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Chapter 1

Introduction

1.1 Motivation

With the rapid development of today's society, the knowledge we learnt at school when we were students are fast becoming outdated. In order to catch up with the fast developing society and not to be legged behind both in professional and daily life, constant learning by oneself becomes more and more inevitable and important. However, leaving school means having no wise teachers to instruct one's learning, and no prepared learning materials are available, and no peer classmates to discuss mutually interested topics. Learning by oneself is not actually as easy as it sounds. For a long time these three major difficulties are the main obstacles for people who are eager to learn by themselves until the coming of internet technology.

After entering 21st century, the internet technology is developing so fast that in a rapid speed people's life is completely changed in every aspect. No exception, the way of learning and receiving information are also greatly changed [5]. No longer does one need to worry about no accessing to interested information which is expected to be on the internet whenever needed. And no longer does one have no ways of reaching to another people with similar learning interests who are expected to be connected by the cable wherever. Therefore, the two difficulties are greatly alleviated and the learning situation is greatly improved. Recently there is enormous number of information serving as learning resources on the internet. Therefore, it has become possible to overcome the restrictions of time and place for people who are learning by themselves.

However, like other new technologies, convenience always comes with consequences. With more than enough information loaded on the web, internet users are required not only to navigate web pages to search for useful information in order to construct their knowledge but also to control

the navigation and knowledge construction process [1]. In most of the cases, internet users need to conduct learning activities by themselves on the internet which is also known as web-based self-directed learning. As a result, web-based self-directed learning has become an important issue in the recent decade. On the other hand, since the internet has connected billions of people around the world, a largest ever learning community has been formed, and inevitably, the involvement with other people sharing similar interest has become an important element in the learning process. As a result community-based learning also attracts much attention along with the fast development of the Web technology, in which learners have informal community-centered communications [2]. There are some difficulties when it comes to web-based self-directed learning and community-based learning. This research is aiming to design and develop a system which is expected to improve the current learning situation and provide some assistance to learners on web-based self-directed and community-based learning.

1.2 Thesis Purpose and Outline

In this paper, I propose an approach which tackles the obstacles occur during self-directed learning on the internet. I designed a model, Multi-layer Map Model based on an ISO standard named Topic Maps. This model visualizes common learning behaviors on the web such as locating suitable learning resources, categorizing found resources and sharing them among community members. And then, according to the model proposed, a pilot system (A Resource Organization System for Web-based Self-directed/Community-based Learning) has been developed. I also propose an evaluation plan to test the effectiveness of this system to see whether or not potential users could improve the efficiency of their self-directed learning. After analyzing the experiment data, some positive conclusions have been drawn, several deficiencies have been detected, and most importantly many challenges are raised as future work of this research.

Chapter 2

Background

2.1 Web-based Learning

After entering the 21st century, the fast renovation of information technology made internet possible which also, as many people believe, completely changed our life and way of doing things. Especially in the light of the occurrence of the World Wide Web, accessing to needed information has become easiest ever. From that time, the information loaded on the Web has been growing exponentially with the constant upgrade of internet technology. At the beginning, only text information was available on the internet, but later on followed with pictures, voices and videos. Furthermore, the prevailing of portable tablet recently unexpectedly made Web-accessing ubiquitous. Gradually, we have changed our habit of turning to wised ones or library whenever having questions to surfing on the internet, and are sure of needed information could be found sooner or later. Easy accessibility and stability make it possible to surpass the restriction of time and space which are once great obstacles to ones learning by themselves [6]. Therefore, in recent decade, Web-based Learning is drawing a lot of attentions from researchers everywhere, and is expected to play much more positive roles in enriching human's knowledge repository. Web-based Learning is often called online learning or e-learning because it includes online course content. Traditional learning behaviors are mostly able to be conducted via the internet such as viewing learning materials, doing discussions, taking e-courses and so on[3]. The most obvious feature of Web-based Learning is that learners use information technologies to quenching their thirst for knowledge by viewing and navigating through the contents as learning resources available on the internet, just as shown in Figure 1.

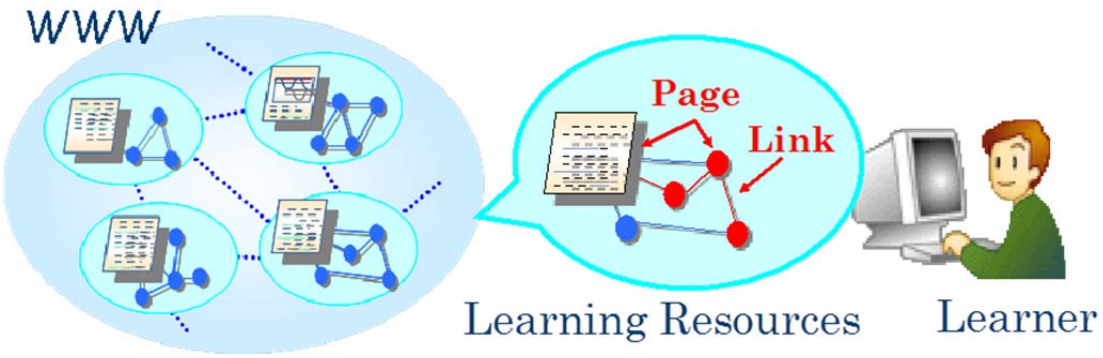

Figure1. Web-based Learning

2.2 Self-directed Learning

After graduation from school, it has become impossible for us to sit in a class room to listen to teacher's lectures. And it is also not always convenient to have some wise ones around us to consult to whenever we have questions needed to be answered. In order not to be legged behind by this fast developing society, people need to conduct Self-directed Learning (SDL) constantly to enrich their knowledge. On the Web, learners can navigate a vast amount of Web-based learning resources to achieve their learning goals. Such resources usually provide them with hyperspace so that they can navigate in a self-directed way by following links among the pages as shown in Figure 2. Especially, it is expected to encourage their information literacy by selecting suitable resources, each of which usually has different credibility and standpoint about the similar topic. Learners need to navigate their way through piles of information and construct their knowledge structure all by themselves. Inevitably we have encountered the self-directed learning in the digital age.

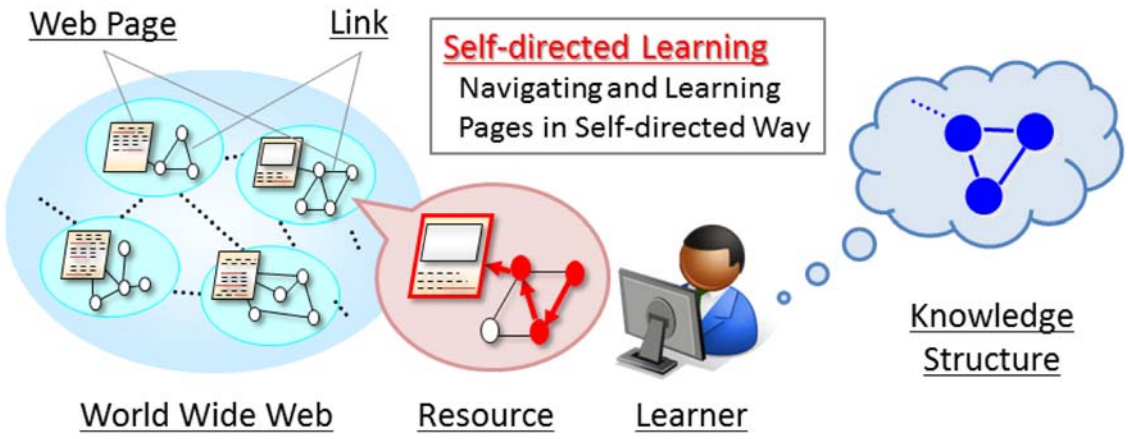

Figure2. Self-directed Learning

2.3 Community-based Learning

There is a famous saying made by Chinese Confucius, after translated by my poor English, it is ”there must be at least one person out of three persons who can serve as your teacher”. This wise saying indicates that collaboration with other people can greatly boost the efficiency of whatever you are dedicating to. As SDL is not always an easy job as one can often get lost or frustrated by studying alone. Since internet has made reaching for people with same interest worldwide possible, Community-based Learning (CBL) has also been drawing attentions from fields of researchers. In this paper, CBL means a process of communication by the community members with the similar learning goals for the purpose of encouraging each self-directed learning activity. Such process involves not only sharing resources but also performing peer review for knowledge learnt. Ordinarily, it is not so easy for self-directed learners to get adequate support since their learning resources and processes are varied from learner to learner. However community-based learning makes them possible to conduct informal communication as feedbacks for the individual self-directed learning processes.

