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博士論文

在知識建構與分享環境中發展概念覺察

Developing Conceptual Awareness in a Knowledge Construction and Sharing Environment

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中華民國九十七年七月

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摘　　要

本論文擬利用資訊科技發展出輔助使用者進行概念覺察的知識建構與分享環境。從一開始的前導性實驗「資訊分享與搜尋」，我認為透過網路傳遞與分享的這些大量資料需要進一步被有效利用，以避免學習者消極的接收資訊而導致學習效果不佳，因此我接著提出「知識主動建構學習」和「創意思考潛能提升」的後續研究。在這一系列的數位學習系統環境中，運用搜尋引擎、概念圖工具與相關資訊技術，我希望以認知與情意的學習理論為基礎，設計出人機介面支援使用者對學習歷程中不同面向的自我覺察，尤其是希望能幫助使用者發展概念覺察，以深化學習效果或提升使用者的創意思考潛能，我將之稱為「創意知識工程」。以下採分點方式條列出各個研究主題。

1. 個人化資訊分享與搜尋: 目前網路上放置著大量群眾分享的資料，因此本論文的前導性實驗關注如何以「搜尋技術」精確的找到對個人具有參考價值的內容。有別於以資料探勘的方式，分析歸納出使用者的搜尋行為模式，我以社會科學的角度出發，嘗試找出影響網路搜尋行為的重要使用者個人因素。

2. 知識主動建構學習：創意知識工程的第二步提出網路知識分享的五層次策略與系統：單向分享、分享並推送通知、分享並給予回饋、分享並雙向互動、以及分享並主動建構學習。我認為網路學習環境除了提供分享的機制之外，並需能提供使用者主動建構或整合知識的活動，以幫助深化學習。

3. 創意思考潛能提升：創意知識工程的第三步希望能突破舊知識的巢臼，支援使用者對概念侷限或概念之間遠端連結的覺察，並探討學生在系統中因自我覺察所能產生的知識架構之改變，以發展使用者的創意潛能。

本研究的實驗對象包括國小學生與大學生。研究結果顯示：1. 幫助使用者覺察資訊

分享與搜尋歷程，以便根據使用者的認知與情意心理特徵，設計出更精準的搜尋人機介面，更有效幫助知識的取得。2.幫助使用者覺察，當使用網路觀看他人作品，或是與他人分享知識或經驗時，需要進行知識主動解構、建構與再累積，才能藉由站在巨人或眾人的肩膀上，有效將知識內化。3.輔助學生藉由觀摩、比較同儕的概念圖，覺察並打破自我概念的侷限，以避免單方面思考所可能造成的盲點，進而產生知識架構之改變與提升創意潛能。

Developing Conceptual Awareness in a Knowledge Construction and Sharing Environment

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ABSTRACT

The goal of this dissertation is to develop a series of Internet-based knowledge construction and sharing environments that facilitate user awareness capabilities, especially in terms of conceptual awareness. The dissertation includes a pilot study that focuses on information sharing and search behavior. It is my contention that information shared via the Internet requires further utilization to benefit learners. I therefore designed and executed two studies on active knowledge construction and creative thinking potential enhancement. To construct these human-computer interaction environments I used a combination of information technology and educational theory to assist users in regulating their efforts to benefit from information retrieval or learning processes. In this dissertation I also propose a *creative knowledge engineering* model to use as a foundation for research. A guiding goal throughout this dissertation is enhancing users' self-awareness for the purpose of reducing or eliminating the restrictive effects of habitual thinking on learning outcome and/or creative potential. Results from experiments involving freshman undergraduates or elementary school students indicate that the activities are practical for (a) identifying the search intention prediction factor to facilitate information sharing and searches, (b) encouraging active

knowledge integration via a "beyond sharing" design through which students are motivated to incorporate valuable shared information into cognitive structures and to elaborate on their knowledge for deeper understanding, and (c) improving conceptual awareness so as to break conceptual boundaries and encourage creative potential via the introspective and comparative features of integrated concept maps. It is my hope that future researchers will be able to extend creative knowledge engineering applications for various purposes and to elaborate on underlying theories and design principles to fully understand the benefits of creative knowledge engineering.

誌　　謝

終於抵達博士研究的最後一個階段了。回顧這幾年的研究歷程，固中滋味還真是難以形容。期間當然有許多辛苦的階段需要突破，而且許多困難是原先想像不到的，多謝老師和家人、朋友們能適時提供幫助或為我加油打氣，讓我能秉持認真作研究的精神，一路走下去，在論文完成的剎那，心中真的感到非常的充實與興奮！

首先感謝孫春在老師這幾年來的指導，讓我對作研究這件事又有了更深一層的認識。老師針對同一件事情總是能提出許多不同的觀點來深入分析，並佐以許多有趣的實例，您獨特的見解和過人的表達能力(是我最好的典範/真是令人佩服)。感謝林珊如老師提供我許多研究設計與統計分析上的建議，讓我作研究的功夫更加紮實，並時常的鼓勵、關心我，讓我倍感溫暖。再來要謝謝口試委員曾憲雄老師、袁賢銘老師、張國恩老師、楊淑卿老師、許聞廉老師、黃國禎老師對我研究的肯定，並給予我許多寶貴的建議。也謝謝實驗室裡一起作研究的夥伴和學弟妹們，由於你們的相互砥礪，讓我的研究生活不孤單。還有要謝謝國中時期的好姊妹們和以前公司同事們對我的期許，讓我不敢懈怠，尤其是筱玲開朗、熱心的個性，讓我感染到妳的熱情，覺得不管作什麼事都要開心。

感謝我的家人能體諒我因為太忙，所以沒辦法常回家。爸爸雖然表面上很嚴肅，但是背後卻一直支持我；媽媽煮的菜最好吃了，真希望可以常回家陪媽媽逛市場、吃媽媽煮的菜；大哥和大嫂一直很關心我的研究狀況，在我出國研修一年的時候，還幫我準備了好多補給品；姊姊會幫我梳妝打扮和講冷笑話給我聽，謝謝你們！最後特別要感謝的是我的男朋友治寰，不管在任何狀況下，永遠的支持和陪伴我，還會逗我玩、幫我舒壓，是我繼續往前進的最大力量，讓我的人生更有意義、更快樂，我相信跟你在一起一定會很幸福！

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Chapter 1. Introduction

1.1. Motivation

A growing number of networked-based information sharing applications and learning environments have been developed for delivering information and instructional materials to Internet users or students. This age is also marked by a sharp increase in the popularity of search engines, which allow users with little or no training to access a seemingly unlimited amount of information. This presents a new challenge for users and instructors: the information itself may have less value than in the past. I therefore believe that information shared via the Internet requires further utilization to benefit users in terms of learning and creative thinking potential. In particular, Taiwanese company executives are placing greater emphasis on manufacturing and Taiwanese educators on learning, in both cases without giving much attention to developing creative thinking potential. This can lead to negative consequences in an age marked by an overabundance of information. After describing a pilot study addressing human factors that influence information search behavior patterns, I will offer suggestions for search interface design to facilitate information sharing and search efficiency. Next, I will address the issue of making the best use of distributed information to facilitate learning, to assist learners in meaningful knowledge construction, and to enhance creative thinking potential.

Educators and many organization managers are acutely aware of the significance of creativity for learning and economic activity. However, creativity involves a complex mix of factors; it is not easy for students to generate creative end products in a short period of time. Therefore, this dissertation mainly serves as an initial step toward achieving greater potential for creative thinking by means of improving conceptual awareness. To assist in this effort, I have used a combination of information technology (IT) tools and education theory to create a methodological model I refer to as *creative knowledge engineering* (CKE) (Fig. 1). The purpose of CKE is to develop multiple Internet-based learning environments in which users can benefit from self-awareness via information sharing or learning processes, especially in terms of conceptual awareness. By establishing self-awareness, users can avoid the restrictive effects of habitual thinking, and consequently deepen their learning based on information shared over the Internet and develop creative thinking potential through the breaking of concept boundaries.

1.2. The creative knowledge engineering model

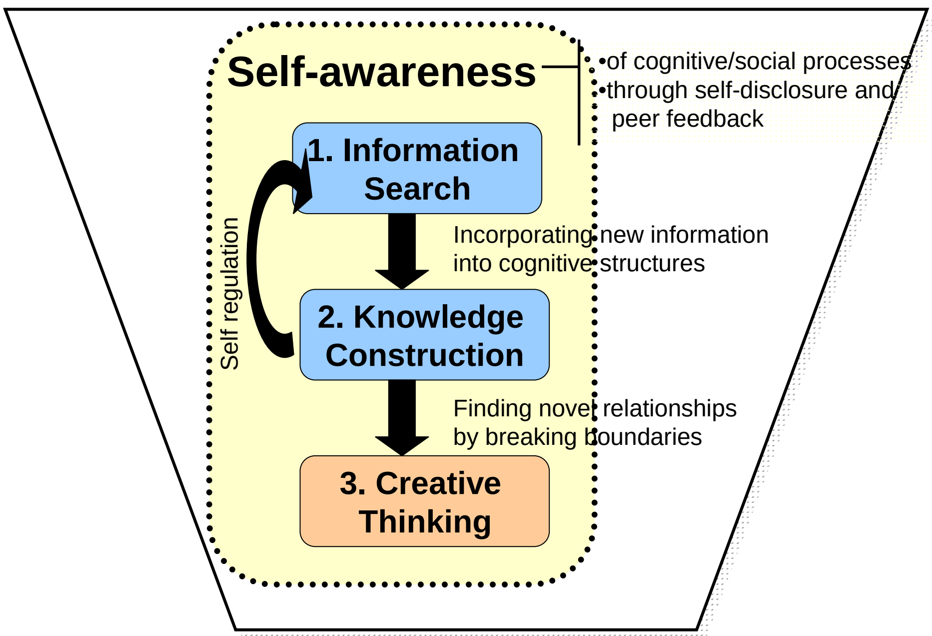


Figure 1. Creative knowledge engineering (CKE) model

The CKE model consists of three phases:

1. *Information sharing and search*. This step involves applying search technologies to

locate valuable information to achieve efficient information retrieval. During this process, users must be aware of what they are looking for and the relationship between required information and acquired information in order to avoid getting off-task or having to deal with irrelevant search results. My belief is that *thinking style*—a distinctly human factor—can be incorporated into search engine interface design to better predict search intentions and to help users comprehend search results.

2. *Active knowledge construction instead of passive information sharing*. CKE considers information sharing as an intermediate step in a process consisting of active engagement in meaningful learning and knowledge integration. As a result of my literature review and from personal observations concerning popular Web applications, I have created four sharing activity categories: *basic sharing, sharing with notification, sharing with feedback, and sharing with interactions*. To overcome the tendency to passively absorb delivered information, I have designed a "beyond sharing" approach that emphasizes the integration of cross-unit knowledge in the pursuit of personal goals to generate productive exchanges among students. Students need to be aware of what they acquire in order to grasp the complexity of a problem and to find special meaning from self-experience to accommodate or assimilate new information into their personal cognitive structures.
3. *Creative thinking potential*. This step emphasizes the idea of using computer technology as an auxiliary tool to externalize multiple viewpoints, facilitate individual awareness of concept boundaries, and enhance creative potential. I believe taking advantage of concept mapping to help students become aware of possible gaps in their existing conceptual structures is an essential step in improving student learning effects and creative potential. Various concepts or leads generated by peers may be used to stimulate creative associations that individuals may not otherwise come up with

because of their inflexibility in utilizing prior knowledge. In this manner, the restrictive impact of habitual thinking on creative potential can be reduced or eliminated.

1.3. Research goal

This dissertation aims to develop a series of Internet-based knowledge construction and sharing environment that facilitate users' awareness ability, especially in terms of conceptual awareness. I will begin with a pilot study that focuses on information sharing and search behavior and proceed to two studies on active knowledge construction and enhancing creative thinking potential to explore the power of utilizing distributed information over the Internet. These research activities are designed and conducted to activate or improve self-awareness and self-regulation of user behaviors when (a) searching for and incorporating valuable information into cognitive structures through a process of active knowledge construction, (b) discovering novel relationships by overcoming conceptual boundaries, and (c) identifying and considering creative ideas. Users can repeat the information search and knowledge construction steps in order to grasp the complexity of an assignment by getting glimpses of what others have done to address the same assignment, by finding reference data, and by identifying problems through knowledge re-construction.

After users collect sufficient information and learn corresponding knowledge that allows them to fully understand the context of a problem, they can further look for either novel relationships or remote associations between ideas in the acquired knowledge. However, simply possessing knowledge is insufficient for creativity to occur—imagination is also required. I believe self-awareness plays an essential role in bridging the gap between imagination and knowledge. Induced by self disclosure or peer feedback, self-awareness can assist in the generation of creative associations, since people with greater self-awareness can more easily observe changes in self or environment and to use such observations to make creative changes and adaptations. Aspects of self-awareness could focus on cognitive and social processes. In this dissertation I emphasize conceptual awareness when building Internet-based knowledge sharing and construction environments. The guiding goal is to deepen users' learning experience and even to remove barriers to creative thinking by giving learners opportunities to observe differences between their own and their peers' knowledge structures.

The participants in the experiments described in this report are from elementary schools and colleges, but future researchers can recruit participants from any age group they desire to replicate these studies, to confirm the results, and to provide more thorough analyses. The knowledge sharing and knowledge construction environments, as well as the beyond sharing and concept boundary-breaking activities presented in this dissertation, can easily be introduced to students of all ages. However, it is important to use learning materials that fit the learners' comprehensive abilities and needs.

Chapter 2. Pilot study: Integrating human factors in information sharing and searches

As one of the most prevalent applications in today's network computing environment, Web search engines are widely used for information seeking and knowledge elaboration. However, search-related technology has not yet reached a level of maturity, therefore academic and private researchers continue to look for "the perfect search technology" (Battelle, 2005). Many researchers are experimenting with ways of predicting user search intentions, with some testing new ideas on presenting information visually so as to help users locate information more efficiently. My assertion is that the concept of *thinking style*—a distinguishing human factor—should be incorporated into any search engine interface design for better search intention prediction and to help users comprehend search results.

2.1. Predicting user intention for narrowing search results

Most search engines use keyword-based techniques as part of their primary interface design. This presents a problem: should users search for what they already know or what they do not know? The answer most likely lies somewhere in between—that is, most searches are for what users "partly" know, since they need prior knowledge of precise keywords in order to find the information they desire. According to Bilal (1998), users without this knowledge frequently choose imprecise keywords and therefore must adjust and re-adjust keywords and filter out large numbers of hits in order to locate information of interest. Even individuals with considerable search engine experience and/or good domain knowledge must deal with this issue.

Many search engine users—especially children and people with little Information Technology (IT) experience—have problems selecting precise keywords. Bilal and Kirby (2002) note that children usually fail to find desired information due to an inclination to use complete sentences, misspelled words, or over-generalized terms. They observe that children have problems formulating adequate or alternative keywords for completing search tasks and usually do not evaluate the quality of search results. In an attempt to help inexperienced users by predicting their intentions to create better search experiences, designers of advanced search engines such as *Ask.com* and *A9.com* recommend the use of relative search results for locating targeted or more precise information. For instance, users who type in the query "How do elephants sleep?" to Ask.com will be presented with such questions as "Why is an elephant called an elephant?" and "How do elephants eat?" This relieves users of the task of keying in relative keywords to explore core search topics.

2.2. Structured presentation of search results

Regardless of the internal algorithm employed—e.g., Bharat and Mihaila's (2001) *Hilltop*, Brin and Page's (1998) *PageRank*, Haveliwala's (2002) *topic-sensitive PageRank,* or Kleinberg's (1998) *HITS*—search results are sorted using relevance-ranking mechanisms that for the most part do not provide significant or structured presentations to help users quickly comprehend the retrieved information. Thus, users are usually required to sift through long lists of excerpts to create an overall picture of the search topic or to glean the best information. Children find it especially difficult to judge and analyze the correctness and value of search results and rarely evaluate or supplement the ones they receive (Hsieh-Yee, 2001).

Categorizing search results is one obvious solution for dealing with information overload. Clustering is one method that allows users to view categorized results without having to deal with the costs and complexities of building taxonomies (see, for example, the *Vivisimo* search engine). Zamir and Etzioni (1999) made an empirical comparison of standard ranked-list and clustered presentation systems when designing a search engine interface named *Grouper*, and reported substantial differences in use patterns between the two. Some researchers who have experimented with highly metaphorical visualizations (e.g. Cugini, Laskowski, & Sebrechts, 2000) present users with structural overviews of result sets and promote visualization as the best approach to dealing with broad search tasks. Visualization structures of this type appear to make it easier for users to locate worthwhile information and to comprehend search results. Based on the hypothesis that thinking style can assist with user interest or intent predictions, my suggestion for search engine designers is to incorporate this human factor into their interfaces to enhance human-computer interaction.

2.3. Related works on searches

2.3.1. Individual differences in Web searches

Web searches involve complex cognitive processes that are strongly affected by individual user characteristics. The literature contains many studies focused on differences in cognitive perspective, especially in the area of prior knowledge (see, for example, Last, O' Donnell & Kelly, 2001; Rouet, 2003; Shapiro, 2000). Kim and Allen (2002) note that cognitive style and task type directly influence search behaviors, and Yuan (1997) adds that search experiences influence search command decisions. Holscher and Strube (2000) and Lazander, Biemans and Wopereis (2000) are among researchers who have explored differences in information search behaviors associated with different levels of information search expertise, which implies different types or strengths of cognitive factors. According to Bilal and Kirby (2002), a list of such factors should include user comprehension of the search task, individual experience with Web surfing, skill level for manipulating search engines, and the amount of attention an individual gives to a search task. All of the researchers listed in this paragraph have considered how differences in user cognitive or skill perspectives impact search behavior.

Groups of users can still develop search strategies based on shared prior knowledge. Ford, Miller and Moss (2005) report that attitudes toward the Internet and demographic factors can also affect Web search strategies. In an earlier study, Ford and Miller (1996) observed females who were unable to find their way, frequently became lost or lacked a sense of control, and tended to only look at items suggested to them. Ford and Miller also studied how self-efficacy (in this context, indicating an individual's judgment of his or her personal ability to find information) impacts perceptions of and approaches to information seeking. Besides human factors, researchers such as Bilal (2000, 2001), Kim and Allen (2002), and Last, O'Donnell and Kelly (2001) state that search task type affects student reactions to hypertext.

