abuse of Reusable Learning Objects, *Journal of Intelligent Information* , Vol.3, No.4, 2006, .

[5] Dortmund, *Ökocheckliste*, http://edu.biologie.uni-dortmund.de/, 31.1.2008.

[6] Hyperwave, *Hyperwave - eLearning*, http://www.hyperwave.com/e/technologies/elearning, 31.1.2008.

[7] e-Learning @ Jewell, *E-Learing@Jewell 2007,* http://moodle.jewell.edu/, 31.1.2008.

[8] Gilliland-Swetland A.J., Kafai Y.B., Landis W.E., Application of Dublin Core Metadata in the Description of Digital Primary Sources in Elementary School Classrooms, *Journal of the American Society for Information Science* , Vol.51, No.2, 2000, pp. 193-201.

[9] Haase K., Context for Semantic Metadata, *MULTIMEDIA '04: Proceedings of the 12th annual ACM international conference on Multimedia,* New York, NY, USA, ACM, 2004.

[10] Anido L., An Observatory for e-Learning Technology Standards, *Adv.Technol.Learn.* , Vol.3, No.2, 2006, pp. 99-108.

[11] AlKhalifa H.S., Davis H.C., The Evolution of Metadata from Standards to Semantics in E-Learning Applications, *HYPERTEXT '06: Proceedings of the seventeenth conference on Hypertext and hypermedia,* Odense, Denmark, ACM, 2006.

[12] Hatala M., Richards G., Eap T., Willms J., The Interoperability of Learning Object Repositories and Services: Standards, Implementations and Lessons Learned, *WWW Alt. '04: Proceedings of the 13th international World Wide Web conference on Alternate track papers \& posters,* New York, NY, USA, ACM, 2004.

[13] Sutton S.A., Mason J., The Dublin Core and Metadata for Educational Resources, *Conf. on Dublin Core and Metadata Applications 2001,* October 22-26, 2001, Tokyo, Japan, National Institute of Informatics, 2001.

[14] DCMI, *DCMI Metadata Terms*, http://dublincore.org/documents/dcmi-terms/, 30.1.2008.

[15] Bermudez L., Piasecki M., Metadata Community Profiles for the Semantic Web, *GeoInformatica* , Vol.10, No.2, 2006, pp. 159-176.

[16] Sheth A., Ramakrishnan C., Thomas C., Semantics for the Semantic Web: The Implicit,

the Formal and the Powerful, *International Journal of Semantic Web and Information Systems* , Vol.1, No.1, 2005, pp. 1-18.

[17] Fellbaum C., *WordNet: An Electronic Lexical Database*, Cambridge, Mass : MIT Press, c1998., 1998.

[18] Batini C., Battista G.D., Santucci G., Structuring Primitives for a Dictionary of Entity Relationship Data Schemas, *IEEE Trans.Softw.Eng.* , Vol.19, No.4, 1993, pp. 344-365.

[19] Gruber T.R., A Translation Approach to Portable Ontology Specifications, *Knowledge Acquisition* , Vol.5, No.2, 1993, pp. 199-220.

[20] Egenhofer M.J., Toward the Semantic Geospatial Web, *GIS '02: Proceedings of the 10th ACM international symposium on Advances in geographic information systems*, McLean, Virginia, USA, ACM, 2002.

[21] Tane J., Schmitz C., Stumme G., Semantic Resource Management for the Web: An e-Learning Application, *WWW Alt. '04: Proceedings of the 13th international World Wide Web conference on Alternate track papers \& posters*, New York, NY, USA, ACM, 2004.

[22] Horrocks I., PatelSchneider P.F., Three Theses of Representation in the Semantic Web, *WWW '03: Proceedings of the 12th international conference on World Wide Web*, Budapest, Hungary, ACM, 2003.

[23] SWEET, *SWEET Ontologies, Semantic Web for Earth and Environmental Terminology*, http://sweet.jpl.nasa.gov/sweet/, 31.1.2008.

[24] Kaczorowska A.K., Teaching on the Threats of Bioterrorism using an e-Learning Platform, *40th Meeting of the Polish Biochemical Society, Session 10: Didactics of biochemistry, molecular biology and biotechnology*, 19-23 September, Lublin, Polish Biochemical Society and of the Committee of Biochemistry and Biophysics, Polish Academy of Sciences, 2005.

[25] ISee, *In Silico Biology E-Learning Environment*, http://www-helix.inrialpes.fr/projects/ISee/, 31.1.2008.

[26] Michener W.K., Brunt J.W., Helly J.J., Kirchner T.B., Sripada L.N., Nongeospatial Metadata for the Ecological Sciences, *Ecological Applications* , Vol.7, No.1, 1997, pp. 330-342.