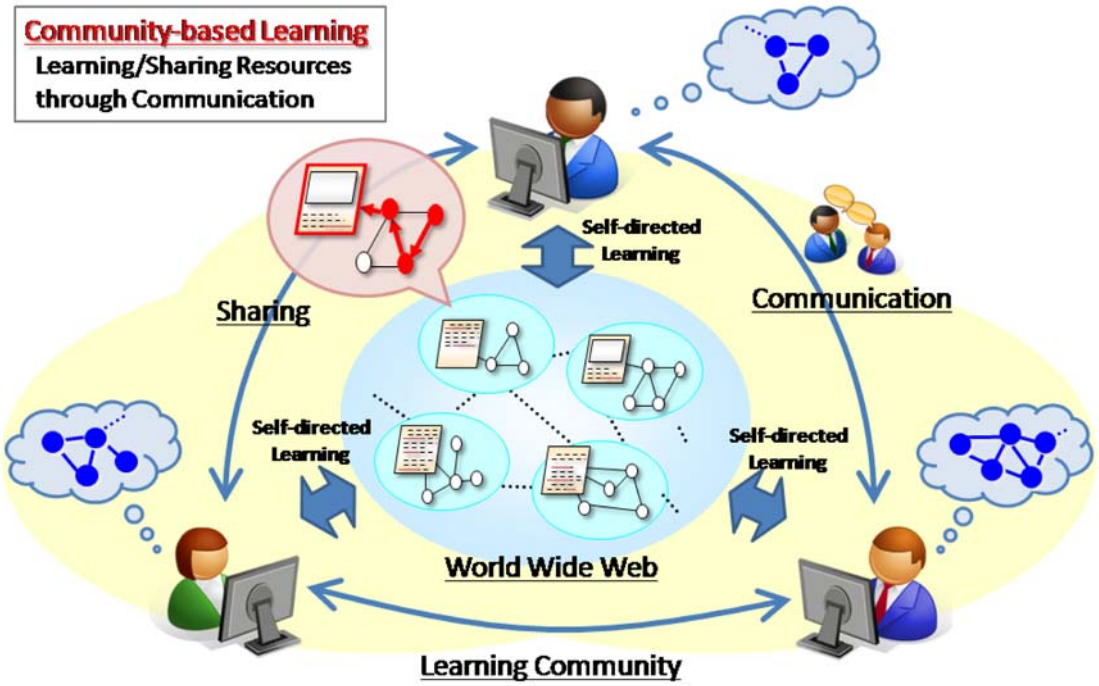

Figure3. Community-based Learning

2.4 Difficulties in Self-directed Learning & Community-based Learning

This paper focuses on these three difficulties: 1. it is difficult to locate suitable learning resources; 2. it is difficult to organize found learning resources; 3. it is difficult to pass learning achievements and get feedbacks from other members of a learning community. There are three major difficulties when it comes to Web-based SDL and CBL. First of all, the large amount of available information on the Web makes it very difficult to locate suitable resources about particular topics of interest [4]. Traditional search engines only order lists of pages ranked according to a particular matching algorithm. The learners therefore have to click into certain Web pages to find out whether they are fit or not to achieve their learning goals. In some cases, there even are hundreds of links in only one web page which could be a painful job to find some useful information out of it. Most of cases are learners may miss the chance of learning after two or three useless clicks since it would be a time-consuming job as previous step of SDL. If the learners finally successfully located sufficient learning resources from several URLs as learning hyperspace; moreover, they have

to organize these resources and to construct their knowledge structures by navigating the hyperspace [5]. Beginners at self-directed learning sometimes lose sight of their learning goal because of the complexity of the hyperspace. Such navigation problems are major issues, and have been discussed regarding the developments of educational hypermedia/hypertext system [1]. Not only they are drowned by the countless information on the internet, but also they have to face the challenge of information organization. Because of the complexity of knowledge structure, simply by storing found links into IE's favorite list apparently cannot fulfill the learning activity. Hence, with some unnecessary pressure usually on the shoulders of SDL beginners, it is natural to take this aspect into consideration. Finally, from an aspect of community-based learning, it is difficult to pass learning achievements and get feedbacks with each member of community who has the similar interests about the certain topics.

Chapter 3

Related Work

As for the importance of Web-based learning becoming more and more obvious, attentions from many researchers of education engineering are being drawn. Among those focusing on improving learning environment in hyperspace, there are tools aiming at providing collection sites for gathering URLs of Web-based learning resources [7, 8], and also research on assisting learners with tools for constructing local index for learning resources found from World Wide Web [9], in which a framework for reorganizing existing Web-based learning resources with indexes representing their characteristics, which consist of “How To Learn” indexes and “What To Learn” indexes, in order to build a learning resource database. And also approach like helping self-directed learners with navigation advises [10], which provides learners with the adaptive preview of a sequence of web pages as navigation path. Moreover, research involving the activities of both instructors and students via developed websites also is conducted by some researchers [11]. As for Community-based learning, the learning opportunities of social bookmarking service have also been discussed [12].

Although, the current researches relating with Web-based learning have greatly enhanced the learning situation on the internet from various points of view, this research is setting off from the basis of visualizing the basic learning behavior on the internet ranging from searching for suitable information to getting access to well-organized learning resources by other people. And the following sections will deliberate on those points.

Chapter 4

Multi-layer Map Model

Visualization is one of the keywords in this research. Because as we all know that in order to make complicated things seem simpler and easy to understand, one of the useful ways to do it is visualization. In order to visualize the common learning behavior of Web-based SDL and CBL, this paper proposes a model which visualizes learning activities by generating maps. This model is called Multi-layer Map model which will be explained in details in the following sections.

4.1 Topic Maps

Topic maps are an ISO standard for describing knowledge structures and associating them with information resources [13]. The Web enables us to create virtually unlimited quantities of information and to make it immediately available to the world. We do not suffer from lack of information availability, but we do have a hard time trying to locate the information we really need. Finding aids are therefore becoming highly desirable. Topic maps provide a standard approach to create and interchange finding aids [14]. While it is possible to represent immensely complex structures using topic maps, the basic concepts of the model—Topics, Associations, and Occurrences (TAO)—are easily grasped [15].

Topics

What are topics? In the widest generic sense, the topics can represent any subjects with meanings perceived by their creator. In this paper, the topics simply mean specific categories of interesting fields of study. This could be created by SDL learners while constructing their knowledge structure.

Associations

Traditional index management environment usually provides “Tree” structure which indexes only are managed vertically; meanwhile however, relationships among same-leveled indexes cannot be represented. Associations of Topic Maps resolve this problem. It provides relationship among topics with semantic meaning.

Occurrences

Occurrences are subordinated to topics. They provide the topics with detailed information in various forms. In this research, we comprehend the occurrence as learning resources form the internet in various digital formats.

Figure 4 illustrates how the three key concepts relate in the Topic Maps standard. The topics represent concepts of a certain field to the learners’ interests. The association links represent hyper-graph relationships between the topics. The occurrence links represent actual Web contents relevant to a particular topic.

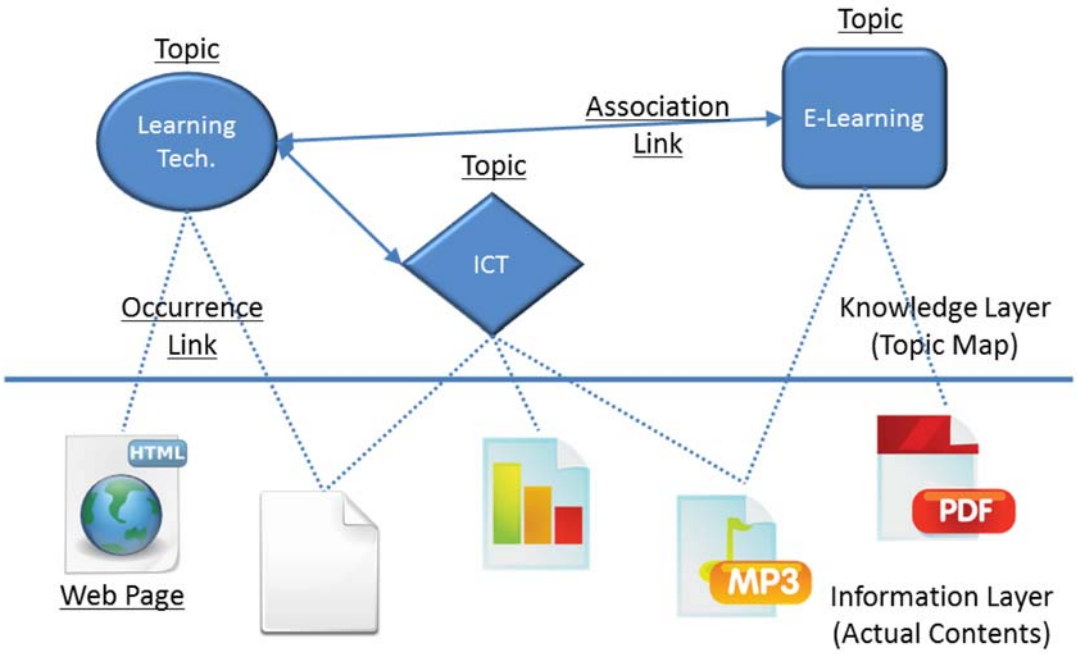

Figure4. Basic Concepts of Topic Maps

Topic Maps can be used to qualify the content and/or data contained in information objects as the topics to enable navigation tools and to link the topics together with multiple, concurrent views on sets of information objects. Here, it is necessary to explain the reason why Topic Maps are suitable for this research. First of all, this ISO standard is mainly aiming at visualizing and classifying indexes and the relationships among them. So it fits our goal of visualizing the basic learning behavior of organizing found information on the internet. Secondly, as mentioned before, even though one has managed to locate right learning resources, it is still very difficult to organize such information. So the occurrences of Topic Maps can help us group the actual web contents under the particular topics. It makes the resources not only easy to classify but also convenient to access. Finally, making Topic Maps needs learners to learn the resources beforehand, and then it is possible for the learners to classify them and connect them with proper topics, and to create associations among topics.

4.2 Multi-layer Map Model

In this research, we divided Web-based SDL into three phases. Firstly,

learners need to locate useful learning resources from the internet based on their interested learning topics. Secondly, learners need to categorize their found learning resources and organize them into meaningful structures. And finally by reviewing the learning results organized by other members of a learning community, they complete their learning information and re-construct their knowledge structure. According to these three phases, and by considering the necessity of visualization, this paper presents the Multi-layer Map Model by referring to the basic concepts of Topic Maps. Multi-layer Map model is the core of the learning environment proposed which is intended to perform as a GUI for self-directed and community-based learning. As its name implies, it has four layers (Content Layer, Resource Map Layer, Personal Map Layer, and Community Map Layer). Figure 5 shows the four layers model with different functions yet dependent on the services provided by the nearest layers. The model provides the community members with communication basis via superposed map representations. It mainly focuses on visualizing the structure of learning contents in term of resource maps. Moreover, this model includes community map where the personal maps are merged, viewed and used by other community members that have the similar interests. The following sections will describe the basic concept of each layer respectively.

