Designing Collaborative E-Learning Environments based upon Semantic Wiki: From Design Models to Application Scenarios

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ABSTRACT

The knowledge society requires life-long learning and flexible learning environment that enables fast, just-in-time and relevant learning, aiding the development of communities of knowledge, linking learners and practitioners with experts. Based upon semantic wiki, a combination of wiki and Semantic Web technology, this paper designs and develops flexible e-learning environments for different application scenarios aiming to facilitate collaborative knowledge construction and maximize resource sharing and utilization. One application scenario is to support hybrid learning by deploying an online course platform and the first round of using has shown that the course platform can effectively facilitate and support students to fulfill task-driven learning in a more flexibly and friendly collaborative manner. The other application scenario is to build a teamwork platform for supporting collaborative e-research. After several months' trial, team members agree that the platform can well meet their collaborative research work demands with the advantage of quick, easy and convenient operating assistance. The kernel idea of the collaborative e-learning environments is to enable structural organization of resources with semantic association while providing diverse customized facilities.

Keywords

Collaborative knowledge construction, E-learning 2.0, Interactive query, Semantic wiki

Introduction

E-Learning has become one of the most popular teaching and learning methods by stretching the spatial and temporal barriers. Various e-learning systems have been developed in the past decade. Learning Management Systems are able to support online training with different levels of granularity and formalization, which focus on automation of some aspects of the design process, execution and assessment (Acqua, 2009). Learning Content Management System expects to provide standard-based content repositories that allow learners to capture, store, deliver, and manage learning resources (Goecks et al., 2002)(Jari et al., 2003). Furthermore, ubiquitous learning environment gains more and more attention in recent years, which aims to provide an interoperable, pervasive, and seamless learning architecture to connect, integrate, and share three major dimensions of learning resources: learning collaborators, learning contents, and learning services (Cheng et al., 2005)(Yang, 2006). However, almost the e-learning systems are self-independent and the learning resources are disordered, isolated, and heterogeneous, and there is no common overarching context for the available resources.

Virtual learning communities are cyberspaces in which individual and collaborative learning is implemented by groups of geographically dispersed learners and providers of knowledge to accomplish their goals of learning. Though there are no agreements on what constitutes a virtual learning community, it has gained widespread acceptance that virtual learning communities are knowledge based social entities where knowledge is the key to their success (Bhatt, 2001)(Malhotra, 2000). An important activity in a virtual learning community is the collaboration. Many virtual learning communities strive to attract new members or encourage members to learn and to contribute knowledge. Nevertheless, such collaboration environment is generally not supported by conventional learning environments (Hage et al., 2008).

E-learning 2.0 emerges inspired by the popularity of Web 2.0, which places increased emphasis on social learning and use of social software such as blogs, wikis, and etc. (Rosen, 2009). Conventional e-learning systems were based on instructional packets that were delivered to students using Internet technologies. The role of students consisted in learning from the reading and preparing assignments. By contrast, E-learning 2.0 is built around collaboration, which assumes that knowledge is socially constructed. Learning takes place through conversations about content and grounded interaction about problems and actions. Misanchuk et al. (2001) propose strategies focus on promoting communication, social interaction and participation to scaffold learning. Therefore, it is desirable to design and develop a sophisticated learning environment to achieve e-learning 2.0, encouraging learners' active involvement of

resource contribution, enabling convenient resources accessing and utilization, and facilitating better interaction and collaboration.

Semantic Web is the emerging landscape of new web technologies aiming at web-based heterogeneous resources that would be understandable and reusable by both humans and machines. Semantic knowledge is playing an increasing important role in order to have heterogeneous resources well organized and managed. Some researches have been done to utilize semantic web technologies to support e-learning (Kolovski et al., 2003)(Stojanovic et al., 2001) (Sampson et al., 2004). Wikis are well-known as online encyclopedias or websites that provide a vast source of information and allow each individual to contribute his own knowledge and experience on any topic (Clark, 2006). But a wiki is essentially a collection of Web sites connected via hyperlinks, which contain many hand-made, redundant, inconsistent lists and links and the meaning of its content is not machine-understood and machine-processable, so finding and comparing information from different pages is challenging and time-consuming.

By combining properties of wikis with Semantic Web technologies, semantic wikis emerged aiming to address problems due to the unstructured accumulated information of conventional wikis. The main idea is to make the inherent structure of a wiki – given by the strong linking between pages – accessible to machines beyond mere navigation. Semantic Wikis are structured, smart and accessible since they contain many lists that are computer-made, up-to-date and consistent. Although there are many researches on semantic wikis, much work focus on developing approaches to combining wikis with semantic technologies, which can be classified into two categories (Buffa, 2006). Most of the current projects on semantic wikis fall into the first category; i.e., they consider the use of wikis for ontologies, and the wikis become the front-end of the ontology maintenance systems, such as Platypus (Campanini, 2004), Rise (Decker, 2005), WikSAR (Aumueller et al., 2005), Semantic MediaWiki (Krötsch et al., 2007), etc. The second family of approaches focuses on the use of ontologies for wikis, and the typical semantic wikis include IkeWiki and SweetWiki (Buffa, 2006). So far, there have been many applications built upon different semantic wikis' engines. Most of the applications are on knowledge management and collaborative knowledge base construction (Oren, 2006) (Lange, 2008) (Happel, 2007), yet few applications on e-learning. With the conception of e-learning 2.0, semantic wiki is suitable to achieve e-learning 2.0 with the advantage of collaborative editing and structural resource organization. Nevertheless, search results on the semantic wiki platforms are displayed in a list of wiki pages, which is not intuitive for learners to understand easily. This appeal to reorganization of search results based on ontology category for quick browse and further study. Furthermore, the usual platforms only support users to view their own contributions and provide statistics on the wiki pages, but not consider the social relationship between users and can't recommend learning peers for collaborative learning and problem-solving. So learners usually feel isolated and are easily tended to become disengaged and inactive when they are outside of the social context.