[27] LTER, *Long Term Ecological Research Network*, http://www.lternet.edu/, 26.3.2008.

[28] AlterNet, *ALTER-Net A Long-Term Biodiversity, Ecosystem and Awareness Research Network*, http://www.alter-net.info/, 26.3.2008.

[29] Schleidt K., Lane M., Schentz H., *Requirements for an IT Framework for ALTER-Net Results from t He Requirements Analysis Conducted by Work Package I6*, A Long-Term Biodiversity, Ecosystem and Awareness Research Network, http://www.alter-net.info/pooled/articles/BF_DOCART/view.asp?Q=BF_DOCART_196115, http://www.alter-net.info/SITE/UPLOAD/DOCUMENT/outputs%5CANet_WPI6_2005_01_IT_Requirements.pdf, 31.1.2008.

[30] Arndt H.K., Bandholtz T., Günther O., Rüther M., Schütz T., EML – the Environmental Markup Language, *Workshop Symposium on Integration in Environmental Information Systems*, May 30 to June 3, Zell am See, Austria, 2000.

[31] EIS, *Environmental Information Systems — School of Business and Economics*, http://www.wiwi.hu-berlin.de/Professuren/quantitativ/wi/forschung-en/uis/view?searchterm=environmental*, 31.1.2008.

[32] Morpho, *The Knowledge Network for Biocomplexity, Morpho User Guide*, http://knb.ecoinformatics.org/software/morpho/, 31.1.2008.

[33] Ellison A.M., Osterweil L.J., Clarke L., Hadley J.L., Wise A., Boose E., Foster D.R., Hanson A., Jensen D., Kuzeja P., Riseman E., Schultz H., Analytic Webs Support the Synthesis of Ecological Data Sets, *Ecology* , Vol.87, No.6, 2006, pp. 1345-1358.

[34] Nogueras-Iso J., Zarazaga-Soria F.J., Lacasta J., Béjar R., Muro-Medrano P.R., Metadata Standard Interoperability: Application in the Geographic Information Domain, *Computers,*

Environment and Urban Systems , Vol.28, No.6, 2004, pp. 611-634.

[35] Lake R., The Application of Geography Markup Language (GML) to the Geological Sciences, *Computers & Geosciences* , Vol.31, No.9, 2005, pp. 1081-1094.

[36] Smits P.C., Friis-Christensen A., Resource Discovery in a European Spatial Data Infrastructure, *Transactions on Knowledge and Data Engineering* , Vol.19, No.1, 2007, pp. 85-95.

[37] Snowflake, *Snowflake Software - GML Viewer*, http://www.snowflakesoftware.co.uk/products/gmlviewer/, 31.1.2008.

[38] Schentz H., Schleidt K., Lane M., *Functional Concept for a Biodiversity and Ecological Network,* A Long-Term Biodiversity, Ecosystem and Awareness Research Network, http://www.alter-net.info/pooled/articles/BF_DOCART/view.asp?Q=BF_DOCART_196115, http://www.alter-net.info/SITE/UPLOAD/DOCUMENT/outputs%5CANet_WPI6_2006_04_Network_Concept.pdf, 31.1.2008.

[39] Schleidt K., Schentz H., *Metadata Required for and ALTER-Net Data and Application Network,* A Long-Term Biodiversity, Ecosystem and Awareness Research Network, http://www.alter-net.info/pooled/articles/BF_DOCART/view.asp?Q=BF_DOCART_196115, http://www.alter-net.info/SITE/UPLOAD/DOCUMENT/outputs%5CANet_WPI6_2006_03_Metadata_Report.pdf, 31.1.2008.

[40] GEMET, *Themes List*, *Thesaurus Version 1.0,* 2004, http://www.eionet.europa.eu/gemet, 31.1.2008.

[41] Protégé, *The Protégé Ontology Editor and Knowledge Acquisition System,* http://protege.stanford.edu/, 31.1.2008.

[42] GBIF, *GBIF Portal: Home,* http://www.gbif.org/, 31.1.2008.

[43] Pangloss, *Metadata for Semantic Web,* http://loki.cae.drexel.edu:8080/~how/pangloss/, 31.1.2008.

[44] Conole G., Dyke M., Oliver M., Seale J., Mapping Pedagogy and Tools for Effective Learning Design, *Computers and Education,* Vol.43, No.1-2, 2004, pp. 17.

[45] Moreno L., Gonzalez C., Castilla I., Gonzalez E., Sigut J., Applying a Constructivist and Collaborative Methodological Approach in Engineering Education, *Computers & Education,* Vol.49, No.3, 2007, pp. 891-915.