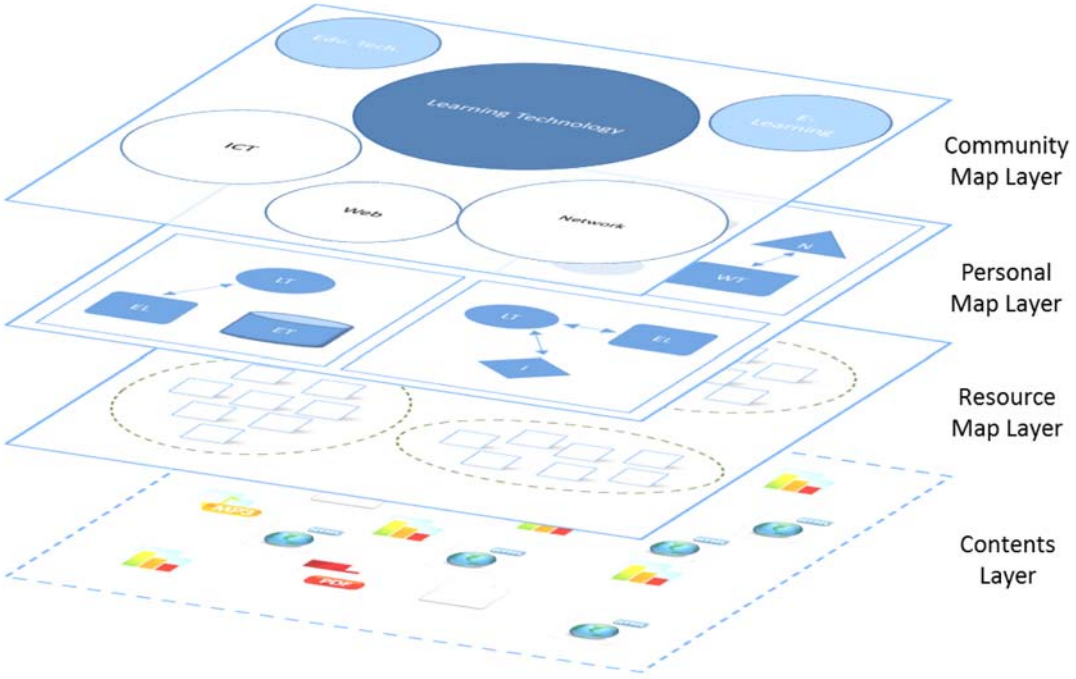

Figure 5 Multi-layer Map Model

4.2.1 Contents Layer

Contents Layer is the lowest layer of this model. It means the actual Web contents such as Web pages, documents, and media files of the Web-based learning resources. It is the place where learners find their learning resources, and as the fast development and renovation of internet technologies, resources are being represented by various digital forms like Mp3, Graphs, Videos and etc. It is also the foundation of this model.

4.2.2 Resource Map Layer

As there are countless learning resources on the internet which although provide the learners with more than enough information to learn, learners can easily get lost in that ocean of information which are presented in various forms and structures. Some important information can be ignored due to the complexity of its representation. In some cases, completely unrelated information in some webpages constantly interrupts with learners learning goals which lead to unexpected distraction. Resource map layer is

the place to visualize structures of the Web contents which provide learners with enough semantic meanings by the learning resources in one-to-one manner as shown in Figure 6. This map provides the learners with an overall perspective of the resources used by the community members. Every node used by community members represents crawling contents information and labeled with typical words such as title of the Web page occurred. The learning behaviors on the environment like searching for resources, selecting real contents, and categorizing contents are conducted at this layer.

4.2.3 Personal Map Layer

Personal map layer is aimed to support learners' self-directed learning. It helps the learners to edit and reconstruct their personal topic maps based on the spatial maps created at the resource map layer. At this layer, learners are capable of defining topics, adding/deleting occurrence links between topics and contents, making the structure among topics by association links, and navigating resources.

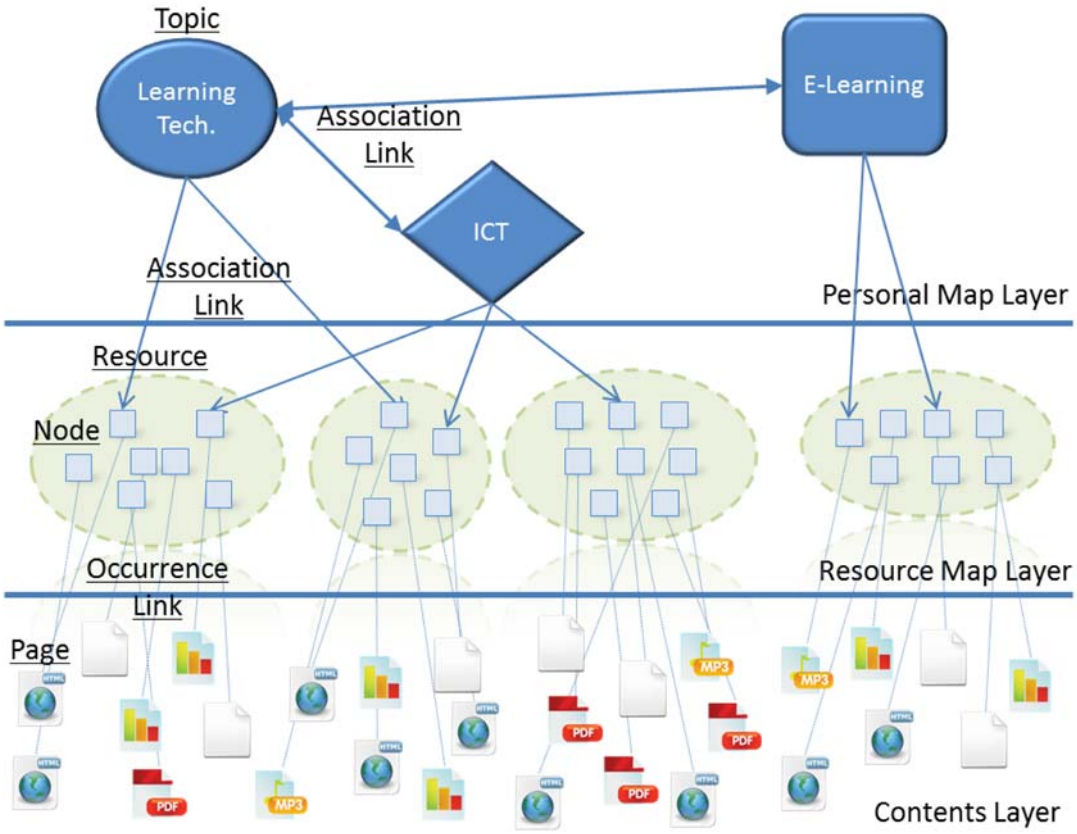

Figure6. Relationship Diagram among Personal Map, Resource Map and Contents

The learners need to clear their learning goals and based on which locate their learning resources from the Web before editing their personal maps. The quality of the personal maps relies on the clearance of learners' learning goals and grasp of their found learning resources.

4.2.4 Community Map Layer

For the purpose of sharing learning achievements in the community, community map layer merges the personal topic maps with that of other community members by displaying bubble form charts based on their features and relations as shown in Figure 7. In order to give out more information, the size of each bubble, the color of each bubble, and the distances among them are all expressing useful information about community learning activities. The size of each bubble represents the

number of the occurrence links in each topic, in another word, the capacity of information storage about that learning topic. The bigger the bubble is the more learning resources it contains. The distance between bubbles is calculated by the number of association links among topics. The nearer they are, the more related the topics are to each other. The color of each bubble represents the relationship between learner's learning topic and the topics created by other community members. In these ways, all the personal topic maps are classified into groups at this layer to be better viewed and shared in community learning. This map also provides glossary, taxonomy, thesaurus of the community by enabling the community members to edit different topics having the same meaning.

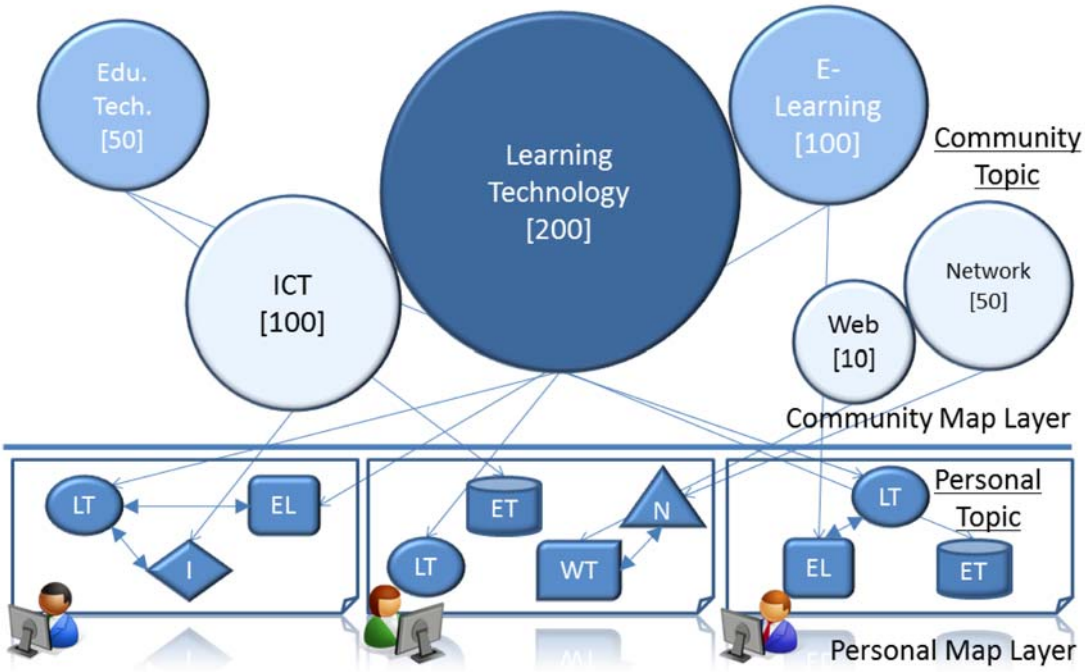

Figure7. Community Map

The size and color of each bubble can be easily managed. However, distance among bubbles is difficult to calculate and dispatch. This will be discussed in Chapter 5.