Based on Semantic MediaWiki, this paper designs and develops Semantic Wiki-based Collaborative e-Learning Environments (SWiCLE) to better support learners collaborate to share, exchange and utilize learning resources in the sphere of e-learning 2.0. The kernel idea is to enable structural organization of learning resources with semantic association while providing diverse customized facilities, such as semantic search, multi-view filter, relevance-recommendation, etc.

Structuring Learning Resources

The kernel to structuring learning resources is to encapsulate learning materials with metadata descriptions and establish semantic linking between them. An ontology gives an explicit specification of a conceptualization with respect to the specific application domains by defining concepts and their properties, which lays the foundation to effectively organize and link resources with semantic relationship in an e-learning environment. Figure 1 illustrates an example of partial ontology within academic settings. As the figure shows, concepts include project, course, person, etc. These concepts' properties are omitted except for their relationship with other concepts. The relationship consists of two types. One type is the usual relationship, including *similar-to, prerequisite*, *is-a*, *part-of*, *related-to*, etc. The other type is the specific relationship between the concepts, such as *develop*, *participate*, and *study*.

In SWiCLE, any multimedia objects (e.g. a block of text, PDF documents, images) and real world objects (e.g. people, organizations and events) are encapsulated as learning objects (LO) with metadata description. The metadata for a generic learning object falls into two categories. One is content description indicating what the learning object

is about, which is the basic information used to select learning object. The other is context description that indicates when to present the learning object, which expresses the pedagogical information of a learning object as well as relationship with other learning objects. Currently, learning object metadata generation mainly depends on the manual annotation of resource contributors based on the pre-designed semantic templates. As a complement, the system can automatically extract some metadata by means of information extraction technology, which won't be discussed in this paper. Furthermore, a semantic link network (SLN) is a model to intuitively represent the semantic relationships between document fragments or documents (Li et al., 2009), and we adopt SLN to represent relationship between learning objects. Therefore, the resource organization structure of SWiCLE can be considered as two interconnected networks or spaces (see Figure 2). The knowledge space depicts the knowledge structure in SWiCLE, which is composed of Ontology and LO-SLNS. Ontology describes the generalized knowledge (concept and relationship between concepts) in an application domain, and a learning object in semantic link networks is an instance of a concept in the ontology. The learning objects belonging to the same concept constitute one LO-SLN, and the lines within one LO-SLN or across different LO-SLNs express the relationship between learning objects. The hyperspace is a network of hypertext pages with learning materials (traditional hyperspace). A learning object corresponds to a page that embodies the learning object's properties and related information (e.g. semantic relationship with other learning objects, annotations, comments).
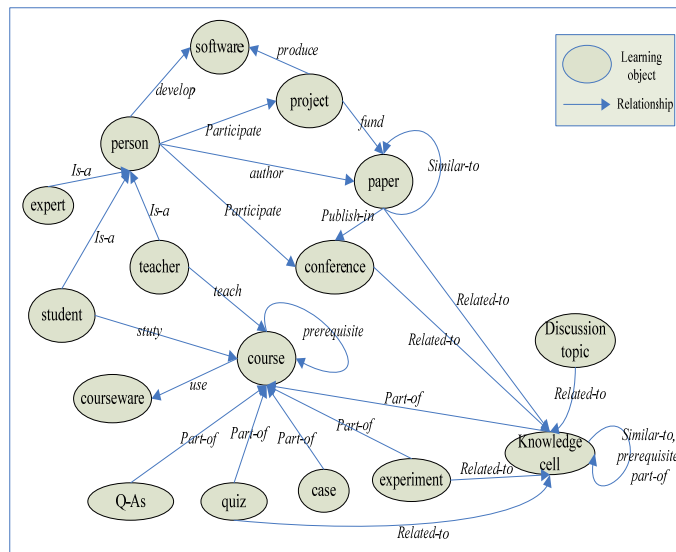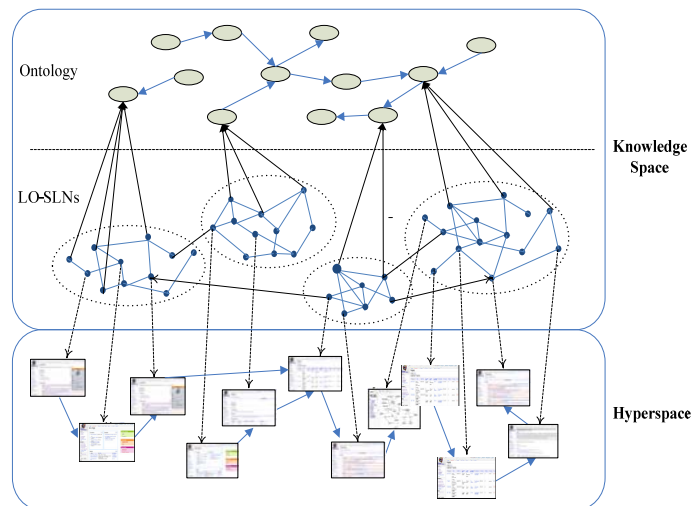

Figure 1. An example of partial ontology

Figure 2. Conceptual model of resource organization

Semantic Search

In contrast to the traditional search, queries within semantic search lead to the focused search and quick location of the precise information and semantic related resources. SWiCLE provides the following three modes of semantic search.