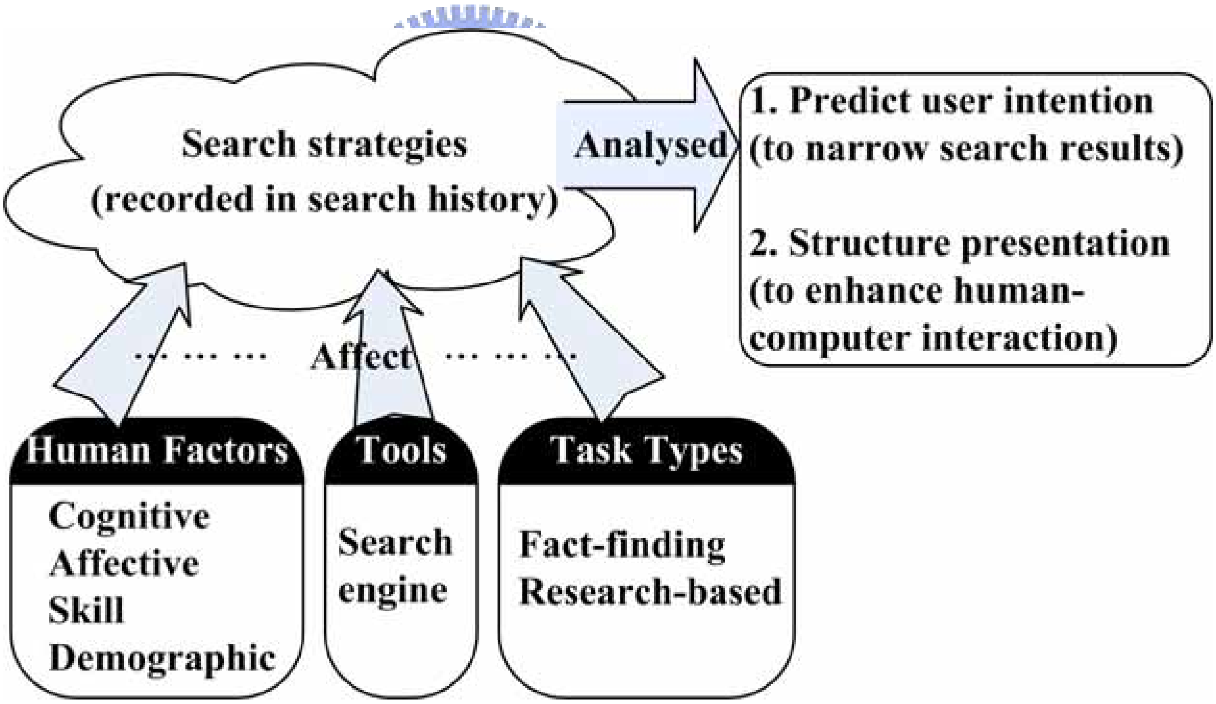


Figure 2.Perspectives (including human factors, tools, and task types) that affect Web search strategies.

The studies cited to this point allow for a summary of human factors that influence search strategies (including cognitive, affective, skill, and demographic) (Fig. 2) and to analyze how thinking style levels (an affective human factor) help determine young students' search strategies—a topic that has not received proper attention in search behavior studies. This dissertation also constitutes an attempt to summarize human, search engine, and search task factors that can serve as indicators of how students interact with and respond to search engine interfaces. Combined, all of these indicators influence search strategies.

One current approach to improving the user search experience consists of providing a personalized interface; most search engines use some form of a personal (*Google*) or social (*Yahoo*) search history mechanism to achieve this. Data mining-related techniques are used to analyze search histories to recognize search patterns (interests) that reflect human factors. Human factors that can be identified as exerting significant impacts on search behaviors can be used to predict search intentions. As an important human factor that strongly affects daily personal behavior, *thinking style* has significant potential for impacting information seeking behavior on the Web. Thus, instead of using data mining techniques to explore raw data for recognizing user search patterns, integrating thinking style into search engine interface design may exert a much greater impact on search intention identification.

2.3.2. Thinking style

Thinking style refers to personal preferences in one's abilities to deal with problems, not the abilities themselves. Accordingly, people with the same abilities may express different behaviors due to the strengths of their preferences (Sternberg, 1988, 1994). Human mental functions can be discussed in terms of five "mental self-government" dimensions: function, form, level, scope, and leaning. The function dimension involves preferences for formulating ideas, carrying out rules initiated by others, or comparing and evaluating ideas. The form dimension concerns various goal-setting and self-management behavioral styles. The level dimension distinguishes between preferences for dealing with problems at relatively abstract or detailed levels. The scope dimension includes a preference for working alone or with others. The learning dimension addresses a preference for working on tasks that involve novelty and ambiguity or tasks that require adherence to existing rules and procedures (Zhang & Sternberg, 2005).

Sternberg and Grigorenko (1995) suggest that individuals look for learning activities that match their preferred thinking style. With the advent of Internet technology, some researchers are focusing on how thinking styles impact Internet-centered learning contexts. However, to the best of my knowledge the literature does not contain any studies on the impacts of thinking style on Internet-based information seeking behavior (frequently referred to as "search behavior"). One of my goals in this dissertation is to determine if a specific thinking style emerges over time when conducting Internet searches in the same manner that it emerges as part of other daily life skills and abilities.

Thinking style can affect judgments concerning immediate issues at hand. In the face of different activities that happen concurrently, individuals may initiate different goals or develop different behavioral patterns. Using goal setting as an example, some people tend toward single-mindedness, others carefully set priorities, and still others are motivated by multiple (often competing) goals perceived as having equal importance. During the search process, some individuals are inclined to grasp the "big picture" of a search task while others focus on a few specific concepts to establish a deeper understanding. The former are satisfied with abstract issues and the latter require detail.

2.4. Study design of information search

2.4.1. Participants

Study participants were 355 fifth grade students attending an elementary school in central Taiwan. Each student's thinking style level was determined using a questionnaire to be described in a later section. Of the 350 students who completed the questionnaire, 311 were instructed to use Google to search for information on pollution and to fill out a worksheet. All of the participants had two years' worth of training in computer usage, meaning that they had basic skills with Windows, Microsoft Word, a Web browser, and Web information search techniques.

2.4.2. Search task

Bilal (2000, 2001) categorizes search tasks as fact-finding or research-based. Fact-finding tasks involve searches for specific answers to simple questions and research-based tasks involve searches for less clear-cut answers to more complex questions. He also notes that different search task types influence children's cognitive and physical search behaviors. My aim was not to address the impact of various search task types, but to analyze the impact of various strengths of thinking style level on search target settings and search behaviors. Achieving this required the use of a research-based search task to encourage students to perform more extensive searches for the purpose of attaining comprehensive understandings of their personal preferences.

The topic chosen for the participating students was "pollution"—something that Taiwanese students are well aware of in their daily lives. They had to establish initial search targets in order to attain desired results. After browsing ordered lists of search results, the students made decisions on refining their targets to move closer to their preferred results. They were asked to write down their "search targets" (i.e., Google search keywords) on their worksheets and to regularly revise their sheets according to their current search target interests. Participants were given 80 minutes to complete the task.

2.4.3. Procedure

Students were given training on basic search skills using the Google search engine. Specifically, they were asked to type in the keyword "energy resources" as practice to ensure that they knew how to use a computer mouse and keypad to browse for information. Next, the 355 students in the original sample were asked to complete the "level dimension" of the thinking styles questionnaire described in the following section. Of the 350 students who completed the questionnaire, 311 performed searches on the topic of pollution and completed their worksheets. Searches were recorded using the *Camtasia Recorder 3.0* screen capture program for further analysis.

2.4.4. Data collection and pre-analysis

1. Investigation of thinking style level

The questionnaire used in this research was adapted from the Sternberg–Wagner Thinking Styles Inventory (Sternberg & Wagner, 1999). A modified version (Huang, 2004) suitable for Taiwanese elementary school students was created to measure the strength of the participants' style preferences when dealing with relatively large and abstract issues (global) compared to detailed and concrete issues (local). The test consists of 10 items with answers measured along a scale of 1 to 5. According to the test results ($N = 311$), 72 students constituting the highest 27% of the global group were classified as high global, 66 students constituting the lowest 27% were classified as low global, and the remaining 173 students were classified as medium global. Using the same percentages, the respective numbers of students in the high local, medium local, and low local groups were 65, 184, and 62.

Representative data were used due to the complexity of analyzing the search strategies and processes of 311 students. I created four conditions: a) 26 students who were concurrently in the highest 27% of the global group and lowest 27% of the local group, designated as the high global style (HG) group; b) 32 students who were concurrently in the highest 27% of the local group and lowest 27% of the global group, designated as the high local style (HL) group; c) 6 students who were concurrently in the highest 27% of the global and local groups, designated as the bi-high style (Bi-H) group; and d) 6 students who were concurrently in the lowest 27% of the global and local groups, designated as the bi-low style (Bi-L) group. The remaining 241 students were excluded from the search behavior analysis.

2. Investigation of student prior knowledge

To determine if the students' prior knowledge of natural science affected the search target setting and search behavior variables, I collected, averaged, and used their grades for introductory natural and social science courses to represent their prior knowledge of the pollution topic. The 87 students in the highest 27% grade group were classified as having high prior knowledge, 81 students in the lowest 27% grade group were classified as having low prior knowledge, and the remaining 143 students were classified as having medium prior knowledge.

3. Investigation of search target settings with worksheets

Students were asked to write down their Google search engine target terms on their personal worksheets and to revise the terms as their search intentions changed. The data were quantified and recorded as *number of search targets (T), coverage of search targets (C),* and *maximum extension of search targets (E)*. As shown in Figure 3, the six search targets could be divided into the concept categories of "air pollution" and "noise pollution," resulting in a coverage value of 2. Four of the six search targets focused on air pollution and the other two on noise pollution, so the maximum extension value was 4. To apply the search targets to subsequent analyses, I divided them into three types: focused (C<=2 AND E>2), dispersed (C>2 AND E<=2), and mixed.

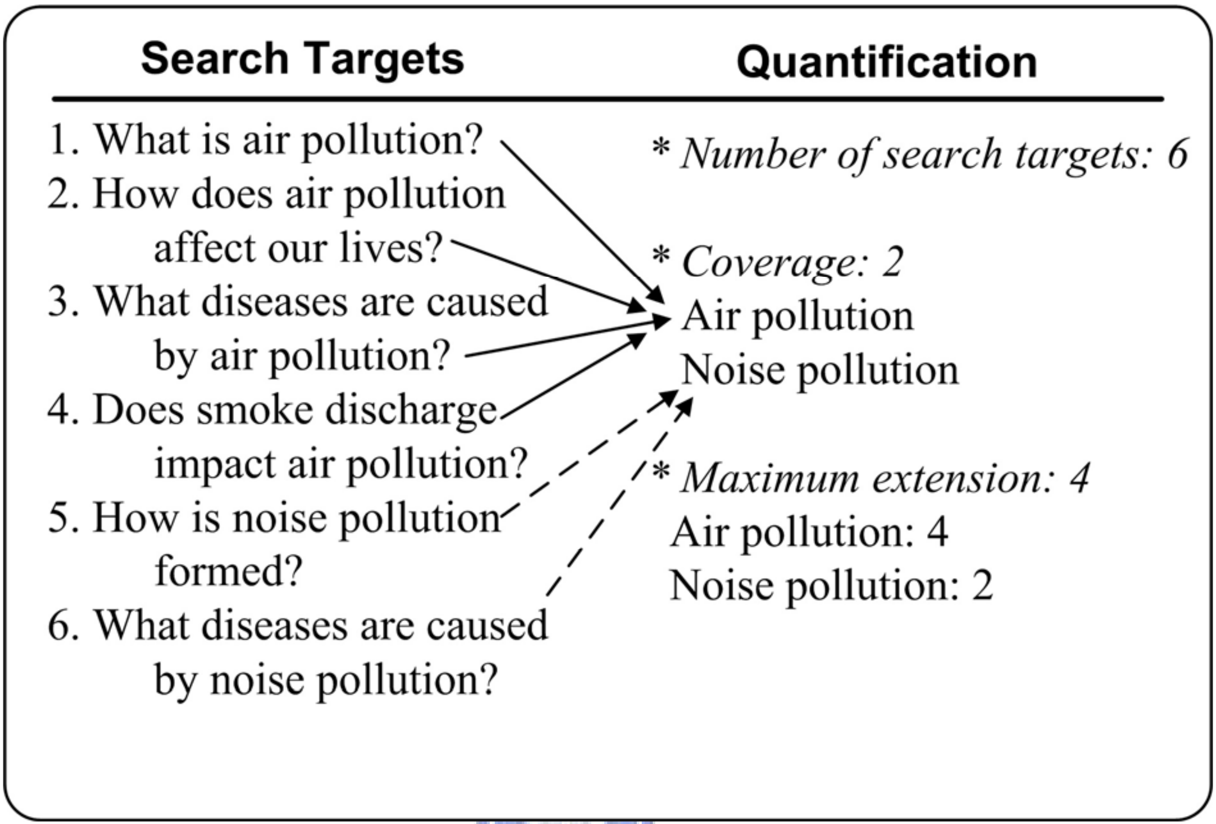


Figure 3. Search target quantification (three indicators).

4. Investigation of search behavior

Files containing data on keyboard and mouse operations were reformatted into *navigation flow maps* (Lin & Tsai, 2005)—graphic displays of relationships among search keywords, visited Web pages, and task questions. The maps and search target settings recorded on the students' worksheets were used to analyze their information search behaviors according to six factors adapted from Lin and Tsai: a) *number of keywords* (variation in searched information); b) *visited pages* (variation in task information sources); c) *maximum depth of exploration*; d) *average depth of Web page adoption* (average exploration depth for task completion); e) *revisited pages* (degree of search navigation recursion); and f) *Web pages for refining answers* (frequency of refining or improving answer quality).

2.5. Analysis and results of search

2.5.1. Relationship between search target setting and thinking style level

One goal was to determine if the participants' prior knowledge affected their search target setting patterns (focused, dispersed, or mixed type). Results from a chi-square test indicate no significant relationship between the two variables ($\chi^2_{(2)} = 6.568$, $p = .161 > .05$), therefore prior knowledge was excluded from subsequent analyses. Next, I combined the high, medium, and low global styles into a single independent variable and performed a chi-square test to identify relationships with the search target dependent variable (Table 1). The results indicate a significant relationship ($\chi^2_{(2)} = 25.351$, $p = .000 < .001$). Among the low global style students, only 20.8% dispersed their search targets, 59.7% focused their attention on concept elaboration, and 19.4% showed no preference for either search target setting type. Among the medium global style students, 34.7% dispersed their search targets, 41.6% focused on similar search targets, and 23.7% showed no preference. Among the high global style students, 59.1% dispersed their search targets, 25.8% maintained a steady scope of interest, and 15.2% showed no preference.

Results from a separate chi-square test revealed a significant relationship between local style (all levels) and search target setting ($\chi^2_{(2)} = 14.174$, $p = .007 < .01$) (Table 2). Among low local style students, 52.3% dispersed their search targets, 26.2% maintained a steady scope of interest, and 21.5% showed no preference for either search target setting. Among medium local style students, 35.9% dispersed their search targets, 44.6% focused on similar search targets, and 19.6% showed no preference. For high local style, only 22.6% dispersed their search targets, 53.2% focused on search result elaboration, and 24.2% showed no preference.

Table 1. Global style percentages of search target-setting patterns.

Pattern Type	Style		
	Low Global	Medium Global	High Global
	(*N*=72)	(*N*=173)	(*N*=66)
Dispersed	20.8%	34.7%	59.1%
Focused	59.7%	41.6%	25.8%
Mixed	19.4%	23.7%	15.2%

Table 2. Local style percentages for search target-setting patterns.

Pattern Type	Style		
	Low Local	Medium Local	High Local
	(*N*=65)	(*N*=184)	(*N*=62)
Dispersed	52.3%	35.9%	22.6%
Focused	26.2%	44.6%	53.2%
Mixed	21.5%	19.6%	24.2%

2.5.2. Differences among the four conditions

The small sample size (indicating that nothing was known about the parameters of the variable of interest in the population) required the use of nonparametric methods for the following analyses. Specifically, Spearman's *r* was used to express relationships between two variables. Results from a Spearman's non-parametric test failed to indicate any clear correlations between prior knowledge of the assigned search task and the six indicators (number of keywords: r = .053; visited pages: r = .060; maximum depth of exploration: r = .181; average depth of Web page adoption: r = -.098; revisited pages: r = -.040; Web pages visited for refining answers: r = -.053). Prior knowledge was therefore excluded from subsequent analyses.

Next, the four thinking style level conditions were compared in terms of the mean rank of each search behavior indicator (Table 3). Kruskal-Wallis statistical tests were performed due to the small sample size (HG: N = 26, HL: N = 32, Bi-H: N = 6, Bi-L: N = 6). The results indicate no significant differences among the conditions in terms of the number of keywords ($\chi^2_{(3)} = 2.191$), number of visited pages ($\chi^2_{(3)} = 4.173$), or number of average depth of Web page adoption ($\chi^2_{(3)} = 4.375$), but significant differences for maximum depth of exploration ($\chi^2_{(3)} = 13.378$, $p = .004 < .001$), number of revisited pages ($\chi^2_{(3)} = 8.604$, $p = .035 < .05$), and number of Web pages visited for refining answers ($\chi^2_{(3)} = 9.254$, $p = .026 < .05$). In addition to identifying states of independence among the significant dependent measures, the Spearman test results indicate a correlation between maximum depth of exploration and Web pages visited for refining answers ($r_s = .301$, $p = .011 < .05$); however, no correlation was identified between maximum depth of exploration and revisited pages ($r_s = .226$), or between revisited pages and Web pages visited for refining answers ($r_s = .235$).

Table 3. Mean rank of each search behavior indicator according to the four thinking style level conditions.