Chapter 5

Sequentially Spring-Model Map for Visualization of Community Map Layer

How to reasonably arrange bubbles in Community Maps is very important for the community members. As the earlier section described above, the bubbles represent all the topics created by each community member, therefore distances among these bubbles can easily be perceived as the level of similarity among topics. The closer the bubbles are, the more related the two topics might be, which gives learners hints of which topics should be viewed prior to others. One of the essentials for Web-based learning is that a learner can learn about a topic from diverse points of view by using a lot of Web-based resources available for learning the topic [16]. In this chapter, we introduce how to visualize the topics as concept map [17] for the community by adapting the spring model approach sequentially. This is expected to provide learners with relationships among the topics, which has multi-dimensional inputting without explicit links, as a community topic map automatically.

5.1 General Spring Model Algorithm

Because of the distances among the bubbles are mainly effected by the community-based learning activities, the relationships among the topics are constantly changing all the time. Sometimes they might be related to each other and need to be brought nearer, but sometimes they might turn out to be less related and need to be brought further from each other. The features of spring are fit to these characteristics and therefore it has been considered for arranging community map. Spring Model is that by using the forces among nodes, and the results calculated by using spring-related algorithm in the arc of the graph, the places for all nodes can be calculated [18]. By using this methodology, maps with fewer nodes and arc lapping is possible

to be generated at a relatively higher speed. However, as for there is no arc in the community map and the need for much time of calculating graph data, it is difficult to use the exactly the same logic presented by Eades Peter. And it is necessary to modify this method for the characteristics of our research.

5.2 Arranging Algorithm

After referring to a former research [19] about how to fast conduct arrangement by using spring model successively. This research sets the importance of each node, and takes "no-arc among nodes" into consideration, and in the end presents the arranging algorithm for community maps.

Calculating the importance of each topic

The importance W_i of Topic i in community map can be calculated by the following formula.

$$W_i = \sum \alpha_j \sum C_{i,j,k} \qquad (1)$$

Where $C_{i,j,k}$ is used to standardize parameter j which is related to a topic i created by a learner k. j represents types of parameters relating to the importance such as frequency of topic appearance. On the other hand, α_j indicates the weight which is set beforehand for each parameter. According to this formula, it is possible to calculate the importance of each topic which could be expressed by the size of bubble in the community map.

Calculating the relationship among topics

The relationship among the topics of the community map $R_{m,n}$ can be attained by the following formula.

$$R_{m,n} = \sum \beta_l d_{l,m,n} \qquad (2)$$

In this formula, $d_{l,m.n}$ is used to standardize parameter l which is related with the relationship between topic m and n. l represents the type which include the relevancy among the topics. It could be indicated by the number of links mutually contained by different topics, the relationship among topics and learners, and the relationship between topics and learning resources. This is intended to indicate the relevancy among topics. On the other hand, β_l indicates the weight which is set beforehand for each parameter. According to this formula, it is possible to calculate the relevancy among topics which could be expressed by the distance among bubbles in the community map.

Setting of initial position

Node with the biggest value W_i from formula (1) will be located in the center of the community map. The other nodes will be located in order according to their importance, and their position will be calculated by formula (2) successively. Because of the community map are changing constantly according to community-based learning activities, the distances of bubbles will be calculated by the following motion equation.

Approximated Calculation of Motion Equation based on Euler's method

As for there is no expression of relationship among links in the community map, we suppose that all the bubbles are connected with implicit springs, and node m and n are moved by the forces calculated by the following formula.

$$F_{m,n} = -K(D_{m,n} - R_{m,n}) \qquad (3)$$

Where K is fixed value representing the strength of spring. $D_{m,n}$ is the actual distance between topic m and n shown in the community map, while $R_{m,n}$ is the expected distance between m and n calculated by the formula (2).

Here, suppose number i node is dragged/repelled by F_i, and the position of this node is X_i, and the mass of the node i is W_i. We can repeatedly use the following motion equation to decide the final position of node i.

$$W_i X_i'' = F_i \qquad (4)$$

However, because of the unnecessary of physic simulation, at the time Δt, we are using Euler's method [9] to approximate the speed and position at the time of $t+1$.

$$V_{t+1} = V_t + (F_t / W_t \cdot \Delta t) \qquad (5)$$

$$X_{t+1} = X_t + (V_t \cdot \Delta t) \qquad (6)$$

Moreover, in the actual calculation, in order to control the distances among nodes and avoid the non-stopping motion of each node. We are using the friction force to control such situation in order to stop the movement of each node at certain time. Figure 8 is the result of the layout of community map based on this algorithm.

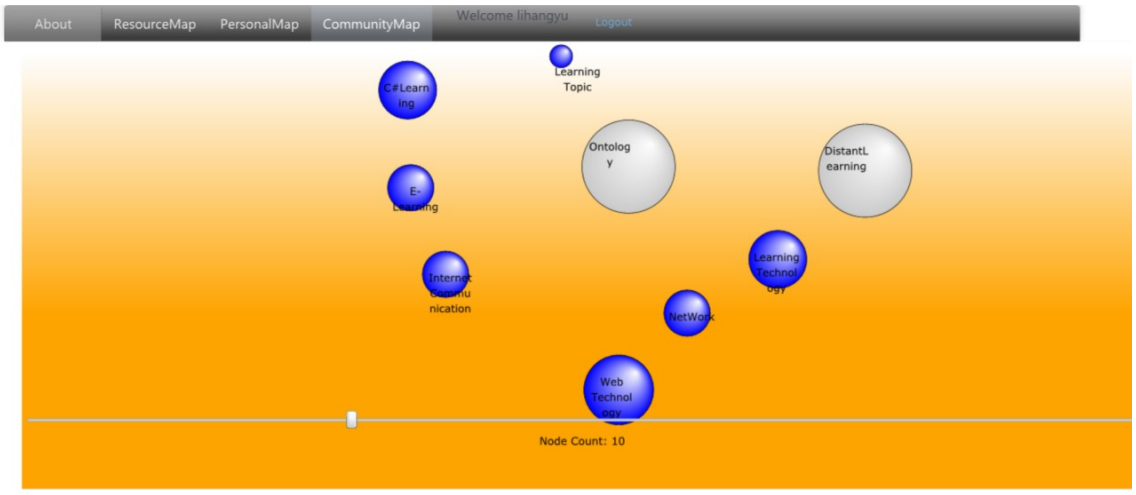

Figure8. The interface of Community Map

Chapter 6

System Overview

In this section, I talk about the architecture of this learning system. Figure 9 shows a block diagram of the whole learning environment.

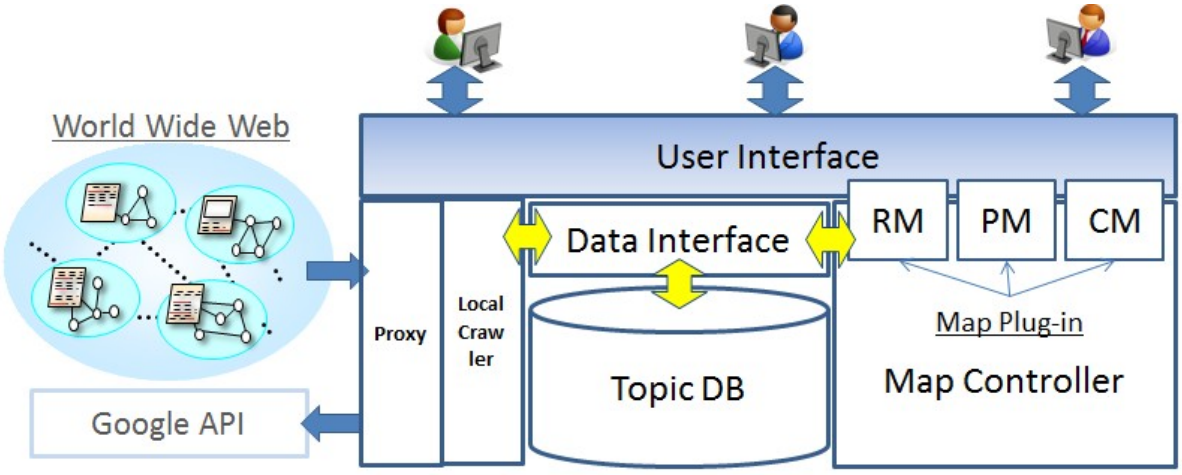

Figure 9 System Architecture

6.1 Proxy and Local Crawler

As we already know that the traditional search engines like Google is the first thing we can think of using when it comes to searching information. We input some keywords, and Google will offer hundreds of lists of links related with the keywords we input (according to its algorithm), and the order of links listed will give us the priority of links needed to be clicked. We are actually doing great as long as we get used to this method, and Google itself also does not fail us in most of the cases. However, once we click into some links Google offered, we immediately jump into a huge pond of information for the links clicked into also contains plenty of other links. Combined with the complexity of web pages itself, we are very much

likely to lose sight of some important information, even got distracted by completely irrelevant information in some extreme cases. In order not to let learners lose sight of their learning goals, and focus only the useful information they tend to search for, this system offers a local proxy for reading pages into the system and a Local Crawler which gathers all the Urls and the information about those Urls of a chosen link. Generally, because of security reasons, the contents from internet are shut down from different domains. This research provides a local proxy which will perform as a mediate agent to read web contents locally. As learners click into some links, the local crawler will automatically gather such information and store them in the format of XML according to Topic Maps format.