Interactive Query

Generally, search results are ranked and sequenced in a descending relevance order, and learners have to browse the results one by one to determine which item is what they really needed. In this way, learners often feel tedious because of too many returned items. By contrast, we propose an interactive search that intends to help learners find what they need in a more easily and friendly way by displaying search results in an intuitive way.

When a learner inputs a query, he or she can search for the page of which title is exactly the same with the query keywords. If so the system will lead to the exact page, otherwise the system will return no matching result. The other situation is to search for related information for the given query. In such case, the system will firstly search for the matching instances in the repository and then return the corresponding categories (i.e. concepts in the ontology) that contain the instances. Each category is marked with a number to indicate the number of matching instances belonging to the category. Afterwards, learners can check which category is what they search for and then click the category. Accordingly, on the basis of matching instances belonged to the specific category, the system will search for more related instances and return to users as well. Taken the matching instances as the anchor ones, this step is to find semantic relevant instances. The simple approach for selecting the target instances for the one matching instance, purely based on the structure of the graph, is to collect the first N triples originated from the anchor instance, where N is the pre-defined traversal constraints. As for the case of two matching instances corresponding to the query, it is the key problem to find all the semantic association paths between the two instances so as to select relevant instances on the paths. The basic idea of the algorithm is to traverse the graph in a breadth-first order starting from the two instances. The following step is to rank the target instances in terms of their association weights. This can be accomplished by enabling a user to browse the ontology and mark a region (sub-graph) of nodes and properties of interest. If the discovery process finds some semantic association paths passing through these regions then they are considered relevant, while other associations are ranked lower or discarded. Furthermore, learners can click "all" to browse all the matching and related instances despite of the belonging category.

Script-based Advanced Query

This mode supports users to search for information with complex constraints, making dynamically generated query results available to users. By writing simple scripts in wiki pages according to syntax rules, users can obtain lists or tables composed of up-to-date information. For instance,

```
{{#ask:
[[Category: expert]]
[[research interests::artificial intelligence]]
|?name =
|?affiliation address=
|sort=name
|order=desc
}}
```

This query can be used to find out all experts whose research interest is "artificial intelligence", and only two properties (i.e. name and affiliation address) of experts are displayed in the descending sequence of expert name. Alternatively, as shown in figure 3, users can use a dialogue box to define the query. That is, input the searching objects and properties in the left and right column respectively. This example is to find out all tasks that are assigned to one specific user and three properties are displayed in the searching results, including *status*, *start time*, and *end time*. Yet this search mode seems difficult for non-technical learners. We are trying to modify this based on visual template, and thus learners only need to set constraints by ticking checkbox.

Ask

Query	Additional printouts (optional)
[[Category:task]][[Performer::user:马韶西]]	?Status ?Start time ?End time

Sort by column (optional) End time   Ascending   [Add sorting condition]

Find results   Hide query | Querying help

Previous   **Results 1– 11**   Next   (20 | 50 | 100 | 250 | 500)

	Status	Start time	End time
JAVA学习-第三周任务	Completed	18 September 2010	24 September 2010
JAVA学习-第五周任务	Completed	30 September 2010	8 October 2010
JAVA学习-第六周任务	Completed	9 October 2010	15 October 2010
推荐英文论文阅读	Completed	9 October 2010	15 October 2010
下周论文阅读-20101014	Completed	14 October 2010	21 October 2010
第7周任务：GWT学习	Completed	16 October 2010	22 October 2010
第8周次任务：Select语句训练	Completed	24 October 2010	30 October 2010
第9周任务：JSP/Servlet学习	Completed	1 November 2010	6 November 2010
第10周任务：GATE的基本功能和JAPE规则学习	To be processed	15 November 2010	21 November 2010
用户主题关系网络构建研究	Processing	9 November 2010	30 December 2010

Figure 3. The interface of script-based semantic search

Comparison Retrieval

Especially, a comparison retrieval mode is designed for learners to find relationships between two learning objects, e.g. the connections between different books or the commonalities of people. For the given keywords, firstly identify the matching learning objects in repository, then their corresponding properties description are analyzed to find the potential connecting terms, and finally the search results are displayed in two columns within one page where the top potential connecting terms are properly highlighted so that the relationships between the two learning objects can be easily identified. For example, input the query to search for two persons as "David W.Johnson" and "Edythe Holubec". Their basic information, teaching courses, books and involved activities will be listed in two columns with the highlighted connecting terms that indicate their commonalities. More information refers to (Li et al., 2009).

Collaboration Structure Analysis for Relevance-Recomendation

In an open e-learning environment, learners usually feel isolated and are easily tended to become disengaged and inactive when they are outside of the social context of the classroom (Wu et al., 2002). Thus, it is important to providing learners with social support according to learners' collaborative structure, which can be achieved by analyzing learners' performances and interaction based on their activities on the platform. In this way, when a learner encounters a problem or asks for help, appropriate learning-companions can be recommended to enhance learners' in-depth communication and learning. Also, the environment can recommend related resources that are contributed or browsed by other closely-related learning-peers.

In SWiCLE, learners can edit a specific page by means of four operations, including initiating a new page, adding text to an existing page, deleting text to an existing page, as well as restoring text to an existing page. As the editing history is all stored, we can compare different versions of a certain page based on text analysis technology to find out the operations executed by different learners.

Accordingly, several indicators can be computed for a learner, including participation, activity, and impact. Participation measures the involvement of a learner in the wiki pages. Activity indicates the activities a learner executed on wiki pages in a certain period of time. Impact is used to indicate a learner's influence degree for his offered information. A learner's impact is increased if other learners follow to edit the page initiated by the learner or view the page edited by the learner. On the contrary, his impact is decreased if his contribution text is deleted by other learners. These indicators can help to find out learners' performances during collaborative learning process, and thus necessary assistance could be timely provided to enhance learning. Furthermore, we assume that it is more possible that two learners have similar interest if the number of pages they both edit is much bigger. So, mutuality is computed based on learners' editing activities to measure the relationship between learners.

Participation:

$$P_i = \sqrt{\frac{N_i + V_{add}^i + V_{delete}^i + V_{restore}^i}{\sum_{f=1..u}(N_f + V_{add}^f + V_{delete}^f + V_{restore}^f)}} \tag{1}$$

Where N_i denotes the number of pages initiated by the ith learner, V_{add}^i, V_{delete}^i, $V_{restore}^i$ denotes the number of pages whose text is added, deleted, and restored by the ith learner, respectively. u denotes the total number of learners.

Activity:

$$A_i = \frac{\alpha \bullet N_i + (1-\alpha) \bullet P_i}{\Delta t_p} \times \frac{1}{(t-t_d)+\tau} \tag{2}$$

Where N_i and P_i respectively represents the number of pages initiated and edited by the ith person during the period Δt_p, t is the current date and t_d is the date when the ith person edits the latest page. τ is the adjust parameter to avoid the denominator is zero, and it is initially assigned 1. α is parameter that adjusts the relative impact of user's operation.

Impact:

$$I_i = \alpha \bullet U_i + \beta \bullet V_i - \gamma \bullet D_i \tag{3}$$

Where U_i denotes the number of learners who edit the page initiated by the ith learner, V_i denotes the number of editing times of a page initiated by the ith learner. D_i denotes the number of times the ith learner's contribution texts are deleted. α, β and γ are ajustable parameters and $\alpha + \beta + \gamma = 1$.

Mutuality:

$$M_{i,j} = \alpha \bullet |A_{i,j}| + (1-\alpha) \bullet (\sum_{u \in A_{i,j}} Min(N_i^u, N_j^u)) \tag{4}$$

Where $A_{i,j}$ denotes the set of pages co-edited by both of the ith learner and jth learner, and $|A_{i,j}|$ is the number of pages co-edited by ith and jth learners. N_i^u (N_j^u) denotes the number of times the ith (jth) learner edits on the uth page that belongs to $A_{i,j}$. So the larger the value of mutuality is, the more close the relationship between the persons is, and vice versa.
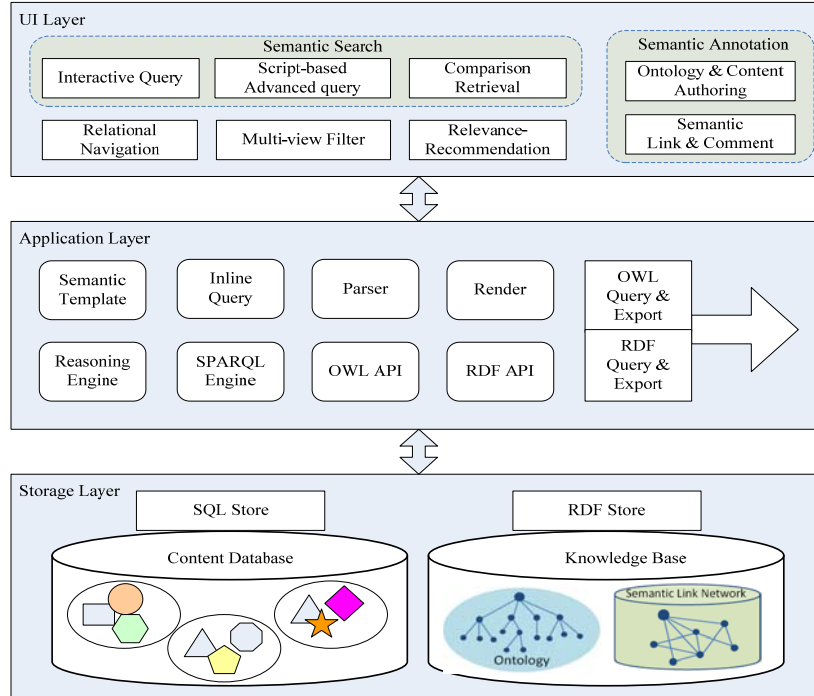

Figure 4. The architecture of SWiCLE

The Architecture of SWiCLE

Figure 4 illustrates the architecture of SWiCLE. As the figure shows, SWiCLE comprises three layers. The storage layer serves as the underlying learning repositories. The application layer consists of modules about processing and exchanging of structural information, which is accomplished by Semantic Web technologies. The UI layer provides various user interfaces for decentralized learners.

The storage layer is comprised of knowledge base and content database. Knowledge base consists of ontology and semantic link networks. The former is an explicit specification of a conceptualization with respect to the specific application domains, and the latter represents various semantic relationships between learning objects. Content database deposits learning materials authored or uploaded by learners and instructors.

In the application layer, semantic template comprises predefined parts of text into pages, and placeholders that are instantiated with user-supplied text when the template is included into a page. By simply adding typed links or attributes to the template text, the semantic template also allows the encapsulation of semantic annotation. Inline query enables editors to add dynamically created lists or tables to a page, thus making up-to-date query results available to readers who are not even aware of semantic queries. Parser is responsible for converting the text written by the user into learning objects. It parses the text for semantic annotations, layout directives, and links. Render takes charge of filling the page dynamically based on semantic templates, which determines the display layout delivered to learners. As extended from RAP (http://sourceforge.net/projects/rdfapi-php), the rest modules are used to create and store knowledge base. OWL Query & Export and RDF Query & Export give direct access to the formalized knowledge, which opens SWiCLE up to a wide range of external applications that will be able to use it as a background knowledge base.