	Condition				Significance
	HG	HL	Bi-H	Bi-L	
	N=26	*N*=32	*N*=6	*N*=6	
Number of keywords	34.40	33.77	46.42	38.58	*ns*
Visited pages	31.88	38.56	44.67	25.67	*ns*
Maximum depth of exploration	27.06	43.70	38.92	24.92	$p = .004$
Average depth of Web page Adoption	30.77	39.91	38.50	29.50	*ns*
Revisited Web pages	30.19	38.22	49.50	30.00	$p = .035$
Web pages visited for refining Answers	30.37	39.53	44.25	27.50	$p = .026$

When Kruskal-Wallis test results were significant at the 0.05 level, Mann-Whitney U tests were performed to measure contrasts between pairs of conditions. Significant pairs are listed in Table 4. A *post hoc* contrast of two conditions revealed a significantly higher maximum depth of exploration scores in the HL condition compared to the HG condition ($U = -3.348$, $p < .001$), suggesting that HL students tended to conduct more detailed searches in order to fully understand specific topics. For example, a depth of exploration score of 7 was earned by an HL student who found information on how air pollution was produced and how to prevent it, but an HG student only earned a score of 2 for surveying the broad topic of "water, noise, air, sea, and trash pollution."

A separate *post hoc* contrast of two conditions revealed a significantly higher number of revisited pages among Bi-H students compared to HG students (U = -2.611, $p < .001$), indicating that Bi-H students were more likely to re-visit Web pages for purposes of knowledge elaboration than for skimming. One student in the Bi-H group revisited the same page 7 times, but an HG student only revisited the same page once and quickly moved on to other pages. A third *post hoc* contrast revealed a significantly higher number of HL (U = -2.324, $p < .05$) and Bi-H (U = -2.412, $p < .05$) students who visited a larger number of Web pages to refine their answers compared to HG students. I observed that one HL student made three revisions to an answer, while an HG student made only one.

Table 4. Statistically significant contrasting pairs of conditions for the three significant search behavior indicators.

	Condition Pair	Mean Rank	Significance
Maximum depth of exploration	HG (*N*=26)	21.88	$p = .001$
	HL (*N*=32)	35.69	
Revisited Web pages	HG (*N*=26)	14.92	$p = .009$
	Bi-H (*N*=6)	23.33	
Web pages visited for refining answers	HG (*N*=26)	25.35	$p = .020$
	HL (*N*=32)	32.88	
	HG (*N*=26)	15.29	$p = .016$
	Bi-H (*N*=6)	21.75	

2.6. Discussion of information search

The study result confirm that students with different thinking style levels perform variously in terms of three search behavior indicators: maximum depth of exploration, number of revisited pages, and number of Web pages visited for refining answers. Future researchers may be interested in testing other thinking style dimensions to determine their impacts on important search behavior indicators. In order to create better search experiences by predicting user search intention, it is suggested that search engine designers consider incorporating such human factors into preference settings. For instance, after users have chosen their first keywords, instead of forcing them to filter large amounts of search results, search engines can be designed to recommend related information and/or search results that match the users' personal thinking style levels. For HL or Bi-H users, more focused and detailed search results can be provided to support in-depth understanding or answer refinement. For HG users, related search results in other categories can be provided to satisfy their curiosity for larger or more abstract issues. For Bi-H users who tend to re-visit Web pages, recent pages in personal search histories should be made accessible as part of a search result presentation (e.g., a nearby cluster or category), thus eliminating the need to redo searches for useful Web pages.

2.7. Conclusion of information search

In addition to providing a review of the current literature on how human factors (cognitive, affective, skill, and demographic) influence search strategies, in this section I examined the topic of thinking style level (an affective factor), which in the past has not received proper attention. No attempt was made to analyze how these human factors influence search strategies, but a summary was offered of human factor, search engine, and search task types that can serve as indicators of how students interact with and respond to search engine interfaces.

The results indicate that thinking style level is indeed reflected in information seeking behavior. HG students are inclined to grasp the overall picture of a search task and HL students tend to investigate and build deeper understandings of specific concepts. Accordingly, HG students are satisfied working on a relatively abstract level and HL students prefer working with details. I therefore suggest that thinking style level influences search target setting and search behavior, and can be used in addition to or apart from data mining techniques to identify user search patterns for predicting search intentions.

The data points to a need for search engine designers to create interfaces that a) help users narrow their searches to reduce information complexity according to their individual information needs and thinking style differences, and b) present large bodies of search results in ways that are easier for users to comprehend. Tailoring search engine interfaces to conform to personal information needs will be an important topic for future research.

Chapter 3. Beyond sharing information: Engaging students in cooperative and competitive active learning

The concept of sharing has taken on new importance in a world that has the Internet—a tool that allows for resource access from any place at any time. Examples of Internet-based sharing include personal websites, blogs, discussion forums, and instant messaging; a growing number of applications support sharing using different media (e.g., del.icio.us, Flickr, YouTube). These tools disseminate individual or group beliefs in a manner that binds geographically dispersed individuals with common interests. When applied to group-based pedagogy, the anyplace-anytime characteristic enables a shift from real-time learning to asynchronous distributed learning (Kreijns et al., 2002). The same characteristic enables researchers to create sharing activities that entail concurrent, multi-user interactions (Greenberg & Marwood, 1994; Yang et al., 2004). One example is the use of information technology tools to share musical ideas via exchanges of audio files instead of through verbal discussions of concepts (McCarthy et al., 2005).

However, many pedagogical or research projects address the how or what of sharing to benefit collaborative learning without questioning the why or examining the effects of sharing on learning contexts. To reap the benefits of collaboration entailing mutual engagement as opposed to simple cooperation entailing labor divisions (Roschelle & Teasley, 1995), teachers and researchers frequently design tasks that involve information sharing followed by discussion (see, for example, Häkkinen et al., 2003). The interactive structure of computer-supported collaborative learning (CSCL) environments creates additional constraints or freedoms for learners. One of several impediments to a desired social interaction is the tendency to assume that it will automatically occur because the environment makes it possible (Baker et al., 1999; Kreijns et al., 2002). Research suggests that few students are willing to participate in CSCL discussion forums without some additional motivation, and that factors such as social loafing (e.g., the "free-rider" and "sucker" effects) can lead to responsibility diffusion (Barron et al., 1992). Consequently, spaces set aside for collaboration or cooperation are often misused for chatting or storage at the expense of the desired goal of collaborative learning through sharing.

Such discrepancies may be due to a lack of sufficient structure—for instance, the failure of teachers to completely organize learning tasks. I addressed this issue by viewing sharing as an intermediate step in a process consisting of active engagement in meaningful learning and knowledge integration. Specifically, learning roles are made more active and meaningful as students (a) construct personal concept maps for an assigned learning unit, (b) share personal concept maps across units while critically evaluating their peers' contributions from other units, and (c) actively integrate concept maps across all units using a meta-plan to create a "patchwork" of knowledge. Process details will be described in a later section.

In other words, BeyondShare approach described in this dissertation emphasizes the integration of cross-unit knowledge in pursuit of personal goals to generate productive exchanges among students. Instead of simply expecting students to automatically share resources and negotiate with each other in a CSCL environment, I tried to inject a sense of competition to encourage active learning. As part of this sharing process, I experimented with a cooperative competitive learning (CCL) strategy (Lin et al., 2002) that accommodates both cooperation and competition in a manner that yields greater intrinsic motivation (Johnson et al., 1981; Tauer & Harackiewicz, 2004).

My formal evaluation of BeyondShare was designed to answer the following research questions:

1. How many students are able to finish "beyond-sharing activities" (to be described

in a later section) using BeyondShare?

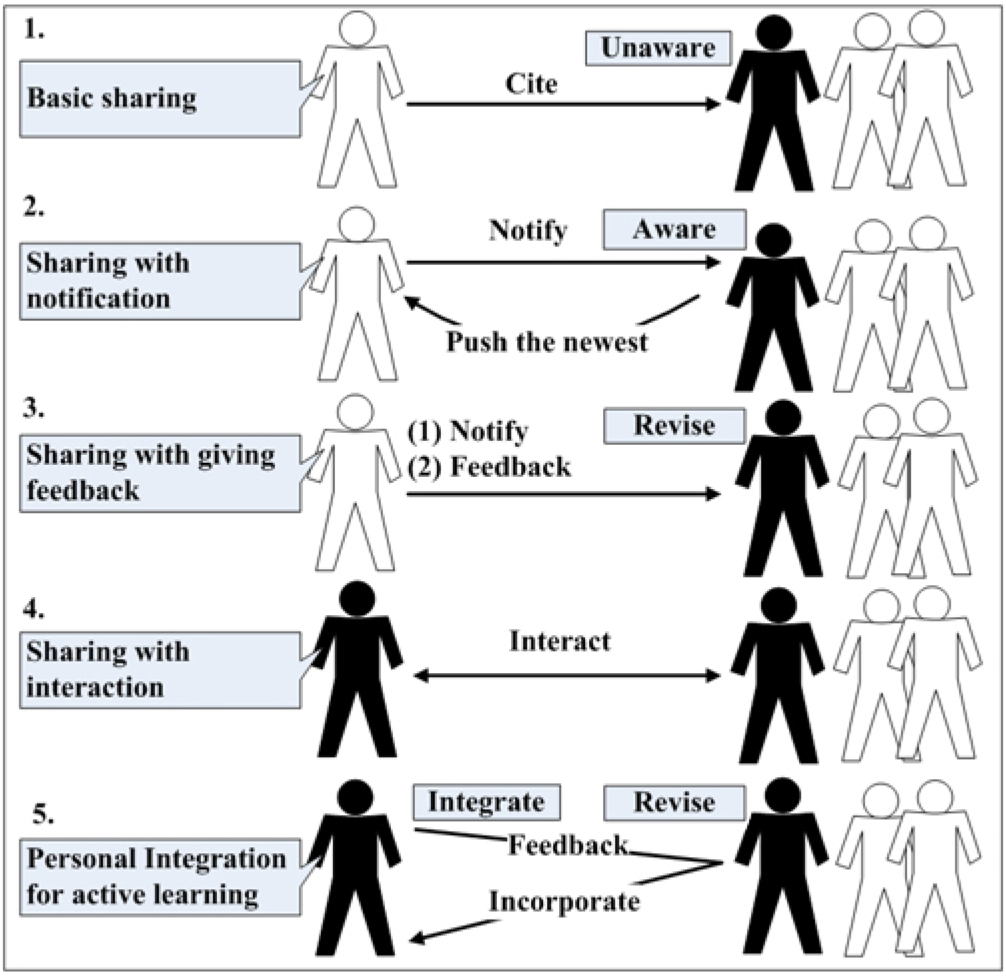
2. Did students perceive BeyondShare as easy to use?
3. Did the three activities designed for BeyondShare evaluation achieve the goal of promoting active learning?
4. What percentage of students became actively engaged in both personal and sharing construction?
5. Did a larger percentage of students engage in active learning during personal construction or sharing construction activities?

3.1. Sharing

A considerable amount of research effort in this area has focused on building a shared sense of understanding or meaning—that is, finding common ground within groups in collaborative learning settings (e.g., Baker et al., 1999; Mulder et al., 2004). Four categories can be created according to this perspective (items 1-4, Fig. 4; black silhouettes represent students who play active roles):

1. Basic sharing. Citing or using an idea from a peer is the most basic sharing format. However, most learning situations lack proper motivation for sharing, therefore some self-regulated individuals model or cite works while others do not, even when requested or instructed. Furthermore, those who benefit from sharing usually have no channel for notifying idea originators, who therefore remain unaware of how others use their ideas.
2. Sharing with notification. In this variation of basic sharing, cited authors are notified that their ideas are being used. Various technologies (e.g., Really Simple Syndication, or RSS) allow authors to push their latest ideas to subscribers, thus facilitating the timely spread of knowledge.

3. Sharing with feedback. By providing feedback, users help the original authors revise and improve their work. The Computer-Supported Intentional Learning Environment (CSILE) constructed by Scardamalia and Bereiter (1991) is one example of a method designed to promote user feedback.
4. Sharing with interactions. Authors can interact via discussion threads—for example, Greenberg & Marwood's (1994) GROUPKIT (see also Yang et al., 2004). However, participation requires individual motivation.



*Note: Black silhouettes represent students who play active roles.

Figure 4. Sharing for shared understanding (item 1-4) and active learning (item 5).

Researchers such as Häkkinen et al. (2003) and Mulder and Swaak (2002) have used qualitative, quantitative, or a combination of the two approaches to assess collaboration during the sharing process. Completed acts of sharing are followed by quality discussions. Special attention must be paid to the effects of group dynamics on shaping shared meaning (Stahl, 2005), as well as acknowledging that shared contributions cannot be accepted as indicators of shared understanding among all team members (Beers et al., 2005). In other words, it is important to separate the term shared knowledge (Edmonds & Pusch, 2002) from shared understanding or shared meaning. While researchers expect to bring shared understanding into full play in a collaborative learning context, they must note whether the learning activities are structured in a manner that facilitates mutual understanding rather than simple exchanges of information.

Today's Web 2.0 (O'Reilly, 2005) technologies facilitate different applications (e.g., blogs, Wikipedia, del.icio.us, Flickr, YouTube) that support the sharing of various kinds of multimedia content. These applications are popular because users enjoy expressing their own viewpoints by distributing their articles, bookmark collections, photos, or video clips, and readers/viewers enjoy or use the information gathered from the shared works. These applications all have the same key element—providing users with spaces to share their work and /or to find others with similar interests. In other words, to some degree they all fit into one or more sharing typology categories. For example, most bloggers are interested in sharing hyperlinks with others interested in the same domain knowledge, yet bloggers in the same domain may compete to attract more visitors to their web sites and therefore work to maintain a favorable page ranking on a major search engine. This phenomenon suggests that competition is a motivating factor for bloggers to update and improve their articles.

3.2. Beyond sharing: Personal integration for active learning

As Suthers (2005) suggests, the online replication of face-to-face learning is not acceptable as a CSCL goal; the same is true for using CSCL to duplicate social interactions over the Internet. Instead, educators should aim at using the unique features of the Internet as a large resource pool, especially its distribution characteristic (Scardamalia & Bereiter, 1991). When designing BeyondShare, I purposefully implemented the sharing construction principle (Resnick, 1996) to encourage students to share and reuse ideas from each other's constructions. Examples of approaches that require students to reuse or model parts of their peers' projects to enhance their own personal integration include LEGO MindStorms (Resnick, 2002) and Knowledge Soup (Canas et al., 2001).

In addition to shared constructions, I injected a sense of competition into BeyondShare to promote active engagement. As depicted in item 5 of Figure 4, students become active learners for the purpose of integrating personal knowledge. They are encouraged to evaluate their peers' efforts regarding other learning units, select "personal best-fits," and incorporate works they define as useful into their final personal products. Understanding of the learning material is strengthened through a process of incorporating ideas from their peers' personal constructions as well as reflecting on feedback concerning their own constructions.

Students compete to have their constructions selected by others as the most useful. As with bloggers, competition is used to motivate students to create, update, and upgrade quality products to share with others, as well as to evaluate their peers' work in a serious manner. Through this competition, they gain a more comprehensive understating of the learning material. Each student plays several roles and has specific responsibilities throughout an activity. The interchangeability of those roles encourages students to become active learners rather than passive information receivers (Table 5). Details will be described in the Procedure subsection of the BeyondShare evaluation section.

The term "beyond sharing" refers to combining the features of structuring and competition to achieve such goals. Many new teachers initially assume that all learning (including listening to lectures) is inherently active. But the preponderance of research over the past few decades suggests that students must do more than just listen—they must actively discover and understand facts through reading and discussion, then transform and construct knowledge by writing or engaging in problem solving (Johnson et al., 1998; Moreno & Mayer, 2000). Active involvement means that students must engage in higher-order thinking tasks that entail analysis, synthesis, and evaluation (Turner et al., 1998). BeyondShare promotes active learning by encouraging (a) deep understanding of learning material via concept map construction (what Novak & Gowin [1984] refer to as "meaningful learning"); (b) active reflection on the quality of individual constructions through sharing and peer evaluation; and (c) the active synthesis of dispersed knowledge by integrating self- and peer-produced constructions (Fig. 7).

Table 5. Beyond sharing activity structure

Expected Learning Outcome	Task Unit	Student Role Interchange	Cooperation Goal	Learning Format	BeyondShare support*
1. Construct a personal concept map.	Within a given unit.	Active sharer vs. passive to-be-shared.	Personal accountability.	*Meaningful learning*: reading, understanding, organization.	Personal construction interface.
2. Compete to be chosen with other students.	Within unit, cross-unit.	Within-unit competitor vs. cross-unit helper.	Positive task interdependence via sharing cross-unit concept maps; sense of competition enhance motivation.	Social facilitation and modeling.	Personal construction interface; sharing construction interface.
3. Evaluate and compare peers' concept maps.	Cross-unit.	Peer assessor vs. receiver of peer feedback.	Help peers revise their work; gain information about other units.	*Active learning*: critical evaluation.	Sharing construction interface.
4. Construct an integrated concept map.	Based on a given unit to link across all units.	Active integrator.	Based on a given unit for interlinking concepts across all units.	*Active learning*: integrate personal and peers' ideas according to a meta-plan.	Sharing construction interface.

*Note: See "Primary Interfaces" section.

3.3. Peer assessment

Peer assessment is a widely used strategy in secondary and post-secondary classrooms for teaching principles in such diverse fields as writing, teaching, business, science, engineering, and medicine (Falchikov, 1995; Freeman, 1995; Rada, 1998; Strachan & Wilcox, 1996). The process requires such cognitive activities as reviewing, summarizing, clarifying, giving feedback, diagnosing errors, and identifying missing knowledge or deviations from an ideal (Van Lehn et al., 1995). Receiving abundant and immediate feedback from peers is strongly correlated with effective learning outcomes (Bangert-Drowns et al., 1991; Crooks, 1988; Kulik & Kulik, 1988). In conventional classroom settings, teacher feedback may be of higher quality but less frequent and immediate than peer assessments (Topping, 1998). In peer assessment scenarios, students have more opportunities to view a larger number of projects, allowing them to gain inspiration from concrete examples instead of relying on models centered on a teacher's cognitive skills or knowledge structure. Peer assessment projects require more on-task time than conventional teacher assessment settings; arguably this is the most important factor in facilitating learning.

Falchikov & Magin (1997), Lin et al. (2002), and Liu et al. (2002) are among researchers who state that reliable and valid peer assessment requires three conditions: (a) students must fully understand and be committed to the purpose of their assessment activities; b) students need to be involved in the process of determining criteria, rating scales, and assessment procedures; and c) students need to receive feedback on peer assessment scores in relation to their own performance as well as to the overall score pattern.

3.4. The BeyondShare environment

I incorporated concept mapping into the BeyondShare environment as an activity based on the assertions of Novak and Gowin (1984), Roth and Roychoudhury (1992), and others that concept maps are effective tools for knowledge construction. Instead of requiring students to participate in group discussions to create collaborative maps (a process that can lead to unequal contributions), I applied the CCL strategy (Lin, Sun , & Kao, 2002) as a more effective approach to evaluating, synthesizing, and incorporating ideas from maps created by their peers. In implementing this strategy, the learning material must be divided into several units (in this study, three units). As part of the BeyondShare process, final concept map products reflect individual and shared construction efforts that fulfill the requirements of independence and interaction (Katz, 2002). In classrooms that have access to state-of-the-art learning technologies, teachers can use concept map approaches that focus on synchronous (real-time) cooperative behavior (Komis et al., 2002). Although these systems have clear advantages, I purposefully designed BeyondShare with the characteristic of asynchronous distributed learning based on the belief that it is available in a larger percentage of classrooms.

3.4.1. Primary interfaces

I used a combination of Microsoft Visual Basic 6.0 and SQL Server7 to design two BeyondShare interfaces:

1. A personal construction interface that provides a form-based environment. This interface is disabled when students proceed to the sharing construction phase, thereby preventing students from modifying their own concept maps based on the work of others in the same learning unit (Fig. 5). After reading personal assignments for a given learning unit, students begin the personal construction activity in the concept mapping section by pressing the start button (which triggers a time log) and using the construction forms to build and connect

self-defined concept nodes with links. A concept map in progress is shown in the current personal concept map section. Concept nodes and linking words are not fixed, giving students greater flexibility for knowledge construction. They use the current personal concept map area to observe and change node positions to revise concept hierarchies. Nodes and linking words can be removed from the storage section once they become irrelevant to the concept map. Students move back and forth between procedures to construct their maps as they see fit.

2. A form-based sharing construction interface consists of interlinks among different concept maps. Interlinks differ from links, which connect ideas within individual concept maps. In Figure 6, the bold arrows with dashed lines indicate interlinked connections between two concept maps. Students can use this interface to view their own completed maps in the personal concept map section. In the modeling section, a system of anonymous selector IDs prevents students from purposefully choosing concept maps made by their friends as their favorites. After choosing selector IDs from the other units, students can study maps in their peer concept map sections, then press the start button to begin the sharing construction process. Students can establish interlinks between their own and their chosen maps in the interlinking section and make comments in the feedback section according to a set of reference criteria. As in the personal construction interface, students can delete interlinks displayed in the storage section. The interlinking process consists of selecting single concept nodes from two maps and adding a linking word. Students can establish as many interlinks as they want between concept map nodes.

During the sharing construction phase, students evaluate all peer concept maps in other units, select “personal best-fit” concept maps, and establish interlinks between their own and selected maps. Interlinks can be established between near concept nodes or nodes in remote categories. Links in the latter category are known as “cross-links,” implying associations between concepts that many people would not recognize (Novak & Gowin, 1984). In BeyondShare, such links are considered signs of creativity.

Choices for establishing interlinks represent cooperative partner selection—the result of a peer assessment evaluation process that encourages critical thinking. Sharing and incorporating information across units with cooperative partners are both encouraged; within units, competition is encouraged.

3.4.2. Teacher observation

BeyondShare contains a teacher interface for monitoring student progress, meaning that students who fall behind the learning schedule can be given special attention. The monitor interface presents a student’s personal concept map, information on the student’s chosen favorites, the number of interlinks between two maps, how much time a student spends on constructing interlinks, and how many other students choose the same map as their favorite. The interface also allows teachers to view information on how many choose the target student’s concept map as their favorite, their personal concept maps, and respective interlinks. All preference data can be logged for peer rating analysis.

3.4.3. Evaluating results

After the sharing construction phase is completed, concept maps are arranged in decreasing order of score (number of votes) for each learning unit. The map receiving the most votes within one unit earns the designation of “best-fit.” Reflective thinking is triggered via comparisons of personal maps with best-fit maps. Furthermore, teachers can construct their own “expert” concept maps for comparison with best-fit maps for two purposes: determining which knowledge structures are acknowledged by the greatest number of students, and helping students make adjustments to incomplete or incorrect concept maps.

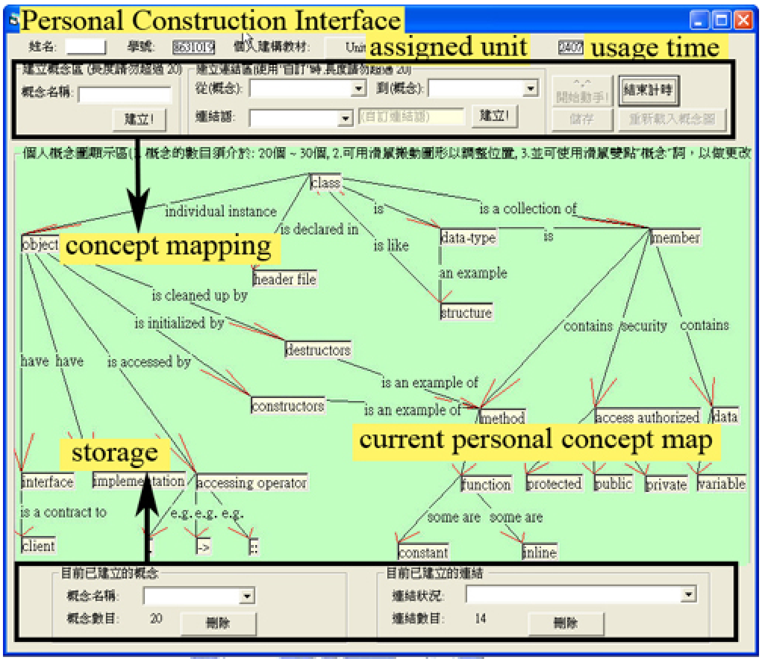


Figure 5. Personal construction interface example

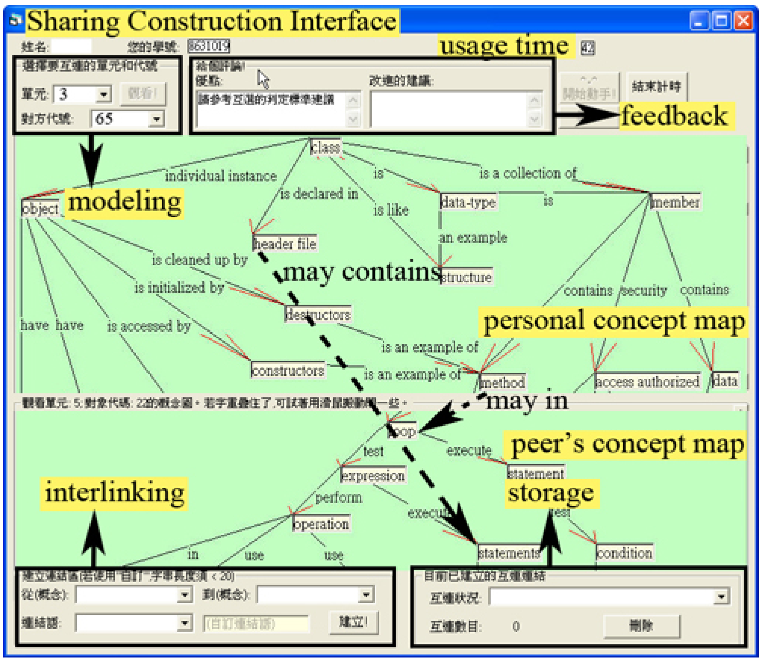


Figure 6. Sharing construction interface example

3.5. BeyondShare Evaluation

3.5.1. Participants

A BeyondShare evaluation test was conducted to determine if the beyond-sharing activities successfully engaged students in meaningful learning and knowledge construction. Participants were 34 college freshmen enrolled in an introductory computer science class at a research university in northern Taiwan. Students were randomly assigned to 3 clusters consisting of 12, 9, and 13 participants, with students in each cluster studying one of three learning units on the topics of function, class, or flow as selected from a C++ textbook. Members of each cluster generated individual concept maps for their assigned unit.

3.5.2. Procedures

I purposefully designed a series of beyond sharing activities to ensure active learning, positive interdependence, and personal accountability. Using BeyondShare features, cooperative learning was structured by having participants work on a multiple-stage concept-mapping task requiring task interdependence (Table 5). After being grouped according to learning material divisions, students were asked to produce their own concept maps (a task that Novak & Gowin [1984] refer to as “meaningful learning”) for their assigned unit and to share their products with peers who worked on other units. Participants were instructed to evaluate, compare, and give feedback for the cross-unit concept maps. Participants therefore contributed to their classmates’ tasks by giving feedback while gaining information and knowledge about the other learning units. Based on a meta-plan, participants were asked to link their own maps with the cross-unit maps they selected during the peer assessment stage to form integrated maps. Participants accepted responsibility for contributing to their cross-unit peers' efforts while competing with same-unit peers. Participant roles switched between active and passive sharers, competitors and helpers, assessors and feedback recipients, and among active integrators, thereby achieving the successful group work components defined by Johnson et al. (1998).

As shown in Figure 7, the evaluation procedure consisted of three stages:

1. Preparation. During week eight of the school semester, students were taught concept mapping techniques and given several examples for practice. During week nine they were introduced to BeyondShare and its activities, after which they were randomly assigned to one of the three units.
2. Personal construction. During week ten, participants used their class time to create their individual maps. In an attempt to prevent social loafing or duplications of their classmates' efforts, the students were not allowed to view their peers' maps during this stage.
3. Sharing construction. During week eleven, students were allowed to view the concept maps created by classmates assigned to the other units. They were instructed to select one personal best-fit map from each unit and to establish interlinks across units. Participants were explicitly instructed to make their selections in terms of cohesiveness and coherence and to avoid making their selections based on friendship or exchanges of favors.

At the end of week eleven, students were asked to complete a questionnaire about the BeyondShare environment and their subjective experiences with and perceptions of the beyond-sharing activities.

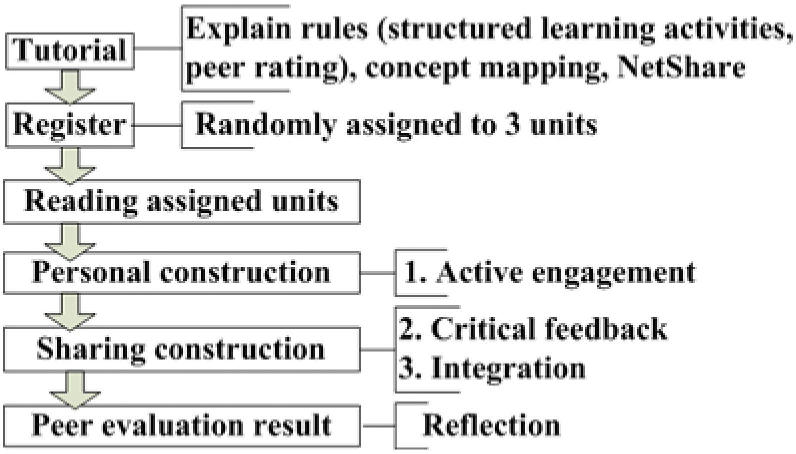


Figure 7. Research flow diagram and three effects

3.5.3. Scoring

1. Personal construction peer rating. Concept maps could be selected by peers assigned to other units based on general appearance or a specific task perspective (e.g., the best fit with a student's own work). The number of votes thus represents the degree of cohesiveness and/or coherence between the concepts and structure of two maps. Personal construction scores accounted for 60% of the total peer rating, reflecting the study goal of emphasizing personal accountability in active learning.
2. Sharing construction peer rating. Based on evaluations of cohesiveness and coherence, this rating (which accounts for 40% of the peer rating total) represents the number of votes earned by an individual student's favorite maps.

Total peer rating. This is calculated as 0.6 x Personal $\text{construction}_{\text{peer}}$ + 0.4 x Sharing $\text{construction}_{\text{peer}}$.

The proposed peer rating system mimics the system of scholarly journal citations—that is, the more citations (votes) a work gets, the more likely the chosen work is of high quality. However, BeyondShare also takes into account the quality of the selected works. In other words, students must take responsibility for their personal best-fit choices because the scores of their selected maps affect their own final scores. This mechanism reduces the odds of students choosing maps created by their close friends regardless of quality.

3.5.4. Questionnaire

A questionnaire was created to measure the participants' subjective perceptions of BeyondShare and beyond-sharing activities. The first section consisted of six items on interface usability—for instance, clarity of screen design, function simplicity and helpfulness, and comparative convenience.

Both time-spent and screen-capture records of construction procedures during the personal and sharing construction stages can serve as measures of active learning. However, it is important to note that active learning can take the form of a few meaningful and effective construction steps being produced quickly, or carefully planned cognitive functions emerging over a long time period. I therefore relied on a combination of learning outcomes and questionnaire responses to estimate how many participants felt that they were engaged in active learning and to gather supporting evidence for their responses.

The nine items in the second section focused on student perceptions regarding personal construction (first level beyond-sharing activity) and approaches to active engagement in meaningful learning. The next six items measured if and how peer assessment (second level) and competition influenced active engagement in knowledge construction. The final six items recorded student perceptions on sharing construction (third level) and approaches to knowledge sharing. Responses were measured along a seven point Likert-type scale, with 1 indicating strong disagreement and 7 strong agreement.

3.6. Results and discussion of beyond sharing

All 34 participants had sufficient time to finish their personal construction projects and to evaluate, select, and integrate ideas from their peers' maps into new, integrated concept maps. Participants needed an average of 2.15 hours to construct their personal concept maps following two one-hour introductions to concept mapping and BeyondShare. Average time spent in the sharing construction process was 1.07 hours. Sample concept maps are shown in Figure 6. Just over one-half (53.5%) of the participants reported positive attitudes about the general ease of use of BeyondShare (Table 6).

Table 6. Student perceptions of BeyondShare ease-of-use

	Percentage of Respondents						
	strongly disagree					strongly agree	
	1	2	3	4	5	6	7
1. In general, *BeyondShare* was difficult to use.	**0.0**	**32.1**	**21.4**	28.6	7.1	10.7	0.0
2. Creating a concept map using *BeyondShare* was more convenient than using pencil and paper.	3.6	17.9	7.1	32.1	**17.9**	**14.3**	**7.1**
3. The personal construction interface was clear and its functional guides were helpful.	0.0	0.0	17.9	14.3	**32.1**	**14.3**	**21.4**
4. The personal construction visual aids were helpful when creating a concept map.	0.0	3.6	14.3	14.3	**14.3**	**39.3**	**14.3**
5. The interlink function procedure was simple and thoughtfully designed.	0.0	0.0	14.3	14.3	**17.9**	**32.1**	**21.4**
6. The system operating description was helpful when I first became acquainted with *BeyondShare*. (n = 26)	0.0	0.0	7.1	21.4	**28.6**	**17.9**	**17.9**

Concept mapping has been criticized for requiring exceptional effort and numerous modifications (Ruiz-Primo & Shavelson, 1996). The questionnaire data indicate that 39.3 percent of the participants regarded concept mapping using BeyondShare as more convenient than using pencil and paper. Negative opinions regarding the procedure were reported by 28.6 percent—an indication that BeyondShare requires revision. Just over two-thirds (68%) stated that the personal construction interface was helpful, with 71.4 percent describing the interlink function as easy to use.

Table 7. Student perceptions of personal map constructions (first level)

	Percentage of Respondents						
	strongly disagree				strongly agree		
	1	2	3	4	5	6	7
1. Constructing a concept map helped me in memorization.	0.0	3.6	3.6	10.7	**7.1**	**57.1**	**17.9**
2. When constructing a personal concept map, I had a chance to summarize critical points of the material.	0.0	3.6	3.6	7.1	**14.3**	**39.3**	**32.1**
3. I tried to use examples of events or concepts outside of textbooks to clarify the meaning of my concept map.	3.6	7.1	21.4	17.9	**25.0**	**17.9**	**7.1**
4. Constructing a concept map encouraged me to rethink relationships between concepts.	0.0	7.1	0.0	3.6	**17.9**	**42.9**	**28.6**
5. Constructing a concept map helped me organize key points in the learning material.	0.0	3.6	3.6	7.1	**14.3**	**39.3**	**32.1**
6. When constructing a personal concept map, organizing a concept hierarchy encouraged me to rethink knowledge synthesis.	3.6	0.0	3.6	14.3	**21.4**	**25.0**	**32.1**
7. When constructing a personal concept map, I understood some of my shortcomings regarding the learning concepts.	0.0	3.6	3.6	7.1	**17.9**	**50.0**	**17.9**
8. Although concept mapping was beneficial for meaningful learning, I felt it was not worth the trouble.	14.3	35.7	17.9	25.0	**0.0**	**3.6**	**3.6**
9. I am willing to construct concept maps to aid my learning in other courses.	0.0	3.6	7.1	14.3	**17.9**	**28.6**	**28.6**

As shown in Table 7, large percentages of students (50-89%) reported that they had actively engaged in the following cognitive functions:

1. Memorization (item 1): 82.1 percent agreed with the statement that concept map construction is an effective way to memorize learning material.
2. Summarization (item 2): 85.7 percent agreed with the statement that concept map construction gave them opportunities to summarize the most important points of the presented material.
3. Understanding (item 3): 50 percent stated that they used other materials in

addition to textbooks when searching for examples that would give them a deeper understanding of a concept.

4. Conceptual organization (items 4, 5, 6): 89.4 percent asserted that drawing a concept map enhanced their comprehension of relationships between concepts, 85.7 percent stated that constructing a concept map helped them organize major concepts, and 78.5 percent agreed that concept hierarchy organization encouraged knowledge synthesis.
5. Reflections on own weaknesses (item 7): 85.8 percent agreed with the statement that drawing a concept map helped them reflect on their deficits, discrepancies, and/or flaws in learning concepts.

Only 7.2 percent of the participating students stated that concept map construction was not helpful in the learning process (item 8). The majority (75.1%) stated a willingness to construct concept maps to facilitate learning in other courses (item 9). These results suggest that personal construction (first-level beyond-sharing activity) encouraged student engagement in low- and high-level cognitive strategies and meaningful learning, which fits well with the active learning and higher-order thinking criteria described by Johnson et al. (1998), Moreno and Mayer (2000), and Turner et al. (1998).

Data on responses to peer assessment and competition (second-level) items are shown in Table 8. A majority (82.2%) agreed that the peer assessment procedure helped them learn how to assess concept map quality (item 1) and 82.1 percent agreed that peer concept map evaluation encouraged them to reflect on properties that a good concept map should possess (item 2).

Most of the participants (75.1%) stated that they were aware of the competitive aspect of BeyondShare and viewed it as motivation to generate better personal construction products (item 3); 74 percent acknowledged that they were expected to compete with their peers for best-fit map votes (item 4). According to these results, the majority of participants were motivated to achieve personal learning goals when constructing quality maps. I believe this awareness of competition can reduce social loafing during beyond-sharing activities.

Approximately one-fifth of the participants (18.5%) complained about their maps not receiving votes even though they felt the quality was high (item 5), and 30 percent complained about a lack of satisfaction with their choices (i.e., they felt forced to choose from collections of poorly constructed maps) (item 6). A discussion mechanism such as that integrated by Scardamalia and Bereiter (1991) into their CSILE might help resolve this issue by encouraging modifications that increase map quality and/or coherence.

Table 8. Student perceptions of peer assessment and competition (second level)

	Percentage of Respondents						
	strongly disagree						strongly agree
	1	2	3	4	5	6	7
1. I learned how to assess concept map quality by evaluating and choosing concept maps from other learning units.	0.0	3.6	3.6	7.1	**17.9**	**46.4**	**17.9**
2. Evaluating and choosing a concept map encouraged me to consider the essential features of a "good" map.	0.0	3.6	3.6	7.1	**21.4**	**28.6**	**32.1**
3. Competition with peers to have my map be selected as "best-fit" for my unit encouraged me to generate a better personal construction.	0.0	7.1	3.6	10.7	**17.9**	**42.9**	**14.3**
4. I tried to gain more votes for "best-fit" concept map by generating a better personal construction.	0.0	7.4	3.7	14.8	**25.9**	**33.3**	**14.8**
5. I felt that the work I did was good, yet my peers did not chose my map as their favorite. (n=26)	7.4	7.4	14.8	44.4	**11.1**	**7.4**	**0.0**
6. During the interlinking stage, I felt dissatisfied with what I chose as my favorite concept maps.	0.0	14.8	22.2	29.6	**29.6**	**0.0**	**0.0**

Data on the extent to which sharing construction (third-level) activities helped students achieve active learning using high- and low-level cognitive strategies are presented in Table 9. As shown, the majority (85.7%) viewed the sharing construction activity as an effective means of helping them inspect and model their peers' maps (item 1); 78.6 percent stated that observing their peers' concept maps helped them make improvements to their own (item 2). Over half (57.1%) acknowledged that the sharing process allowed them to summarize key concepts in the chapters they did not work on and therefore gain general knowledge of all learning units (item 3), 57.2 percent agreed with the statement that they had achieved an in-depth understanding of the target material via the sharing construction procedure (item 4), and 64 percent agreed that the sharing construction approach was meaningful because it provided opportunities to integrate concepts from different units (item 5). However, 78 percent agreed with the statement that it required much effort to create meaningful interlinks between concepts (item 6). In summary, between 57 and 85 percent of the participating students agreed that the BeyondShare approach encouraged them to use the cognitive functions emphasized by Johnson et al. (1998), Moreno and Mayer (2000), Novak and Gowin (1984), and Turner et al. (1998).

The actively engaged students created high quality concept maps for sharing, offered valid ratings of their peers' concept maps, and constructed coherent global concept maps that integrated ideas from other units. Different combinations of high and low personal and sharing construction scores were used to create the four cells presented in Table 10. High scores indicate that the student's work exceeded the mean. According to the peer rating scores, 38 percent were high active learners (i.e., active in both sharing and personal construction), 29% were active only in terms of sharing construction, and 9% were active only in terms of personal construction. In other words, approximately 75 percent were active in at least one part of the beyond-sharing activities and 25 percent were not active during any part of the BeyondShare evaluation project. According to these results, it was easier for the participating students to actively engage in sharing construction than in personal construction.

Table 9. Student perceptions of sharing construction (third level)

	Percentage of Respondents: strongly disagree 1	2	3	4	5	6	strongly agree 7
1. The sharing construction process allowed me to model my peers' works.	0.0	3.6	0.0	7.1	**25.0**	**35.7**	**25.0**
2. The sharing construction process gave me chances to observe my peers' works in a manner that helped my subsequent work. (n = 27).	0.0	7.1	3.6	7.1	**17.9**	**39.3**	**21.4**
3. The sharing construction allowed me to concentrate on my own work while referring to others' concept maps for quick impressions of the other learning units.	0.0	7.1	17.9	14.3	**21.4**	**21.4**	**14.3**
4. The sharing construction process helped me achieve an in-depth understanding of the learning material.	0.0	7.1	7.1	25.0	**17.9**	**28.6**	**10.7**
5. The sharing construction process which encouraged me to integrate concepts from different learning units was a meaningful learning approach.	0.0	7.1	10.7	14.3	**21.4**	**21.4**	**21.4**
6. It was difficult to think of meaningful interlinks between two concepts.	0.0	0.0	0.0	17.9	**17.9**	**28.6**	**32.1**

Table 10. Scores on personal and sharing construction

		Sharing construction scores: H	L	Total
Personal construction scores	H	13/34 (38.23%) – A	3/34 (8.82%) -- B	16/34 (47.06%)
	L	10/34 (29.41%) – C	8/34 (23.53%) --D	18/34 (52.94%)
Total		23/34 (67.64%)	11/34 (32.35%)	34 (100%)

3.7. Conclusion of active knowledge construction

After defining four types of sharing construction (basic, with notification, with feedback, and with interaction), I proposed a structured "beyond sharing" method to encourage personal integration for active learning. Most current Web 2.0 applications support knowledge sharing or cooperation tools that fit in with at least one of the four categories.

These tools provide rich opportunities for users to experience sharing using various media (e.g. text, photos, music, video clips) or to co-write articles (e.g. Wikipedia). Researchers can utilize these applications as new platforms in order to observe how sharing activities or cooperation evolves in computer supported cooperative work (CSCW) environments. To achieve the benefits of learning in a CSCW environment, I emphasized its active learning aspects over simple information-sharing activities (although users can benefit from shared knowledge) by adopting a CCL strategy for structuring learning activities (Lin, Sun, & Kao, 2002). By injecting competition into a sharing activity, students are motivated to elaborate on their knowledge for deeper understanding.

I believe BeyondShare is capable of eliciting active knowledge contributions and empowering users to accumulate knowledge via social construction. Engaging students in active learning was a specific focus of the evaluation test—that is, determining to what extent participants perceived other student maps as information resources and used that information to develop a sense of a learning community via peer assessment. Results from a formal evaluation with 34 Taiwanese college freshmen support BeyondShare's ease-of-use and ability to promote active learning. The same results also indicate that (a) BeyondShare was easy to use by students who did not have advanced computer/Internet skills; (b) the personal construction process helped create a sense of meaningful learning in terms of both low-level (e.g., memorization and summarization) and high-level cognitive strategies (e.g., deep understanding, conceptual organization, and reflection); (c) the sharing construction process helped create a sense of meaningful learning in terms of low-to-high level cognitive strategies; (d) peer assessment helped foster active learning; (e) BeyondShare's competitive aspect was generally viewed as a motivating factor; and (f) approximately 25% of the participants were not active at all during the BeyondShare evaluation experiment; 75% were active during at least one part.

One study limitation is that the sample was relatively small and limited—that is, all students were recruited from a single class at one university. Sampling bias and participant homogeneity could detract from the generalizability of the findings. Researchers may be interested in testing BeyondShare or similar online learning environments with students at different age levels and from a variety of schools, as well as in determining whether the beyond sharing concept can be applied to tasks associated with skills development—for example, programming, graphic design, and Web page design. Others may be interested in using personality inventories such as Big Five Personality Traits (Saulsman & Page, 2004) or 16 Personality Factors (Conn & Rieke, 1994) to identify successful and less successful learner characteristics for beyond-sharing activities.

To my knowledge, BeyondShare is the first learning product aimed at combining the features of structuring and competition, which distinguishes it as an environment that serves an active learning purpose instead of using the Internet to simply share information. BeyondShare also differs from other systems in that it tries to achieve active learning by accommodating cooperation and competition. In other words, students must decide how to use or incorporate parts of their peers' ideas into their own work for a more comprehensive understanding of a topic. During this process of integrating their concept maps with others, students gain a deeper understanding of material across several learning units.

Teachers interested in using BeyondShare are suggested to develop comprehensive plans, with special consideration given to selecting authentic learning materials to introduce the social construction concept to students, dividing the material into independent but related subtopics, teaching concept map skills, and giving direct instruction on how to use the program. During the personal construction phase, teachers need to closely monitor their students to make sure they adhere to the principle of personal accountability and are not intimidated by competition. During the sharing construction phase, teachers need to encourage peer observation, critical evaluation, sharing, and unbiased peer ratings.

It is my contention that learning activities should be structured so as to create a balance between cooperation and competition in order to enhance motivation and learning performance (Johnson et al., 1981; Tauer & Harackiewicz, 2004), but I also acknowledge the difficulty of maintaining such a balance. Teachers may find that some of their students are more focused on competition, indicating a need for emphasizing other beyond sharing activities and benefits. Some teachers may be interested in creating a greater sense of cooperation by asking certain groups to discuss and reach a consensus in terms of interlinks, thereby encouraging the collective consideration of high-quality concept map properties. In short, teachers are encouraged to experiment with the BeyondShare environment to make learning activities either more competitive or more cooperative. The activities are sufficiently flexible to accommodate these kinds of modifications.

Chapter 4. Breaking concept boundaries to enhance creative potential

New ideas and applications must be expressed and externalized in order for social evaluation to occur (Fischer, Giaccardi, Eden, Sugimoto, & Ye, 2005). During the process of externalizing concepts, there is a need to let different voices be heard to prevent dominance, to accommodate representations of potentially valuable ideas, and to enable reflective thinking in a manner that allows for conceptual awareness. In this dissertation I test my belief that computer technology can be used as an auxiliary tool to externalize multiple viewpoints, facilitate individual awareness of concept boundaries (see section 4.5.1), and enhance creative potential.

Concept mapping (Novak & Gowin, 1984), an approach to knowledge structure externalization, helps learners internally reconstruct their concepts and consider ways of visually representing their conceptual structures. Ausubel (1968) supported the ability of learners to actively link new knowledge to previously constructed concepts and propositions as a vital factor in meaningful learning. Malone and Dekkers (1984) describe concept mapping as a "window to the mind" because it allows for the observation of others as well as self-reflection. Fisher (1990) and Reader and Hammond (1994) are among researchers who have proposed various computer-assisted systems for facilitating concept map construction, whereas Chiu, Huang, and Chang (2000), Chung, O'Neil, Herl, and Dennis (1997), Okebukola and Jegede (1989), and Roth and Roychoudhury (1992) have focused on collaborative efforts to generate group concept maps. Group concept mapping (a text-based brainstorming technique) is commonly used to achieve meaningful collaborative learning. While brainstorming is widely used to encourage individuals to contribute ideas and build creative thinking skills, its critics (e.g., Mullen, Johnson, & Salas, 1991) assert that brainstorming can create high levels of pressure in participants so as to stifle creativity. Group concept mapping has some of the same drawbacks as brainstorming, including hitchhiking and dominance tendencies (Lin, Sun, & Kao, 2002). In this chapter I will look at the merits of concept mapping for concept externalization and meaningful learning by requiring all learners to visually express individual ideas in the form of concept maps as a means of encouraging them to express personal opinions.

Either consciously or unconsciously, learners tend to use habitual thinking patterns to solve problems (Finke, Ward, & Smith, 1992; Ford, 1996). This usually reduces the time required to develop solutions at the expense of experimenting with and testing alternatives. Asking learners to reflect on what they already do or do not know without external assistance may result in huge cognitive loads or cost too much in terms of mental effort. To take advantage of concept mapping to improve student engagement and creative potential, I believe an essential initial step is helping students become aware of what may be lacking in their existing conceptual structures. As Burleson (2005) observes, awareness and reflective technologies can be instrumental in developing meta-cognitive skills that enhance learning, expertise, creativity, and self-actualization. Since creativity involves a complex mix of factors, enhancing conceptual awareness alone may not result in more creative products, but instead serve as an initial step for achieving greater creative potential.

Human tendency is to think within concept boundaries constrained by personal backgrounds, educations, living environments, etc. Working with other individuals from diverse backgrounds can help ameliorate the effects of these constraints. Selker (2005) notes that sharing parts of tasks with others is useful for eliciting critiques and evaluations of creative possibilities. In practice, different designers working on the same problem often reach different solutions (Bisseret, Figeac-Letang, & Falzon, 1988). In the framework discussed in this chapter, personal concept maps that represent students' unique concept structures are viewed as sources of variation to be combined into integrated concept maps (ICMaps). The goal is to use various concepts or leads generated by peers to stimulate creative associations that individuals may not otherwise come up with because of their inflexibility in utilizing prior knowledge. The purpose of the integrated concept mapping system (ICMSys) described in the following sections is to assist learners in building self-awareness of conceptual structures (from this point forward I will use the term *conceptual self-awareness*) through a process of identifying knowledge structure insufficiencies, differences, and boundaries via comparisons with other learners' concept maps. In this manner it is possible to reduce or eliminate the restrictive impact of habitual thinking on creative potential.

4.1. Computer-assisted concept mapping system

Collaborative concept mapping is recognized as an effective means of promoting meaningful learning (Okebukola & Jegede, 1989), which explains in part the emphasis on collaborative concept map construction in Computer Supported Collaborative Learning (CSCL) environments. Examples include Kmaps (Gaines & Shaw, 1995), KSIMapper (Kremer, 1996), and CmapTools (Cañas, Hill, Carff, Suri, Lott, Eskridge et al., 2004). However, these approaches tend to focus on reproducing face-to-face discussions on group concept map collaboration while neglecting the impacts of concept mapping on changes in individual conceptual structures and the preservation of ideas offered by individuals. One result is that existing collaborative concept mapping systems are not appropriate for research on conceptual self-awareness.

Chang, Sung, and Lee (2003) emphasize the value of searching for better ways of creating group products that preserve individual uniqueness. For this reason, I deemphasized the collaborative aspect of concept mapping in favor of preserving individual ideas by requiring each learner to construct his or her own concept map and focusing on individual conceptual awareness as stimulated by variations in their peers' concept maps. The ICMSys encourages students to adopt various viewpoints to address tasks and projects in hope of bending or breaking individual concept boundaries and sparking creative ideas. The system allows learners to request various ICMaps for inspection, thus allowing them to make comparisons among concept maps without requiring detailed inspections. Again, the central goal is to have students concentrate on conceptual self-awareness.

4.2. Meta-cognition

Meta-cognition is defined as the conscious inspection of one's own cognitive system (Bandura, 1986; Flavell, 1976). Coffey (2007) believes that the primary focus of meta-cognitive applications to date has been on helping students gain awareness of how they approach reading and writing. The goals of the learning system described in this chapter are to help students become aware of the boundaries of their prior knowledge or their habitual thinking habits and to encourage them to make conceptual changes in hope of enhancing creative potential. Garner and Alexander (1989) propose three approaches to measuring children's meta-cognition: (a) asking them, (b) having them think aloud while performing a task, and (c) asking them to teach a younger child a good solution for a problem. Fry and Lupart (1987) have established a "confidence rating method" for measuring meta-cognition levels in terms of performance prediction. Following an exam, they asked students to predict their performances before learning their results. They concluded that the closer a student's prediction was to the real score, the greater that student's meta-cognitive and monitoring abilities. I chose this method for measuring conceptual self-awareness levels among the student participants—specifically, smaller differences between a student's self-assessment and an actual assessment made by a team of experts were viewed as indicators of greater self-awareness.

4.3. Self-awareness

Improvement is difficult for individuals who are not aware of their shortcomings, indicating a need for a conceptual self-awareness dimension. Duval and Wicklund (1972) define self-awareness as occurring whenever one's attention is directed toward oneself, while Brown (1987) describes self-awareness as a condition of self-understanding and introspection of one's own thoughts. The assumption used in this study is that self-awareness is promoted when individuals focus their attention on their minds and inspect their thoughts and consciousness.

However, Nisbett and Wilson (1977) found that self-observations are imprecise because of a human tendency to find reasons (which may or may not be true) to interpret situations in a specific manner. Therefore, ideas, suggestions, feedback, and other resources provided by peers are essential stimuli for discovering what I will call the "unaware zone." Michinov and Primois (2005) further note that the social comparison process has a positive impact on productivity and creativity. Accordingly, my approach encourages conceptual self-awareness via introspection and social comparison (Suls & Fletcher, 1983). In addition to asserting that conflicts arising from comparisons of concept maps among peers promote learner self-awareness and therefore minimize the unaware zone, I also believe this process can encourage learners to reconsider concepts they may have overlooked or alternative approaches to task resolution in a manner that is beneficial to breaking concept boundaries for problem solving.

4.4. From self-awareness to creative potential

Conceptual awareness is central to bringing out creative potential. For many decades creativity has been viewed as a gift (Gardner, 1993)—that is, if you aren't born with knowledge of how to be creative, it is very difficult to learn. Thus, the goal of most school systems is to equip students with skills or domain knowledge only, which might eliminate individual potential for developing creativity. Knowledge is only one aspect of creativity; others include (but are not limited to) imagination, evaluation skills, and awareness (Feldhusen, 1995). Among students who have similar background knowledge, those who can bring other factors into play are more likely to reach their creative potential. However, the traditional approach involves teaching students to solve problems quickly within limited personal search spaces without considering more innovative possibilities. As Finke et al. (1992) observe, creativity is stifled when individuals become fixated on a single interpretation or approach. To overcome functional fixedness and related tendencies, they recommend creating an attitude of looking beyond conventional ideas—an attitude that may benefit from promoting conceptual self-awareness.

Some researchers have recently suggested that individual creativity can be greatly enhanced by establishing supportive socio-technical settings (Fischer et al., 2005). This suggestion implies the feasibility of developing creativity and underscores the importance of providing applicable interfaces or environments to achieve that goal. Burleson (2005) adds that awareness and reflective technologies can be instrumental in developing meta-cognitive abilities that enhance creativity. Accordingly, I developed the ICMSys to bend or break concept boundaries and to enhance creative potential via self-awareness and social comparison processes. The goal is to help willing individuals think outside of concept boundaries and break habitual thinking whenever they find their personal ideas or solutions are not sufficient for the task at hand.

4.5. Study design of breaking concept boundaries

4.5.1. Concept boundaries

Concept boundaries are detectable when students become aware of conceptual differences between their own and integrated concept maps. Initial unaware zones are reduced while students' conceptual awareness levels are increased. With the ICMSys, similar concept propositions are integrated for better presentation in hope of facilitating a conceptual introspection process in learners. Using Figure 8 as an example, after Alice externalizes her concepts or ideas on a personal concept map, she manipulates the ICMSys to compare her map with those created by her peers. I believe this process lessens the burden of identifying differences between Alice's map and her peers' maps. She may discover that her map lacks certain concepts or good examples, and therefore decide to add them to better express her ideas. She may also decide to delete some concept nodes she believes are inappropriate. A third possibility is that she may notice creative concept relationships or cross-links that she did not recognize before; both are viewed as beneficial for learning or triggering new ideas. Or, she may adjust the concept hierarchy to better categorize ideas or accommodate concept changes. In other words, the breaking down of concept boundaries is observable whenever students make improvements in any one of Novak and Gowin's (1984) assessment criteria: examples, relationships, hierarchies, and cross-links.

Since the ICMSys emphasizes user potential to break concept boundaries, it is very important to help users recognize existing boundaries and reflect on their conceptual differences in order to identify valuable ideas. This process assumes that users have contributed conceptually correct ideas from different viewpoints about the topic of interest.

However, there is a concern that students may model or imitate erroneous maps based on their current knowledge limitations. I therefore trained study participants in concept mapping and peer assessment skills prior to conducting the actual experiments. Realizing that some concept maps created by the participants might be inaccurate in some areas but valuable in others, I asked three experts to assess the quality of the students' redrawn maps to verify the benefits of modeling the first concept maps in the resource pool. In actual classroom situations, teachers will be responsible for correcting misconceptions or errors in revised concept maps.

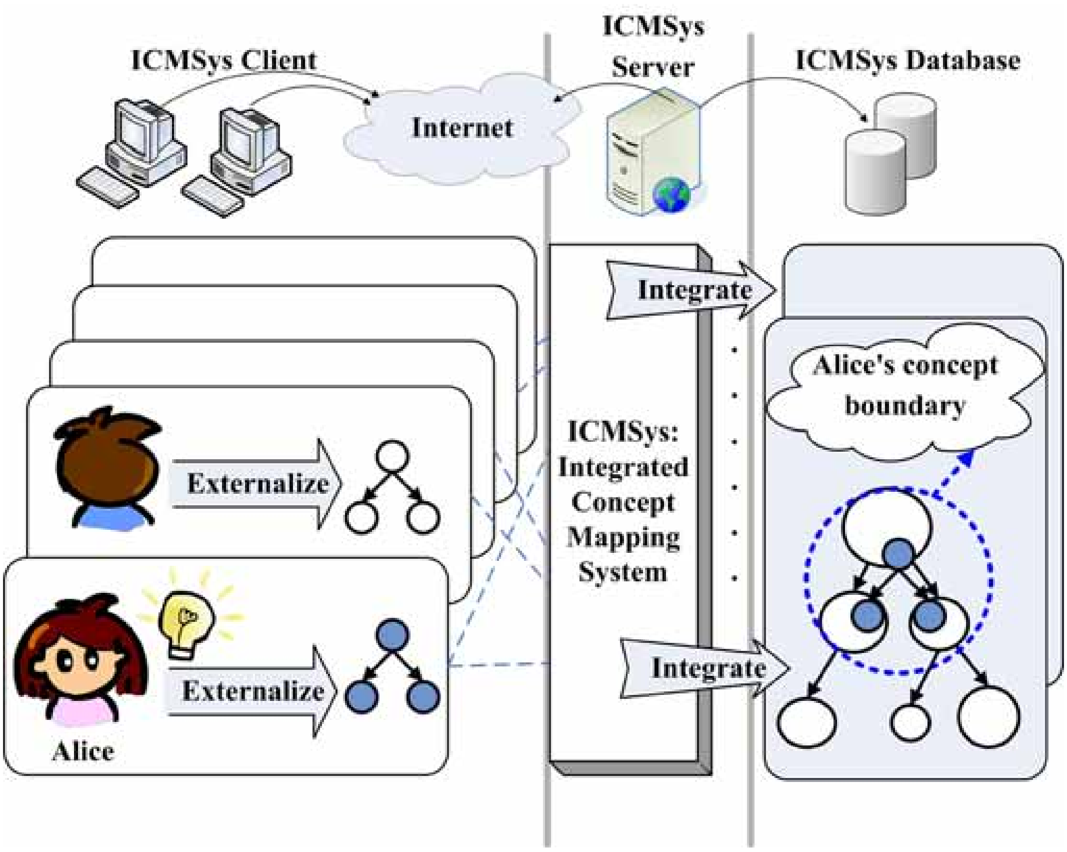


Figure 8. Research focus and Integrated Concept Map System architecture.

4.5.2. Research questions and framework for conceptual self-awareness

The research questions address four areas of concern:

Q1. Can learner conceptual self-awareness be promoted using the ICMSys?

Q2. Do revised concept maps contain evidence of conceptual improvements? Specific goals are to determine if students acknowledge insufficiencies and concept boundaries in their initial concept maps and construct extensions after viewing various ICMaps.

Q3. Does ICMap viewing frequency affect the level of conceptual self-awareness?

Q4. Do students with higher levels of conceptual self-awareness make better quality and larger numbers of improvements when redrawing their concept maps?

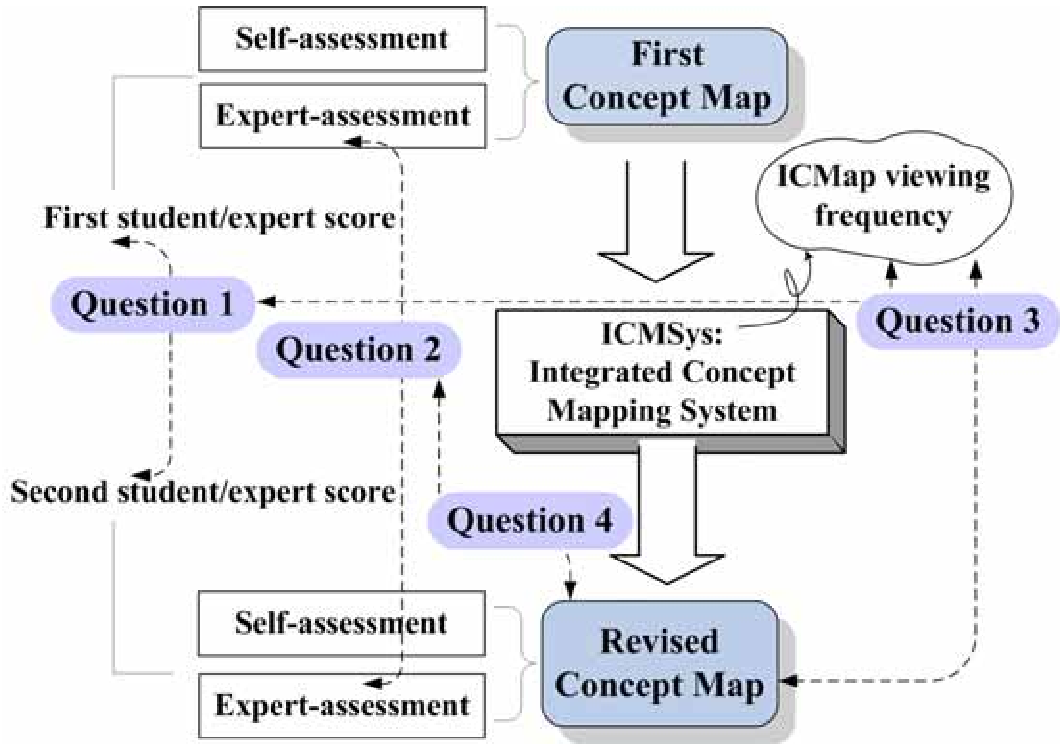


Figure 9. Main research framework and questions.

My approach consists of three steps: constructing a personal concept map, observing various combinations of ICMaps, and redrawing the original personal concept map (Fig. 9). Map quality self-assessments and assessments by the three experts were collected twice for each student—once after the first maps were drawn and once after they were revised. The number of times that students viewed ICMaps was also recorded. As stated earlier, during the personal concept mapping process, students are encouraged to express ideas on which they can elaborate by comparing those ideas with their peers'. This allows for different voices to be heard without any single voice becoming dominant. After being instructed to share their individual concept maps, students are introduced to the ICMSys and begin reflective thinking based on ideas and concepts garnered from peer maps. Once their conceptual self-awareness is improved and concept boundaries are established, students are asked to consider how they can extend or elaborate their thinking in revised maps by incorporating new ideas or finding new relationships between concepts.

4.6. The Integrated Concept Map System (ICMSys)

Based on Selker's (2005) suggestion that productive and non-intrusive interfaces allow individuals to focus on creative tasks, I set out to develop an integrated concept mapping system (ICMSys) for a distributed networking environment. As shown in Figure 8, the ICMSys goals are to externalize each learner's ideas, integrate them into a representation that accommodates different viewpoints, and provide a convenient interface to help learners become aware of their concept boundaries. The four main ICMSys design principles were:

1. Students occasionally come up with different concept words that have the same meaning. To reduce redundancy, I purposefully placed certain concept words into the ICMSys that the participants could use when constructing concept maps—for instance, "memory unit" and "CPU" within the "computer hardware" topic. Concept word lists are expanded each time a student-created concept is entered into the ICMSys database. Learners can therefore use the list to choose words they find to be most appropriate, or create a new concept node to better describe their ideas.
2. To assist with concept map integration, a lexical database for the targeted learning material (in this case, "computer hardware") must be generated in advance. To address the redundancy issue in principle number 1, the ICMSys takes synonyms

into account when integrating similar terms. Kornilakis, Grigoriadou, Papanikolaou, and Gouli (2004) suggest using Wordnet (an electronic database) to support comparisons of concept words between student and expert concept maps. However, Wordnet is in English, meaning that a complete Chinese-language database of technology vocabulary needs to be constructed.

3. To promote self-awareness of concept boundaries, the ICMSys designates each individual's work as a default setting for concept map integration. Each ICMap consists of the learner's own map and learner-selected peer maps. Students can quickly move to the main task of making comparisons and finding differences between their own and their peers' maps.
4. Proposition integration categories include: (a) two propositions (each consisting of two concept words and one linking word) are completely identical, (b) the two concept words in each proposition are identical but the linking word is not, or (c) only one concept word in each proposition is identical (Fig. 10). In case (a), the two propositions are integrated into one. In (b), the two linking words are retained to preserve the uniqueness of each student's proposition, since a different linking word can change a proposition's meaning (Fig. 10a). In (c), even though the linking word "needs" is identical, only partial integration (i.e., branching) occurs because the phrases "leaf needs oxygen" and "leaf needs water" have different meanings (Fig. 10b).
5. Numbers in parentheses next to concept words indicate how many times the concept is mentioned in his/her and selected peers' concept maps (Fig. 10).

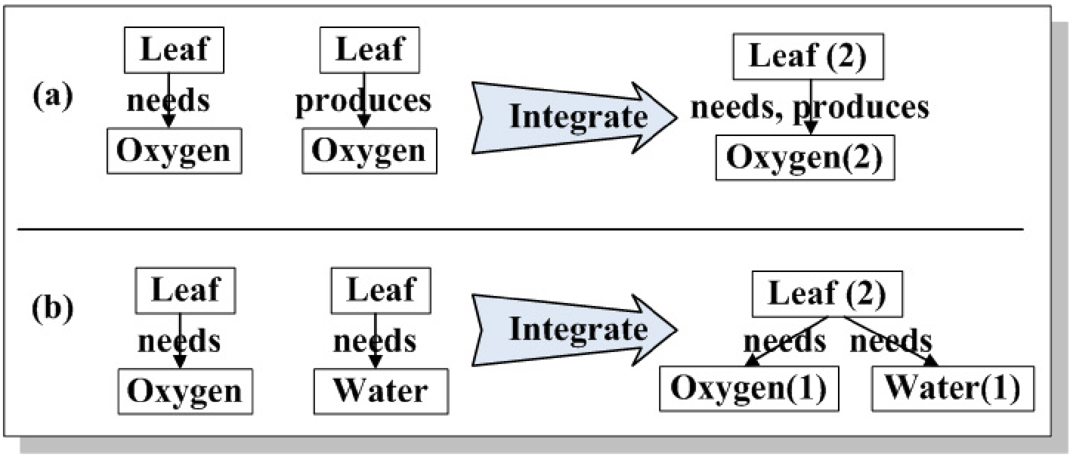


Figure 10. Two proposition integration patterns.

4.6.1. ICMSys interface

To create a Web-based distributed learning system, I used a combination of Java and JDBC to design the ICMSys interface (Fig. 11). In the "Personal concept mapping" section, students can use the form-based interface to externalize their ideas (i.e., map construction and connecting concept nodes with links). Concept nodes and linking words are not fixed, giving students greater flexibility for concept expression. As with many good tools, the learning system's main strength is its simplicity. Based on the above-mentioned design principles, the ICMSys accommodates ideas contributed by different peers and offers a convenient interface for making comparisons so as to lower the cognitive load of learners (i.e., there is no need to intensively study individual concept maps and memorize every difference in detail). In the "Integrated concept mapping" section, students select some of their peers' aliases from a popup window, and then press the "OK" button for the content of an integrated map to be shown. This process can be repeated as many times as desired, which allows students to view various combinations of ICMaps to discover what is lacking or at fault in their own concept maps.

Identical concepts are marked with numbers in parentheses, indicating how many times the concept is mentioned in a student's and selected peers' concept maps. This makes the integrated maps more concise and easier to analyze in terms of similarities. Students can then decide to adopt some of their peers' ideas to address the task at hand, or those ideas may stimulate reflection that allows students to see creative connections they had previously overlooked. An example of an integrated concept map (translated into English) is presented in Figure 11.

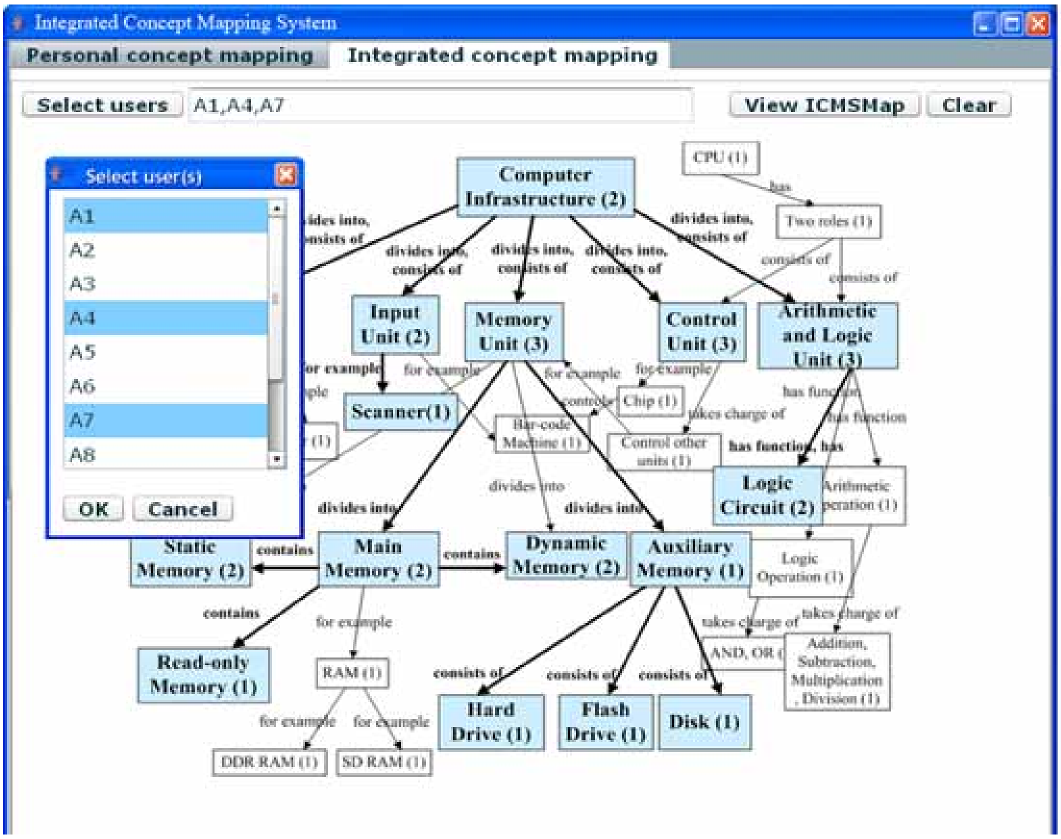


Figure 11. Integrated Concept Map System user interface and an integrated concept map with student A1's map highlighted (translated into English for demonstration purposes).

4.7. Case study of improving conceptual self-awareness

4.7.1. Participants and materials

Study participants were 32 information management freshmen enrolled in a computer hardware course offered by a Taiwanese technology institute. Course content focused on (but was not limited to) basic computer infrastructure, PC components, and storage processes. The ICMSys can be used in combination with any subject whose domain knowledge can be expressed in concept map format to assist students in elaborating concepts, engaging in reflective thinking, or breaking concept boundaries.

4.7.2. Procedure

The study procedure is shown in Figure 9. At some time during the first two weeks of the class, the instructor explained to students the concept mapping technique, concept map assessment criteria, and how to use the ICMSys. The three experts were also given training in concept mapping and assessment skills during this period. The training was based on Novak & Gowin's (1984) suggestions for concept map quality. For example, a linking word should describe a precise and meaningful relationship between two concept words, upper-level concept words should be more abstract, and general and lower-level concept words should be more detailed and concrete. At the end of week 2, students were given the learning material and task. In week 3, the participants constructed personal concept maps and made self-assessments of map quality; separate assessments were made by the three experts. In week 4, students were asked to assemble ICMaps for establishing personal concept boundary awareness via the peer map modeling process. In week 5, students redrew their personal concept maps and made self-assessments of revised concept map quality; again, separate assessments were made by the three experts. At the end of week 5, participants were asked to complete a questionnaire designed to measure their perceptions of the ICMSys (Table 11).

After the activity, the instructor could use a combination of the revised concept maps and reflective writing by the students to correct misconceptions.

4.7.3. Conceptual Self-awareness rating method

Pre- and post-tests are commonly used to measure variation in learning achievement across individual students (Wallace & Mintzes, 1990). In this study, pre- and post-tests consisted of self-assessments of personal maps by individual students and separate assessments of the same maps by three experts in computer science and information management. A 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) was constructed to assess concept map quality in terms of four criteria: examples, relationships, hierarchies, and cross-links (Novak & Gowin, 1984) (Table 12).

Table 11. Questionnaire to measure student perceptions of the ICMSys.

Item content	Percentages of responses				
	Strongly disagree				Strongly agree
	1	2	3	4	5
1. The ICMSys helped me discover major concept words.	3.13	6.25	12.50	68.75	9.38
2. The ICMSys helped me quickly comprehend a large number of others' concept maps.	0	3.13	6.25	84.28	6.25
3. The ICMSys facilitated my understanding of the learning material.	3.13	6.25	25.00	59.38	3.13
4. The ICMSys facilitated comparisons of my own and others' concept maps.	0	3.13	12.50	68.75	15.63
5. I found insufficiencies in my concept boundaries after viewing ICMaps.	3.13	6.25	3.13	71.88	15.63
6. The ICMSys helped me find mistakes in my concept map.	3.13	21.88	50.00	25.00	0

7. The ICMSys made it easier for me to make concept map extensions and revisions.	0	3.13	6.25	81.25	9.38
8. The ICMSys interface is easy to use.	3.13	9.38	15.63	68.75	3.13
9. I would like to use a similar concept mapping system for learning in the future.	3.13	12.50	37.50	46.88	0
10. Did you revise your own concept map after using the ICMSys? Why or why not?					

Table 12. Concept map scoring.

In the concept map…
1. are all concept words correct and representative?
2. does the constructed linking word describe a precise and meaningful relationship between the two concept words?
3. are the concept and linking words (propositions) detailed and plentiful?
4. are the characteristics of concept map hierarchies presented correctly? (E.g., are upper-level concept words more abstract and general and lower-level concept words more detailed and concrete?)
5. are hierarchies and branches detailed and plentiful?
6. are meaningful cross-links constructed to link concept words that belong to different branches?
7. are there detailed and plentiful examples?
8. are specific and representative examples outside of the learning material cited?

According to Fry and Lupart's (1987) confidence rating method, the difference between self- and expert-assessment ("student/expert score") is an indicator of self-monitoring and comprehension ability. In the present study, the difference represents the level of conceptual self-awareness: the smaller the difference between self and expert assessment scores, the greater the student's conceptual self-awareness. This approach is referred to as a "conceptual self-awareness rating method." To determine if the gap between student and expert assessments decreased or increased during the study period, the assessments were performed twice—once for the initial map and once for the revised map. Differences between the first and second student/expert scores represent change in the level of conceptual self-awareness. A change greater than zero indicates a reduction in the gap between student and expert assessments and an improvement in student conceptual self-awareness. Expressed as equations:

1. Level of conceptual self-awareness (student/expert score) = student's self assessment – expert's assessment
2. Change in level of conceptual self-awareness = student/expertfirst – student/expertsecond

4.8. Results and discussion of improving conceptual self-awareness

4.8.1. Does the ICMSys promote conceptual self-awareness?

As shown in Table 13, the first student/expert score (M = 5.84, SD = 3.61) represents the level of conceptual self-awareness for the first concept map and the second (M = 4.38, SD = 2.96) represents the level for the revised map. Results from a paired *t*-test using the two scores indicate a statistically significant improvement in conceptual self-awareness ($t = 2.31$, $p < 0.05$), suggesting that the students were more capable of assessing their map quality without overestimation. Results from paired-sample *t*-tests for measuring improvement in conceptual self-awareness in specific concept map criteria are presented in Table 14. They indicate statistically significant improvements in examples ($t = 2.52$, $p < 0.05$) and relationships ($t = 2.18$, $p < 0.05$) but not in hierarchies ($t = 1.05$, *ns*) or cross-links ($t = 1.67$, *ns*). A possible explanation is that the students found it easy to identify differences in the first two areas using the ICMSys, but the above-mentioned hierarchy issue made it more difficult for students to find differences in the hierarchy criterion. These results find support in Novak and Gowin's (1984) observation that students find it difficult to construct and understand the real meaning of cross-links.

Table 13. Statistics for the student, expert, and student/expert conceptual structure scores.

Assessment source	First map		Revised map		*t*	Significance
	M	SD	M	SD		
Student	28.72	3.26	29.69	3.11		
Expert	22.88	4.65	25.31	4.90		
Student/expert	5.84	3.61	4.38	2.96	2.31	$p < 0.05$

Table 14. Improvement in conceptual self-awareness in terms of the four criteria.

Criterion	Student/expert score					
	First map		Revised map		*t*	Significance
	M	SD	M	SD		
Examples	1.84	1.42	1.18	1.03	2.52	$p < 0.05$
Relationships	1.87	1.64	1.37	0.97	2.18	$p < 0.05$
Hierarchies	1.53	0.80	1.31	0.98	1.05	*ns*
Cross-links	0.60	0.53	0.52	0.31	1.67	*ns*

4.8.2. Does the ICMSys help learners make positive conceptual changes in their revised maps?

At issue here is the possibility that students could make negative conceptual changes even though their conceptual self-awareness had improved. To address this question, the experts examined the revised maps in terms of quality. A Kendall's coefficient of concordance was performed to measure inter-rater reliability. Agreement rates for both original and revised maps were statistically significant ($W = 0.82$, $p < 0.01$ and $W = 0.73$, $p < 0.01$, respectively). I therefore combined and averaged the ratings to provide a composite expert assessment figure for each concept map; *t*-tests were used to determine improvement in the quality of student concept maps as judged by the three experts as well as improvements in specific criteria. As shown in Table 15, the students made statistically significant improvements in examples ($t = 3.22$, $p < 0.01$), relationships ($t = 2.35$, $p < 0.05$), and cross-links ($t = 2.10$, $p < 0.05$). In other words, they regularly assimilated propositions, cross-links, or new concepts that they found to be meaningful into their conceptual structures with a few changes in existing hierarchies. This suggests that the study participants made significant and positive conceptual changes by breaking conceptual boundaries while their conceptual self-awareness levels improved.

Even though the increase in the hierarchy scale was not statistically significant, increased scores were observed (from M = 6.64, SD = 1.43 to M = 6.95, SD = 1.50) (Table 15). This suggests that the participants made the necessary adjustments to concept hierarchies to better organize their ideas whenever they found major mistakes in their concept maps or irreconcilable differences between their maps and those of other students. One possible explanation for their limited improvement in the hierarchy scale may be the nature of the concept mapping technique—that is, more general concepts are situated in higher map positions and more specific concepts in lower positions. Some students adhered to this model while others did not, causing inconsistency in their hierarchy presentations. To encourage greater flexibility in hierarchy integration, the ICMSys allows students to manually adjust ICMap hierarchies.

Table 15. Concept map quality as assessed by experts in terms of the four criteria.

Criterion	Experts (average from three)					
	First map		Revised map		*t*	Significance
	M	SD	M	SD		
Examples	5.50	1.40	6.41	1.63	3.22	$p < 0.01$
Relationships	9.53	2.05	10.48	2.20	2.35	$p < 0.05$
Hierarchies	6.64	1.43	6.95	1.50	1.47	*ns*
Cross-links	1.23	0.62	1.45	0.76	2.10	$p < 0.05$

4.8.3. Does ICMap viewing frequency affect conceptual self-awareness level?

According to the three experts, the participating students tended to select complete concept maps with lots of examples during the viewing process, perhaps because they felt they could make more worthwhile extensions and revisions based on those maps.

The participants were divided into two groups of 16 students each according to ICMap viewing frequency (group 1 = high and group 2 = low). The *t*-test results shown in Table 16 indicate a statistically significant difference between the first (M = 5.31, SD = 3.07) and second (M = 3.13, SD = 2.45) student/expert scores for group 1 ($t = 2.95$, $p < 0.05$) but not for group 2, meaning that group 1 students made a larger contribution to the overall improvement in conceptual self-awareness. The Table 16 data also indicate a significantly smaller ($t = -2.52$, $p < 0.05$) student/expert score for revised maps among group 1 students (M = 3.13, SD = 2.45) compared to group 2 students (M = 5.63, SD = 3.12), suggesting that group 1 students had better conceptual self-awareness than group 2 students, as reflected in the revised concept maps.

Table 16. Data for Integrated Concept Map (ICMap) viewing frequency. Group 1 = high, Group 2 = low.

Student/expert score	Group 1 (N = 16)		Group 2 (N = 16)		*t*	Significance
	M	SD	M	SD		
First map	5.31	3.07	6.38	4.11	-0.83	*ns*
Revised map	3.13	2.45	5.63	3.12	-2.52	$p < 0.05$
t	2.95		0.70			
Significance	p<0.05		*ns*			

4.8.4. Is there a correlation between conceptual self-awareness level in the revised map and conceptual improvements?

A significant Pearson correlation was found between level of student conceptual self-awareness in revised concept maps and actual conceptual changes as measured by the three experts (r = 0.38, $p < 0.05$). Specifically, the students did not overestimate or underestimate their concept maps after viewing many of their peers' maps. They used other maps as models, located their concept boundaries, understood the relative quality of their own concept maps, and were more self-aware of those boundaries when revising their maps. Furthermore, the students' concept maps significantly improved in terms of overall quality. Again, a possible explanation is that the social comparison process helped students learn previously unknown concepts and incorporate them into their revised maps.

4.8.5. ICMSys questionnaire responses

Data on student perceptions of the ICMSys are shown in Table 11. In the "practicality for comprehension" category, the responses indicate that the majority of students found the ICMSys to be a convenient method for helping them observe (item 1, 78%) and comprehend (item 2, 91%) major concepts and to understand the target material (item 3, 63%). This suggests that the students' ideas are not only externalized, but can also be selectively accommodated in representations considered practical for concept comprehension. Under "capability for conceptual awareness," the majority of students found the ICMSys to be helpful in terms of comparing their maps with their peers' maps (item 4, 84%), and therefore helpful in terms of finding concept boundaries (item 5, 88%) and adding extensions or making revisions to their own maps (item 7, 91%). These responses suggest that the ICMSys can assist students in conceptual reflective thinking, as well as in identifying and perhaps breaking through their existing concept boundaries.

Only 25% agreed that the ICMSys helped them find conceptual faults (item 6). The students admitted their limitations in presenting thorough/comprehensive concept maps, yet they asserted that the ideas they presented in their maps were almost correct. A possible explanation is that the students could not recognize their faults; this can be addressed by including expert concept maps as comparison sources or asking teachers to help correct misconceptions in the revised maps. Next, 72% felt that the ICMSys interface was easy to use (item 8), but only 47% stated an interest in using similar systems in the future (item 9). The vast majority of participants made changes to their original concept maps (item 10, 94%). When asked to identify factors that encouraged them to make revisions, they replied (a) some extensions could be added to make their concept maps more complete and thorough, (b) some previously unknown concepts were essential for inclusion in their revisions, or (c) their concept maps were inferior to their peers'.

4.9. Conclusions of breaking concept boundaries

I believe the introspective and comparative features of integrated concept maps can promote conceptual self-awareness, and that conceptual self-awareness can lead to personal conceptual change. Sometimes students are just a step away from coming up with their own comprehensive solutions or new ideas, and cannot utilize their prior knowledge flexibly due to their tendencies to frame their thinking within habitual concept boundaries. Thus, their attention is aimed at specific points or details to such a degree that they lack awareness of other possible solutions—what I call the "unaware zone." A review of concepts generated by peers may help students consider ideas they could not identify on their own.

Case study results show improvement in the students' conceptual self-awareness and evidence of their breaking concept boundaries due to their ability to use others' ideas to create quality revised maps. In other words, it is possible to design a learning system as an auxiliary tool to encourage conceptual self-awareness as a step toward breaking concept boundaries and making conceptual changes. Most existing e-learning systems aim at boosting learning performance, with little effort made to promote self-awareness in terms of meta-cognition. The concept mapping system described in this chapter differs in that it does not take the traditional approach to using concept mapping in collaborative meaningful learning. Using meta-cognition theory and the concept mapping technique, the system allows students to break through concept boundaries by improving conceptual self-awareness. Promoting self-awareness may not directly result in greater creativity, but it can be an important step toward overcoming personal barriers to creativity. I believe such experiences can exert lifelong impacts on learners: appreciating others' viewpoints, recognizing their own thinking habits, and encouraging creative mindsets.

The topic used in the case study, computer hardware structure, may not be appropriate for encouraging the full use of creative potential. I therefore suggest that future researchers take care in selecting more suitable subject domains for creative thinking. The ICMSys can be used in combination with any subject whose domain knowledge can be expressed in concept map format to assist students in elaborating concepts, engaging in reflective thinking, or breaking concept boundaries. For conceptual courses, the ICMSys can help students expand or elaborate their knowledge for better conceptual understanding. For example, teachers in introductory biology, psychology, or physics classes can use the ICMSys to make students aware of what they already know or don't know; students can consequently determine what concepts need to be incorporated into their cognitive systems and what links need to be created or deleted. Furthermore, they can consider how to restructure their concept maps to make them more meaningful. For design courses (e.g., industrial design or management), the ICMSys can assist students in creative thinking or innovative problem solving for assigned case studies or product design assignments. Instructors may also be interested in asking students to write reflective essays to demonstrate their creative ideas and conceptual change outcomes in addition to having them construct revised concept maps. The strength of the ICMSys software is that it provides opportunities for students to take responsibility for reflecting on what they did, what others did, and what improvements might be made by choosing and viewing, making comparisons, and engaging with their peers' maps.

In this study, the ICMSys was used as a personal conceptual self-awareness tool for emphasizing the importance of breaking concept boundaries via the modeling of peer concept maps. It can also be used as a good model for distributed learning or as a basis for collaboration and debate. Finally, when utilizing the ICMSys or a similar system, teacher expectations and other sources of motivation need to be considered to determine how and why students break through concept boundaries and generate creative ideas.

Chapter 5. Conclusion and future works

With the goal of furthering the use of IT to facilitate learning and to enhance creative potential, in this dissertation I have described a "creative knowledge engineering" model consisting of three phases: information sharing and search, active knowledge construction, and creative thinking. Based on this model, I developed a series of Internet-based learning activities and environments in which learners can experience multiple aspects of self-awareness regarding information retrieval or learning processes to facilitate learning and creative thinking (Fig. 12).

	Self-awareness / Outcomes
Study1 Information search	awareness of information sharing and search process
	better search intention prediction
Study2 Knowledge construction	awareness of shared resources and knowledge construction process
	active knowledge elaboration
Study3 Creative thinking	awareness of conceptual structure
	breaking conceptual boundaries and improving creative potential

Figure 12. Features of the 3 studies.

According to the study results, (a) the distinctively human factor known as thinking style was identified as a central factor in predicting search intention, (b) active knowledge construction can be encouraged through the design of a "beyond sharing" process for knowledge elaboration within social communities, and (c) concept boundaries can be broken and creative potential developed by improving learner conceptual self-awareness using the introspective and comparative features of the integrated concept map system (ICMSys).

Future researchers may be interested in elaborating on the underlying theories or design principles to create better understanding of the benefits of creative knowledge engineering, or to extend CKE application domains. For example, tailoring search engine interfaces to conform to personal information needs has the potential to reduce information complexity in order to increase user comprehension. By retrieving shared information from the Internet more efficiently, users can focus on active knowledge integration by incorporating proper information into existing cognitive structures. Researchers can adopt the CCL strategy used in the BeyondShare activity to extend simple information sharing to active learning and to develop a sense of a learning community via peer modeling and assessment in a CSCW environment.

Furthermore, researchers and teachers may be interested in using the ICMSys to help learners identify novel relationships between ideas by improving conceptual self-awareness and breaking habitual concept boundaries. Promoting self-awareness may not directly result in greater creativity, but it may represent an important step toward overcoming personal barriers to creativity. The CKE application domain may include IT applications, educational technology, digital content, or information communication. Researchers or teachers can apply parts of the CKE model to devise activities for specific purposes, with the goal being to help learners appreciate others' viewpoints, recognize their own thinking habits, and encourage creative mindsets.

References

Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. New York: Holt, Rinehart & Winston.

Baker, M., Hansen, T., Joiner, R., & Traum, D. (1999). The role of grounding in collaborative learning tasks. In Dillenbourg, P. (Ed.), *Collaborative learning: Cognitive and computational approaches*, Amsterdam: Elsevier, 31-63.

Bandura, A. (1986). *Social foundations of thought and action: A Social cognitive theory.* Englewood Cliffs, New Jersey: Prentice Hall.

Bangert-Drowns, R. L., Kulick, C. L. C., Kulick, J. A., & Morgan, M. T. (1991). The instructional effect of feedback in test-like events. *Review of Educational Research, 61,* 213-238.

Barron, R. S., Kerr, N. L., & Miller, N. (1992). *Group process, group decision, group action.* Bristol, PA: Open University Press.

Battelle, J. (2005). *The search: How Google and its rivals rewrote the rules of business and transformed our culture.* New York, USA: Portfolio Hardcover.

Beers, P. J., Boshuizen, H. P. A., Kirschner, P. A., & Gijselaers, W. H. (2005). Computer support for knowledge construction in collaborative learning environments. *Computers in Human Behavior, 21*, 623-643.

Bharat, K., & Mihaila, G. A. (2001). When experts agree: Using non-affiliated experts to rank popular topics. *Proceedings of the 10th International World Wide Web Conference,* Hong Kong. Available online at http://www.www10.org/cdrom/papers/474/index.html

Bilal, D. (1998). Children's search processor in using World Wide Web search engines: An exploratory study. *Proceedings of the 61st American Society for Information Science Annual Meeting* (pp. 45-53). Pittsburgh, PA.

Bilal, D. (2000). Children's use of the Yahooligans! Web search engine. I. Cognitive, physical, and affective behaviors on fact-based tasks. *Journal of the American Society for Information Science, 51,* 646-665.

Bilal, D. (2001). Children's use of the Yahooligans! Web search engine. II. Cognitive and physical behaviors on research tasks. *Journal of the American Society for Information Science, 52,* 118-137.

Bilal, D., & Kirby, J. (2002). Differences and similarities in information seeking: Children and adults as Web users. *Information Processing and Management, 38,* 649-670.

Bisseret, A., Figeac-Letang, C., & Falzon, P. (1988). Modelling opportunistic reasonings: The cognitive activity of traffic signal setting technicians. INRIA Technical Report No. 893. Rocquencourt: INRIA.

Brin, S., & Page, L. (1998). The anatomy of a large-scale hypertextual Web search engine. *Proceedings of the 7th International Conference on the World Wide Web* (pp.107-117). Brisbane, Australia.

Brown, A. L. (1987). Metacognition, executive control, self-regulation, and other more mysterious mechanisms. In F. E. Weinert & R. H. Kluwe (Eds.), *Metacognition, motivation, and understanding* (pp. 65–116). Hillsdale, New Jersey: Lawrence Erlbaum.

Burleson, W. (2005). Developing creativity, motivation, and self-actualization with learning systems. *International Journal of Human-Computer Studies, 63*, 436–451.

Canas, A. J., Ford, K. M., Novak, J. D., Hayes, P., Reichherzer, T., & Suri, N. (2001). Online concept maps: Enhancing collaborative learning by using technology with concept maps. *The Science Teacher, 68*(2), 49-51.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., Gómez, G., Arroyo, M., & Carvajal, R. (2004). CmapTools: A knowledge modeling and sharing environment. In *Proceedings of the first international conference on concept mapping* (pp. 125–133), Pamplona, Spain.

Chang, K. E., Sung, Y. T., & Lee, C. L. (2003). Web-based collaborative inquiry learning. *Journal of Computer Assisted Learning*, 19, 56–69.

Chiu, C. H., Huang, C. C., & Chang, W. T. (2000). The evaluation and influence of interaction in network supported collaborative concept mapping. *Computers & Education, 34*(1), 17–25.

Chung, W. K., O'Neil, F., Herl, E., & Dennis, A. (1997). Use of the networked collaborative concept mapping to measure team processes and team outcomes. *Paper presented at the annual meeting of the American Educational Research Association*, Chicago, Illinois.

Coffey, J. W. (2007). A meta-cognitive tool for courseware development, maintenance, and reuse. *Computers & Education, 48*(4), 548–566.

Conn, S. R., & Rieke, M. L. (Eds.) (1994). *l6PF (5th ed.): Technical manual.* Champaign, IL: Institute for Personality and Ability Testing, Inc.

Crooks, T. J. (1988). The impact of classroom evaluation practices on students. *Review of Educational Research, 58,* 45-56.

Cugini, J., Laskowski, S., & Sebrechts, M. (2000). Design of 3D visualization of search results: Evolution and evaluation. *Proceedings of IST/SPIE's 12th Annual International Symposium—Electronic Imaging 2000: Visual Data Exploration and Analysis* (pp. 23-28). San Jose, CA.

Duval, S., & Wicklund, R. A. (1972). *A theory of objective self-awareness.* New York: Academic Press.

Edmonds, G. S., & Pusch, R. (2002). Creating shared knowledge: Instructional knowledge management systems. *Educational Technology and Society, 5*(1), 100-104.

Falchikov, N. (1995). Peer feedback marking: Developing peer assessment. *Innovations in Education & Training International, 32*, 175-187.

Falchikov, N., & Magin, D. (1997). Detecting gender bias in peer marking of students' group process work. *Assessment and Evaluation in Higher Education, 22*, 385-396.

Feldhusen, J. F. (1995). Creativity: A knowledge base, metacognitive skills, and personality factors. *Journal of Creative Behavior, 29*(4), 265–268.

Finke, R. A., Ward, T. M., & Smith, S. M. (1992). Creative cognition: Theory, research, and applications. Cambridge, MA: MIT Press.

Fisher, K. M. (1990). Semantic-networking: The new-kid on the block. *Journal of Research in Science Teaching, 27*, 1001–1018.

Fischer, G., Giaccardi, E., Eden, H., Sugimoto, M., & Ye, Y. (2005). Beyond binary choices: Integrating individual and social creativity. *International Journal of Human-Computer Studies,* 63, 482–512.

Flavell, J. H. (1976). Metacognition aspects of problem-solving. In L. B. Resnick (Ed.), *The nature of intelligence* (pp. 231–235). Hillsdale, New Jersey: Lawrence Erlbaum.

Ford, C. M. (1996). A theory of individual creative action in multiple social domains. *Academy of Management Review, 21*(4), 1112–1142.

Ford, N., & Miller, D. (1996). Gender differences in Internet perception and use. *Proceedings of the 3rd Conference on Electronic Library and Visual Information Research (ASLIB)* (pp. 183-192). London, UK.

Ford, N., Miller, D., & Moss, N. (2005). *Web search strategies and human individual differences: Cognitive and demographic factors, Internet attitudes, and approaches.* NY, USA: John Wiley & Sons, Inc.

Freeman, M. (1995). Peer assessment by groups of group work. *Assessment & Evaluation in Higher Education, 20*, 289-300.

Fry, P. S., & Lupart, J. L. (1987). *Cognitive Processes in Children's Learning.* Springfield, MA: Charles C. Thomas.

Gaines, B. R., & Shaw, M. L. G. (1995). Concept maps as hypermedia components. *International Journal of Human Computer Studies, 43*(3), 323–361.

Gardner, H. (1993). *Creating minds: An anatomy of creativity seen through the lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Gandhi.* New York: Basic Books.

Garner, R., & Alexander, P. A. (1989). Metacognition: Answered and unanswered questions. *Educational Psychologist, 24*(2), 143–158.

Greenberg, S., & Marwood, D. (1994). Real time groupware as a distributed system: Concurrency control and its effect on the interface. In Furuta, R. & Neuwirth, C. (Eds.), *Proceedings of the ACM CSCW'94 Conference on Computer Supported Cooperative Work*, New York: ACM Press, 207-217.

Haveliwala, T. H. (2002). Topic-sensitive PageRank. *Proceedings of the 11th International Conference on the World Wide Web* (pp. 517-526). Honolulu, HI.

Häkkinen, P., Järvelä, S., & Mäkitalo, K. (2003). Sharing perspectives in virtual interaction: Review of methods of analysis. In Wasson, B., Ludvigsen, S. & Hoppe, U. (Eds.), *Designing for change in networked learning environments, Proceedings of the International Conference on Computer-Support for Collaborative Learning*, Dortrecht: Kluwer Academic Publishers, 395-404.

Hogarth, R. M., & Einhorn, H. J. (1992). Order effects in belief updating: The belief adjustment model. *Cognitive Psychology, 24,* 1-55.

Holscher, C., & Strube, G. (2000). Web search behavior of Internet experts and newbies. *Computer Networks, 33,* 337-346.

Hsieh-Yee, I. (2001). Research on Web search behavior. *Library & Information Science Research, 23,* 167–185.

Huang, C. Y. (2004). *The establishment of a thinking style questionnaire for elementary students and its creativity related research.* Unpublished master's thesis, National Hsinchu University of Education, Taiwan.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (1998). *Active learning: Cooperation in the college classroom.* Edina, MN: Interaction Book.

Johnson, D. W., Maruyama, G., Johnson, R., Nelson, D., & Skon, L. (1981). Effects of cooperative, competitive, and individualistic goal structures on achievement: A meta-analysis. *Psychological Bulletin, 89*, 47-62.

Katz, Y. J. (2002). Attitudes affecting college students' preferences for distance learning. *Journal of Computer Assisted Learning, 18*(1), 2-9.

Kim, K. S., & Allen, B. (2002). Cognitive and task influences on Web searching behavior. *Journal of the American Society for Information Science, 52*(2), 109-119.

Kleinberg, J. M. (1998). Authoritative sources in a hyperlinked environment. *Proceedings of the 9th Annual ACM-SIAM Symposium on Discrete Algorithms* (pp.668-677). San Francisco, CA.

Komis, V., Avouris, N., & Fidas, C. (2002). Computer-supported collaborative concept mapping: Study of interaction. *Education and Information Technologies, 7*(2), 169-188.

Kornilakis, H., Grigoriadou, M., Papanikolaou, K. A., & Gouli, E. (2004). Using WordNet to support interactive concept map construction. In *Proceedings of the fourth IEEE international conference on advanced learning technologies*, Joensuu, Finland.

Kreijns, K., Kirschner, P. A., & Jochems, W. (2002). Sociability in computer-supported collaborative learning environments. *Educational Technology and Society, 5*(1), 8-22.

Kremer, R. (1996). Toward a multi-user, programmable web concept mapping "Shell" to handle multiple formalisms. In *Proceedings of the tenth Banff knowledge acquisition workshop*, Banff, Alberta, Canada.

Kulik, J. A., & Kulik, C. L. C. (1988). Timing of feedback and verbal learning. *Review of Educational Research, 58,* 79-97.

Last, D. A., O' Donnell, A. M., & Kelly, A. E. (2001). The effects of prior knowledge and goal strength on the use of hypertext. *Journal of Educational Multimedia and Hypermedia, 10*(1), 3-25.

Lazander, A. W., Biemans, H. J. A., & Wopereis, I. G. J. H. (2000). Differences between novice and experienced users in searching information on the World Wide Web. *Journal of the American Society for Information Science, 51*(6), 576-581.

Lin, C., & Tsai, C. (2005). Navigation flow map method of representing students' search strategies on the Web. *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications* (pp. 3229-3236). Chesapeake, USA: AACE.

Lin, S. S. J., Liu, E. Z. F., & Yuan, S. –M. (2002). Student attitudes toward networked peer assessment: Case studies of undergraduate students and senior high school students. *International Journal of Instructional Media, 29*(2), 241-254.

Lin, S. S. J., Sun, C. T., & Kao, G. Y. M. (2002). Designing a networked-sharing construction environment. *British Journal of Educational Technology, 33*(4), 489-492.

Liu, E. Z. F., Lin, S. S. J., & Yuan, S. –M. (2002). Alternatives to instructor assessment: A case study of comparing self and peer assessment with instructor assessment under networked innovative assessment procedures. *International Journal of Instructional Media, 29*(4), 1-10.

Malone, J., & Dekkers, J. (1984). The concept map as an aid to information in science and mathematics. *School Science and Mathematics, 84*(3), 220–231.

Michinov, N., & Primois, C. (2005). Improving productivity and creativity in online groups through a social comparison process: New evidence for asynchronous electronic brainstorming. *Computers in Human Behavior, 21*(1), 11–28.

Moreno, R., & Mayer, R. E. (2000). Engaging students in active learning: The case for personalized multimedia messages. *Journal of Educational Psychology, 92*(4), 724-733.

McCarthy, C., Bligh, J., Jennings, K., & Tangney, B. (2005). Virtual collaborative learning environments for music: Networked drumsteps. *Computers & Education, 44*(2), 173-195.

Mulder, I., & Swaak, J. (2002). Assessing group learning and shared understanding in technology mediated interaction. *Educational Technology and Society, 5*(1), 35-47.

Mulder, I., Swaak, J., & Kessels, J. (2004). In search of reflective behavior and shared understanding in ad hoc expert teams. *CyberPsychology & Behavior, 7*(2), 141-154.

Mullen, B., Johnson, C., & Salas, E. (1991). Productivity loss in brainstorming groups: A meta-analytic integration. *Basic and Applied Social Psychology, 12*, 3–23.

Nisbett, R. E., & Wilson, T. D. (1977). Telling more than we can know: verbal reports on mental processes. *Psychological Review, 84*(3), 231–259.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn.* Cambridge, MA: Cambridge University Press.

Okebukola, P. A., & Jegede, O. J. (1989). Cognitive preference and learning model as determinates of meaningful learning through concept mapping. *Science Education, 71*, 232–241.

O'Reilly, T. (2005). *What is Web 2.0: Design patterns and business models for the next generation of software*, retrieved October 30, 2006 from http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html.

Rada, R. (1998). Efficiency and effectiveness in computer-supported peer-peer learning. *Computers and Education, 30*(3/4), 137-146.

Reader, W., & Hammond, N. (1994). Computer-based tools to support learning from hypertext: Concept mapping tools and beyond. *Computers & Education, 22*, 99–106.

Resnick, M. (1996). Distributed constructionism. *Proceedings of the International Conference on Learning Science, Northwestern University,* retrieved May 20, 2004 from http://llk.media.mit.edu/papers/archive/Distrib-Construc.html.

Resnick, M. (2002). Rethinking learning in the digital age. In Kirkman, G. (Ed.), *The Global Information Technology Report: Readiness for the networked word,* Oxford: Oxford University Press, 32-37.

Roschelle, J., & Teasley, S. (1995). The construction of shared knowledge in collaborative problem solving. In O'Malley, C. E. (Ed.), *Computer supported collaborative learning*, Springer-Verlag, Heidelberg, 69-97.

Roth W. M., & Roychoudhury, A. (1992). The social construction of scientific concepts or the concept map as a conscription device and tool for social thinking in high school science. *Science Education, 76*, 531-557.

Rouet, J. F. (2003). What was I looking for? The influence of task specificity and prior knowledge on students' search strategies in hypertext. *Interacting with Computers, 15*(3), 409-428.

Ruiz-Primo, M. A., & Shavelson, R. J. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching, 33*(6), 569-600.

Saulsman, L. M., & Page, A. C. (2004). The five-factor model and personality disorder empirical literature: A meta-analytic review. *Clinical Psychology Review*, *23*, 1055-1085.

Scardamalia, M., & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: A challenge for the design of new knowledge media. *Journal of the Learning Sciences, 1*(1), 37-68.

Selker, T. (2005). Fostering motivation and creativity for computer users. *International Journal of Human-Computer Studies, 63*, 410–421.

Shapiro, A. M. (2000). The effect of interactive overviews on the development of conceptual structure in novices learning from hypermedia. *Journal of Educational Multimedia and Hypermedia, 9*(1), 57-78.

Stahl, G. (2005). Group cognition in computer-assisted collaborative learning. *Journal of Computer Assisted Learning, 21*, 79-90.

Strachan, I. B., & Wilcox, S. (1996). Peer and self assessment of group work: Developing an effective response to increased enrollment in a third year course in microclimatology. *Journal of Geography in Higher Education, 20*(3), 343-353.

Sternberg, R. J. (1994). *Thinking and problem solving*. San Diego, USA: Academic Press, Inc.

Sternberg, R. J. (1997). *Thinking styles*. New York: Cambridge University Press.

Sternberg, R. J., & Grigorenko, E. L. (1995). Styles of thinking in school. *European Journal for High Ability, 6,* 201-219.

Sternberg, R. J., & Wagner, R. K. (1999). *Readings in cognitive psychology*. Orlando, USA: Harcourt, Brace, Jovanovich.

Suls, J., & Fletcher, B. (1983). Social comparison in the social and physical sciences: An archival study. *Journal of Personality and Social Psychology, 44*, 575–580.

Suthers, D. (2005). Technology affordances for intersubjective learning: A thematic agenda for CSCL. *Paper presented at the International Conference of Computer Support for Collaborative Learning*, May 30-June 4, 2005, Taipei, Taiwan.

Tauer, J. M., & Harackiewicz, J. M. (2004). The effects of cooperation and competition on intrinsic motivation and performance. *Journal of Personality and Social Psychology, 86*(6), 849-861.

Topping, K. J. (1998). Peer assessment between students in colleges and universities. *Review of Educational Research, 68*, 249-276.

Turner, J. C., Meyer, D. K., Cox, K. E., Logan, C., DiCintio, M., & Thomas, C. (1998). Creating contexts for involvement in mathematics. *Journal of Educational Psychology, 90*(4), 730-745.

Van Lehn, K. A., Chi, M. T. H., Baggett, W., & Murray, R. C. (1995). *Progress report: Towards a theory of learning during tutoring.* Pittsburgh, PA: University of Pittsburgh Learning Research and Development Center.

Wallace, J. D., & Mintzes, J. J. (1990). The concept map as a research tool: Exploring conceptual change in biology. *Journal of Research in Science Teaching, 27*(10), 1033–1052.

Yang, S. J. H., Chen, I. Y. L., & Shao, N. W. Y. (2004). Ontology enabled annotation and knowledge management for collaborative learning in virtual learning community. *Educational Technology & Society*, 7(4), 70-81.

Yuan, W. (1997). End-user searching behavior in information retrieval: A longitudinal study. *Journal of the American Society for Information Science, 48*(3), 227-229.

Zamir, O., & Etzioni, O. (1999). Grouper: A dynamic clustering interface to Web search results. *Proceedings of 8th WWW Conference* (pp. 1361-1374). Toronto, Canada.

Zhang, L. F., & Sternberg, R. J. (2005). A threefold model of intellectual styles. *Educational*

Psychology Review, *17*(1), 1-53.