6.2 Map Controller

Map Controller is responsible for map editing and visualizing function through layers of the resource, personal, and community maps. As for the maps created at the upper three layers have their own features, each layer has their own plug-in map controllers. Resource map plug-in generates spatial maps automatically based on the results crawled by the local crawler. It shows the contents of selected links in term of spatial map which represents the actual contents for the learners to view in a much easy way. Personal map plug-in drafts the personal topic map initially. The learners can edit their own personal topic maps by adding or deleting certain nodes, building association and occurrence links. Several association types are defined in the plug-in such as super-sub (is-a), related term, synonym, antonym, etc. Not only in this way leaners can more easily organize their found information, but also the found information gets organized both horizontally and vertically. Usually, we do not have the habit of inserting interested links into IE's favorite list, let alone getting them organized. But this system will make learners to do this by making personal topic maps. Community map plug-in merges the personal maps in the community members and represents them with conclusive bubble charts. It also provides associative search and community filtering functions for the purpose of sharing their learning achievements.

6.3 How to Construct Multi-layer Maps

Now, it is necessary to summarize the procedures of making the topic maps by using this system.

At beginning, learners input keywords into search engine APIs in order to get related search results so that they can look for the topics of interest under certain field at the content layer. If the learners select interesting Web resources from search results, the local crawler gathers information of the Web pages from the resources selected and stores it to the database.
Then, the learners create their own topic maps by trimming occurrence links defined by the initial maps and improving upon relations among topics while learning the pages in self-directed way; meanwhile they can add notes and restructure relationships among topics and nodes.

As community-based learning, the learners search topics from the community topic map merged by other learners associatively and modify them into forms of their own. As for beginners of Web-based self-directed learning, it could be helpful getting informed with useful learning resources organized by community members with similar interest. The community map of each field of interest would become more and more complete and sophisticated by the progress of community-based leaning. Figure 10 illustrates a flowchart for constructing the multi-layer maps. This research developed a pilot system which is also called resource organizing system for self-directed learning and community-based learning. It almost realizes all the key functions mentioned in the above sections. In the next section, the functions and features of this pilot system will be introduced.

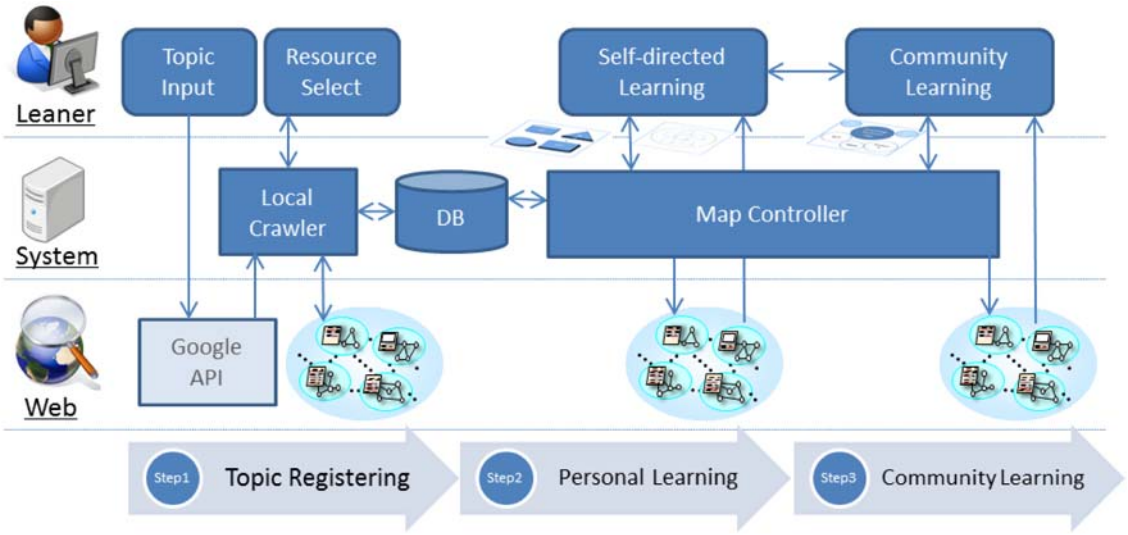

Figure 10. Flowchart for Constructing Topic Maps

Chapter 7

System Overview

7.1 Interface of Contents and Resource Map

Based on the Multi-layer Map Model proposed and system architecture designed above, we developed a system using Microsoft .NET framework and Silverlight interface.

After logging into the system, learners select the most relevant link from the list offered by embedded Google API, the system will visualize the contents crawled by local crawler contained in the selected link as shown in Figure 11. There are two blocks in this interface, one (Block 2) is the contents layer which shows the web page of selected link after being re-written by local proxy, and the other (Block 1) is showing the visualized map from crawled data. The learners can view the contents and the visualized resource map at the same time in order to grasp the main contents of selected link as explicitly and quickly as possible. They can not only click some link on the left while the visualized map will be shown on the right automatically, but also can view the contents by clicking into the nodes on the right side as shown in Figure 12.

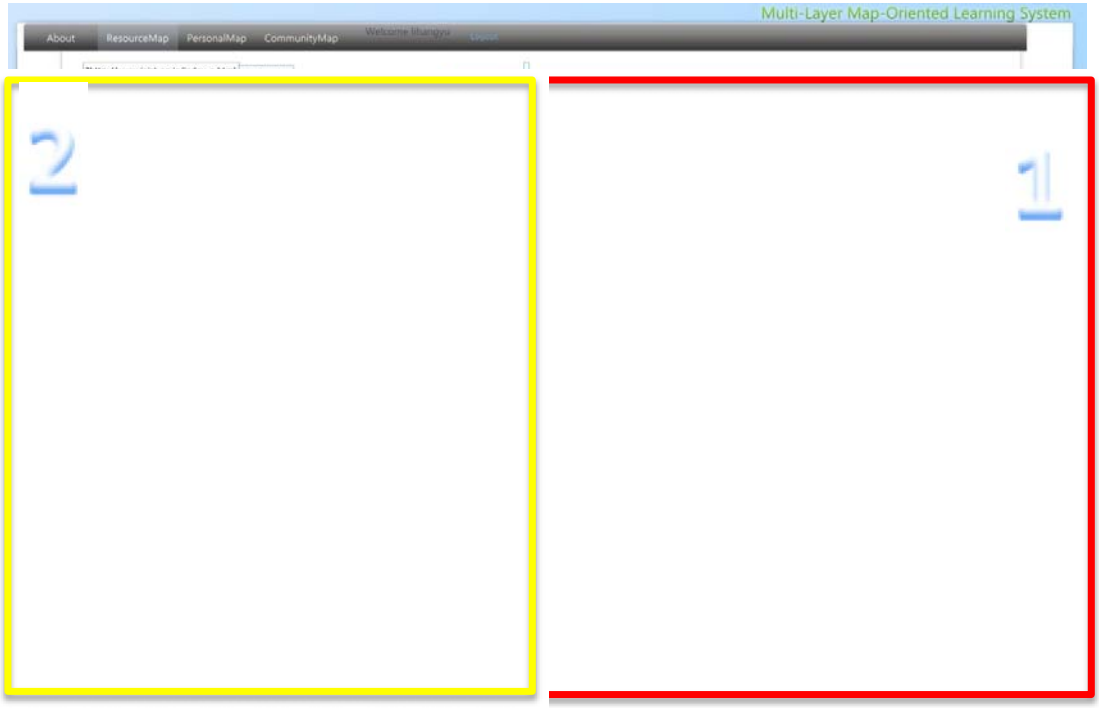

Figure11. Interface of Contents and Resource Map Layer

Figure12. Viewing Contents at Resource Map Layer

After browsing both contents and resource map layer, the learners have

grasped enough knowledge to categorize the information they thought useful. As Figure 13 shows, learners can create new topics or keep using existing topics. They can also build up associations among topics based on the knowledge they have perceived. When they have decided on the topic, a little icon will appear on the upper corner of the graph, and learners can drag and drop the nodes selected into the icon which means the information has been categorized. In this phase of learning, learners can both search for information needed and organize found resources.