Regarding the UI layer, several distinctive functionalities are provided. Semantic search comprises three search modes that are detailed in the former section. With the assistance of Ontology & Content authoring module, experts or administrators can construct and modify the domain ontology, and learners can create and edit learning objects along with properties via templates. Semantic linking allows learners to annotate links between learning objects via a special type of markup, while Comment empowers learners to evaluate learning objects with certain grading and remark. Relational navigation function offers additional information on the relation the semantic link describes, which changes the way content is presented based on semantic links and enables the content aggregation from different pages. This can include enriching pages by displaying of semantically related pages in a separate link box, displaying of information that can be derived from the underlying knowledge base, or even rendering its content of a page in a different manner that is more suitable for the context (e.g. multimedia content vs. text content). Multi-view filter offers faceted browsing to learners with advanced text search and filtering functionalities. With this function, property values of learning objects that occur more often can be grouped. Learners can select the values they would like to see by checking them, and then query results that do not hold the selected values will vanish. Relevance-recommendation function is to proactively recommend learning companions and related resources that are contributed or browsed by other closely-related learning-peers. This function is implemented based on analyzing learners' collaborative structure.

Applications

With an integrated, scalable and easy-to-use interface, SWiCLE serves as an entry point for learners to conveniently author, access, reuse and aggregate resources via diverse intelligent facilities, such as semantic search, relational navigation, relevance-recommendation, multi-view filter, etc.

Application Scenario 1: An online course for hybrid learning

As a preliminary application built on SWiCLE, we have developed an online course "Introduction to Artificial Intelligence". By adopting task-driven collaborative learning strategy, the online course is flexibly designed to support hybrid learning. Figure 5 shows the semantic linked pages guided for relational navigation. During learning process, learners can browse learning content sequentially or click the marked blue text in the right flowing panel to study other content such as key concepts, previous task, etc. Meanwhile, learners can collaboratively edit each page

and comment on each page as well. To motivate students' collaboration, the final assignment of this course comprises three stages: individual design; mutual evaluation; and modification. Figure 6 shows one student's final assignment and mutual discussion with other students on the assignment. Additionally, as figure 7 illustrates, the course management module is especially designed for teachers allowing them to lookup students' activities, manage course resources and etc. Herein the interface shows students' contributions.

Figure 5. Semantic linked pages for relational navigation

Figure 6. Collaborative discussions on a student's final assignment

Twenty-two junior undergraduate students enrolled in the one-semester optional course. The course was carried out from March 2010 to June 2010 and took place 3 hour per week in a classroom. Besides listening in the classroom, students were required to finish one or two tasks for each learning unit through the online course platform. Each task is composed of several sequential learning steps.

An experimental study is conducted to understand students' perceived attitudes toward the use of semantic-wiki-based course platform. Furthermore, this study is to investigate the effects of course platform on quantity of collaborative editing and its influence on learning achievements. Thus, this study proposes two interesting research questions: 1) Students' attitudes toward the course platform; 2) Is the course platform able to improve students' learning results?

Figure 7. Course management for teachers

When the course ended up, a questionnaire to evaluate students' attitudes toward the course platform based on the semantic wiki was given to 22 students and 20 valid answer sheets were returned. The questionnaire included thirteen questions using a five-point Likert scale, which can be classified into four dimensions: (1) Perceived usefulness of the course platform; (2) Perceived ease of using the course platform; (3) Learning satisfaction of the course platform; (4) Willingness for future use. This questionnaire was originally developed by Davis (1989) and Azouaou et al. (2004), which is modified to evaluate how students come to accept and use PAMS 2.0 (Addison, 2010). Likewise, we modified the questionnaire based on the four dimensions. During questionnaire design process, we invite four experts whose major is psychology and computer to evaluate the validity of questions in terms of each dimension, and accordingly delete or modify some ambiguous or unsuitable questions. On the other hand, we asked students to complete the same questionnaire after three months, and then computed the test-retest reliability (r=0.816), which implies that the reliability of the questionnaire is sufficiently high.

Table 1 shows the result of this questionnaire. In terms of perceived usefulness, 100% students agree that course platform is useful to support their collaborative learning as indicated in question 1. In question 2, 85% of the students think that the course platform is useful to organize individual and group knowledge within a group. Likewise, in question 3, 95% of the students agree that the course platform is useful to share their thoughts with group members or all students. Nevertheless, regarding question 4, only 65% students think that the relational navigation is useful for learning. The reason for the unexpected results is that some students thought that the hierarchical task-step navigation mode is too deep to use, which lessen their enthusiasm to a certain degree. In terms of perceived ease of use, regarding question 5, 6, 7 and 8, most of students agree that it is easy to use the course platform. It's worthwhile to point that 25% students are not sure about the easiness of the course platform as indicated in question 7. The reason behind it is that these students seldom or never use web 2.0 systems before. In terms of learning satisfaction, 100% students are satisfied with the discussion function in the course platform. Likewise, regarding question 10 and 11, most of the students are satisfied with the course platform. In terms of willingness for future use, 80% students are willing to keeping using the semantic-wiki-based platform in the future while the rest remain neutral. As for the last question, 75% students prefer using the course platform in other courses, 15% students do not decided, and 10% students are reluctant to use it in other courses. After interviewing with several students, we know that students are required to use different platform in different courses, which increases their working load and lessen their enthusiasm on using the platform for the formal learning. Yet they admit that they would like to use the platform for informal learning.

