

# Ontology-Based Ecological System Model of e-Learning

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**Abstract**—The problems of too much emphasis on technology lack of people-centered educational philosophy, and the construction of the e-learning system lack of system concept and the overall view. In this paper, e-learning ecosystem models based on ontology in developed. This paper analyses the learner model specification established by the Committee of Chinese education information technology standards, the ontology-based e-learning ecological subject is constructed. After analyzing cognitive psychologists Anderson's Taxonomy of Educational Objectives, ecological environment ontology is promoted. On this basis, e-learning ecosystem model is designed. The paper focus on the use of e-learning ecological ontology in modern distance education ecosystem. This paper provides theoretical support for the building of e-learning ecosystem, and the technical guidance for the design of e-learning ecosystem.

**Index Terms**—Ontology, e-learning ecology ontology, e-learning ecosystem.

## I. INTRODUCTION

E-learning is a new-type education form characterized mainly of online interactive learning by taking the learners as the subject and utilization of the network technology, multimedia technology and other modern information technical means. E-learning provides abundant learning resources for students, who can receive the education they need conveniently overcoming the limitations of time and space, presenting great flexibility and convenience. However, current e-learning system puts more focus on the realization of technology [1][2] and development of teaching resources[3] without fully considering or attaching importance to the positions and roles of the educator and the educated in the e-learning system failing to highlight the education concept of “Putting People First”[4].

The e-learning ecosystem is constructed through studying the interactional processes and laws between the people, learning activities[5] and learning environment[6]. Taking the subject and learning environment of e-learning as a unified whole[7], this system conducts studies on the type, quantity, learning ability and learning habit of subjects in certain regions, the action of factors of the learning environment on the subjects, the reaction of the subjects on the learning environment and the application rules of the teaching resources and learning strategies. The ontology engineering theory and technology are utilized to solve the issues concerned with knowledge representation and sharing in the e-learning ecosystem[8][9]. The e-learning ecosystem

based on ontology incorporates the educational resources, people and educational environment into a shared knowledge base based on the semantics technology[10]. This knowledge base provides common understanding for the knowledge in the e-learning ecosystem, determines the words commonly recognized in the ecological system of e-learning as well as the unambiguous definition of the interrelationship between word and word. Students could construct the learning environment by themselves to participate in the autonomous learning activities in an active and proactive manner. Tutors and resources management personnel could bring into play their group initiative to construct teaching resources cooperatively as a group for the purpose of creating more effective learning platforms for the students.

## II. ECOLOGICAL ONTOLOGY OF E-LEARNING

Semantic annotation has been applied to the ecological subject and environment involved in the e-learning ecosystem. Through capturing the knowledge in the e-learning ecosystem the common understanding for the knowledge in the e-learning ecosystem is provided. The ecological subject of e-learning includes the ontology of ecological subject, ontology of learning resources and ontology of teaching strategies. Among which, the ontology of ecological subject is to summarize and generalize the characteristics and status attribute of the ecological subject based on the Learner Model Standard (CELTS-11) established by the Educational Informationization Technology Standard Committee in China. Constituted by the ontology of knowledge points(KP) and learning object metadata (LOM), the ontology of learning resources is used for teaching knowledge modeling in e-learning system. The ontology of teaching strategies exhibits a series of macro teaching design and micro teaching activities implemented in order to realize the teaching objectives.

### A. Ontology of Ecological Subject

The ecological subject in the e-learning ecosystem is divided from the three levels of species, population and community. The species is the biological group with certain morphological characteristics and the most basic unit in the classification system. The species in the e-learning ecosystem include the producer species of learning resources, consumer species of learning resources and decomposer species of teaching resources. The producer species of learning resources mainly provides the establishment and issuance functions of learning resources and teaching strategies. The consumer species of learning resources views and browses the learning resources and teaching strategies. The decomposer species of learning resources mainly monitors and reviews the learning resources.

The population refers to the collection of individuals

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belonging to one species living in a certain space. The population in the e-learning ecosystem includes the learning resources producer with the tutors as the subject, the learning resources consumer with the students as the subject and learning resources manager with the resources management personnel as the subject. It's worth noting that the tutors, as the producer as well as the consumer of the resources at the same time, absorb the feedback comments on the learning effect of students through learning the teaching resources to promote the optimization of the teaching resources. As the teaching resources consumer, the students could fabricate new teaching resources or come up with the comments on teaching resources optimization based on their own learning experience or as the teaching resources producer for the convenience of regeneration of the teaching resources. The resources management personnel could act two or more than two roles as well as the teaching resources producer or consumer.

The community refers to the collection of all biological populations accumulated in a certain region or ecological environment at a certain time. The community in the e-learning ecosystem refers to the tutors, students and resources management personnel involved in the teaching plan establishment and implementation for the purpose of achieving the same teaching objectives. In the same community good interactivity exists between learners, between learners and tutors, between learners and managers and even between managers. The tutors, students and resources management personnel in the e-learning ecosystem are not isolated resources fabricators, learners or resources managers. Interaction exists between various types of personnel; cooperative fabrication of teaching resources or collaborative learning of distance education of different degrees exists among various types of personnel as well.

The ontology of ecological subject in the e-learning ecosystem refers to the concepts describing the ecological species based on OWL as well as the relations between these concepts. Completion of formalized description of the ecological species information is convenient for information discovering and sharing between the ecological population and ecological community in the e-learning ecosystem. The application of the ontology of ecological subject is beneficial to understand the students' learning status and learning style and helpful for the selection of learning content, selection and utilization of teaching method as well as the design of teaching plan. It is beneficial to understand the tutors' teaching experience and teaching preference and helpful for the description of teaching objective, planning of teaching strategy and fabrication of teaching resource.

Using the Learner Model Standard (CELTS-11) in the network education technology standard system established by the Educational Informationization Technology Standard Committee in China for the reference, the information of the ecological subject is categorized into the identification information, relation information, safety information, personality information, performance information and history information. The identification information contains the general information related to the ecological subjects such as the name and email address, which has no direct relation with the distance education. The relation information contains the relation of the ecological principal part with

other ecological subjects such as students and tutors. The safety information includes the security credential information related to the ecological principal part such as the password. The personality information refers to the information related to the individual characteristics of the ecological subject such as learning style, preferred language and learning deficiency, which is beneficial to provide personalized service by the system. The performance information contains information related to the representative works and certification concerned of the ecological subject, which is used to describe and certify the ability of the ecological subject and content grasped already such as the result. The history information describes the accomplished work and projects of the ecological subject, which is the record of the previous experience of the ecological subject with the focus on the description of the history and experience of the ecological subject.

## *B. Ontology of Ecological Environment*

### *1) Ontology of learning resources*

The ontology of learning resources in e-learning consists of the ontology of knowledge point and the ontology of learning object metadata (LOM). The ontology of knowledge points records the information of descriptions of the knowledge points themselves and the relation between the points. The ontology of LOM describes the information of own attributes of various learning resources like learning courseware and teaching program. The aforementioned information determines the selection and organization of the learning resources while drawing up the teaching plans based on the demand of the personalization of students.

The ontology of knowledge points is used to describe the concepts of knowledge points and the relation between these concepts so that the knowledge points could be reused and shared between different systems. The ontology of knowledge points describes the information of the knowledge points themselves and information of relation of these knowledge points.

The information of the knowledge points themselves is used to describe the general attributes of the knowledge points including the name, type, importance and contained learning resources. Among which, the name of knowledge point is the unique identification of a knowledge point. Using the description of the knowledge dimension in the taxonomy of educational objectives proposed by Anderson, the cognitive psychologist, for the reference, the type of knowledge points includes the factual knowledge, conceptual knowledge, procedural knowledge and metacognitive knowledge. The factual knowledge refers to the data or examples whose description content is specific and unique. The conceptual knowledge refers to the items, words or ideas with characteristics and the name in common. The procedural knowledge refers to a series of steps and procedures implemented for the purpose of attaining the objectives. The metacognitive knowledge refers to the data or examples of principles based on which, people could make forecasts and inference. The importance of the knowledge points represents the important degrees of the knowledge points including being non-important, ordinary, important and very important. The learning resources contained in the knowledge point represent various types of learning

resources provided by the system for the purpose of acquiring the knowledge point including the teaching courseware, teaching program, exercises and examination questions.

The relation information of the knowledge points defines the types of relations between the knowledge points including the inclusion relation, ordering relation, similarity relation, exclusive relation and association relation. The inclusion relation refers to the hyponymy in concept existing between one knowledge point and other knowledge points, namely, this knowledge point is constituted by other knowledge points. The ordering relation is used to describe the logic relation existing in the learning process of the knowledge points, for example, learning Knowledge Point A is the precondition of learning Knowledge Point B, which means one must learn Knowledge Point A first, pass certain examinations and then start to learn Knowledge Point B. The similarity relation is used to describe the knowledge points with similar meanings, which is helpful for better grasping of the knowledge points. The exclusive relation is used to describe the knowledge points with opposite meanings. If Knowledge Point A and Knowledge Point B are mutually exclusive, the learners could achieve the learning through comparison, which is beneficial to deepen the understanding. The association relation refers to the relation between the knowledge points, which does not conform to any of the above-mentioned several types of relations but does exist and therefore is referred as the association relation.

In the field of e-learning, the learning object(LO) mainly refers to the digitized teaching resource generally smaller than the course granularity. The learning object metadata provides a unified description method for the content of learning resources. Through independently recording related attributes of the learning objects, the learning object metadata information is helpful for the reusing and sharing of learning objects between different learning systems, which provides data basis for the automatic generation of the dynamic and personalized learning units. Users can utilize the learning object metadata information to quickly find the needed learning objects, which improves the utilization rate of the learning objects. Based on the learning object metadata information, it is more convenient for the classification and orderly management of the learning object resources. Users add the evaluation of learning into the learning object metadata information, which facilitates the circulated use of the quality learning objects.

LTSC is a standardization organization established by IEEE specialized in the standards of system development management and maintenance of educational software, teaching resources and educational information. This organization has expanded the attributes of the learning resources on the basis of Dublin core and come up with LOM, which is currently the most important learning object metadata model related to the network teaching resources. In LOM, the learning objects refer to the digital or non-digital entities that could be used, reused or cited under the environment with technical supports.

The description of learning resources metadata adopts a form bound with XML generally. The XML binding of learning resources metadata represents the LOM metadata like General and Educational with elements of XML, and the layers of metadata with the data model structure of XML. The

metadata model defined by LOM includes 9 categories of data elements: general information, lifecycle, data description information (Meta Metadata), technical information, educational information, cost information, relation information, annotation information and classification information.

## *2) Ontology of Teaching Strategies*

The teaching strategies refer to the teaching behavior patterns or teaching activity patterns adopted for the purpose of realizing the teaching objectives and meeting the learning demands of students under certain teaching situations. The teaching strategies serve as the bridges converting the teaching knowledge into teaching behaviors based on the learning objects. The factors affecting the effective establishment of the teaching strategies mainly include the teaching objectives, demands of students, teaching experience, teaching resources and teaching environment. The teaching objective is the destination of teaching and a decisive factor in the selection of teaching strategies. The learning state and learning ability of learners determine the starting point of teaching, which is the basis of teaching strategy establishment: the teaching experience of tutors themselves is a major factor determining the effective establishment of teaching strategies. The teaching resources serve as the material basis affecting the effective establishment of the teaching strategies. The teaching environment is the effective guarantee of establishment or selection of the teaching strategies.

Ontology of teaching strategies includes four layers, namely, condition layer, objective layer, action layer and resource layer.

The condition layer defines the learning state to be attained or learning activities to be accomplished by the students for the purpose of implementing a certain strategy, which is used to describe the applicable scope of the strategy. For example, before the teaching starts, the students must pass the tests of some knowledge points(KPs) to prove that their knowledge states are up to the required layer; or, the students must fulfill the learning work of some knowledge points to possess the knowledge ability required for carrying out the learning activity.

The objective layer defines the teaching objectives. The description of the objective layer is by way of a verb-object expression among which, the verb describes the expected cognitive process and the noun describes the knowledge points expected to be grasped by students. Based on the description of the cognitive process in the taxonomy of educational objectives proposed by Anderson, the verb part in the teaching objective includes memorize, understand, apply, analyze, evaluate and create; the definitional domain of the noun part in the teaching objective consists of the ontology of knowledge points. The teaching objective could be constituted by a series of related sub-objectives. The objective layer displays the macro design of teaching implementation.

The action layer is constituted by a series of teaching steps, which is used to describe the teaching approaches and teaching processes implemented in order to realize the teaching objective. The action layer does not focus on the organization situation and presentation method of the teaching content; the teaching behavior is constituted by a

series of sub-behaviors with the actual teaching behavior to be determined by the learning state and knowledge grasping degree of the learners. The action layer exhibits the micro teaching activities in the teaching implementation.

The resource layer describes the teaching resource applied for the purpose of realizing the teaching behaviors with its definitional domain as the ontology of the learning object metadata. The teaching resources and the teaching behaviors are separated from each other so that the teaching behaviors are not restricted by the teaching resources and this is beneficial for the reuse and upgrading of the teaching resources.

### III. ECOLOGICAL SYSTEM MODEL OF E-LEARNING

The ecological system model of e-learning is as shown in Figure 1. The model includes four layers : data layer, ontology layer, ontology access layer and business service layer. The data layer consists of currently existed various information like the educational resources information, personal information of students, tutors and resources management personnel, learning information of students and operation record information of tutors or resources management personnel. The ontology layer consists of the ontology of ecological principal part, ontology of teaching resources and ontology of teaching strategies. The ontology access layer could realize the logics and inference of ontology based on the current ontology operating tools, namely, protégé ontology editing tool and Jess rules inference engine. The business service layer could realize the cooperative management of teaching resources and personalized collaborative learning based on the ontology operating interfaces provided by the ontology access layer.

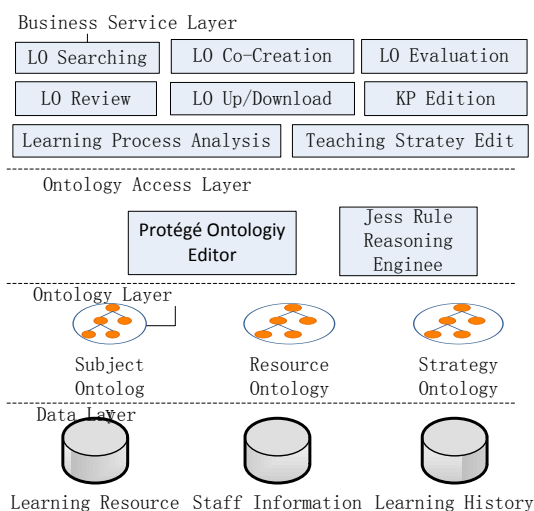


Fig. 1. Ecological system model of e-learning

The system modules of the business service level provide the three major functions of user management, cooperative management of teaching resources and personalized collaborative learning. The user management function is realized by the user management module. The function of cooperative management of teaching resources is realized by the learning object searching module, learning object cooperative creation module, learning object evaluation module, learning object review module and learning object

upload/download module. The function of the personalized collaborative learning is realized by the teaching strategy editing module, learning state qualification module and learning process analysis module.

The user management module provides the functions such as searching, addition, modification and deleting for the ontology information of the ecological principal part of the students, tutors and resources management personnel. The ontology of the ecological subject records the personal information, preferences and other personalized information of students based on which the appropriate teaching methods are selected. The user management module is used to describe the preference characteristics of the ecological subject in the e-learning ecosystem and is the basis for establishing appropriate teaching methods.

The cooperative management of teaching resources provides the management of the learning object metadata and teaching knowledge points. Based on the ontology searching function provided by Protégé, the learning object searching module could acquire the teaching resources needed by users by way of searching the ontology of teaching resources through the words. The ecological principal part could utilize the learning object cooperative creation module to create new learning objects in a cooperative manner based on the learning experience or teaching experience and release them through the learning object review module to realize the regeneration of the teaching resources. At the meanwhile, the ecological principal part could provide corresponding evaluation for existing learning objects based on the learning effects and through the learning object evaluation module to improve the utilization rate of the quality learning objects. The knowledge point editing module has realized the organization and management of the teaching knowledge points. The teaching knowledge points shall be organized and sorted to find out related learning resources through the connection between the teaching knowledge points and teaching resources so as to realize the orderly organization of the learning resources, which is helpful to establish effective teaching approaches.

As a major constituent part of the e-learning ecosystem, the personalized collaborative learning could generate the teaching plans in a dynamic manner based on the personal characteristics and performance information provided by the user management module and in accordance with the teaching strategies, which is helpful for effective organization of the learning approaches. The teaching strategy editing module provides the teaching strategy establishing functions based on SWRL form. The establishment of the teaching strategies includes four major steps, namely, determination of teaching conditions, description of teaching objectives, organization and sorting of teaching behaviors and selection of teaching resources. The learning state qualification module provides the function of recording and recognizing the state of knowledge acquisition by the students. The learning state qualification module would read the students' performance information when the students start study and record the learning objective and learning result of the students. The learning process analysis module provides the learning approaches and instructions for students to receive the e-learning education. Based on the current state information of users fed

back by the learning state qualification module, the applicable learning strategies shall be selected; rules and statements of inference and query shall be constructed; the ontology query shall be realized by utilizing Jess rules; and the most appropriate teaching plans shall be calculated in a dynamic manner.

#### IV. CONCLUSION

The paper provides herein a description of the ecological subject and ecological environment in the e-learning ecosystem based on the ontology theory and technologies. The establishment of the accurate and non-ambiguous knowledge bases facilitates the knowledge exchange, conversion and sharing. The ecological system model of e-learning is proposed with the focus on the system architecture of the model based on the ecological ontology of e-learning, which provides theoretical instruction for the design of the e-learning ecosystem. The author would further provide detailed discussions on the methods of teaching process analysis based on the teaching strategies and learning states in the subsequent studies for the purpose of generating personalized teaching plans in a real-time and dynamic manner to provide guidance for students' learning activities. In addition, actual teaching application practice will be carried out with the developed e-learning ecosystem tools and the results will be analyzed in the hope of being able to provide references for the promotion of the e-learning ecosystem.

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