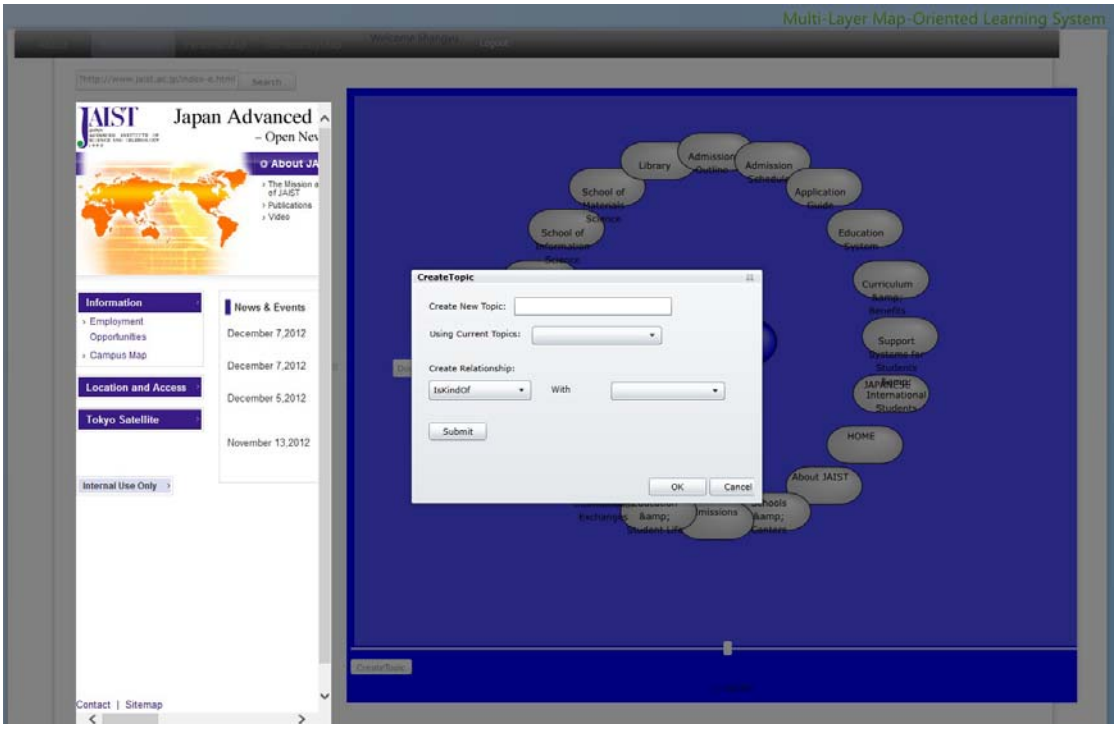

Figure 13. Create Topic and Build Associations

Figure 14. Store Links by Drag and Drop

7.2 Interface of Personal Map Layer

The learners can view and edit the personal maps they have created. As shown in Figure 15, block 1 shows all the topics of personal maps had been created by individual learner, by clicking each topic, the personal map accordingly will appear in block 2. In block 2, the topic selected is shown in the middle, and the other topics related with the selected one will also be shown and the type of associations also. This map is created during the search for suitable learning resources by learners in the contents and resource map layer.

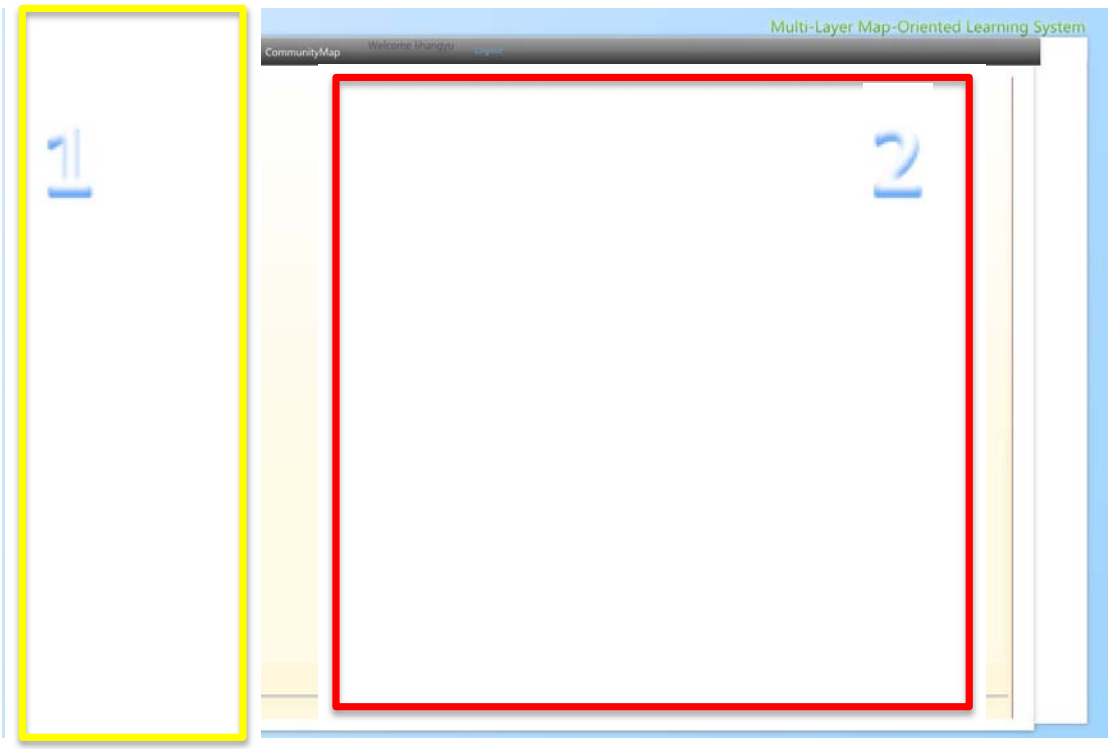

Figure 15. Interface of Personal Map Layer

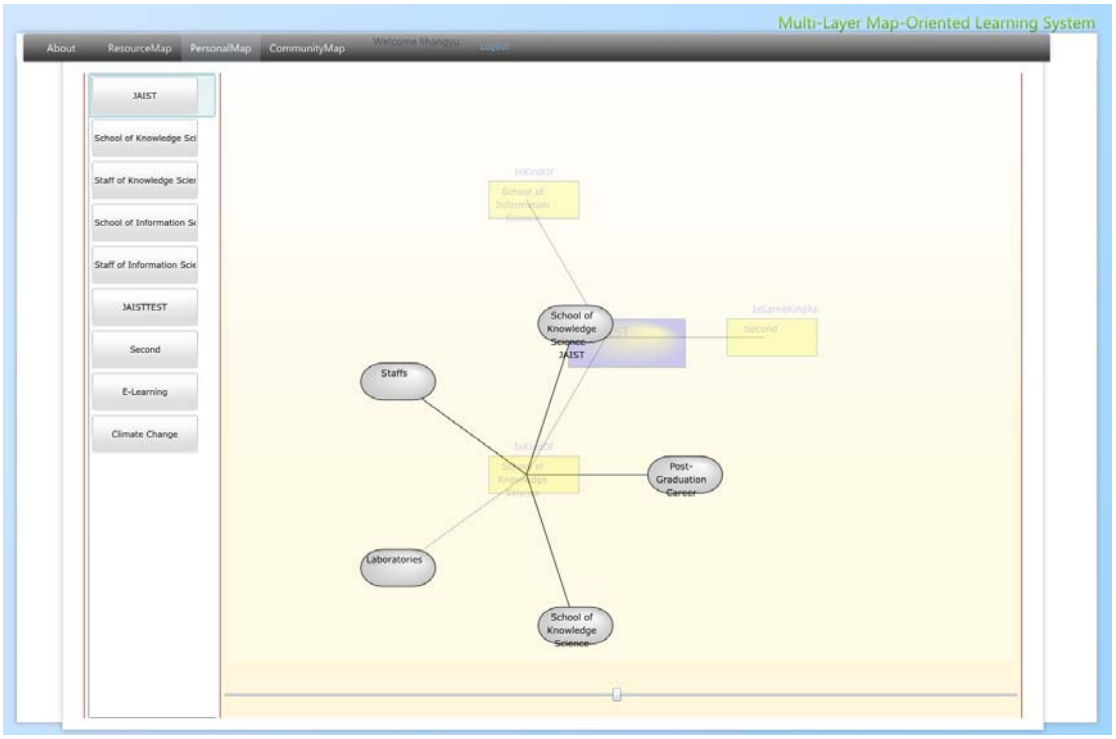

Figure 16. Viewing and Editing Personal Map

Also as shown in Figure 16, by clicking into each rectangle in Block 2, the links stored before will be shown, and by using the same method in the layer of resource map, the contents behind each node can be viewed.

7.3 Interface of Community Map Layer

In the community map, all the topics created by community members will be shown in term of bubble chart. Each bubble represents one topic, the distance among bubbles means the relevance among topics which means the nearer they are, the more related they might be. The colored bubbles mean the relevancy with the learner's learning interests. This kind of information will offer learners with some hint of which bubble should be checked first.

After making his decision about which one should be clicked into, the resources which were found by all the members of the learning community under that topic will be shown with different color. The colored ones mean that the resources have not been included under the same topic of that learner. The uncolored ones mean the opposite. And the stars above each node are the evaluations of the learning resource given by all the members of the community. All this information will help the learners to choose which one will be added into their own personal maps. Of course, they also can click into each node to see the actual contents behind it.

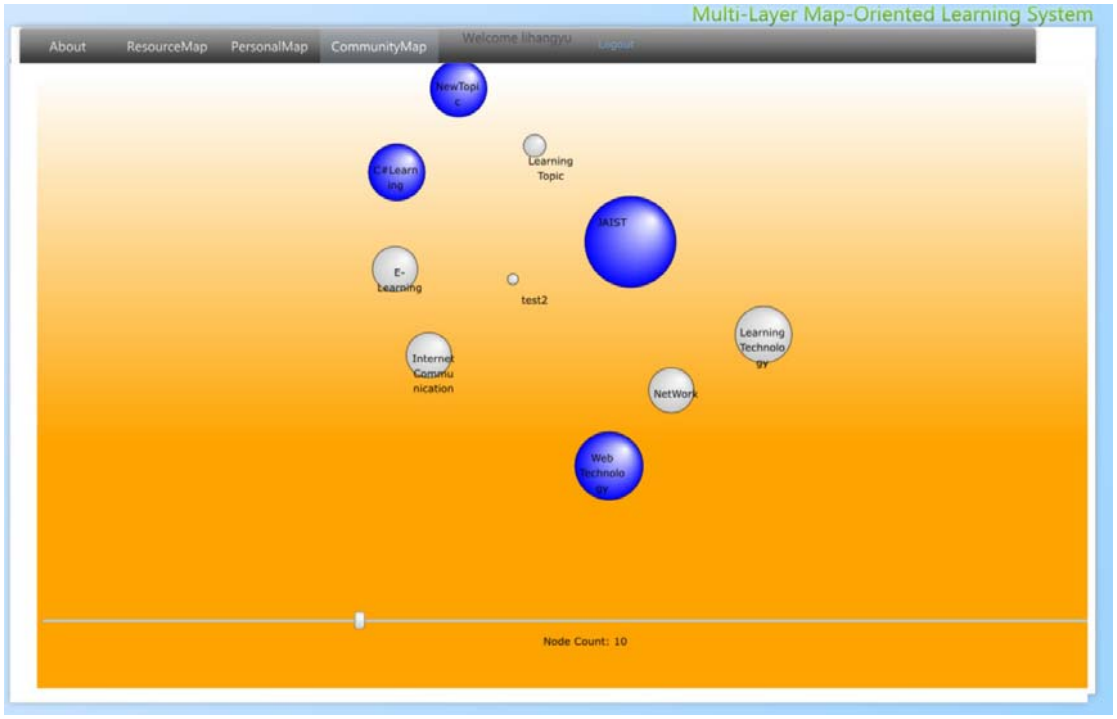

Figure 17. Interface of Community Map Layer

Figure 18. Completing Resources by Viewing Others'

Figure 19 shown below describes the flowchart of making personal maps.

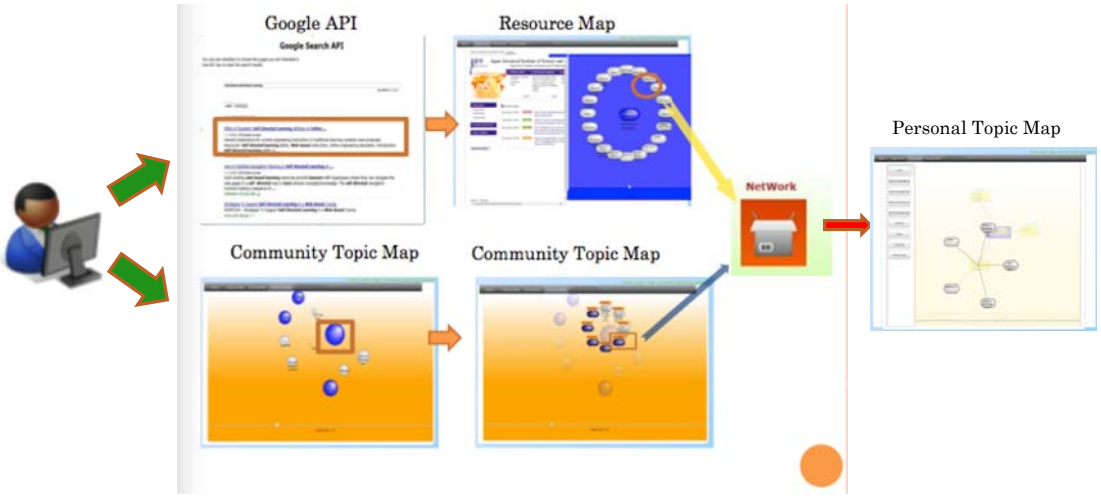

Figure19. The Flowchart of Editing Personal Map

Chapter 8

Case Study

In order to evaluate the effectiveness of the developed system based on the Multi-layer Map Model proposed, we conducted a case study as an important part of this research. The case study was completed by 16 participants who are all graduate students of JAIST with high skill and frequency of using internet. As for the experimental environment is English, they also have the similar level of English proficiency.

8.1 Evaluation Method

Considering the fact that ordinary self-directed learners are accustomed to using IE to search for information on the internet, in order to clarify the advantages of using the developed system when it comes to self-directed learning on the internet, this evaluation plan is designed as contrast experiment. Since this system was developed for alleviating the three difficulties described before, the evaluation plan needs to be considered especially to emphasize the features of the system which are particularly aiming at the three major difficulties.

8.1.1 Experiment Scenarios

The experimental subjects are required to use both IE and the system respectively to obtain their feedbacks. However, there must be some affection generated when jumping from IE to the system under only one learning theme, or the other way around. In order to make this evaluation as objective as possible, not only there were two separate learning themes prepared, but also the learning websites were provided beforehand.

Table 1. Experiment Scenarios

	Name	Website
Theme one	E-learning	http://www.grayharriman.com/index.htm
Theme two	Protecting Environment (PE)	http://www.epa.gov

Because that these two websites contains hundreds of links themselves and sub-themes, letting the experimental subjects choose whatever they want to learn might cause someone got lost and as a result affecting the objectiveness of the evaluation. Therefore, there are twenty keywords prepared for each learning theme (it is can be assured that enough learning contents in the websites), and the experimental subjects are asked to learn according to those keywords as much as they can in fixed amount of time.

8.1.2 Experiment Arrangement

By considering all the experimental circumstances, at least four of which need to be conducted for counterbalancing. Since one experimental subject needed to use IE and the system to conduct different learning theme separately in different order, each subject was arranged like the following table.

Table2. Experiment Arrangement

	Phase One (30 minutes)	**Phase Two(30 minutes)**
Subject One	System(E-Learning)	IE(PE)
Subject Two	System(PE)	IE(E-Learning)
Subject Three	IE(E-Learning)	System(PE)
Subject Four	IE(PE)	System(E-Learning)

Since the experiment instruction time is needed and so as the refreshment

time between phases, extra 30 minutes are added into experiment time which makes the total of 1.5 hours for a complete session. Each individual was asked to conduct self-directed learning using either IE or the system under the theme of both E-learning and PE.

8.1.3 Experiment Procedures

The goal set for experimental subjects is that: Finding suitable web pages and build up knowledge structure. First of all, the subject was asked to find suitable web pages from the websites provided by using IE and the system separately. In the IE case, the found pages need to be saved in the favorite list of IE. And then, based on the resources found either in IE favorite list or system's personal topic map, the subject was asked to draw Keyword map. Keyword map consists of keywords extracted or concluded by the subject when reviewing the found learning resources. I believe in this way, the LEARNING process can be assured and irresponsible actions could be effectively avoided. Finally the subject was asked to review the resources collected by the community members and add new keywords into the keyword map they drew before. Here, I know that community-leveled learning resources are very difficult to build since not only does it need time but also certain number of people to complete and both of that are not easy to assure without affecting the objectiveness of the evaluation itself. Therefore, we built two community resource bases according to the two theme from the two provided websites in advance. In IE, they were expressed in term of bookmark list, and in the system they were expressed in term of community maps. These contents were the same.

8.1.4 Evaluation Factor

As described in last section, experimental subjects were asked to conduct three procedures in two different phases while using IE and the system respectively. In either phase, they must follow "Finding resources (Procedure 1)"→Drawing Keyword Map (Procedure 2)→Supplementing Keyword Map (Procedure 3)" these three procedures, in each of which

there was one evaluation factor indicating the effectiveness generated during the process.

Number of Suitable Pages Found in Procedure 1

This procedure in both phases was considered to be the process of summarizing useful learning resources. In fixed period of time, the number of found pages can best illustrate the resource locating and organizing capabilities of IE and the developed system.

Number of Keywords drawn and Webpages Viewed in Procedure 2

In order to find out the privileges of constructing knowledge structures while using this developed system, the participants needed to read into the found links and draw their keyword map, this not only filtered out the irrelevant links accidentally stored due to the rush, but also can evaluate the accessibility to found learning resources. Moreover, by counting the number of webpages viewed and from which the keywords were written, we could deduce the effectiveness of finding related Urls whether using IE or the system. One point needed to be pointed out was that it must be the number of pages from which keywords were drawn, not those from which no keyword were drawn.

Number of Keywords Added and Webpages Viewed in Procedure 3

We designed the third procedure as community-based learning where the participants were asked to view the learning resources found by other members to complete the resource bases they built before. In order to evaluate the accessibility to learning resources and convenience for judging the usability of some others-organized learning materials, the number of keywords newly added into the previous map and the webpages viewed in order to write new keywords seemed really necessary. The reasons for this were similar with that of the procedure 2.

Number of Keyword Islands Drawn within Keyword Map Eventually

This evaluation factor was added after finishing the actual experiment. When viewing the keyword maps drawn by all the subjects, we found that the number of keyword islands (cluster of keywords) were very different between using IE and the system. This could best describe on which extent the participants could build their knowledge structure and to which level they could strengthen the meta-cognition during the process.

8.2 Data Analysis

Sixteen volunteers were gathered to conduct the experiment, and four groups of data were collected. The details are shown in Table 3.

Table3. Experiment Data

Experiment: System VS IE											
Links (Sys.VS IE)		Keywords (Sys.VS IE)		Pages (Sys.VS IE)		Keywords Added (Sys.VS IE)		Pages Newly Viewed (Sys.VS IE)		Islands drawn (Sys.VS IE)	
64	13	39	19	16	6	28	26	15	10	2	7
49	17	40	24	15	7	32	17	13	8	1	4
65	23	53	27	18	10	36	20	15	6	1	6
73	16	66	17	17	4	40	14	8	3	2	2
62	12	44	21	12	8	37	15	16	7	2	6
76	15	52	20	15	6	21	20	10	8	1	3
57	21	46	21	13	5	31	19	9	9	1	3
63	31	53	20	16	6	36	17	12	6	2	4
46	13	30	28	14	8	27	18	12	8	2	7
67	17	52	25	17	10	55	16	20	7	2	7
83	23	42	20	10	7	43	16	16	8	3	4
68	16	40	20	11	8	27	14	7	8	2	4
63	15	55	24	16	5	42	6	11	4	2	6
61	16	50	20	13	6	31	10	13	3	2	5
68	23	52	24	14	6	46	15	15	5	3	6
59	15	59	17	14	6	35	16	8	5	1	3

From the data itself, we could easily see the difference between using IE and the system in each group of data. However, in order to filter out the accidental elements which might exist somewhere, we were using T-test, which assessed whether the means of two groups are statistically different from each other to see if the difference was meaningful or not. The following table describes the result of T-test used for every group of data.

Table4. T-test Table

	Average(System)	Average(IE)	T Stat.	t Critical two-tail	P(T<=t) two-tail
Num. of Links Found	64	17.875	19.65474	2.13145	4.06E-12
Num. of Keywords Drawn	48.3125	21.6875	10.05209	2.13145	4.67E-08
Num. of Pages Viewed	14.4375	6.75	11.18182	2.13145	1.13E-08
Number of Keywords Added	35.4375	16.1875	7.066501	2.13145	3.83E-06
Number of Pages Newly Viewed	12.5	6.5625	6.188345	2.13145	1.74E-05
Number of Islands Drawn	1.8125	4.8125	-7.74597	2.13145	1.28E-6

We could easily see from the table, *t Critical two-tail* < |T stat.|, and $p < 0.05$ from all the data. We can conclude that differences within each group were statistically reasonable.

8.3 Discussion

From the result of evaluation, we can conclude that more suitable pages can be found by using the system. Moreover, the easy accessibility to found learning resources provided by the system enabled the subject to draw more keywords in their own keyword map and to view more webpages they thought related. In community-based learning, the visualization of relevancy among topics and possession situation of the member indeed

enable the subjects to fast locate their needed learning resources and also more keywords can be drawn based on the relationships among topics.

Another unexpected result would be the number of the keyword islands drawn eventually. The reason for this was that the system provided the subject with the function of building relationships among the topics while they were searching for useful information. While the subjects did not have the intention to categorize their found information in IE condition, they just stored the pages under their names in IE favorite list. This difference caused the subject in IE condition drew more number of islands in their keyword maps. Basically, no relationships could be seen among keywords in their maps. However, in the case of the system, the keyword islands number was drastically reduced and we could clearly see the connections among keywords from which we deduced that using the system could better help the subject build knowledge structure and strengthen their ability of absorbing knowledge. The below are examples of the actual keyword maps drawn by one experimental subject.

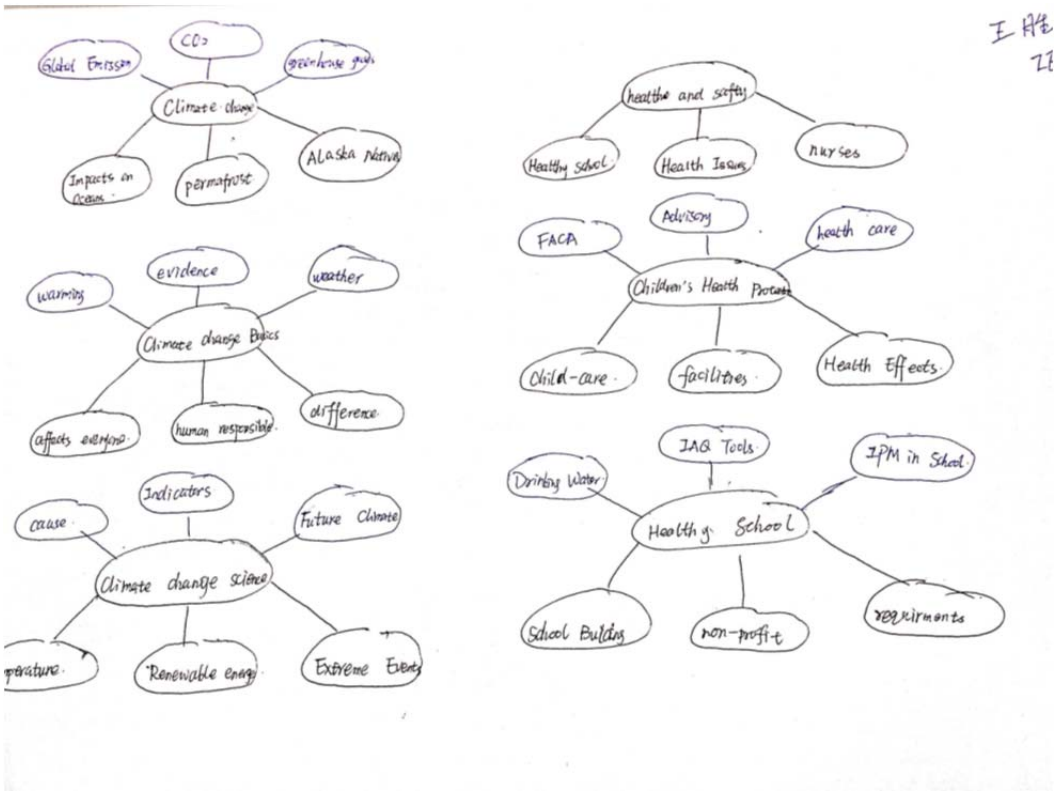

Figure20. Example of Keyword Map When Using IE

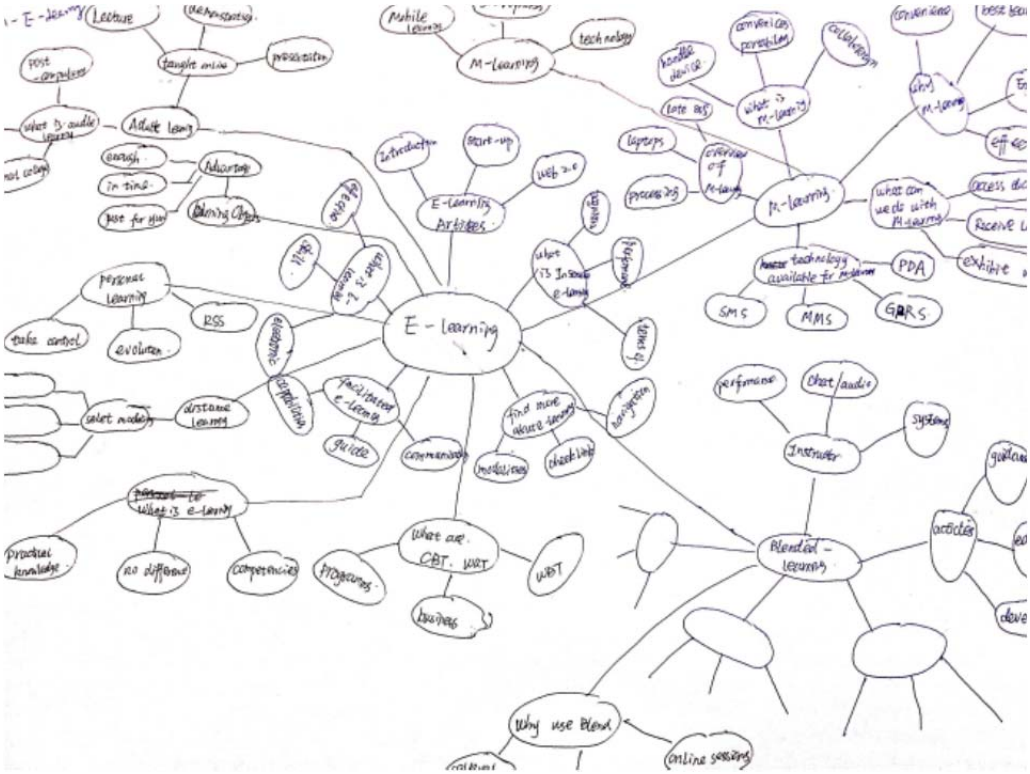

Figure21. Example of Keyword Map When Using the System

Chapter 9

Conclusion and Future Work

This research proposed Multi-layer Map Model according to the difficulties in web-based self-directed learning, and also by referring to the methodology of Topic Maps. I have also developed a resource organization system by using Microsoft .Net and Silverlight which visualized the basic learning behaviors when searching for information on the internet. From the result of the evaluation, we conclude that this research improved the learning situations and provided learners a better way of organizing their learning resources. Also, on some level, we can say that the connections among the topics can be subconsciously built in the learners' minds which can be deduced from the structures of the keyword maps they created.

In the future, while improving the current research on to another level by adding more useful functions to support self-directed learning on the internet, we also want to focus more on CBL. Community in CBL means a group of people sharing similar learning interest but with different knowledge level and learning goals. Such diversities inside the community make it possible for the community members to interact with each other, which are expected to improve each individual's learning activity if such interactions could be better utilized and community knowledge or skill can be shared and inherited. However, current learning environment does not take complete advantages of CBL activities such as communications cannot be passed promptly, advanced learning skills cannot be properly learnt, and community-leveled knowledge structure is difficult to abstract.

Firstly, I will build a model which can help the community members to personalize community knowledge and skills from CBL activities. Secondly, a prototype of the learning environment will be developed based on the model and Topic Maps approach. And then, I will make a case study

for validating effectiveness of the proposed environment, and finally, publish the system in public.

Chapter 10

Acknowledgement

When I finish writing this thesis, I could not help looking back these three and half years and retrospect upon those things happened to me, which are now could not be more vivid. Here, I want to thank this great school who offered me not only spectacular learning environment but also the peaceful mind which appears really rare in nowadays society. From an ignorant young man who just quit his job in China and was always dreaming about earning big money, I have grown into an adult who become responsible for himself and seemingly finally figured out what he wants in his life. Anyway, thank you Jaist where I will be spending another three years.

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Publication List

- **H. Li**, and S. Hasegawa: Multi-layer Map-oriented Learning Environment for Self-directed/Community-based Learning, Workshop of The 18th International Conference on Computers in Education (ICCE2010), pp.109-116(2010).
- 長谷川忍，**李航宇**，柏原昭博：マルチレイヤマップによる Web-based Learning 支援環境の構築，人工知能学会先進的学習科学と工学研究会資料 SIG-ALST-B101-01-07, pp.33-38, (2011).
- 長谷川忍，**李航宇**：概念空間の可視化における逐次的バネモデルマップの提案，人工知能学会先進的学習科学と工学研究会資料 SIG-ALST, pp.55-58, (2012).
- **Hangyu Li**, Shinobu Hasegawa, and Akihiro Kashihara: Resource Organization System for Self-directed/Community-based Learning, Work-In-Progress Poster(WIPP) Proc. of the 20th International Conference on Computers in Education (ICCE2012), Singapore, pp.1-4 (2012).

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