Table 1. Questionnaire results (N=20)

	Questions	SA	A	U	D	SD	Mean
Perceived usefulness	1) I think the course platform is useful for supporting collaborative learning.	5 25%	15 75%	0 0%	0 0%	0 %	4.25
	2) I think the course platform is useful to organize individual or group knowledge in a group.	10 50%	7 35%	3 15%	0 0%	0 0%	4.35
	3) I think the course platform is useful to share individual thoughts with group members or all students.	8 40%	11 55%	1 5%	0 0%	0 0%	4.35
	4) I think the relational navigation function of the course platform is useful for learning.	5 25%	8 40%	4 20%	2 10%	1 5%	3.7
Perceived ease of use	5) I think the co-edit function of the course platform is very easy to use.	6 30%	10 50%	3 15%	1 5%	0 0%	4.05
	6) I think the discussion function of the course platform is very easy to use.	7 35%	10 50%	2 10%	1 5%	0 0%	4.15
	7) I think it is easy for me to learn how to use the course platform.	5 25%	10 50%	4 20%	1 5%	0 0%	3.95
	8) I think the course platform is easy to express individual thoughts.	5 25%	13 65%	2 10%	0 0%	0 0%	4.15
Learning satisfaction	9) I am satisfied with the discussion function in the course platform.	5 25%	15 75%	0 0%	0 0%	0 0%	4.25
	10) I am satisfied with peer interaction function in the course platform.	5 25%	13 65%	2 10%	0 0%	0 0%	4.15
	11) I think the course platform is suitable for collaborative learning.	6 30%	13 65%	1 5%	0 0%	0 0%	4.25
Willingness for future use	12) I would like to keep using the semantic-wiki-based platform in the future.	6 30%	10 50%	4 20%	0 0%	0 0%	4.1
	13) I would like to use course platform in other courses.	5 25%	10 50%	3 15%	2 10%	0 0%	3.9

Note. SA, strongly agree; A, agree; U, undecided; D, disagree; SD, strongly disagree.

Regarding the second research question, we perform significant correlation analysis between students' activities on the course platform and their learning achievement. Students' activities are mainly reflected by their editing behavior, and thus we adopt the formula $A_i = N_i + 2 * \sqrt{M_i - N_i}$ to compute the ith student's activities (A_i), where N_i denotes the number of pages initiated by the ith learner, M_i denotes the number of times of editing operation performed by the ith student. Students' learning achievement refers to their final grade that is obtained based on students' mutual marking and teacher's marking. The result of Spearman correlation analysis between students' behaviors and grades is shown in table 2. From the table, we can see that the two variables are moderately positive correlated (R=0.548, p=0.012), which denotes that students' activities on the course platform can affect their final grades to a certain degree.

Table 2. Correlation matrix for variables grade and behavior

Correlations

			grade	behavior
Spearman's rho	grade	Correlation Coefficient	1.000	.548[*]
		Sig. (2-tailed)	.	.012
		N	20	20
	behavior	Correlation Coefficient	.548[*]	1.000
		Sig. (2-tailed)	.012	.
		N	20	20

*. Correlation is significant at the 0.05 level (2-tailed)

Application Scenario 2: A teamwork platform for collaborative e-Research

Scientific documents, research instruments, researchers' competence and cooperation among researchers are fundamental resources of scientific research. Research teams usually construct a platform or website to manage and

deliver their scientific resources, yet almost the platforms serve as the information propogation portals with simple documents management and communication functionalities. Based upon SWiCLE, We have constructed a sustainable teamwork platform to effectively support team members to capture, publish, share and manage explicit knowledge resources, to aid efficient scholarly communication and development of communities of knowledge, and to link novice with experienced researchers for better team building.

Figure 8. Ontology browser
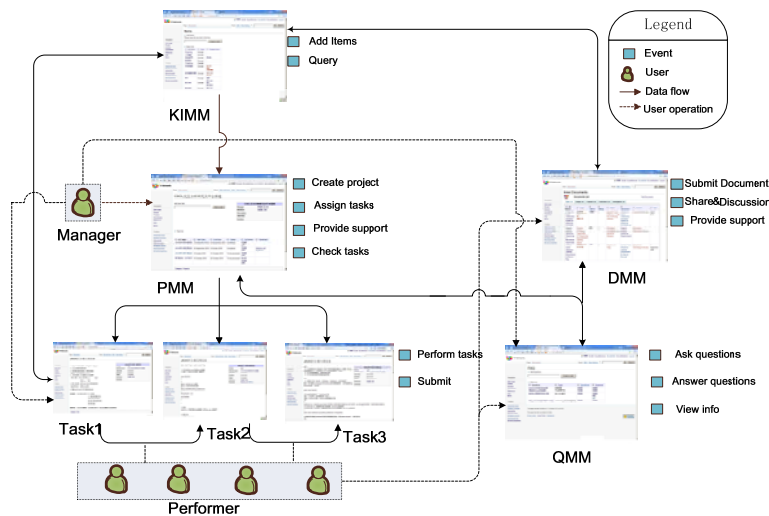
Figure 9. Collaborative working mode

