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博 士 論 文

在各類型多媒體搜尋引擎中

個人特質對搜尋行為、策略與成效之影響

Effects of Individual Differences on Search Behaviors, Strategies and Performance in Various Types of Multimedia Search Engines

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摘 要

網路資訊搜尋是現代人獲得資訊最主要的方法，因此搜尋引擎設計者在設計產品時應考量使用者的個別差異，以便個體能利用搜尋引擎獲取知識。關於影響搜尋歷程與成效之因素，之前已經累積了一些研究成果，但大多數研究都是探討影響文字搜尋的原因，很少針對其他種類搜尋引擎去探討，但搜尋文字、圖像、影音和地標所經歷的認知歷程是不一樣的，且圖像搜尋、影音搜尋、地標搜尋比文字搜尋更為複雜，故影響其搜尋行為與成效的因素可能更多。本研究要探討個人特質（含認知、情意與行為層面）對各式多媒體搜尋的影響，讓網路搜尋能夠提供更多個人化的服務，幫助使用者提高搜尋的準確率，而不是加重認知負荷。

本研究設計了 4 階段實驗，分別使用文字（Google）、圖像（Google Image）、影音（YouTube）和地標（Google Earth）搜尋引擎作為研究工具。受試者分別為 5~7 年級學生，藉由對搜尋歷程的觀察與質性分析以及對搜尋行為與結果的量性分析，進一步瞭解不同特質的受試者在處理各種搜尋任務時會運用哪些搜尋策略與行為，他們的搜尋歷程、成效以及學習成效又是如何。

實驗結果發現在眾多個人特質中「認知方面」的因素影響搜尋行為、策略、成效的效果最為顯著，包括閱讀能力影響圖像搜尋，後設認知能力影響影片搜尋，環境認知能力、空間能力以及地理知識影響地標搜尋。「情意方面」的因素僅有思考風格（幅度）會影響文字搜尋，認知風格則對影片搜尋沒有影響。「技能方面」的因素，網路使用經驗對圖像搜尋沒有影響。因此學生認知的能力在網路資訊檢索中扮演重要的角色。此外，我們發現在不同形式（文字、圖像、影片、地標）的搜尋引擎中，使用者必須使用不同的搜尋策略（例如：在文字搜尋中要使用多個關鍵字並靈活變化，但在圖像搜尋中要多比對審視搜尋結果，而在影音搜尋中則要鍵入精簡明確的關鍵字，並根據目標簡要審視搜尋結果），才能尋獲正確且符合需求的資料。

Effects of Individual Differences on Search Behaviors, Strategies and Performance in Various Types of Multimedia Search Engines

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ABSTRACT

Web information retrieval is, for most people, the most popular method of acquiring information. Therefore, when creating search engines, designers should take into account human factors (including cognitive, affective, skill, and demographic factors) in order to increase the degree of user-friendliness. Many researchers have examined the factors impacting information-seeking behaviors, strategies and performance and have accumulated fruitful results, but they have generally focused on text rather than on other multimedia searches. However, the cognitive processes underlying search for texts, images, videos, and landmarks are very different. Search for images, videos, and landmarks require more complicated procedures than search for texts do; therefore, more factors could influence search behaviors and performance in these complex processes. This study aimed at investigating how individual factors influenced a variety of multimedia searches (including search for texts, images, videos, and landmarks). We hope that search engines can provide more personalized services and that these personalized functions will push for the accuracy of search results instead of pulling for greater burdens on cognitive loads.

A four-phase study was conducted to explore multimedia searches with increasing complexity. The search engines “Google” was used in search for texts, “Google Image” was used in search for images, “YouTube” was used in search for videos, and “Google Earth” was used in search for landmarks. Study participants were fifth through seventh graders. This study was conducted to explore the impacts of (a) thinking style level on search for texts; (b) reading ability and Internet experience on search for images; (c) metacognitive strategies and verbal-imagery cognitive style on search for videos; and (d) geographical knowledge, spatial ability and environmental cognition on search for landmarks. As a result of the quantitative data analysis and qualitative process observations, I can explore the participants with different characteristics used what types of search strategies and behaviors when they undertook various search tasks. Furthermore, I can understand the search performance and learning effectiveness of the participants.

The results support the conclusions that many cognitive factors

significantly influenced search behaviors, strategies and performance. Examples include “reading ability” influencing image search; metacognitive strategies influencing video search; and “environmental cognition”, “spatial ability”, and “geographical knowledge” influencing landmark search. In terms of affective factors, only thinking style levels were significant factors influencing text search, whereas verbal-imagery cognitive style did not exert a strong influence on video search. A skill factor (Internet experience) did not influence image search. In sum, cognitive abilities, compared with affective, skill and background factors, played more important roles in web information retrieval. Moreover, our results show that the users adopted different search strategies when using the various types of search engines, such as using more keywords in text searches, evaluating more search results in image searches, and entering concise and accurate descriptions with fewer keywords in video searches.

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Chapter 1. Introduction

1.1. Motivation

Digital data and information have become necessities of modern life. However, the increased volume of information incorporated in webpages has skyrocketed beyond our imagination. For example, in 2012, the number of non-duplicate webpages indexed in Google search engines was approximately 30 trillion (Sullivan, 2012; Wikipedia, retrieved July 25, 2012). We are inundated with unprecedented volumes of information. Moreover, given that the Internet is a dynamic hypermedia system for acquiring information, users easily become lost when looking for information (Navarro-Prieto, Scaife, & Rogers, 1999). Therefore, each individual should be aware of effective ways to search for the information that they need in this era of explosive information.

As software and hardware constantly evolve to further advancement and the technology of webpage design and the bandwidth of the Internet are drastically enhanced, the modern webpage has transformed from text information into multimedia platforms offering auditory, pictorial and animated information. The search indexes of Yahoo search engines included approximately 19.2 billion web documents, 1.6 billion images, and over 50 million audio and video files in August of 2005 (Yahoo, 2005; Boutell.Com, 2007). Thus, all types of search engines have been flourishing. Examples include Google, Yahoo, Google Image, Google Maps, Google Earth and YouTube. Additional new search functions providing extra help for users emerge every single day. For example, there is a search engine providing users with selections of words to be added before or after original keywords or with other related keywords. By means of search engines, users are free to locate the information they want in the massive sea of digital resources.

The invention of the search engine has changed the ways in which everyone in the world pursues knowledge and studies. Today, people (including students) immediately turn to the Internet to meet a large majority of their information needs. This transformation has brought about changes to education because transmission and instilment of knowledge are no longer the first and foremost goals of education. Students are now trained to actively seek and evaluate information and to construct knowledge from online searches performed on a daily basis (Bilal & Kirby, 2002). They are required to integrate the acquired information with their prior knowledge in order to cope with other tasks and problems (Brand-Gruwel, Wopereis, & Vermetten, 2005). The "ability of information search" has been elevated to the status of a new problem-solving skill (Laxman, 2010; Park & Black, 2007; Walraven, Brand-Gruwel, & Boshuizen, 2008). The collection, analysis, assessment and integration of online information impacts everyone's learning effectiveness and quality of life.

The information search process is the user's constructive activity of finding meaning from information in order to extend or change his or her state of knowledge on a particular problem or topic. Thus, information search is a form of learning (Kuhlthau, 1991; Marchionini, 1995). Before embarking upon any meaningful search activities, the searcher must understand the questions that they have, or the nature of the search tasks, by means of their existing knowledge. They must decide upon the approximate whereabouts of their target in the cyber world (for example, the user must decide between searching general webpages, news articles, blogs, pictures or maps) and choose a search engine. Then, they can formulate keywords for the search. In the course of the search, the searcher must review each search result and move on to subsequent searches if necessary after the assessment, during which they may be required to modify their techniques, adjust their keywords or rephrase their questions in order to achieve their purposes. The entire process comprises planning, monitoring, evaluating, and revising activities; these are also metacognitive learning strategies (Brown, 1987). It is also a self-regulated learning process. In addition, because many search results are now displayed in some form of multimedia, learners have more opportunities to repeatedly use sounds, pictures and text to construct knowledge, thus making knowledge acquisition is a concrete representation of cognitive elaboration (Reigeluth & Stein, 1983). This study regards search as an active process of cognition and learning when learning tasks occur until the learner completes their tasks. This study aims at investigating how different learners “learn” to look for the information that they need on the Internet and how they locate useful results.

People possess individual differences in learning. Individuals tend to use distinctly different behaviors and strategies to perform identical search tasks, such as reading multiple pages of search results in detail versus skimming one page of results before trying a new keyword, following multiple links versus stopping after the first webpage, and utilizing one versus multiple search engines. Accordingly, individuals achieve different search outcomes and learning effects. Regarding differences in text search behaviors and performance, researchers have looked at individual difference factors, such as personal experiences (e.g., background, Internet experience, and experience with Boolean searching), personal cognition (e.g., domain knowledge, reading skill, problem-solving ability, and understanding of the search task), personal approaches (e.g., study approaches, perceptions of and preferred approaches to web-based information seeking, and cognitive style), environmental factors (e.g., search engines), and task types (e.g., locating web sites versus locating information, close-ended versus open-ended) (Bystrom & Jarvelin, 1995; Allen, 1998, 2000; Hsieh-Yee, 2001; Bilal & Kirby, 2002; Kim & Allen, 2002; Rouet, 2003; Ford, Miller, & Moss, 2005; Park & Black, 2007). While it seems obvious that differences in individual characteristics and cognitive development may influence text search behaviors and performance (Ford, Wood, & Walsh, 1994; Kim & Allen, 2002), very few researchers have made the effort to test these ideas or to identify specific factors that influence other types of searches.

However, there is a drastic difference between search for texts and search for other types of information (such as images, landmarks, music, and videos). According to the cognitive theory of multimedia learning (Mayer, 2001), humans have two information processing systems; one is for verbal material, and the other is for visual material. Some people are more advanced in dealing with words, while others show better performance with images (Mayer & Massa, 2003). In presenting an instructional message to learners, designers have two main formats available: words and pictures. Words include speech and printed text, while pictures include static graphics (such as illustrations and photos) and dynamic graphics (such as animations and videos). Because different types of search engines possess different search and cognitive processes, it seems reasonable to consider search engines within four types of formats: (1) text search, where the searched information is mainly printed text (such as Google, Yahoo, and Bing); (2) image search, where the searched information is mainly static photos (such as Google Image and Yahoo! Image Search); (3) video search, where the searched information mainly consists of dynamic graphics (such as Google Video, YouTube, and Yahoo! Video Search); and (4) landmark search, where the searched information mainly includes static illustrations (such as Google Maps, Google Earth, and Yahoo! Maps).

Text searches require the comprehension of connotations for a given topic and the use of related ideas to formulate keywords. Because it is easy for students to focus on and search for information via definitive keywords, it only takes them a few searches to retrieve the correct documents or answers.

In contrast, picture or image searches require theme formulation and the ability to envision potential results. Given that many current image retrieval systems are keyword-based, users must translate their visions into literal descriptions, and pictures stored in databases must have descriptive words or metadata that match selected keywords (Fukumoto, 2006; Hou & Ramani, 2004). Search systems transmit some pictures for users to compare, assess, and decide whether or not they need to continue a search. Accordingly, image searches can be analyzed as mixed acts of image-text cross-referencing, observation, judgment, decision-making, and correction. Note that the existence of semantic gaps and the lack of precise characteristics make image searches more abstract and complex than text searches (Choi, 2010; Cunningham & Masoodian, 2006). In image searches, descriptive and thematic queries are more commonly used than unique term queries. Most users perform a large amount of query modification but they seem unable to find the images they desire in an effective way (Jörgensen & Jörgensen, 2005). Approximately one-fifth of all image search queries result in zero hits (Pu, 2008). Yet little is known about what factors improve the odds for successful image searches.

In terms of video searches, video search engines provide a tool that is less frequently observed in the other types of search engines: the video recommendation system. Such a tool “recommends” other videos that are relevant to the viewed video (regardless of the keyword usage) for the users’ reference by analyzing the search processes of individual users and the knowledge structure within the system. This function is very common on video and music sharing websites for business purposes. Such a design aims to bring convenience to users rather than to help them learn better. Thus, it may be an additional significant factor in the video search process. The retrieved videos may come from the suggestion of the users based on the relevance between the pictures and the texts, and they may also be contributed from the recommendations made by the system. In terms of learning, we must be careful in distinguishing the attributions to the search results – from the students or from the guidance of the system? Will the issue related to recommendation by the system be aggravated if the students use improper keywords or view irrelevant videos? The “video recommendation system” can bring about both benefits and risks for the users. This function allows users to quickly browse videos related to the topics that they care about, but it could also lead the users to watch a series of videos irrelevant to their original search targets, which may induce them to believe that such search results are useful.

Thus, when evaluating learning effectiveness in the course of a video search, we must take this function into consideration.

When we use geographic information systems to search for landmarks, the basic steps of collecting spatial information from Internet are described below. To successfully complete search of the given famous landmarks when only the names of the landmarks are provided, one must have rich knowledge of global landmarks -- knowing at which place(s) the landmark may be. Some landmarks may be learned through the textbooks and geography instructions; while others may be gained from real life experiences by viewing the landmarks or walking in/surrounding by them. Personal environmental experiences are processed and stored through the function named as large scale environmental cognition (Evans, 1980; Hegarty, Montello, Richardson, Ishikawa & Lovelace, 2006). Landmark searches involve internal representations of correct spatial information, a cognitive function referred to as spatial ability by Linn and Petersen (1985). If a landmark does not appear at a predicted location, an individual must use a combination of reasoning, guessing, exploring, using partial correct geographical knowledge and excluding incorrect hypotheses. This type of abstract reasoning is considered a central characteristic of general intelligence. In sum, landmark searches require complex cognitive processing.

In sum, the similarities and differences of four types of search engines are compared and presented in Table 1. These show that various types of multimedia search engines possess different search and cognitive processes. Therefore, different types of search engines may lead to diverse factors to influence search behaviors, strategies and performance due to different search and cognitive processes. This study aims at analyzing, as well as defining, which cognitive abilities or individual characteristics affect students' abilities to effectively search using a variety of multimedia search engines.

Table 1. The similarities and differences of four types of search engines.

	Text search	**Image search**	**Video search**	**Landmark search**
Input	Keywords	Keywords	Keywords	Keywords or navigation
Output	Texts	Images	Videos	Landmarks
Information presentation	Printed text	Static photos/pictures	Dynamic graphics /motion pictures, printed text, speech text	2D - 3D static illustrations/maps
Search result	Open answers	Open answers	Open answers	Single answer
Distinctive processes	Not specified	Image-text cross-referencing , observation, judgment, decision-making, and correction	Visual channel and verbal channel operate at the same time	Locating landmarks or streets on e-maps
Distinctive functions	Not specified	Not specified	Video recommendation system	Zooming in, zooming out, rotating, and moving the e-maps
Prerequisites for search	Reading comprehension skills	Visual literacy	Absorbed in the information of many different formats such as images, words, and audio sounds	Mental rotation, non-verbal reasoning ability, personal environmental experiences, rich knowledge of global landmarks
Representative search engines	Google, Yahoo	Google Image, Yahoo! Image search	YouTube, Google Video	Google Earth, Google Map

1.2. Goal

The purpose of this research is to investigate the effects of individual characteristics (including cognitive factors, affective factors, and skill factors) on search behaviors, strategies and performance in relation to a variety of multimedia search engines, including Google (text search), Google Image (image search), YouTube (video search), and Google Earth (landmark search). As mentioned above, different types of search engines may lead to diverse factors to influence search behaviors, strategies and performance due to different search and cognitive processes. I aimed at the distinguishing features of different types of search engines to explore the impacts of various independent variables on text, image, video and landmark search respectively. I address the subjects as the following: (1) text search strategies and behaviors are considerably affected by an affective factor, particularly thinking style levels; (2) image search behaviors and performance are considerably affected by a cognitive factor (reading ability) and a skill factor (Internet experience); (3) video search behaviors and performance are considerably affected by a cognitive factor (metacognitive strategies) and an affective factor (verbal-imagery and cognitive style); and (4) landmark search performance is considerably affected by at least four cognitive factors: abstract reasoning ability, small scale spatial ability, large scale environmental cognition and prior knowledge of the landmark. Our research design is illustrated in Figure 1.

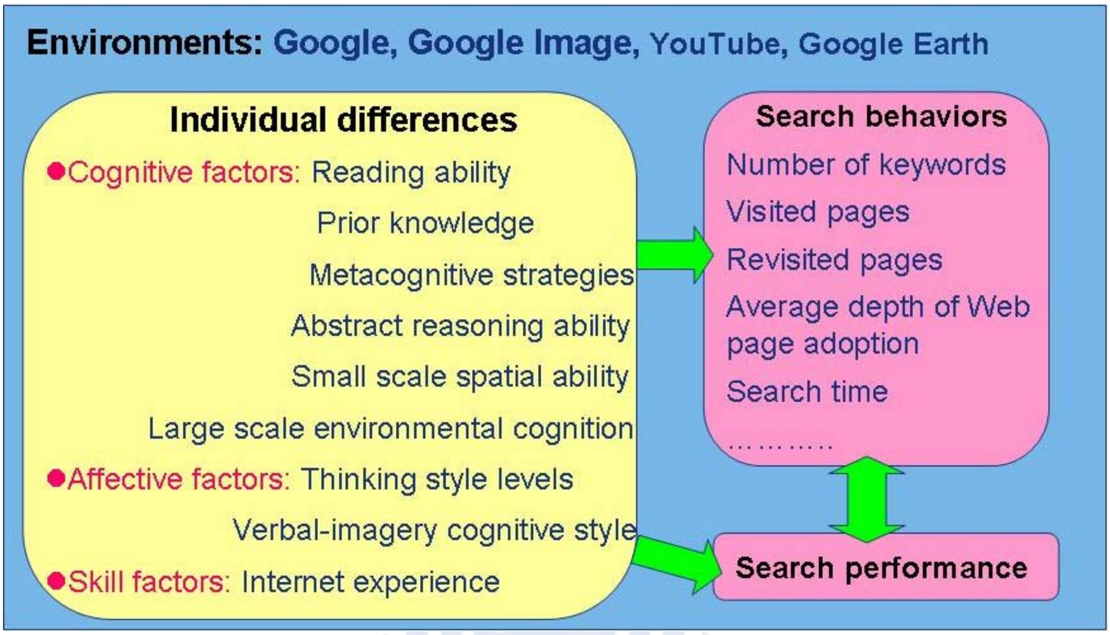

Figure 1. Main study architecture.

1.3. Importance

Search engines are tools used by the public to locate information for free. When these tools were being developed, designers usually considered the usage habits or search history of the general users but did not pay attention to individual differences (Google, retrieved January 13, 2013; Youtube, retrieved January 13, 2013); however, if people begin to leverage search engines for acquiring knowledge, the issues of individual differences will have to be considered. That is to say, designers need to be careful of whether search engines inhibit users from locating information on the Internet, mislead them to false information, or prevent them from learning. Therefore, we would like to observe how people with unique characteristics and cognitive abilities utilize search engines, with hopes of understanding the advantages and disadvantages of each search engine. Hopefully, the functions of search engines will, in the future, be even more diverse and personalized, corresponding to the demands of all types of users. Thus, the original one-size-fits-all search engines will gradually be able to provide private and professional services for different segments of users.

Chapter 2. Literature review

2.1. Information Search

The “information seeking behaviors” refers to a scenario when an individual realizes his or her demand for information and in search for information to fulfill such demand officially or unofficially until the successful acquisition of the related information or give up (Wilson, 1999). Marchionini (1995) lists the seven steps of information seeking as follows: 1. Recognize and accept; 2. Define problem; 3. Select source; 4. Formulate query; 5 Execute query; 6. Examine results; and 7. Extract information. Brand-Gruwel, Wopereis, and Vermetten (2005) define the information-problem solving procedures as follows: 1. Define the information problem; 2. Select sources of information; 3. Search and find information; 4. Process information; and 5. Organize and present information. The process of information seeking is not linear; instead, there are multiple steps and requires many acts. Some of the steps require repetitive execution and sometimes require continuous try and errors until final confirmation of the search results (Marchionini, 1995). Every individual adopts different methods and sequences in quest for the same subjects; accordingly, information searches are considered complex cognitive processes (Hsieh-Yee, 2001; Rouet, 2003; Walraven, Brand-gruwel, & Boshuizen, 2008).

Of the many strategies and techniques that Internet users employ, proper keyword selection is perceived by many researchers as pivotal to online search success (Bilal, 1998, 2000; Fukumoto, 2006; Hsieh-Yee, 2001; Liu, 2003; Lu, 1998; Pu, 2008; Schacter, Chung, & Dorr, 1998; Spink, Wolfram, Jansen, & Saracevic, 2001; Tu, 2005; Wang, Liu, & Chia, 2006; White & Iivonen, 2001). During search, the users often need to key in the suitable keywords. When the search result does not meet their expectation, they tend to choose other keywords or add/delete certain words to modify their keywords for the next search (White & Iivonen, 2001; Spink, Wolfram, Jansen, & Saracevic, 2001). They also use Boolean operators to proceed even more accurate search (Liu, 2003). Search engine hits tend to be more relevant as the number of keywords used for an individual search—as Hsieh (2000) observes, the more definitive the query, the more accurate the findings. According to Spink et al. (2001), the average American online search entails 4.86 keywords. They note that Americans often key in short phrases, use a small number of keywords at high frequencies, and generally refrain from modifying their queries. In comparison, the average Taiwanese online search is based on 1.5 Chinese keywords, with many individuals using only 1 (Hsieh, 2000). According to Lu (1998), Pu (2008), and Walraven et al. (2008), many Internet users (regardless of country) have trouble executing successful searches due to inaccurate statements or inappropriate structure—that is, they select keywords that are either too wide or too narrow. Most users do not use advanced search method (such as Boolean operators) (Spink, Wolfram, Jansen, & Saracevic, 2001).

The children cannot make a well-plotted search. During the course of search, they are most likely to enter into natural or vernacular languages as keywords. Sometimes they misspell or key in phrases that are too inclusive. Sometimes they would even use the entire question as their keywords and rarely develop complex search statements or Boolean operators (Schacter, Chung, & Dorr, 1998; White & Iivonen, 2001). Only very few children conduct refined search with synonyms. The above observation indicates that children are still inherited with many difficulties to interpret the search topics, formulate relevant keywords, and key in right phrases during keyword search (Bilal, 1998, 2000; Hsieh-Yee, 2001; Tu, 2005). So they usually fail to acquire the information they need at the end.

Wang et al. (2006) note that hits from keyword-based image searches generally consist of text located near pictures (e.g., captions). This approach gives the impression of user-friendly search tools and acceptable search result accuracy. Fukumoto (2006) describes a typical image search process as typing in one or two keywords, viewing the resulting images, using the “home” or “previous page” buttons, and repeating. Since the large majority of search engines require keywords to locate text, picture, and video or audio files, user selection of appropriate keywords is essential to success. Accordingly, the study (besides landmark search) focuses on the “keywords” entered by users as an indicator to measure and analyze search behaviors.

Other focal points include how users compare, evaluate, and verify information in terms of purpose, trustworthiness, and accuracy. Tsai (2004) notes that in addition to formulating clear ideas about search goals, Internet searchers must evaluate the information they find until they identify the best results. Rouet (2003) suggests that users improve their chances of success when they double-check search results, but others observe that most searchers want to use as little effort as possible to find the information they need. Liu (2000) describes how searchers generally lose interest after skimming 30 to 50 search engine hits. According to Spink et al. (2001), approximately one-half of all users visit a maximum of one or two pages of search results (usually containing ten web sites per page) and make a minimum effort at assessment. Furthermore, children show great difficulty in judging the quality of webpage because they have difficulty in locating the points and without reading through each link carefully. They barely make assessment and judging for search results either (Bilal, 1998; Hsieh-Yee, 2001; Tu, 2005; Walraven, Brand-gruwel, & Boshuizen, 2008). Assuming that judgments of accuracy influence search result precision, we investigated the ability or motivation of users to accurately assess information. Our belief is that the number of search engine pages users view and evaluate plus search time can be used as indicators of search behaviors.

From the above-stated documents, we know that "selection of keywords" may be pivotal to a successful search. Search for pictures, general documents, and videos all originate from keywords. However, the difference between search for pictures, videos, and general texts still exists because it is hard for people to describe the essence of pictures or videos with exact keywords. And if that is the case, the usage of keywords correctly and search performance are highly related. Thus, the "usage of keywords" plays a major role in the study. Moreover, most searchers hope to acquire the information they need with the fastest and easiest approach. Nonetheless, in the series of procedures of information processing, the judgment for accuracy of webpage information will also influence the exactness of search results. Accordingly, how students compare, evaluate and verify the information they find is also a focal point for observation in the study.

We need to observe the search behaviors of web users via some quantitative indicators. Debowski (2002) proposes that there are three major scopes to evaluate information search behaviors: 1. Task-focused efforts: including search time and the number of entries; 2. The wasted efforts: including repetitive and redundant search and wrong entries; 3. Search quality: evaluating the search quality with the range, depth, and order of search. Lin and Tsai (2005, 2007) analyze the students' search behaviors and record the entire process with Web navigation flow map to define 6 quantitative indicators as the basis for analyzing search strategies. They are as follows: 1. Number of keywords: it indicates the range of information search; 2. Revisited pages: it describes the recursion of browse; 3. Maximum depth of exploration: it shows the maximum depth of navigating webpages; 4. Webpage adoption: it depicts the variation of information sources; 5. Average depth of webpage adoptions for each task question: it shows the average depth of exploration to complete a task; and 6. Additional webpages for refinement: it indicates the frequency of refining or improving the quality of answers. Tu (2005) also analyzes the search process of students by means of Web navigation flow map based on the 6 quantitative indicators of Lin and Tsai (2005, 2007) to modify some of them and propose 5 quantitative indicators: 1. Number of keywords: it implies the variation of information search. 2. Visited pages: it depicts the variation of navigating webpages. 3. Maximum depth of exploration: it shows the maximum depth of navigating webpages. 4. Average characters composing a keyword: it shows the ability to refine keywords; usually the fewer the characters are, the better the users leverage keywords. 5. Number of characters used in the first keyword: it shows how users refine main ideas from the prior knowledge or experience when accepting a new assignment; usually if a user utilizes fewer characters, he or she is more capable of summarizing main ideas, which is related to metacognitive abilities. In a nutshell, the total number of keywords and average number of Chinese characters per-keyword in the study aim at investigating the ability of students to select and refine keywords; the visited pages, maximum depth of exploration, revisited Web pages, and total number of viewed videos are to explore how degree of students refine their answers; and with search time, the study seeks to understand the efforts of the search process.

2.2. Individual differences in Web searches

Researchers have looked at the factors of impacting searching behaviors and performance: Bystrom and Jarvelin (1995) contend that information seeking behaviors are influenced by individual experiences and cognition. It includes personal factors (e.g., attitude, motivation, mood), organizational factors, situational factors (e.g., available time) and the personal information-seeking style. Rouet (2003) pinpoint that surfing the Internet for information requires complicated cognition abilities (such as reading skills). In addition, information search is influenced by a complex combination of individual characteristics, task constraints and display features. The studies of Allen (1998, 2000) show that cognitive abilities influence search performance in a variety of information systems. Hsieh-Yee (2001) contends that different users tend to have distinguishable patterns of seeking information and that their cognition of tasks and problem-solving strategies influence their search behaviors. Kim and Allen (2002) propose that cognitive abilities and search engines are two cornerstones to decide how users utilize website for search purpose. Both the cognitive abilities and problem-solving styles will interact with each other to influence search activities. Individuals with better cognitive abilities perform better in the term paper tasks and less impressive in the newspaper article tasks whereas others with lower cognitive abilities display the opposite pattern. Ford, Miller, and Moss (2005) believe that individual differences will influence web search strategies. These differences include perceptions of and preferred approaches to Web-based information seeking, study approaches, cognitive styles, cognitive complexity, and levels of experience of Boolean searching. Bilal and Kirby (2002) investigate the information seeking performance and behaviors on students of different age groups from the perspectives of cognition, physical condition and affection. The cognition part includes knowledge, comprehension, problem solving, and critical interpretation. Bilal and Kirby also bring forth that while children's cognitive behaviors reflect an understanding of the search tasks, term relationships, search formulation, and subject hierarchies, it shows that children experience difficulties in using the engine. Park and Black's studies (2007) indicate that domain knowledge is irrelevant from search behaviors; nonetheless, it will affect the search outcome precision, rather than cognitive style, which affects the search time instead.

Jacobson and Fusani (1992) discover that system knowledge and computer experiences affect the effectiveness of searching database. The studies of Yuan (1997) dictate that the search experience will influence the decision on entering queries. White and Iivonen (2001) hold that the rate of successful search depends on several latent variables, such as different ways of "collecting" web sites from diverse search engines, types of search questions, and users' characteristics (e.g. background, cognitive styles, and search experience). Users' cognitive styles influence the search performance of novice Web searchers more than the performance of experienced Web searchers. (Palmquist & Kim, 2000)。Lazonder, Biemans, and Wopereis (2000) discover that experienced users show better performance in terms of success rate, time management, the number of tasks successfully completed per time, and the number of actions to successfully complete a task than novice users. The observed differences are ascribed to the experts' superior skills in operating Web search engines. However, on tasks that require subjects to locate information on specific Web sites, the performance of experienced and novice users is equivalent. The results imply that experienced Web users are more proficient in finding correct web sites but not more proficient in identifying desired information on Web sites. Kim (2001) is convinced that cognitive styles (the independence and dependence of locations), search experiences of online database (experts and rookies) and task type (known-item vs. subject search tasks) influence users' search behavior on the Web. Tu (2005) has investigated and concluded that students with more Internet experience perform better on close-ended search tasks (i.e., "What kind of energy sources do we currently use in Taiwan?") aimed at finding specific answers, while students with better overall knowledge are more adept at open-ended tasks (i.e., "What kinds of energy sources are better than others? Explain why.") aimed at finding less specific and more analytical information. Wang, Hawk, & Tenopir (2000) detect that experienced participants tend to apply advanced approaches in search (such as Boolean Operators); nonetheless, their search performance are not enhanced. According to Hölscher and Strube (2000), Internet experts tend to show more complicated behaviors if they do not find relevant sources during online search. For example, they are likely to reformulate or reformat original queries, try alternative search engines, and use advanced search options like Boolean operators, modifiers, and phrases etc. For Internet newbies, they usually will just go backward-oriented rather than try out alternative strategies when faced with barriers. In a study of search strategies used by college students (ages 21-30) and non-students (ages 35-62), Matusiak (2006) found that students preferred keyword searches to browsing pathways, and felt more confident about their search skills due to their regular Internet usage. Non-students were less confident with their skills and more likely to use pathway browsing techniques. The causes to such difference include the familiarity of using computers, prior knowledge and cognition etc.

To sum up, information search on the Internet is a complicated cognitive process. Many studies on "what factors impact information search behaviors" include individual characteristics (comprising cognitive abilities, understanding of tasks, and Internet experience etc.) as important elements. Despite constant advancement in the platform and index of search engines, the individual differences of each user still play a crucial role in deciding the success of search.

2.3. The cognitive theory of multimedia learning

In multimedia environments, users often read or scan both texts and pictures. Some users have advanced verbal skills, while others perform better when dealing with images (Mayer & Massa, 2003). Note that in many situations, learners can now find "Help" information in the form of either graphics or text. Paivio’s (1971, 1986) dual-coding theory (DCT) explains how people receive, handle, and integrate information from two subsystems: a verbal system for dealing with language, and a nonverbal system for dealing with nonlinguistic objects and events. The verbal representations contain visual, auditory, articulatory, and other modality-specific verbal codes. Nonverbal representations include modality-specific images for shapes (e.g., a chemical model), environmental sounds (e.g., school bell), actions (e.g., drawing lines or pressing keys), skeletal or visceral sensations related to emotion (e.g., clenched jaw, racing heart), and other nonlinguistic objects and events (Clark and Paivio, 1991).

Mayer and Sims (1994) refer to the DCT concept and note that when the perceptive organs receive verbal information, human beings would transfer the information to a mental representation of verbal system via verbal encoding process within the learner’s working memory. This process is referred to as building verbal representation connections. Likewise, when the perceptive organs receive visual information, the learner would transform the visual information to mental representation of visual system in working memory through visual encoding process. And this procedure is referred to as building visual representational connections. Individuals build referential connections between these mental representations in verbal and visual information processing systems. Comprehension depends on the successful storage of these connections along with two forms of mental representations of propositions and/or ideas in long-term memory (Plass, Chun, Mayer, & Leutner, 2003). The effectiveness of learning depends on the learner’s verbal representational connections, visual representational connections, and referential connections. The building of these three connections depends on the formulation quality. If the learner is capable of processing information by leveraging the verbal and visual system of mind simultaneously to catalyze the formulation of these three connections, the learner can retain and transfer the information effectively and enhance learning performance (Mayer & Sims, 1994).

According to Mayer's (1997, 2001) generative theory of multimedia learning, meaningful learning requires the dual construction of a coherent mental representation of verbal and visual systems in working memory, plus systematic connections between verbal and visual representations. Mayer suggests that when dealing with complex multimedia materials, learners must select relevant verbal information from a text, plus visual information from an illustration, and then construct verbal and visual mental representations and organize them in separate systems. In the final stage, learners build connections between verbal and visual representations at the same time that corresponding text and picture representations are actively being processed in memory, and then integrate the two (see also Mayer, Steinhoff, Bower, & Mars, 1995). A knowledge constructor must actively select and connect pieces of visual and verbal knowledge to achieve meaningful learning (Mayer, 1997).

Clark and Paivio (1991), Mayer and Sims (1994) all contend that human's cognitive system is comprised with verbal and visual representation systems. Human beings process descriptive information (words) and depicted information (pictures/animations) results in two mental models, a "verbal mental model" and a "visual mental model" (Mayer, 2005; Mayer & Johnson, 2008). And these two systems are connected together while they support each other. Adding illustrations in the text will help readers build runnable mental model, as well as their comprehension and memory (Clark and Paivio, 1991). And inserting annotation, captions and labels beside photos will provide clues for readers; thus it helps them build referential connections between visual and verbal representations, and enhance cognitive processes (Mayer, Steinhoff, Bower, and Mars, 1995). Concurrent representation of verbal information, along with visual information, is more effective to build “referential connection” than successive one to boost learning performance.

In using search engines to search images, maps or videos, individual must process verbal and pictorial information simultaneously. Users have to read written information about what they need to search and process pictorial information including the static pictures, the dynamic transformations of static pictures to animation or the rotating animations that simulate globe function. The search process may resemble this multimedia learning process. It is reasonable to consider similar factors that affect multimedia learning also affect image, video or landmark search because search results incorporate complex information as it is in multimedia learning materials.

Chapter 3. Experiment 1 – Search for texts

3.1. Study design

The studies cited to this point allow for a summary of human factors (including cognitive, affective, skill, and demographic) that influence search behaviors and to analyze how thinking style levels (an affective human factor) help determine young students' search behaviors —a topic that has not received proper attention in search behavior studies. This project also constitutes an attempt to summarize character, 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 behaviors.

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.

Our 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.

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, 1994, 1997). 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 our 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 our goals 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.

3.3. 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 we will describe 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.

3.4. Measures

3.4.1. Text search worksheets

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. Our 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 min to complete the task.

3.4.2. 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 1–5. 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.

We used representative data due to the complexity of analyzing the search strategies and processes of 311 students. The four conditions that we created were (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) six 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) six students who were concurrently in the lowest 27% of the global and local groups, designated as the bi-low style (Bi-L) group (see Figure 2). The remaining 241 students were excluded from the search behavior analysis.

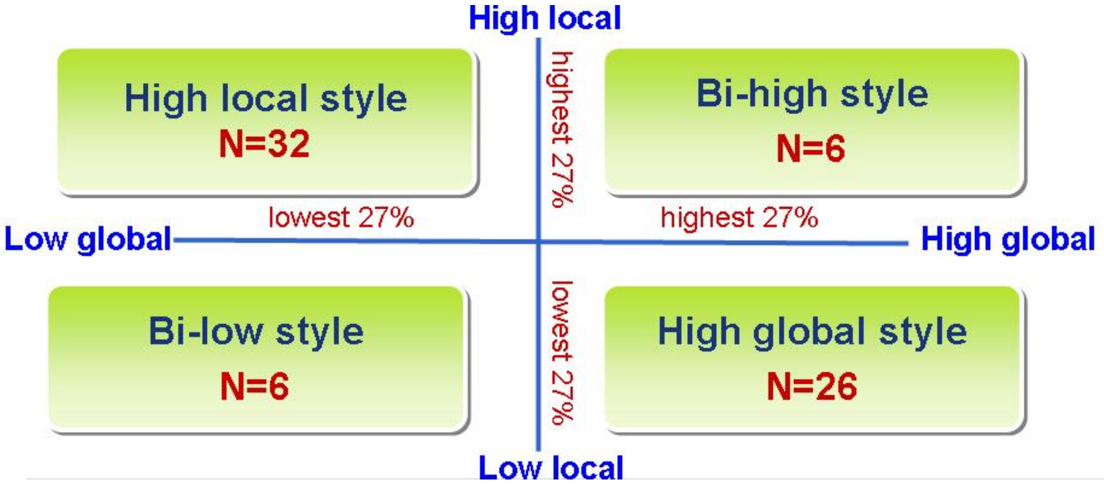

Figure 2. The four groups of thinking style level.

3.4.3. Investigation of student prior knowledge

To determine if the students' prior knowledge of natural science affected the search target setting and search behavior variables, their grades for introductory natural and social science courses were collected, averaged, and used 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.

3.4.4. 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, we divided them into three types: focused (C <= 2 AND E > 2), dispersed (C > 2 AND E <= 2), and mixed.

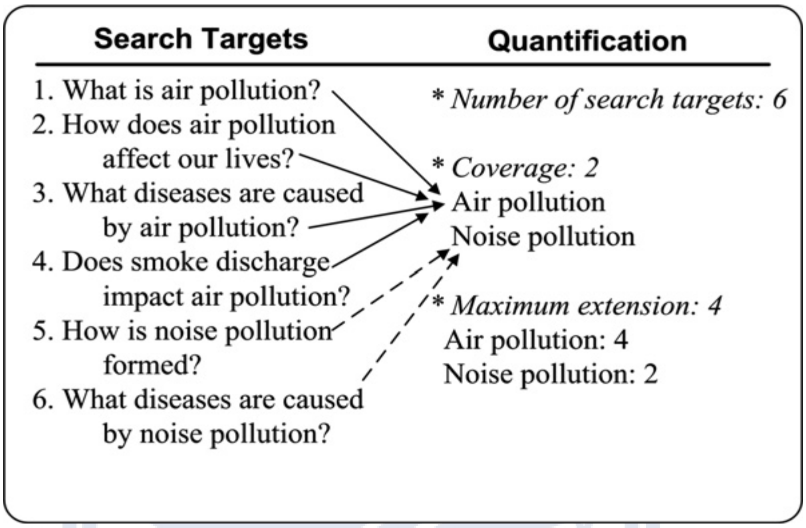

Figure 3. Search target quantification (three indicators).

3.4.5. 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).

3.5. 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.

3.6. Result

3.6.1. Relationship between search target setting and thinking style level

One of our goals 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, we 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 2). 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.

Table 2. 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%

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 3). 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 3. 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%

3.6.2. Differences among the four conditions

Our 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 listed in section 3.4.4. (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 4). 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 4. Mean rank of each search behavior indicator according to the four thinking style level conditions.

	Condition				
	HG	HL	Bi-H	Bi-L	Significance
	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, ManWhitney U tests were performed to measure contrasts between pairs of conditions. Significant pairs are listed in Table 5. 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.”

Table 5. 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	

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. We observed that one HL student made three revisions to an answer, while an HG student made only one.

3.7. Discussion

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. 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 revisit 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.

Our 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. We 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.

Chapter 4. Experiment 2 – Search for images

4.1. Study design

Many individuals now consider digital cameras, cell phones with photo functions, and online photo-sharing websites as indispensable tools for daily use. This explosion in image taking and sharing has also expanded the need for accurate online image search strategies, which we believe will continue to grow and evolve. Many researchers have examined information-seeking behaviors and performance, but generally their focus has been on text rather than image searches. Text searches require the comprehension of connotations for a given topic, as well as the use of related ideas to formulate keywords. In contrast, picture or image searches require theme formulation and the ability to envision potential results. Given that many current image retrieval systems are keyword-based, users must translate their visions into literal descriptions, and pictures stored in databases must have descriptive words or metadata that match selected keywords (Fukumoto, 2006; Hou & Ramani, 2004). Search systems transmit some pictures for users to compare, assess, and decide whether or not they need to continue a search. Accordingly, image searches can be analyzed as mixed acts of image-text cross-referencing, observation, judgment, decision-making, and correction. Note that the existence of semantic gaps and the lack of precise characteristics make image searches more abstract and complex than text searches (Choi, 2010; Cunningham & Masoodian, 2006). In image searches, descriptive and thematic queries are more commonly used than unique term queries. Most users perform a large amount of query modification but they seem unable to find the images they desire in an effective way (Jörgensen & Jörgensen, 2005). Approximately one-fifth of all image search queries result in zero hits (Pu, 2008). Yet little is known about what factors improve the odds for successful image searches.

Many image searches are aimed at locating pictures or illustrations that support text, abstract concepts, or other pictures and images. Motivations include a perceived need for illustrations, paintings, maps (geographic or flow), and cartoons while reading textual descriptions or looking at pictures, as well as a need for images to interpret abstract contents. One of the most common motivations is to find an image in response to a paragraph that lacks illustrative examples, therefore for this study we purposefully designed image search tasks associated with text.

Reading ability seems to play an important role in image searches triggered by texts. During the search process, users are required to read sentences, comprehend the meaning, and consider relevant keywords for picture retrieval. Part of their task is to compare multiple search results and evaluate whether the concepts of pictorial information meet their requirements. In addition, experience with the Internet and/or search engines is another factor that may affect search behaviors and task performance (Bilal & Kirby, 2002; Hsieh-Yee, 2001). Internet novices (who are generally less flexible in terms of search strategies) tend to perceive information searches as difficult, laborious, and frustrating (Hölscher & Strube, 2000). More experienced Internet users are more likely to try a variety of techniques (e.g., Boolean operators) or to experiment with unfamiliar tools in order to achieve better search performance.

To explore the effects of reading ability and Internet experience on image search behaviors and performance, we created a sample of seventh grade Taiwanese students who practiced their basic computer and Web literacy skills in elementary school—at minimum, how to use word processors, simple graphics programs, Power Point, email programs, and Web browsers. Although increasing Internet literacy is a major junior high school objective, image search strategies have not yet been added to national computer course curriculums.

We established three research questions for this project:

1. Given specific search tasks, how do students perform image searches (search behaviors) in terms of total number of keywords, average number of Chinese characters per-keyword, maximum number of viewed pages per-keyword, total number of viewed pages per-task, and search time? How successful are their image searches (search performance)?

2. What are the effects of reading ability and Internet experience on image search behaviors and performance? We collected quantitative indicators of search behaviors and performance as well as qualitative observational descriptions about search process.

3. Do correlations exist between individual search behaviors and search performance?

4.2. Reading ability

Reading is a complex cognitive process involving meaning encoding, decoding, and construction. Just and Carpenter (1980) describe reading comprehension as an ongoing process of identifying words, formulating propositions, and integration until full sentence or paragraph comprehension is achieved. When readers encounter a word, they formulate an interpretation (bottom-up model) that supports an expectation for the next word (top-down model). When expected and actual words agree, readers form propositions to be integrated into comprehension; they may also review preceding sections in hope of finding other suitable propositions. Gagne (1985) suggests that readers leverage four procedures in support of comprehension: (a) decoding, meaning that readers unlock the codes of printed texts to acquire meaning; (b) literal comprehension, so as to form propositions by combining the meanings of words after acquiring vocabulary-based connotations; (c) inferential comprehension, including integration, summarization, and elaboration in support of a deeper understanding of context; and (d) comprehension monitoring, referring to the ways that individuals establish reading goals, select appropriate reading strategies, determine goal achievement, and adopt alternatives if necessary.

Goodman (1986) describes reading as a dynamic process in which readers interact with visual, perceptual, syntactic, and semantic cycles. He believes readers formulate mental images with visual messages that include what they actually read and what they expect—that is, they determine surface linguistic structures and phraseology before constructing connotations via in-depth structural analyses. Throughout these cycles, readers who encounter barriers re-read their texts to acquire additional messages in an effort to reconstruct meaning.

According to the Programme for International Student Assessment (Organisation for Economic Co-operation and Development, 2000), reading skills can be measured in terms of (a) information retrieval, meaning whether readers actually find the information they need from texts; (b) information comprehension, meaning whether readers accurately interpret meaning; or (c) thinking and judgment, referring to how readers link their original knowledge, thoughts, and experiences with the content they read, so as to produce their own perspectives based on integrated judgment. Individuals with stronger comprehension skills are more capable of collecting and judging information to achieve their goals, enhance personal knowledge, and develop self-potential.

4.3. Internet experience

Kim (2001), Lazonder et al. (2000), and White and Iivonen (2001) are among researchers describing associations between search behaviors/performance and online search experience. Lazonder et al. (2000) ascribe differences in success to superior skills in the use of search engines, and assert that hands-on experience is required for novices to develop basic skills in this area. In a study of search strategies used by college students (ages 21-30) and non-students (ages 35-62), Matusiak (2006) found that students preferred keyword searches to browsing pathways, and felt more confident about their search skills due to their regular Internet usage. Non-students were less confident with their skills and more likely to use pathway browsing techniques. According to Yuan (1997), search experience enhances both user speed and the ability to make adjustments in online search approach or technique. Park and Black (2007) describe a correlation between search experience and both search time and outcome, and suggest that search experience increases user familiarity with search strategies and supports the development of information search schema. According to Hölscher and Strube (2000) and Wang et al. (2000), the most experienced Internet users tend to apply more advanced techniques and express more complex behaviors in response to not immediately finding what they are looking for. Examples include using advanced search options, trying alternative search engines, and reformulating or reformatting original queries to take advantage of Boolean operators, modifiers, and phrases. Newbies are more likely to simplify their searches in response to perceived barriers.

Alternatively, there is some evidence indicating that experience does not automatically result in enhanced search performance. Wang et al. (2000) report that regardless of experience, participants in their study spent very little time (0.3-0.8 minutes) looking at individual pages. Yuan (1997) asserts that experienced users may make the same number of errors as less experienced users—for instance, not knowing how to navigate around error messages to the point of requiring assistance. According to Lazonder et al. (2000), experienced Web users are very proficient at finding websites, but less successful in finding specific information within websites. Since finding information within a website requires scanning, reading, and evaluation, there may be little difference between Internet novices and experts in terms of these skills or subject matter knowledge. Tu (2005) suggests that students with more Internet experience perform better on close-ended search tasks (i.e., “What kind of energy sources do we currently use in Taiwan?”) aimed at finding specific answers, while students with better overall knowledge are more adept at open-ended tasks (i.e., “What kinds of energy sources are better than others? Explain why.”) aimed at finding less specific and more analytical information. Experienced users may be faster in locating correct answers, but more knowledgeable users may be better equipped to deal with complexity and ambiguity.

Finally, according to the data of comScore (2006), collected from international users, average time spent on the Internet internationally is 31.3 hours per month. Taiwanese users are in the top five nations on this list, with an average of 43.2 hours per month. Results from an investigation by the Taiwan Network Information Center (2009) indicate that between 2007 and 2009, approximately one-third of all Taiwanese Internet users spent between 1 and 3 hours per day online, including weekdays and weekends. These data should be taken into consideration when analyzing our findings.

4.4. Participants

Our participants were selected from 227 seventh grade students in a junior high school located in central Taiwan. According to past high school entrance exam records, students from this school generally score well below the top 15% nationally. Students with identifiable learning disabilities were excluded. To magnify differences within the sample, we selected 33 students identified as having strong reading skills (1 SD higher than the mean score of reading ability described in section 4.5.1.) and 43 with weak reading skills (1 SD lower than the mean score). From these 76 students, 28 were identified as frequent Internet users (8 hours or more per week) and 30 as infrequent users (5 hours or less per week). The high reading ability group consisted of 13 frequent and 15 infrequent Internet users; the respective numbers for the low reading ability group were 15 and 15.

4.5. Measures

4.5.1. Reading ability test and Internet usage questionnaire

The reading ability test used in this study consisted of items selected from Chinese reading comprehension questions in the Basic Competence Test for Junior High School Students (2001-2007), a national entrance examination used to screen students for high school placement. Test items for Chinese language arts and four other domains are created and modified by a group of domain and test experts, with reliability, validity, and Rasch model data regularly monitored by the Basic Competency Test for Junior High School Center. The test is based on norm- and criterion-referenced principles using core competence criteria listed in the Grade 1-9 Curriculum published by the Taiwan Ministry of Education. Due to the rigorous design and revision process associated with this exam, we did not make any modifications for our own purposes. Test items measure students' ability to understand vocabulary in the contexts of factual and narrative passages. A typical passage consists of 200 to 300 words on a topic such as "Advice from a Father." For each passage, two questions are designed to measure basic understanding plus the ability to make inferences and extend passage meanings. We used 12 passages and 24 multiple choice questions to measure the reading levels of the 227 students in the original participant pool. Maximum possible score was 24; the mean score in our sample was 11.16 (SD=4.16).

Our Internet usage survey was designed to measure weekly Web experiences (including information searches, gaming, chatting, exchanging emails, or downloading files). According to their responses, they spent an average of 7.21 hours per week online.

4.5.2. Image search worksheets

Based on Cunningham and Masoodian's (2006) observation that image searches usually originate from specific information requirements regarding persons, events, or activities, we created four search tasks—two on the topic "animal activities" and two on the topic "human activities." Target sentences were (a) "In a thick patch of grass, a fierce giant tiger lies looking off into the distance"; (b) "Two tiny and graceful sparrows clean their feathers in a clear stream"; (c) "A group of young boys jogs energetically on a red oval track"; and (d) "Two carefree elderly men sit at a square brown table, absorbed in a chess game."

In order to avoid the possibility of finding the images simply, each task was researched in advance by the authors. We made sure that right images could not be found by simply cutting and pasting the four sentences into search engine query boxes. Furthermore, we also tried to maintain a consistent difficulty level for the four sentences in terms of length, use of terms frequently encountered in daily life, and complexity of structure (Cheng, 2005). First, each of the four sentences consisted of 25 Chinese characters—the basic unit of the Chinese language, with the large majority of words consisting of two characters. For example, "tiger" is expressed as 老虎, two characters with the literal meaning of "old tiger." Second, we used a software program from a Chinese language learning and teaching website (http://nflcr.im.knu.edu.tw/read/modules/working2.php) to analyze vocabulary frequency, and found that all words in the four sentences were at the 3,000 level of 5,056 words said to be used most frequently by Taiwanese elementary school students. Finally, sentences were revised to achieve syntactic consistency.

After the participants finished their image search tasks, three raters (including a computer teacher, an art teacher, and a linguistic teacher) were asked to individually judge how well the retrieved images matched the topic sentences as search performance. Total scores for each task ranged from 0 to 9. Students received four points for images that matched the primary subject term—tiger, sparrows, boys, or elderly men. Single points were given when images matched task sentence elements such as the main verb (e.g., lies), noun (e.g., stream), adverb (e.g., energetically), or adjective (e.g., fierce). A Kendall coefficient of agreement was used to examine consistency among the three raters; the results indicate a high level of inter-rater reliability for search performance scores ($W = .75$, $p<.01$). Finally, we looked for correlations between total numbers of search results for certain keywords and search performance, and calculated correlation coefficients ranging from -0.25 to 0.06 (n.s.). In other words, no significant connections were observed between numbers of available online images and participant search performance.

4.5.3. Google Image

"Google Image Search" is an image search engine. The major purpose of the image search engine is to provide users with pictures they want to find conveniently and quickly. The usage of this search engine is similar to others. Only key in the keywords in the search box and click “search” or push the “enter” button on your keyboard, and then some web pages appear related to the searching results. Google image search engine adopted the PageRank technique of order, which was like web linking and calculating method of citation analysis technique to analyze the index anchor texts, image file names or the text that surrounds images of the web page then decide the contents of images. In addition, Google also adopted an extremely accurate algorithm to exclude the images which were already got and make sure the high quality images could be in the top order of the searching result (Chitu, 2008). It’s an ideal platform for users of image search because they can have access to plentiful resources in a short period. The reasons for adopting this system to image search test were as follow:

1. Google Image contains over 390 million image indexes with huge search database. It is the most advanced image search tool (Wikipedia, retrieved June 10, 2012).
2. Like other search skills, it’s easy to get used to it. Only key in the keywords and click search. In this case, the impacts of computer ability could be minimized.
3. It’s convenient to view the result via saving or printing the result of search.

After entering the keywords in the image search box, a thumbnail appears as well as simple descriptions of the thumbnail, including names, sizes and types of those files. Click the thumbnail, you can enlarge the image and see which web page the image is on.

4.5.4. Web navigation flow map

In this study, search behaviors refer to the methods used by the participants to perform image searches. We used Lin and Tsai's (2007) web navigation flow map to quantify these behaviors. CamStudio was used to record screen displays in real time; the authors reviewed these video files and recorded behaviors according to five indicators: (a) total number of keywords used to search for relevant information (reflecting the amount of keyword revising); (b) average number of Chinese characters used per-keyword (total number of Chinese characters divided by total number of keywords used during a search task); (c) maximum number of viewed pages per-keyword (it means surfing search result lists, usually consisting of twenty images per page); (d) total number of viewed pages per-task; and (e) search time from entering the first keyword(s) to downloading the final image. We used this data to create web navigation flow maps, such as the one shown in Figure 4 (in that figure, total number of keywords = 4, average number of characters used per-keyword = 3.5, maximum number of viewed pages per-keyword = 8, total number of viewed pages per-task = 18, and search time 332 seconds).

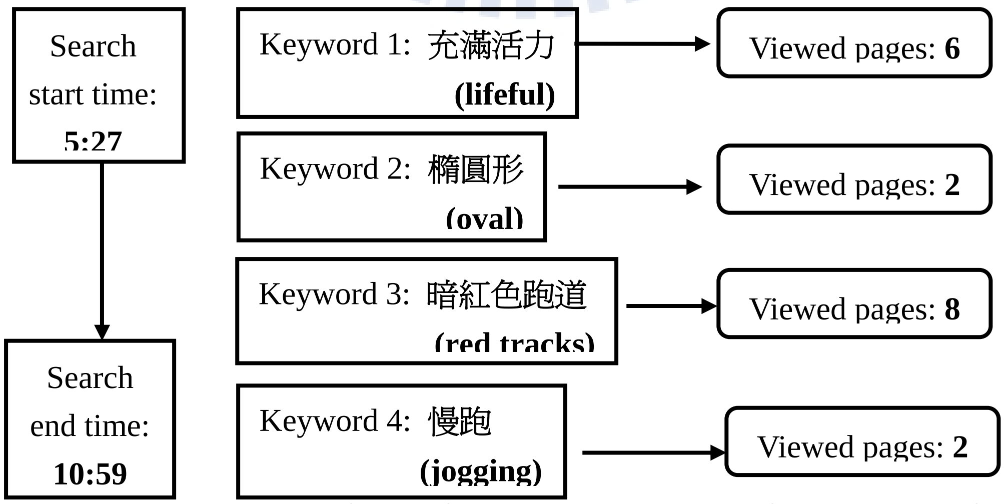

Figure 4. Search behavior quantification (five indicators). An example of a web navigation flow map. Chinese keywords 1-4 were translated into English in parenthesis () with bold type.

4.6. Procedure

The study was conducted over three weeks. The reading ability test was given during week 1 (35 minutes). The Internet usage questionnaire was completed and Google Image features and methods were taught during week 2 (40 minutes total). Image search tasks were completed during week 3 (50 minutes). Search processes were recorded in the form of computer screen shots (qualitative data). Following task completion, individual search processes were interpreted and illustrated as web navigation flow maps (search behaviors, quantitative data), and retrieved images were scored as performance.

4.7. Result

4.7.1. Image search behaviors and performance

Mean and standard deviation statistics for search behaviors and performance among the four groups are shown in Table 6. On average, the participants used 1.20 to 2.13 keywords per-task. Our results are in general agreement with Hsieh's (2000) finding of an average of 1.5 keywords per text search for Taiwanese junior-high-school students. The participants used 2.52 to 3.23 Chinese characters per-keyword, and viewed between 1.50 and 3.08 pages per keyword search. Total number of pages viewed per-task ranged from 1.72 to 4.17. Average time spent per-task was 92.9 to 153.8 seconds. Combined, the participants needed little time and expended little effort completing the assigned tasks. Search performance scores ranged from 2.72 to 8.05.

Table 6. Mean and standard deviation statistics for search behaviors and performance for the four groups.

Reading ability	High (N=28)						Low (N=30)					
Internet experience	Frequent (N=13)		Infrequent (N=15)		Subtotal		Frequent (N=15)		Infrequent (N=15)		Subtotal	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Total number of keywords	2.13	1.69	1.70	0.56	1.90	1.21	1.20	0.29	1.35	0.54	1.28	0.43
Average number of Chinese characters used per-keyword	2.73	0.65	2.77	0.82	2.75	0.73	3.23	2.25	2.52	1.00	2.88	1.75
Maximum number of viewed pages per-keyword	2.48	1.47	3.08	2.06	2.80	1.80	1.50	0.78	2.17	1.12	1.83	1.00
Total number of viewed pages per-task	4.15	3.36	4.17	2.39	4.16	2.83	1.72	1.15	2.73	1.82	2.23	1.58
Search time	151.29	108.38	153.80	68.64	152.63	87.55	92.95	42.83	153.62	79.85	123.28	70.11
Search performance	8.04	0.87	8.05	0.89	8.04	0.87	3.15	1.47	2.72	1.53	2.93	1.49

4.7.2. Effects of reading ability and Internet experience on search behaviors

We found a significant main effect of reading ability on total number of search keywords ($F=7.359$, $p<.01$), but no main effect from either Internet experience or interaction between reading ability and Internet experience. Participants with better reading comprehension skills tended to use more keywords in their searches. According to these data and search process observations, better readers were more likely to find appropriate images from the search engine hits they received from initial keywords, or to quickly and continuously modify keywords when results did not meet their expectations. An exemplar of search task (b), a high reading ability student conducted 6 searches using various keywords: “stream”, “two sparrows”, “sparrow in stream”, “clean feathers”, “sparrows clean feathers in stream” and “clean feathers & sparrows”. This explains why the standard deviation of “total number of keywords” for the high reading ability group (SD=1.21) was significantly larger than that for the low group (SD=0.43, F=2.81, $p<.01$). Low-ability readers often used keywords that reflected less important aspects of the task sentences (e.g., “grass”, “looking off”, “clear stream”, “red oval track”, or “a brown table”) or keywords that were irrelevant to the task descriptions (e.g., “bear”, “cat”, “flower”, “waterfall” or “gun”).

Freeman (2001) suggests that during the reading process, continuous changes occur between actual texts and texts constructed in the minds of readers. Even when reading the same article multiple times, readers are sensitive to differences among reading experiences. We observed better readers quickly re-reading topics and constructing new keywords, while poor readers used only one keyword and tended to terminate searches when results did not immediately match the requirements. This suggests that students with poor reading skills have difficulty in interpreting search topics, formulating appropriate keywords, and using correct terms.

No significance was noted for main and interaction effects of reading ability and Internet experience on average number of Chinese characters per-keyword. Keyword lengths among the four groups were very similar—between 2 and 3 characters. Students in the high reading/frequent Internet user group used an average of 2.73 characters per-keyword, with relatively small dispersion (SD=0.65). Students in the low reading/frequent Internet user group used an average of 3.23 characters per-keyword, with a much larger dispersion (SD=2.25, F=3.61, $p<.001$). According to search process observations, better readers tended to use fewer than 4 characters in their keywords, while poorer readers frequently used whole sentences or longer phrases. In addition, poor readers tended to add (or delete) one or two words to (or from) original keywords when those keywords were unsuccessful, for example, for task (c) one low-ability reader initially used the keywords “red oval track,” then added the verb “<jog> red oval track,” and finally added the subject “<boy> jog red oval track.” These results imply that better readers are more capable of using concise, accurate phrases to perform successful image searches.

We found a significant main effect of reading ability on maximum number of viewed pages per-keyword (F=6.312, $p<.05$); other effects were not significant. According to this finding, better readers were more competent to view more pages of image search results. We also observed that most students in the high reading group continued checking/rechecking images even after finding pictures that met the task criteria, implying that they took greater care in evaluating retrieved images.

There was a significant main effect of reading ability on total number of viewed pages per-task (F=10.431, $p<.01$); other effects were not significant. In other words, better readers viewed almost twice as many search result pages for each task compared to poorer readers. According to our observations, better readers were more likely to review a larger number and broader range of images due to their ability to try various keywords and to evaluate whether retrieved images matched the task descriptions.

Significance was not found for main and interaction effects of reading ability and Internet experience on search time. Although time differences were observed between the two groups (152.63 seconds for high reading versus 123.28 seconds for low reading; 122.12 seconds for frequent users versus

153.71 seconds for infrequent users), between-group differences were not significantly larger than within-group differences. In short, each search task required between 2 and 3 minutes for completion.

4.7.3. Effects of reading ability and Internet experience on search performance

The data indicate a significant main effect of reading ability on search performance ($F=243.747$, $p<.001$); other effects were not significant. Search performance was measured as degree of relevance between a downloaded picture and the concepts expressed in the task sentence. According to search process observations, pictures selected by poor readers frequently matched a single feature of the search requirements (e.g., general pictures of tigers, sparrows, stream, boy or track), but did not reflect other features such as verbs, adjectives, or adverbs in the topic sentences. For example, task (a), the two pictures (Figures 5A and B) were chosen by two high-ability readers both were given 9 points (the highest score) because they matched multiple aspects of the text descriptions, while the three pictures (Figures 6A, B and C) chosen by three low-ability readers received scores of 4, 4 and 1 because they only matched the terms “tiger” or “grass.” The results indicate that better readers evaluated texts and images carefully and critically. They tended to discriminate, analyze, and interpret texts and images to ascertain meaning, and to understand the subject matter of texts and images. Then they cross-referenced and integrated visual and textual actions, objects and symbols.

Figure 5. Examples of pictures chosen by high-ability readers in response to the prompt, “In a thick patch of grass, a fierce giant tiger lies looking off into the distance.”

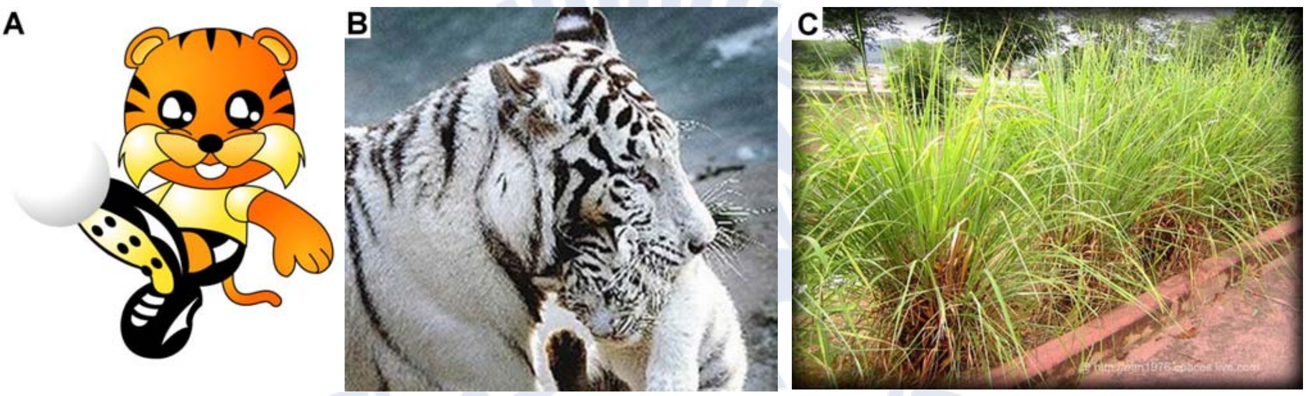

Figure 6. Examples of pictures chosen by low-ability readers in response to the prompt, “In a thick patch of grass, a fierce giant tiger lies looking off into the distance.”

Students in the low reading ability/infrequent Internet user group had more difficulty choosing keywords and were less familiar with Google Image—two factors that affected their search efforts and the time required for task completion. In contrast, students in the low reading/frequent Internet user group tended to type in any single keyword, randomly scan search results, and show less care in completing tasks. They were less likely to make the effort to verify information. This observation is consistent with Shenton and Dixon’s (2004) assertion that teenagers are less likely than older Internet users to evaluate information quality, and more likely to believe that the most easily accessed information is sufficient for answering inquiries.

4.7.4. Correlations between search behaviors and performance

Significant positive correlations were found between performance and both the maximum number of viewed pages per-keyword ($r=.362$, $p<.01$) and total number of viewed pages per-task ($r=.386$, $p<.01$), but not for any other indicator. These two indicators signify student ability or motivation to view and evaluate image contents. The more effort the participants allocated to reviewing and evaluating search results, the greater the potential that their images would be relevant to all perspectives of task concepts.

No relationship was found between performance and keyword-based behavior indicators. These results are not consistent with those reported by Tu (2005) for text searches. Tu found positive relationships between search performance and both the total number of keywords and average number of Chinese characters per-keyword. We believe the difference lies in the distinction between image and text searches—that is, the requirement for keyword-based image searches that search engines compare keywords with image topics, image file names, and/or text attached to images. There are many examples of image descriptions that do not accurately reflect image content, therefore users may not be able to find corresponding pictures even when they make good decisions regarding keywords. For example, although many participants used identical keyword “sparrows,” they selected very different pictures from the search results. Figures 7A and B were retrieved from page 7 and 8 respectively of the returning search results both were given 9 points because they matched all text descriptions of task (b), while Figures 7C and D were both retrieved from page 1 of the returning search results both received scores of 4 because they only matched a single element “sparrows”. In such cases, in order to obtain accurate pictures, users must be careful when evaluating pictures. These results support our assertion that maximum and total numbers of viewed pages serve as indicators of image search success.

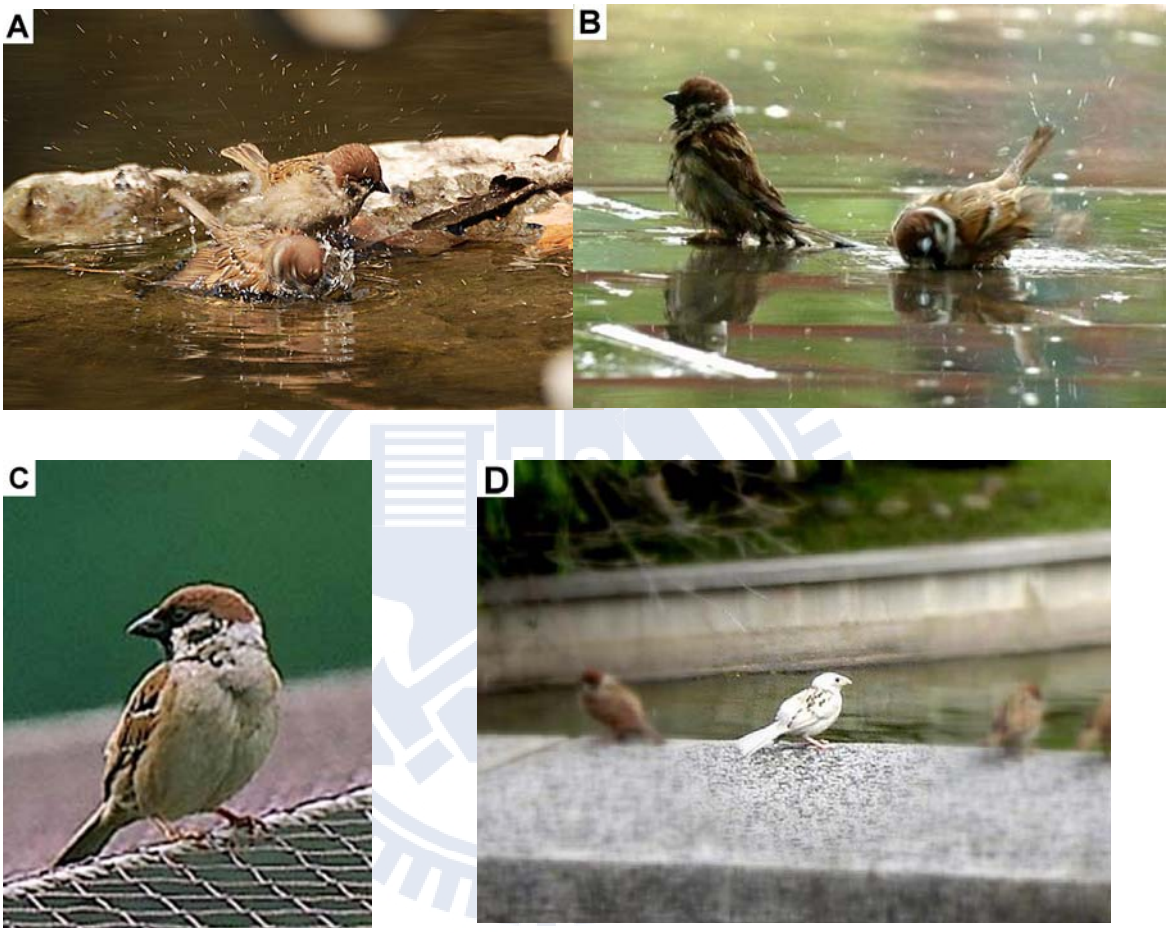

Figure 7. Four pictures A to D were found via the identical keyword “sparrows” for search task (b) “Two tiny and graceful sparrows clean their feathers in a clear stream.”

4.8. Discussion

Our data support the notion of reading ability being an important factor influencing keyword-based image search success. Compared to less skilled readers, better readers were more likely to find appropriate images based on effective keywords, or to be more adaptive in changing keywords when results were inadequate. Better readers were also more effective in terms of selecting and evaluating search results to obtain quality images. Our data also support the notion that successful image searches (including understanding textual intention, generating mental image, making inferences, generating accurate keywords, evaluating pictorial intention, and comparing image content with text descriptions) require the incorporation of both verbal and pictorial systems. Image search success represents a manifestation of visual literacy; according to our results, reading comprehension is probably a fundamental factor in visual literacy.

Internet experience did not exert a strong influence on image searches, a finding that agrees with text search results reported by Wang et al. (2000), Lazonder et al. (2000), and Tu (2005). Since learning how to use image and text search engines is an easy task for most Internet users (Wang et al., 2006), we believe the key to teaching image search skills resides in task description and evaluation. This would explain why online experience does not directly add to or detract from search behaviors and performance.

Chapter 5. Experiment 3 – Search for videos

5.1. Study design

This study focuses on the impact of the learners' metacognitive strategies and cognitive style on video search behaviors and performance. In terms of metacognition, the planning, monitoring and evaluating strategies with reference to Brown's (1987) perspectives were adopted. As for cognitive style, the "verbal-imagery" cognitive style (VICS) based on the ideas of Riding & Cheema (1991) was employed. The popular and mature platform "Youtube" was used to investigate how learners locate the videos they need. Participants were asked to search for videos related to natural science teaching materials. CamStudio was used to record screen displays in real time so as to capture users' search process. After watching the videos, the students were asked to write down the knowledge concepts of animal courtship in the worksheet. Following task completion, individual search process was quantified as search behaviors. Three raters (including a computer teacher, an art teacher, and a natural science teacher) were asked to individually judge how well the retrieved videos and the duly filled worksheets matched the topic as search performance.

Our research design is illustrated in Figure 8. We established three research questions for this project:

1. Given specific search tasks, how do elementary school students perform video searches (search behaviors)? How successful are their video searches search performance)?

2. What are the effects of metacognitive strategies (planning, monitoring, and evaluating) and verbal-imagery cognitive style on video search behaviors and performance?

3. What are the effects of video search behaviors on search performance? Are search behaviors mediators?

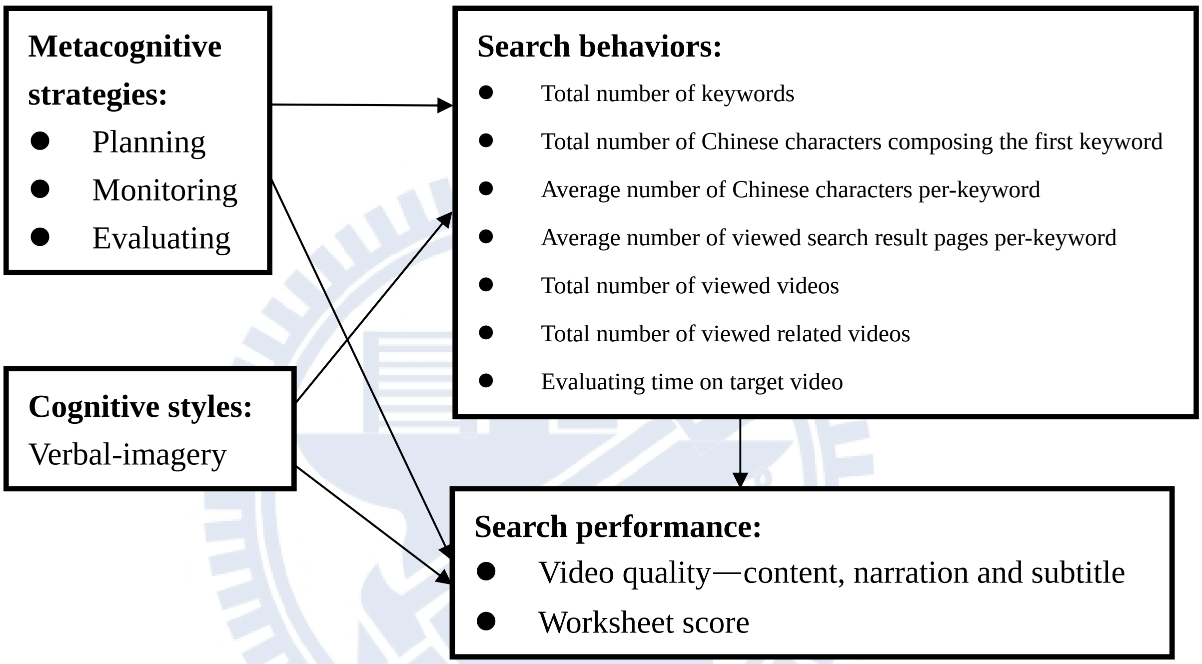

Figure 8. The concepts of experimental design.

5.2. Metacognition

Metacognition is used as a hypernym encompassing the structures that are related to individuals' thinking processes and information (Leader, 2008). For example, metacognitive beliefs, metacognitive awareness, metacognitive experiences, metacognitive knowledge, feeling of knowing, judgment of learning, metamemory, metacognitive skills, metacomponents, metacognitive strategies, learning strategies, heuristic strategies, and self-regulation are the terms associated with metacognition (Akturk & Sahin, 2011; Veenman, Van

Hout-Wolters, & Afflerbach, 2006). Metacognition is defined as "cognition about cognition" or "knowing about knowing" (Metcalfe & Shimamura, 1994); it occurs as a result of individual evaluation and observation of their cognitive behavior in a learning environment (Ayersman, 1995). Therefore, metacognitive activities usually occur before cognitive activities (planning), during activities (monitoring) or after activities (evaluating) (Akturk & Sahin, 2011).

Metacognitive learning strategies involve individuals' planning of their information about their own and others' cognitive processes before they fulfill their task, observing their thinking, learning and understanding while performing a task, controlling and regulating their thinking by making arrangements on site, and evaluating after they have completed their task (Akturk & Sahin, 2011; Scott, 2008). The processes of Web information retrieval entail planning appropriate search strategies, monitoring progress, and evaluating search results. These behaviors are associated with metacognitive learning strategies (Brown, 1987; Israel, 2007). Therefore, the study aims at excavating a deeper understanding and clarification on the connection between each individual difference in metacognitive strategies and their search behaviors, performance, and learning performance.

5.3. Verbal-imagery cognitive style

Some researchers think that cognitive styles are critical factors to influence learning performance especially in the development of hypermedia-based learning (Park & Black, 2007; Rezaei & Katz, 2004; Riding & Rayner, 1998). Cognitive styles are an individual's preferred and habitual ways to organize, process, and represent information (Riding & Rayner, 1998). A number of different labels have been given to cognitive styles and many of these are different conceptions of the same dimensions (Riding & Sadler-Smith, 1992). For this reason, Riding and Cheema (1991) surveyed approximately 30 different cognitive styles and concluded that most of them may be grouped into two basic style dimensions—the verbal-imagery dimension (which indicates a preference for processing information using pictures or words) and the wholistic-analytic dimension (which indicates a preference for information to be structured to get the whole or the detail). Because locating videos from YouTube search engine involve verbal and visual information, including watching video frame and subtitle, hearing narration, and reading text description from uploader, this study investigates the possible influences of verbal-imagery cognitive style on video search behaviors, performance, and learning performance.

5.4. Participants

Study participants were 100 fifth graders (48 boys, 52 girls) from three classes from an elementary school located in central Taiwan. The sample consisted of students that were normal grouping. Students with identifiable learning disabilities were excluded. Students had practiced their basic computer and Web literacy skills—at minimum, how to use word processors, simple graphics programs, Power Point, email programs, and Web browsers. Many students had used YouTube to watch movies on computer course. Participants understand the interface of search engines.

5.5. Measures

5.5.1. Metacognitive strategy use questionnaire

According to Brown (1987), metacognitive strategy use questionnaire (MSUQ) consists of three subscales: planning, monitoring, and evaluating strategies. This study adopted Chiu’s (2006) MSUQ, which was modified from Lin’s (2002) MSUQ. The questionnaire consists of 30 items (7 items for planning strategy, 16 monitoring strategy, and 7 evaluating strategy). All items of this questionnaire are measured on a four-point Likert scale. Chiu’s (2006) has reported that the internal consistency (Cronbach’s alpha) of planning strategy was .7429, monitoring strategy was .8184, evaluating strategy was .7346, and the whole scale was .9086, that were regarded as acceptable. The mean scores of the subscale in our sample were: planning, 2.67 (SD=0.59); monitoring, 2.80 (SD=0.47); and evaluating, 2.93 (SD=0.56).

5.5.2. VICS questionnaire

VICS questionnaire was adopted from Tsai's (2008) Learning Style Questionnaire – Cognitive Preference. It aims to measure students’ tendency toward verbal or imagery when they study natural science. Tsai's questionnaire of 11 test items was modified from Felder and Silverman’s (1988) Index of Learning Styles Questionnaire. Each item includes two options: A (prefer to learn with image information) and B (prefer to learn with verbal information). The higher the score, the more the person tend to imagery style; the lower, the more tend to verbal style. The internal consistency coefficient in our sample was .71 that was regarded as acceptable. Maximum score of cognitive style in our sample was 11; minimum score was 1; the mean score was 5.86 (SD=2.34). Most participants' scores were concentrated in zone of normal distribution, and they belonged to verbal-imagery mixed style.

5.5.3. Video search worksheets

The task is: We can observe that most of the animals in the wild nature have courtship behaviors. For example, the light bugs beam lights and frogs croak to attract potential mates. Please search for a video of the animal courtship from Youtube and record what you saw in the video.

The grading of the video submitted by the students would be divided into 2 parts: (a) Video quality and content (whether the topics are definitive, whether the concepts are complete and accurate, whether the visual effect of the video is clear)—from 0 to 10 points. (b) Video narration and subtitle (whether the narration is explicit, whether the sound quality is clear, whether the subtitles are accurate and complete)—from 0 to 10 points. The grading of the submitted worksheets also ranged from 0 to 10 points. The grading would be based on whether the student specifies the animal names, behaviors, and actions. A Kendall coefficient of agreement was used to examine consistency among the three raters; the results indicate a high level of inter-rater reliability on video quality and content ($W=.90$, $p<.001$), video narration and subtitle ($W=.95$, $p<.001$), and worksheet scores ($W=.85$, $p<.001$).

5.5.4. Search behavior indicators

In this study, search behaviors refer to the methods used by the participants to perform video searches. The seven indicators were (a) total number of keywords—it indicates the range of information search (Lin & Tsai, 2007); (b) total number of Chinese characters composing the first keyword—it shows how users snag main ideas from the prior knowledge or experience when accepting a new assignment; (c) average number of Chinese characters per-keyword—it shows the ability of the users to refine keywords; (d) average number of viewed search result pages per-keyword—it means the amount of pages that the participants viewed search result lists, usually consisting of twenty videos per-page; (e) total number of viewed related videos—it means the amount of videos that the participants selected from related video lists; (f) total number of viewed videos—it means the amount of videos that the participants watched on the Youtube interface; and (g) evaluating time on target video—it means the time span that the participants expended in watching target video.

5.6. Procedure

The study was conducted over two weeks. Participants performed the task in computer classroom. The MSUQ and VICS questionnaire were given during week 1 (30 minutes). The video search task was completed and the worksheet was filled in during week 2 (60 minutes total).

5.7. Result

5.7.1. Video search behaviors and performance

Descriptive statistics for search behaviors and performance of the participants are shown in Table 7. The participants used an average of 3 to 4 keywords per search task and 29.5% of them only entered single keyword to find the videos they needed. On average, the participants used 3 to 4 Chinese characters composing the first keyword and many students used “courtship” as the first keyword (“courtship” is expressed as 求偶, two Chinese characters with the literal meaning of “seek partner”). The participants used about 4 to 5 Chinese characters composing each keyword and the majority would add (or delete) a certain animal name to (or from) original keyword when the first keyword was unsuccessful. For example, “tiger courtship” was used as the keyword (it is expressed as 老虎求偶, four Chinese characters with the literal meaning of “old tiger seek partner”).

Table 7. Descriptive statistics for search behaviors and performance (N=100).

Variable	Mean	SD	Minimum	Maximum
Search behaviors:				
Total number of keywords	3.78	3.19	1	16
Total number of Chinese characters composing the first keyword	3.78	1.70	1	7
Average number of Chinese characters per-keyword	4.10	1.28	1	8
Average number of viewed search result pages per-keyword	1.61	0.88	1	5
Total number of viewed related videos	1.42	0.75	1	6
Total number of viewed videos	3.06	2.51	1	13
Evaluating time on target video	61.75	66.36	1	360
Search performance:				
Video quality and content	5.84	1.97	0	10
Video narration and subtitle	2.03	2.96	0	10
Worksheet score	6.67	1.92	1.67	10

The participants viewed between 1 and 2 search result pages per-keyword search and the majority tended to modify their keywords to continue a new search when search results did not meet their expectations. The participants viewed average of 1 to 2 related videos that were recommended via YouTube. The participants viewed an average of 3 videos to accomplish their video searches. Four students used up all time to watch more than 10 videos and 35.2% of participants only viewed one video to acquire the target video. Judging from the above, approximately a half of videos they viewed were from YouTube recommendations. Positive relations were found between total number of viewed videos and average number of viewed search result pages per-keyword (r=.533, p<.01), and total number of viewed videos and total number of viewed related videos (r=.522, p<.01). We found the videos that students viewed were picked not only from YouTube's search result lists but also from related videos of YouTube recommendations.

Average time spent on the target video was 61.75 seconds. Some students only spent 1 or 2 seconds to watch a video and easily believed this video was sufficient for answering inquiries, while some students spent more than 300 seconds to watch the whole video from beginning to end.

The mean scores of video quality and content, video narration and subtitle, and worksheet were 5.84 (SD=1.97), 2.03 (SD=2.96), and 6.67 (SD=1.92). The video narration and subtitle scores were low because many videos were found by participants were no aside or subtitle. Positive relations were found between worksheet score and video quality and content (r=.332, p<.01), and worksheet score and video narration and subtitle (r=.302, p<.01). The better quality the videos that students watched, the better performance they acquired on worksheets. These show that better videos can bring about better learning effectiveness.

5.7.2. Effects of metacognitive strategies and VICS on search behaviors and performance

In order to clarify the impacts of individual differences on search behaviors and performance, a multiple regression (stepwise method) was performed to predict the contribution of different learner characteristics (metacognitive strategies and VICS) to search behaviors and performance.

Results for data pertaining to correlations are shown in Table 8. Significant correlations were found between planning and total number of keywords (r=-.212, p<.05), planning and evaluating time on target video (r=-.231, p<.05), and planning and worksheet score (r=.228, p<.05). Students with better planning skills tended to use fewer keywords in searching, take less time in viewing and evaluating the target video, and get higher scores on worksheets. Significant correlations were found between evaluating and total number of keywords (r=-.252, p<.05), evaluating and total number of viewed videos (r=-.272, p<.05), and evaluating and worksheet score (r =.237, p<.05). Students with better evaluating skills tended to use fewer keywords in searching, view fewer videos in browsing, and get higher scores on worksheets. No correlation was found between monitoring and video search indicators, and VICS and video search indicators.

Further, the results show that evaluating strategy accounted for 6.4% of the variance for keyword usage (R^2=.064, F=5.835, p<.05). There was a significant measure of relationship when evaluating strategy was used to predict the total number of keywords (beta=-.252, t=-2.416, p<.05). Evaluating strategy accounted for 7.4% of the variance for browsing through videos (R^2=.074, F=6.875, p<.01). A significant measure of relationship was found when evaluating strategy was used to predict the total number of viewed videos (beta=-.272, t=-2.622, p<.01). Planning strategy accounted for 6.4% of the variance for evaluating the target video (R^2=.064, F=5.858, p<.05). A significant measure of relationship was found when planning strategy was used to predict the evaluating time on target video (beta=-.253, t=-2.420, p<.05). Evaluating strategy accounted for 5.6% of the variance for learning performance (R^2=.056, F=5.102, p<.05). A significant measure of relationship was found when evaluating strategy was used to predict the worksheet score (beta=.237, t=2.259, p<.05). Monitoring strategy and VICS did not account for any search behaviors and search performance using YouTube.

Table 8. The coefficient of correlation between video search and learner characteristics.

Learner characteristics / Video search	Planning	Monitoring	Evaluating	Cognitive style
Search behaviors:				
Total number of keywords	-.212*	-.202	-.252*	-.053
Total number of Chinese characters composing the first keyword	.184	-.018	.095	-.042
Average number of Chinese characters per-keyword	.027	-.125	-.036	.124
Average number of viewed search result pages per-keyword	-.111	-.117	-.181	.069
Total number of viewed related videos	-.111	-.099	-.171	.085
Total number of viewed videos	-.197	-.141	-.272*	.164
Evaluating time on target video	-.231*	-.158	-.164	.117
Search performance:				
Video quality and content	.088	.062	.111	.099
Video narration and subtitle	.041	-.032	-.058	.117
Worksheet score	.228*	.203	.237*	.073

Our data support that video search success was more likely for students with greater capacities for metacognitive strategies, especially planning and evaluating strategies. In terms of “total number of keywords” and “worksheet score,” the relative predictive power of evaluating strategy was stronger than planning strategy. In other words, evaluating strategy was a more important factor influencing video search behaviors and performance. However, VICS did not exert an influence on video search.

5.7.3. Effects of search behaviors on search performance

A multiple regression (stepwise method) was performed to predict the contribution of search behaviors to search performance. Results for data pertaining to correlations show that significant negative correlations were found between total number of keywords and video quality and content ($r=-.229$, $p<.05$), total number of keywords and video narration and subtitle ($r=-.248$, $p<.05$) , and total number of keywords and worksheet score ($r=-.336$, $p<.01$). The fewer keywords students used to search videos, the better performance they acquired on both videos and worksheets. No correlation was found between performance and other behavior indicators.

Further, the results show that the total number of keywords accounted for 11.3% of the variance for learning performance ($R^2=.113$, $F=10.936$, $p<.001$). There was a significant measure of relationship when total number of keywords was used to predict the worksheet score ($beta=-.336$, $t=-3.307$, $p<.001$). Other search behavior indicators did not account for any search performance.

To clarify whether “total number of keywords” was a mediator, a hierarchical multiple regression was performed to predict the contribution of learner characteristics and search behaviors to search performance. In step 1, search performance was the dependent variable and (a) the subscales of metacognitive strategies and (b) cognitive style were the independent variables (stepwise method). In step 2, the subscales of search behaviors were entered into the step 1 equation (stepwise method). The results of step 1 indicate that evaluating strategy accounted for 5.6% of the variance for learning performance (R^2=.056, F=5.102, p<.05). There was a significant measure of relationship when evaluating strategy was used to predict the worksheet score (beta=.237, t=2.259, p<.05). In step 2, evaluating strategy and total number of keywords accounted for 13.8% of the variance for learning performance (R^2=.138, F=6.776, p<.01). However, there was an only significant measure of relationship when total number of keywords was used to predict the worksheet score (beta=-.295, t=-2.834, p<.01). Other search behaviors and learner characteristics did not account for any search performance. The results show that the total number of keywords was a mediator, in other words, evaluating strategy may affect worksheet score through keyword usage. In video search, students with better evaluating ability tended to complete a task by reading video descriptions patiently, watching videos carefully, and evaluating videos matched the task concepts discreetly.

5.8. Discussion

Our findings indicate that video search success is dependent on metacognitive strategy and keyword usage. Students with better evaluating and planning ability found the videos that fulfilled the task requirements by using accurate keywords or reading video metadata information. Therefore, they got better grades in worksheet since they watched better videos and understood more about the process of animal courtship. When the videos have large size or the speed of Internet connection is slow, the videos become hard to watch as the signals are broken off constantly. Under this circumstance, students with better planning and evaluating ability still did a better job. Students with better evaluating ability were more cautious in selecting keywords without trying all types of keywords aimlessly and wasting their time watching irrelevant videos. In addition, most students did not finish the entire video. Some participants only watched some fragments of the first parts, while the others would select some clips randomly by dragging the bar below. Nonetheless, they still got hold of the essence of the video content, picked the right video, and learned the accurate information about animal courtship. Students with better planning ability found their ways to understand the video content by reading the metadata information on the search engine interface (such as the miniature pictures, file names, titles and summaries etc) before deciding whether or not they wanted to watch the video. By doing so, they didn't waste time watching irrelevant videos. Instead, they could quickly find the relevant videos and understand their content. The above-stated findings are quite different from most of the results found in text and image search. As a result, we can conclude that there are indeed differences in the nature of video search and text/image search. The findings from this research may not be applicable to text and image search.

Cognitive styles did not exert a strong influence on video searches. The videos provide not only visual information, but also narration or subtitles that help the viewers to understand video content. On the other hand, YouTube interface provides the titles, the descriptions, keywords and the reviews from other viewers etc to fill in the gap of the video itself. Some users would even read the descriptions beside the video to select which one they want to watch. Each individual learner has their own preference when it comes to select their source of information; however, the learners should still absorb the information of many different formats such as images, words, and audio sounds to make sure they receive all the necessary messages to make their own judgment. Thus, they can achieve better search and learning performance.

Chapter 6. Experiment 4 – Search for landmarks

6.1. Study design

Since Geographic information system (GIS) are now considered effective visualization aids in the teaching of spatial enquiry, they are becoming classroom learning tools in Taiwan and many other developing and developed countries (Meyer, Butterick, Olkin & Zack, 1999; Sanders, Kajs & Crawford, 2002, Ramadas, 2008). Instructors are encouraged to master skills in the use of multiple e-map search functions provided by many web-based e-map providers. The current list of e-map portals includes Google Earth, a search system that simulates a bird's eye view of earth from outer space and transforms the original 2-D results of GIS searches to 3-D images that users can zoom in to or out from. Google Earth makes use of GIS to create images of the entire planet in the form of 3-D maps, to perform searches for small-scale geographic images that perfectly resemble the large-scale real-world landmarks, and to present search results in the form of 3-D images. The study adopted Google Earth Free that high school students could easily download from the website. The free trial of Google Earth provides different levels of satellite imagery all over the world. The satellite imagery is up to 0.61 meter resolution for some urban areas. Most general users find it an ideal platform because they can access to a huge amount of resources and data.

The technology is exciting, but educators in Taiwanese junior high schools are only starting to experiment with and discover how to use Google Earth to replace tradition memorization approaches to teaching geography, earth science, and history concepts with constructivist-based active learning and hands-on experiences (Duffy & Jonassen, 1992; Mayer, & Moreno, 2002; Roth & Roychoudhury, 1992; von Glasersfeld, 1989). Constructivist theory encourages teachers to act as facilitators of active processes in which students discover principles, concepts, and facts for themselves (Di Vesta, 1987). Accordingly, teachers who engage in promoting spatial enquiry may ask students to use GIS-based search functions to search for countries, cities, and landmarks, to observe borders between countries and to use such information to contemplate national and regional economic development, international relations, population growth, and cultural issues. In this project our focus was on the study of geographical landmark search as supported by the Google Earth search function. Our specific study goals were to observe how classroom teachers could apply this innovative technology and how students' capacities influenced their learning through Google Earth search. Google Earth allows users to key in addresses (for a limited number of countries) or coordinates to browse locations. What users have to do would be typing-in the location names (keywords) and then the system will automatically perform landmark search tasks. It is mainly image search through semantic completion and users are not required to use their spatial ability or geographical knowledge; they simply do not have to put mind in. We purposefully disabled this function—as well as the layers, places, and search panels—in order to stimulate image search behaviors and avoid the interference of using semantic search strategy in image search task. In other words, participants did not have access to keyword searches, but were required to use the mouse and the zoom-in and zoom-out features for navigation. