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AN E-LEARNING SEMANTIC GRID FOR LIFE SCIENCE EDUCATION

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Abstract. There are a lot of life science databases and services on the Internet nowadays, especially in life science e-science. In this paper, we will present an E-Learning Semantic Grid that integrates these resources provided by both teachers and scientists for life science education. It uses domain ontologies to integrate these heterogeneous life science database and service resources, and supports ontology-based e-learning data-sharing and service-coordination for life science teachers and students in an e-learning virtual organization. Our system provides life science students with semantically superior experience in learning activities, and also extends the function of life science e-science. It has a promising future in the domain of life science education.

Keywords: E-learning, semantic grid, e-science, life science education, resource sharing, service coordination

1 INTRODUCTION

Today, there are thousands of different life science databases with contents ranging from gene-property data for different organisms to brain image data for patients with neurological disorders [26]. Also there are countless services for life science research papers to be published on the Internet. E-science intends to integrate heterogeneous database and collaborates various service in life science research domain. It greatly helps scientists collaborate in their research efforts.

One of the main driving froces of e-science in life science is the "data deluge". The volume of scientific data generated by highly instrumented research projects (linear accelerators, sensor networks, satellites, seismographs, etc.) is so great that it can only be captured and managed through information technology. The amount of data far exceeds the capability of any manual techniques for data management, and thus the need of control over the data becomes the essential driving force of e-science in life science. Once part of the data can be made available for other application, such as e-learning (learning platform on the Internet), it helps life science education greatly, and also there will be many other opportunities, economically and politically, to leverage the investments in life science e-science. Besides the data, part of the web services in e-science could also be made available for e-learning applications. It makes the function of learning platform more extendable.

When scientists provide part of the e-science resources to our e-learning system, the system construction becomes very complicated. Mainly, there are two kinds of resources in our e-learning VO (Virtual Organization). One comes from life science teachers and is designed and structured mainly for life science education; the other comes from life science scientists in e-science and is designed and structured mainly for life science research. These two kinds of resources differ to each other greatly. On top of that, the resources provided either by teachers or scientists come from different organizations, which are distributed and decentralized geographically. Therefore, the learning resources in e-learning VO are greatly different and heterogeneous to each other. The massive volume and their diversity nature make it quite difficult to achieve a seamlessly integrated e-learning for life science students. The heterogeneity and distribution of the independently designed and maintained resources are the main target for the development of our e-learning system. In short, information integration and service coordination are the two main challenges to our e-learning VO.

In this paper, we will present an e-learning platform based Semantic Grid. The platform is designed and developed as a layered structure to deal with the requirements of life science students and teachers. The proposed method aims at facilitating the integration and reusing of distributed life science database and service resources. It uses domain ontology to integrate life science database resources and services in a semantic cyberspace and provides users with semantically superior experience including browsing, and querying.

The rest of the paper is organized as follows: In Section 2, we introduce the basic technical approach about how our e-learning platform is implemented. In

Section 3, we present the use case diagrams and the architecture of this platform. In Section 4, we give the definition of our e-learning metadata, and also the design of our e-learning ontology. In Section 5, we present the implementation of ontology-based e-learning data sharing on our e-learning platform. In Section 6, we present the implementation of ontology-based service coordination. Section 7 gives an overview of related works and Section 8 concludes this paper with an outlook to future research directions.

2 TECHNICAL APPROACH

2.1 Semantic Grid

The Semantic Web is an effort to improve the current Web by enriching current Web resources with machine-understandable semantics [5, 6]. It provides a common framework that allows data to be shared and reused across applications, enterprises, and community boundaries. It is based on the Resource Description Framework (RDF), which integrates a variety of applications using XML as syntax and URIs for naming. The Semantic Grid [4] is an Internet-based interconnection environment which effectively organizes, shares, clusters, fuses, and manages globally distributed versatile resources based on the interconnection semantics. In short, the Semantic Grid [7] vision is to achieve a high degree of easy-to-use and seamless automation in an effort to facilitate flexible collaborations and computations on a global scale. It takes advantage of machine-understandable knowledge on the Grid.

Heterogeneous resources in life science could be easily integrated through the technology of Semantic Grid. We have built a semantic grid to provide the necessary support for the implementation of our e-learning platform.

2.2 RDF and OGSA/WSRF

At present, the most popular languages for data semantics are RDF framework and OWL language. OWL language is proposed in Semantic Web research area and standardized by W3C organization. The Resource Description Framework (RDF) is a language to describe web information in the least constraining way. However, it is still extensible and meaningful. The RDF structure is generic in the sense that it is based on the Directed Acyclic Graph (DAG) model. RDF is based on the idea of identifying things using Web identifiers (called Uniform Resource Identifiers, or URIs), and of describing resources in terms of simple statements about the properties of resources. Each statement is a triplet consisting of a subject, a property and a property value (or object). For example, the triple (“`http://example.org`”, ex:createdBy, “Wenya”) has the meaning of “`http://www.example` has a creator and its value is Wenya”.

RDF also provides a way to define classes of resources and properties. These classes are used to build statements that assert facts about resources. While the grammar for XML documents is defined by DTD or XSchema, RDF uses its own syntax (RDF Schema or RDFS) to write a schema for resources. RDFS is expressive and includes sub-class/super-class relationships as well as constraints on the statements. The generic structure of RDF makes it easier for data interoperability and evolution because different types of data can be represented using the common graph model, and it also offers greater value for data integration over disparate web sources of information. OWL is an extension of RDF/RDFS and supports more sophisticated knowledge representation and inference.

In our work, RDF is used to describe the semantics of e-learning data and define the e-learning ontology in order to integrate heterogeneous databases and services.

OGSA/Web Service Resource Framework focuses on service-oriented architecture for grid application[20]. In a grid, computational resources, storage resources, networks, programs, databases are represented as services. A service-oriented view allows us to address the need for a standard interface definition mechanism, local/remote transparency, adaptation to local OS services, and uniform service semantics. The open source Globus Toolkit is a fundamental technology for the "Grid", that enables people to share computing power, databases, and other tools securely online across corporate, institutional, and geographic boundaries without sacrificing local autonomy. The toolkit includes software services and libraries for resource monitoring, discovery, and management, plus security and file management.

In our work, the e-learning services conform to the OGSA/WSRF specification, and are implemented based on Globus 4 toolkit. Globus 4 is also used as the service container for the e-learning grid application.

3 USE CASE DIAGRAM AND SYSTEM ARCHITECTURE

3.1 The Use Case Diagram of E-Learning System

Before constructing our e-learning platform, the requirement analysis of our system should be conducted. It will help the construction and implementation in the end. There are three actors and fourteen use cases in the Use Case Diagram of the system, illustrated by Figure 1.

The actors of e-learning platform are life science students, life science teachers and life science scientists. From the Use Case Diagram, we can find that the e-learning resources for life science education are mainly provided by life science teachers and life science scientists. The resources provided by life science scientists are parts of the resources in life science e-science, we make them available to e-learning to improve the function of life science e-science and provide the life science education more exposures. On this e-learning platform, a teacher will give students learning tasks and provide them with the learning schema. As a result, life science students will take part in a series of learning processes by using the semantic toolkits supported by e-learning platform. Teachers and students share three use cases including Resource Browse, Resource Download and Resource Search. All these cases

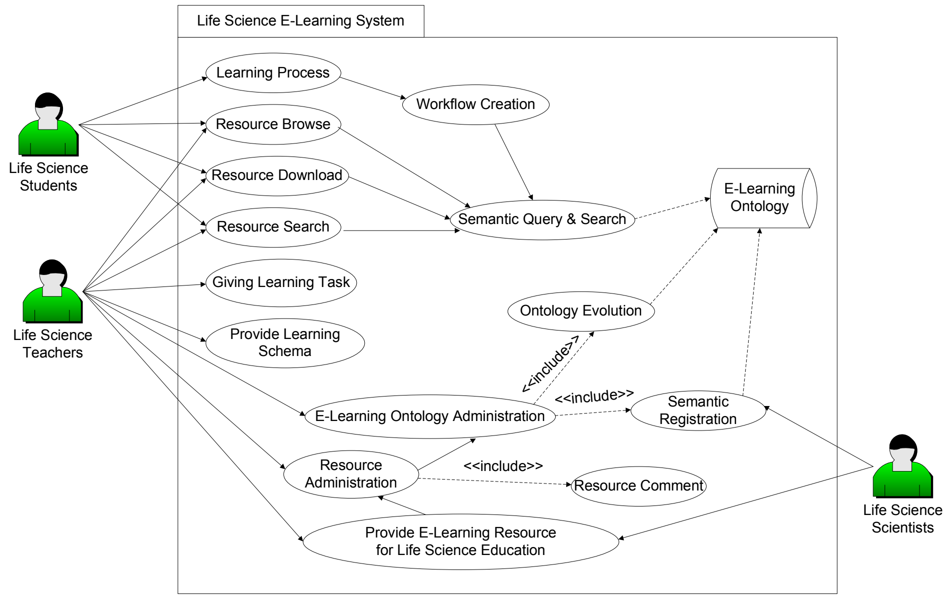

Fig. 1. The Use Case Diagram of e-learning system

are associated with Semantic Query & Search use case. This e-learning platform provides teachers and students with semantic Query & Search for e-learning resources. When the new resources are provided to e-learning platform, teachers should give these new resources standardized annotations, which will facilitate the integrating of heterogeneous resources coming from decentralized nodes. Resource administration and e-learning ontology evolution are also one of teachers' responsibilities to maintain our platform.

3.2 The Architecture of E-Learning Platform

After the requirement analysis of our system is done by constructing a Use Case Diagram mentioned before, we would like to present the architecture of e-learning platform now. In our approach, a life science e-learning platform is composed of client and server sides. According to the Use Case Diagram of our system, the server side is designed and developed as a layered structure including resource layer, semantic layer and function layer as Figure 2 illustrates.

3.2.1 E-Learning Resources

At the bottom of our system architecture, there are two kinds of resources provided to e-learning platform. One is provided by life science teachers. These resources always are basic database for e-learning (Exam Lib, Courseware Lib, etc.) and

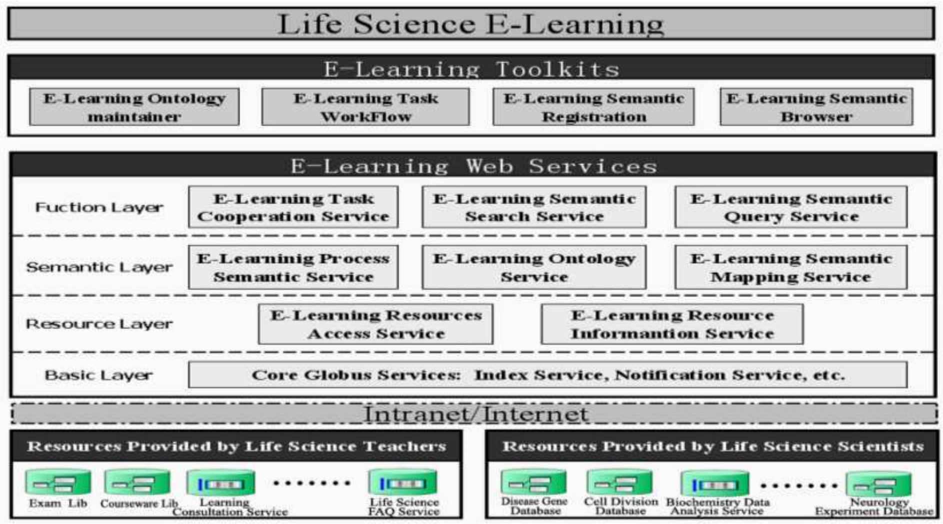

Fig. 2. The Abstract Architecture of e-learning Platform

services (Learning Consultation Service, Life Science FAQ Service, etc.), especially for life science education. The other one is provided by e-science as part of the resources used by scientists in life science e-science. These resources are database storing life science experiment results, lib for records of frontier research, experiment data analysis service, life science experiment reports and so on. When these e-science resources are used and referenced in the process of life science learning, life science students will understand some life science knowledge more easily and quickly. It also helps extend the function of resources in life science e-science. This combination of e-science and e-learning will generate many chances for the development of life science education and research. These two kinds of resources are distributed on different nodes in network and heterogeneous to each other. We should integrate these heterogeneous database and services in a semantic cyberspace on our e-learning platform.

3.2.2 E-Learning Web Services

As the core of the system architecture, e-learning Web Services runs at the e-learning Server and provides many e-learning web services based on semantic grid to achieve semantic-based learning activities. There are four layers in the e-learning Web Services Server, namely Basic Layer, Resource Layer, Semantic Layer and Function Layer.

The basic layer contains some core Grid services from the Globus platform. The whole e-learning system is built on these Grid services that provide the basic communication and interaction mechanism for life science e-learning.

The resource layer mainly supports the typical remote operations on the contents of databases on the Web and inquiring about the meta-information of databases. There are two services provided by this layer. *E-Learning Resource Access Service* supports the typical remote operations on the contents of databases on the Web. To relational databases, the operations contain query, insertion, deletion, and modification. *E-Learning Resource Information Service* supports inquiring about the meta-information of databases including relational schema definition, DBMS descriptions, privilege information, and statistics information (CPU utilization, available storage space, active session number, etc.).

The semantic layer is mainly designed for semantic-based information manipulation and integration. This layer contains three services. *E-Learning Process Semantic Service* is used to export services as OWL-S descriptions. *E-Learning Ontology Service* is used to expose the shared life science e-learning ontology and provides basic operations on the ontology. Ontology is used to mediate and integrate heterogeneous databases and services on the Web. *E-Learning Semantic Mapping Service* establishes the mappings from local resources to the e-learning ontology. Semantic Mapping Service maintains the mapping information and provides the mechanism of registration and inquiring about the information of e-learning resources.

The function layer provides life science teachers and students with semantically superior experience including semantic search, semantic query and collaborative service to support collaborative learning task and information sharing. *E-Learning Semantic Query Service* accepts ontology-based semantic query, inquires of Semantic Mapping Service to determine which database are capable of providing the answer, then rewrites the ontology-based queries in terms of database schema. A semantic query can be ultimately converted into a set of SQL queries. The results of SQL queries will be wrapped by semantics and returned as triples. *E-Learning Semantic Search Service* indexes all databases that have been mapped to mediated ontology and accepts semantic-based full-text search. The standard classes and instances from the e-learning ontology are used as the lexicon in establishing indexes. *E-Learning Task Cooperation Service* can discover and coordinate various services in a workflow to support the high-level learning activities in a virtual community for life science students.

3.2.3 E-Learning Toolkits

E-learning Toolkits is a set of toolkits running at the client site. They are interfaces for life science teachers and students to perform the life science education via network. Teachers and students could be facilitated by these semantic-based toolkits in information sharing and collaborative learning task. To provide the e-science resources for e-learning, life scientists also use E-Learning Semantic Registration toolkit to register the e-science resources for resources sharing between teachers and students.

4 THE METADATA DEFINITION AND E-LEARNING ONTOLOGY

As the foundation of the Semantic Web, ontology is the specification of conceptualizations to help programs and humans share knowledge [15]. In real applications, different ontologies focus on different domains and could even have different views of the same domain. Ontologies are also developed in light of different applications and consequently with the logic that is only appropriate for these applications [24]. The main aim of life science e-learning platform is to facilitate the life science education for students and the design and development of our e-learning ontology should focus on this goal.

In this section, we will first present the definition of e-learning resources metadata which is associated with e-learning ontology in a mutual way; then we will present the design of our e-learning ontology.

4.1 Definition of Metadata

Metadata is the total sum of what one can say about any information object at any level of aggregation, considering that an information object is anything that can be addressed and manipulated by a human or a system as a discrete entity [12]. Metadata enable effective search of resources across multiple repositories since dealing with descriptive surrogates of resources is easier than dealing with the resources themselves. The metadata can standardize description of all e-learning resources, but it has no semantic mechanism. Only after the e-learning ontology is associated with the metadata, the e-learning resources sharing and services coordination could be realized on our platform. Before the development of e-learning ontology, we define the metadata of e-learning resources to give a reference to the design of e-learning ontology.

According to life science learning, searching the learning resources refers to the following actors. Firstly, we should take the resources content into consideration; secondly, the context should also be considered. Thirdly, the resources are linked to each other. We should consider the relationship among all earning resources. Therefore, the element of content, context, and relationship should be included in our metadata. There are many standards (DCMES, DC-Education, CELTS-3, etc.) [10] for defining learning resources metadata. In the definition of our e-learning resources metadata, we choose DC-Education standard and take seven elements from DC-Education as the elements of our metadata. The e-learning resources metadata for our platform are defined in Table 1.

There are twelve elements in e-learning resources metadata; seven of them are taken from DC-Education standard, and the other five ones are defined according to the requirement of our e-learning platform. Unlike XML, RDF can provide semantic description ability for e-learning resources metadata. Therefore, we chose the RDF binding to bind the metadata with corresponding e-learning resources.

Elements	Meaning	Elements	Meaning
dc:title	The name of e-learning resource	dc:creator	The creator of e-learning resource
dc:subject	Description	cou:Course	Corresponding course of resource
dc:description	Description of resource subject	cou:Know-ledgePoint	The content of e-learning resource
dc:language	The language of resource	ext:Context	The context of e-learning resource
dc:date	The creation date of resource	str:Prev-Resource	The previous e-learning resources
dc:type	The type of e-learning resource	str:Next Resource	The next e-learning resource

Table 1. The definition of e-learning resource metadata

4.2 The Design of E-Learning Ontology

According to the Use Case Diagram and the definition of e-learning resource metadata, we construct three ontologies to build the whole e-learning ontology of the system. The three ontologies are Course Ontology, Content Ontology, and Context Ontology. Now, we will present the way how we have built each one of them.

4.2.1 Course Ontology

Course Ontology describes the concepts and attributes of a life science course. In Course Ontology, six classes are defined to describe the life science course. They are *CourseSort Class, Course Class, Creator Class, Content Class, Context Class* and *Structure Class*. We also have defined four types of ObjectProperty for Course Ontology, they are *BelongTo Property* which illustrates the relationship between life science courses, *PriorTo Property* which illustrates the learning sequence of life science courses, *RelatedContent Property* which illustrates the association between Content Ontology and Course Ontology and *RelatedContext* property which illustrates the association between Context Ontologies. Course Ontology has reused five attributes from Dublin Core Standard including dc:title, dc:description, dc:date, dc:subject, and dc:creator. The last attribute illustrate the creation relationship between *Course Class* and *Creator Class* while others illustrate the information of the course. The other attributes defined for Course Ontology are dc:title, BelongTo, RelatedContent, RelatedContext and RelatedStructure; all of them could have only one value.

4.2.2 Content Ontology

Content Ontology describes the basic concepts and the relationship of concepts in the process of life science learning. For example, Gene Mutation is part of the Genomic course and the Genomic is part of Genetics. Therefore, the Content Ontology describing Genetics should take "is part of" as one of its relationships and also should have the inferable mechanism upon this relationship. When users are searching the information on Gene Mutation, e-learning can help them figure out that the information about Gene Mutation could be found in the Genetics information. This design makes the search on life science resources more efficient. According to the above analysis, a *KnowledgePoint* Class and four ObjectProperties including *ConceptOf Property, SubConceptOf Property, Pre Property* and *Next Property* are defined for the Content Ontology. The *KnowledgePoint Class* describes the knowledge point for life science learning and its attribute is dc:Title. The *ConceptOf Property* and *SubConceptOf Property* describe the relationship between including and included. These two ObjectProperties are TransitivProperty and mirror to each other. The *Pre Property* describes the direct pre-relationship between two KnowledgePoints, while the *Next Property* describes the direct next-relationship between two KnowledgePoints. They also mirror to each other.

4.2.3 Context Ontology

Context Ontology describes the concepts and relationships when e-learning resources are put into context condition. The context of e-learning can be built by Example, Introduction, Exercise, RelatedResource, FAQ, and so on. Using the describing e-learning resources, the Context Ontology can help the users do context-relation search. For example, a life student wants to have a deep understanding of a biology subject on our e-learning platform; s/he needs to get an example about this subject. When s/he does the semantic search for example about the corresponding subject, e-learning platform will perform a context-relation search according to the Context Ontology. In the end, the user not only gets the explanation of this subject, but also gets the examples about this subject. The e-learning platform facilitates the learning process of life science students greatly through Context Ontology. The mode of Context Ontology was illustrated in Figure 3. Six classes are defined, namely *Context Class, FAQ Class, Introduction Class, Exercise Class, Example Class* and *RealtedResource Class*. The relationship between *Context Class* and the other classes is listed below and we could use the subClass of relationship in OWL to define it.

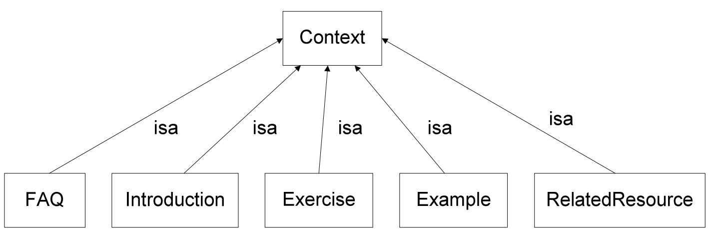

Fig. 3. The Mode of Context Ontology

5 ONTOLOGY-BASED E-LEARNING DATA SHARING

We integrate the decentralized and heterogeneous e-learning database as a global virtual database by using ontology semantics. The database sharing for life science students and teachers will become more easily achieved when e-learning ontology is involved. In this section, two semantic-based toolkits will be introduced and they can help users integrate and share e-learning information in distributed databases.

5.1 Semantic Registration

Relational schemata of distributed databases provided either by scientists or teachers are mapped to our e-learning ontology according to their intrinsic relations. To facilitate the process of semantic mapping between the schemata of database and the semantics of our mediated ontology, we have developed a visual tool called Semantic Registration for integrating relational databases in a semantic way. The tool provides two major functions: establishing semantic mapping from heterogeneous relational database to the mediated ontology semi-automatically, and converting relational databases schema to ontology statements based on the semantic mapping information.

As Figure 4 shows, the user can use the database resource panel (the upper-left part of Figure 4) to view the table and column definition of the relational database, and use the ontology browsing panel (the low-left part of Figure 4) to browse the RDF ontology graphically. The user can then specify which RDF class and property one table column should be mapped onto. Mapping result can be exported as XML files and reused by applications.

Semantic Registration is always used by scientists or teachers to provide local resources to e-learning platform. The mapping operation is also a semantic registration process. It will register the local resources in the e-learning ontology at Semantic Registration Center. For example, after finishing an experiment report about an experiment of Cell Division, a biology scientist stores the report into local experiment report database. S/he wants to provide this report to e-learning platform because his/her experiment report could help students understand this knowledge point more clearly. S/he would then use the Semantic Registration to register the experiment report about Cell Division. S/he fills out each item of the metadata for his/her experiment report to finish the mapping process. Semantic Registration directly registers the experiment report to the Semantic Registration Center. It is a semantic mapping from the local experiment report database to the sharing semantic ontology. During the registration, mapping information is written into a semantic registry. The experiment report about Cell Division is not uploaded to the registration center or other centralized nodes. When a life science student wants to understand the Cell Division better, s/he will search resources about Cell Division on the e-learning platform. Semantic Registration Center will look up the records in the registration table and find out the record about the Cell

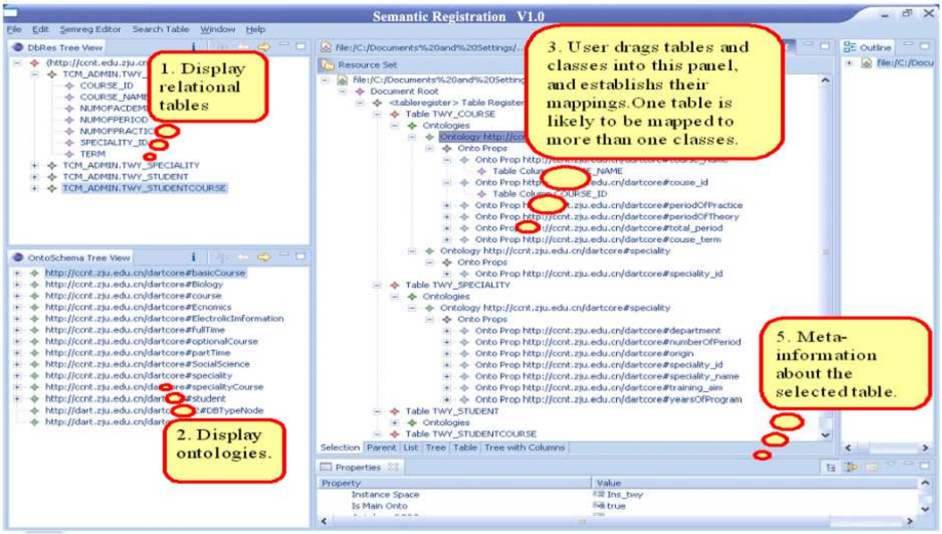

Fig. 4. Semantic Registration

Division experiment report mentioned before. And then the student will browse this experiment report to learn more about Cell Division from the corresponding node in e-science directly.

5.2 Semantic Browser

A Web-based tool called Semantic Brower is provided for life science students and teachers to dynamically query over distributed databases. Users can search the frontier life science information provided by scientists on this e-learning platform. The information comes from the distributed nodes, but users will feel as if they were doing the search on the same database at a server. This form-like query interface is intended to facilitate the life science teachers and students in constructing semantic queries on e-learning platform. Now, we would like to introduce a scenario to illustrate the data sharing mechanism through Semantic Browser.

Steven is an undergraduate student whose major is bioengineering. He wants to have a deep understanding of the plant cell which is a very important knowledge point for life science students. He types in "Plant Cell" as the keyword and submits it (the upper-right part of Figure 5). The Semantic Browser automatically constructs the semantic query into SPARQL query language, which is the standard semantic query language proposed by W3C. Then, this semantic query would be submitted to the semantic query service and translated into a set of SQL queries according to the mapping information between database schemata and the e-learning ontology. The SQL queries are then dispatched to specific databases for information retrieval. The query would return all satisfactory records from databases that are mapped to the ontology. The system would convert the database record-set into a data stream in RDF/XML format. Finally, there are 6 results appearing on the result panel for Steven to learn this knowledge point more extensively (the low-right part of Figure 5). Each result has five attributes. They are Name, Provider, Context, Keyword, and Date. Illustrated in the low-right part of Figure 5, the third and sixth learning resources come from e-science while the others come from teachers. The knowledge point, "Plant Cell", could be preliminarily learned in the first learning resource called "Discussion on Plant Cell". It was not enough to get a deep understanding of "Plant Cell" by reading over the first learning resource only. Fortunately, there are additional five learning resources providing relevant knowledge point for him to learn "Plant Cell" more comprehensively. It helps Steven greatly in learning "Plant Cell". These six learning resources are distributed at the decentralized nodes in the network; and their format and design are heterogeneous to each other. But Steven feels as if he learned the knowledge point of "Plant Cell" on the same database at e-learning platform server.

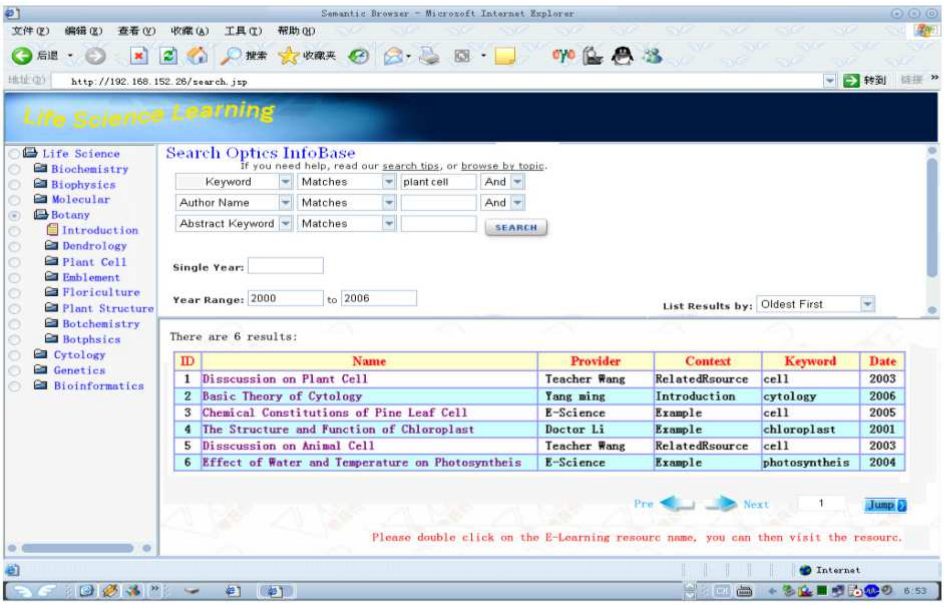

Fig. 5. Semantic browser for e-learning

6 ONTOLOGY-BASED E-LEARNING SERVICES COORDINATION

The technique of Web Service is widely applied to take advantages of the Internet. More and more resources in e-science or e-learning are made available as

Web Services nowadays. The distributed and decentralized nodes in our life science e-learning VO have provided numerous Web Services for life science education.

The Web Services in life science e-science are developed mainly for life science research while in e-learning for the life science education. The nodes providing Web Services to our platform are decentralized and not compatible to each other. The service resources from distributed nodes are so different and heterogeneous to each other that we must design a good mechanism to coordinate these service resources for life science e-learning.

In this section, we will present the ontology-based method to facilitate the service coordination for our system. We will also give a collaborative learning scenario based on our e-learning platform.

6.1 E-Learning WorkFlow

We have applied Semantic Web techniques to facilitate the coordination and composition of service resources. We have also developed a web-based service coordination tool (see Figure 6) called e-learning WorkFlow. E-learning WorkFlow is designed to provide a convenient and efficient way for life science students and teachers to collaborate with each other in life science learning. It offers interfaces for users register, query, compose and execute services at the semantic layer. Life science students can use it to discover, select and compose services to achieve a complex learning task.

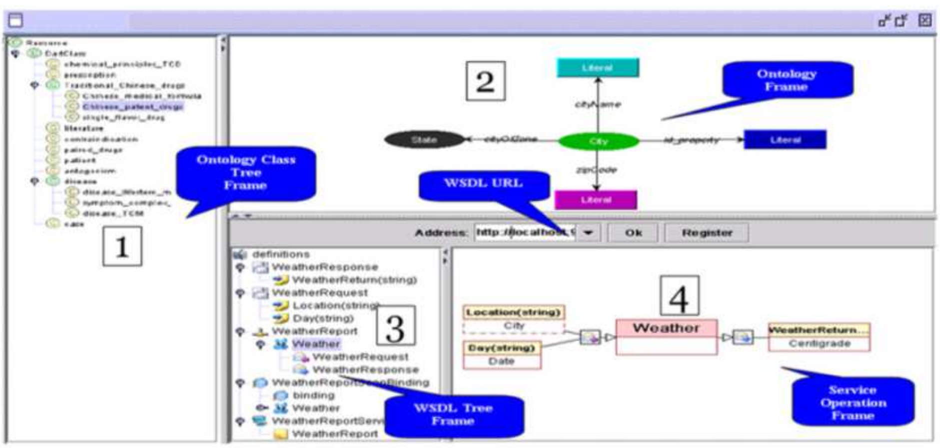

Fig. 6. E-learning WorkFlow

Component Web Service needs to be registered into the VO first before it can be used. E-learning WorkFlow integrates a service registration portal for service provider to register new services. The class hierarchy (1) and class properties (2) of the e-learning ontology are displayed graphically. Service description (e.g. the input and output parameters) is displayed in hierarchy (3). Like semantic mapping in database integration, service providers can create mappings between e-learning ontology classes and service descriptions (4). The mapping information is stored in the repository of the portal. Automatic service discovery and service matchmaking can be achieved based on semantics.

When our e-learning VO is filled with various applied services, life science students can build service flow to achieve complex learning tasks in WorkFlow. They should retrieve enough services in order to compose a service flow. If students want to query services, they can submit a service profile (e.g. a service to simulate a biology experiment) to the portal specifying their requirements. The portal invokes suitable matchmaking agent to retrieve target services for users. The agent has been implemented according to some semantic-based service matchmaking algorithm. Students can compose retrieved services into a service flow in the workspace to build a life science learning task. After a service flow is designed graphically, the corresponding OWL-S file is generated according to the semantic information. Students can validate the service flow in terms of its logic as well as its syntax with a valuator in WorkFlow and the validated service flow will be executed ultimately to finish the task.

6.2 Life Science Collaborative Learning Scenario

A high school student Chen has a good preparation on every biology knowledge point except for gene mutation for his National Biologic Contest. He wants to have a great improvement on the understanding of gene mutation for this contest. Then Chen visits our life science e-learning platform and enjoys a superior learning experience on gene mutation.

He opens the e-learning WorkFlow by setting the service profile as “Gene Mutation” and submits it to the server for relative learning services. The server invokes an ontology-based matchmaking agent to retrieve the relative services. A list of e-learning services shows up (see Table 2).

After reading over the Service Description of each learning service, Chen selects five services and builds a service flow for his task of further understanding on the gene mutation knowledge point. The sequence of his task is illustrated in Figure 8.

According to the service flow, firstly, Chen watches an online video called “The Affect of Gene Mutation to Life-form”. He learns enough understanding about the basic theory of gene mutation from the online class without performing an experiment on Simulator. Then, he asks a few questions about the aspects which he feels puzzled about. After getting the satisfactory answer from the FAQ service, Chen does a hard-level test about the gene mutation and gets a perfect score on the test. Chen believes that he has got enough understanding about the gene mutation knowledge point from this learning service flow and ends the procedure at last.

ID	Service Name	Service Description	Provider
1	Onlining FQA Service on Genics	Asking questions about Genics, you will get reply in a short moment	Teacher Wang
2	DataMining in Inherited Disease Database	You can get underlying knowledge about some Inherited Disease	e-science
3	Online Examination on Genics	You can get the tests on any knowledge points in Genics	Teacher Zhang
4	Drosophila Reproduction Simulatior	Submitting the parameters of Drosophila Reproduction environment, you will get the results immediately	e-science
5	Online Consultation for Boilogy Study	It will give you valuable advices on Boilogy study according your condition	Teacher Li
6	Online Classes for Boilogy Learning	Watching videos of famous biology teacher's lectures online	Teacher Zhen
7	Chromosome Analysis Service	Submitting description of chromosome, you will get some anlysis results about it	e-science

Table 2. The relative learning services for "Gene Mutation"

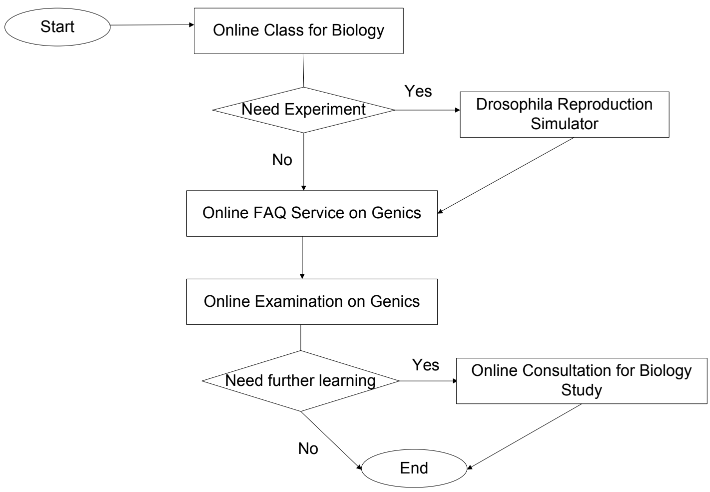

Fig. 7. The Serviceflow for the learning task

7 RELATED WORK

Within the domain of Grid research, there are many efforts about accessing and integrating e-learning database under the grid framework. Typical example is Realcourse [3]. Realcourse is a successful application of distributed computing [13] technology in a geographically wide area. Unlike some traditional distributed fault-tolerant services like ISIS [14], Realcourse emphasizes giving clients' access to the service reasonable response time. For most cases, it means as much of the time as possible.

In [12], it is clear that standards like LOM, or Dublin Core, are gaining importance. They provide more information on the learning material that is to be found on the web. However, their simple structure prevents them from being used for modeling more complex knowledge. [10] explains how Semantic Web technologies based on ontology can improve different aspects of the management of e-learning resources. Indeed, ontology is a way of specifying the concepts and their relationships in a particular domain of interest. Web Ontology languages, like OWL, are specially designed to facilitate the sharing of knowledge between actors [17] in a distributed environment. We wish to emphasize here that Web Ontology languages have various advantages.

There are numerous research works mainly focusing only on the integration of e-learning resources as mentioned before. However, little research has been done about extending e-learning resources by semantic grid technique. We integrated e-learning resources from both teachers and scientist in order to develop an E-Learning Semantic Grid for life science education. That way, we extend our e-learning resources to the life science e-science and help students with their life science learning.

8 SUMMARY AND FUTURE WORK

The Semantic Grid will play a very important role for the wide acceptance of the Grid [25]. It will provide enhanced support for end users to access heterogeneous Grid services and resources by understanding their domain problems and providing solutions. RDF-based and semantic web oriented approach will also be widely used for e-learning to integrate the heterogeneous resources in distributed nodes. We have presented an E-Learning Semantic Grid for life science education. Parts of learning resources for our e-learning platform come from life science e-science. We use domain ontologies to integrate decentralized databases and service from both e-science and teachers in a semantic cyberspace. That way, we provide life science students with semantically experience including browsing, searching and querying. When the scientists provide some e-science resources to e-learning, students can acquire a large volume of frontier information about corresponding domain in life science through our e-learning platform. It will help life science education greatly and also make the e-science more prosperous in many domains.

There will be much work to be done to perfect this e-learning platform. The validation between e-learning and e-science should be highly rigorous, and the access to e-science via e-learning should take security into cosideration. Thus, we would like to do much research on the middleware between e-science and e-learning. The design of e-learning ontology in our platform is not very suitable to the fast increase of resources provided by e-science and life science teachers. It should have a better automatic renewal mechanism to cope with the fast increase. We will design some toolkits to help perfect the e-learning ontology in future research. We would also like to apply this e-learning platform into other disciplines, such as medicine, chemistry, and traditional Chinese medicine.

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