As figure 8 shows, we have built an ontology for scientific research. The three colored parts from left to right displays the tree-structure categories (i.e. concepts), instances and corresponding properties, which allows users to easily browse ontology in an intuitive and friendly way. The teamwork ontology concepts comprise *project*, *task*, *people*, *document*, *question*, etc. Correspondingly, we design several modules to manage resources, such as project management module (PMM), document management module (DMM), knowledge item management module (KIMM), and question management module (QMM). Figure 9 illustrates the collaborative working mode. All the team members can share documents, propose questions or add knowledge items during working process. A manager can create a new project, assign relevant tasks to other team members, and submit some referential materials if needed. Then each team member can examine the projects or tasks allotted to him in his personal working space as illustrated in figure 10. In the personal working space, each user can also know about recent events and changes on the platform, manage his own documents, find all the questions he proposes for others or other team members

propose for him, as well as calendar setting and favorites management. Figure 11 is the interface to lookup timeline of the team. When the mouse moves upon any event, a small window will pop up automatically showing the event description. This function allows the users to have a quick view of the whole team's working planning and progress.
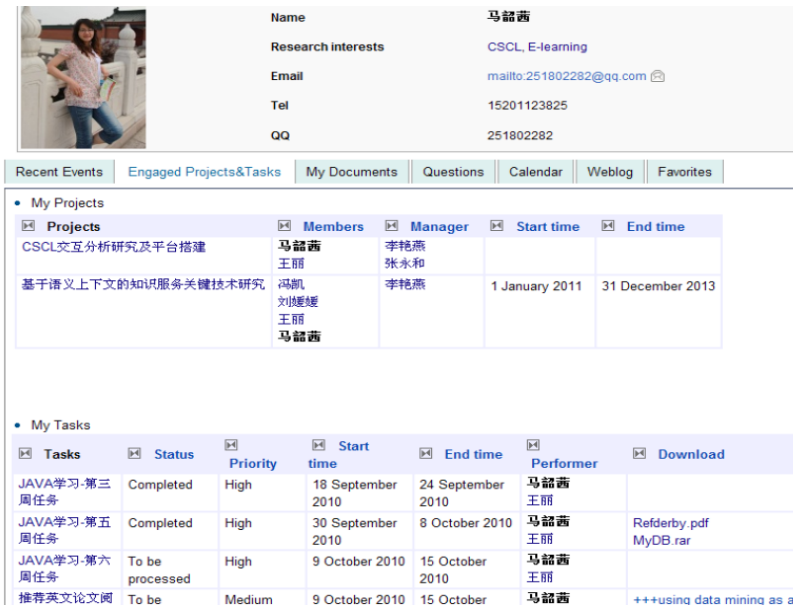

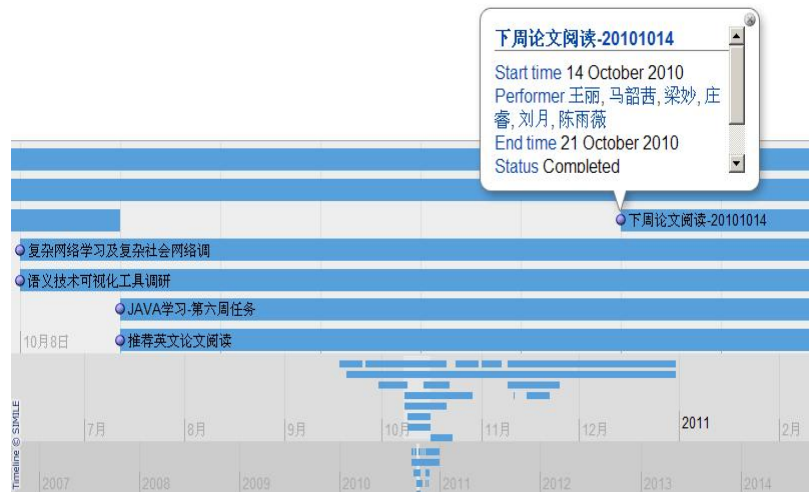*Figure 10*. Personal working space

Figure 11. Team working timeline

To find out user's individual behaviors on the platform as well as mutual interaction among team members, we adopt the formulas mentioned before to conduct analysis in terms of users' participation, activity, impact and interaction for a period of 10 weeks. Figure 12 shows team members' participation statistics result. As the figure shows, there is a large gap between the users. The team member with the highest participation is the postgraduate who is responsible for the platform maintenance, and the team members with lower participation are almost undergraduates who less participated in the research. To further understand users' behaviors, figure 13 illustrates the changing trend of specific team members' activities over the period. There is one member who edits one page in the first week and no activities anymore because this student changed to other team. The user "yuanyuan liu" who is responsible for the platform maintenance are active during the period except one week, and the other two users' activities are relatively steady. Figure 14 shows team members' impact and mutual interaction, in which the node represents team member and the edge represents mutual interaction between team members. The bigger the node is, the higher impact of the member is. It is obvious that there are two members who have no interaction with others since they join the team very late; and besides, the team leader "yanyan li" has the highest impact, and then members "yuanyuan liu",

"yonghe zhang" as well as "shaoqian ma" have higher impact compared with others. Furthermore, the thickness of the edge denotes the interaction degree between team members. The thicker of the edge is, the closer interaction between members is and vice versa. Apparently, there is a clique within which the members have intensive interaction while the rest have fewer interactions with others. From figure 12 to 14, we can find that computation of indicators such as participation, activity, impact and mutuality can actually reflect users' actions and interactions. This provides the basis to develop visualization modules that allow teachers or monitors to understand users' performances on the platform in a more intuitive and convenient way.
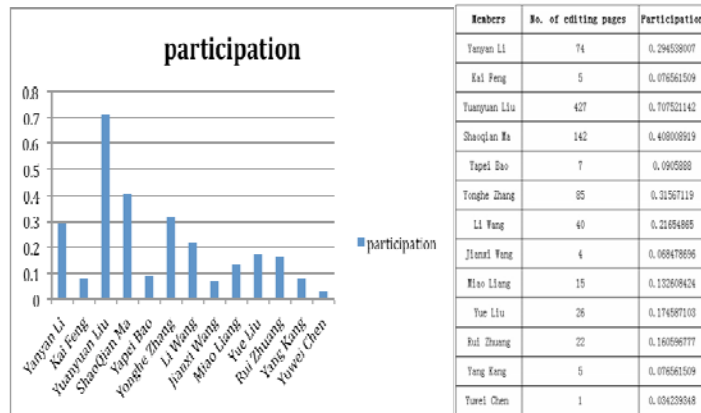

Members	No. of editing pages	Participation
Yanyan Li	74	0.294538007
Kai Feng	5	0.076561509
Yuanyuan Liu	427	0.707521142
Shaoqian Ma	142	0.408008919
Yapei Bao	7	0.0905888
Yonghe Zhang	95	0.31567119
Li Wang	40	0.21654865
Jianxi Wang	4	0.068478696
Miao Liang	15	0.132608424
Yue Liu	26	0.174587103
Rui Zhuang	22	0.160596777
Yang Kang	5	0.076561509
Yuwei Chen	1	0.034239348

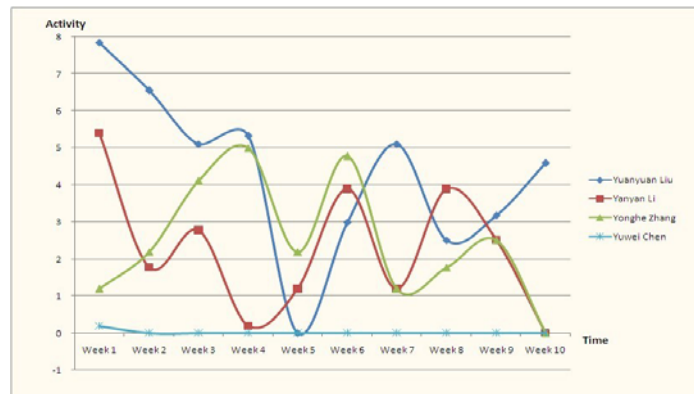*Figure 12*. Participation statistics

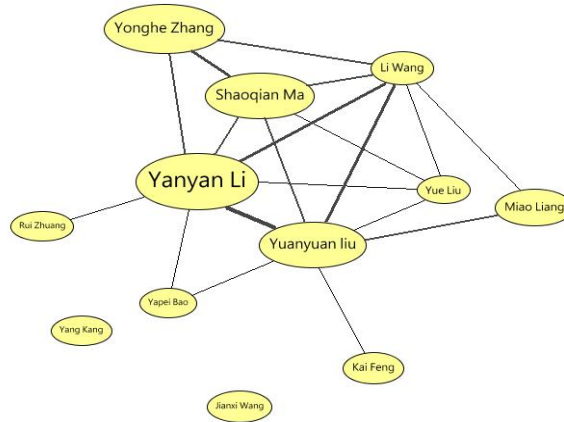*Figure 13*. Changing trend of team members' activities

Figure 14. Team members' impact and mutual interaction

Discussion and Conclusion

Collaboration becomes an essential competency in the current knowledge society. In this study, a collaborative e-learning environment SWiCLE is designed based on semantic wiki to better support resource authoring, accessing, sharing and reusing via friendly facilities and to facilitate flexible collaborative learning as well. Compared with general e-learning platforms such as BlackBoard, Moodle, or other specific collaborative platforms (e.g. BBS, blog), Semantic wiki, a combination of wiki and Semantic Web technology, not only provides full functionalities of wikis for flexible interaction by allowing each individual to contribute his own knowledge and experience on any topic, but also enables structural organization as well as semantic association of resources.

As a preliminary exploratory application, we have developed an online course platform to support hybrid learning. Because it is an optional course, we don't know the students in advance. So we designed and developed the course based on task-driven mode without requirement analysis. The course comprises nine learning units and each unit comprises several tasks. To fulfill each task, students are required to follow the predesigned learning steps. Furthermore, several facilities are provided to support students' collaborative learning. Our initial thought is that the task-driven mode with collaborative knowledge building scaffold can lead students through learning process in an easier and effective way. When the course ended up, by means of questionnaire and interview, we learn that most of students are satisfied with the semantic-wiki-based course platform. Yet some students thought that this kind of hierarchical task-step navigation mode is too deep to use, which lessen their enthusiasm to a certain degree. On the other hand, the situation that some students are not familiar with wiki operation on the platform hinders them in learning process.

Regarding the collaborative teamwork platform, we conducted requirement analysis in advance and determined to design a lite platform to serve collaborative e-research within a team, such as task management, document management, discussion, etc. In order to organize various resources in a coherent and structured manner, we design an ontology and thus the increasingly added instances can be automatically semantic-linked according to the relationship between concepts defined in the ontology. Accordingly, each user own a personal working space in which he can conveniently view all the tasks assigned to him, all the documents shared with others, and all the questions proposed to him and he propose to others. As well, he can check his calendar and favorites easily. So far, almost each user agrees that the platform can satisfy his or her routine work in an easily and friendly manner, and especially, the platform can effectively support their collaborative research work.

Based upon the two applications, it can be seen that semantic-wiki-based platforms could provide diverse useful facilities for different application scenarios by enabling structural organization and semantic association of resources. Yet, it is worthwhile to note that ontology design plays an important role in resource structuring and semantic association. In addition, it is indispensable to conduct requirement analysis and then accordingly design different functionalities to cater for different applications.

Future work is to build a large-scale teacher training community based on SWiCLE to support life-long learning, whilst investigate the information flow and interaction content among users to analyze the community structure and user role, based on which to provide intelligent learning support for users in the community.

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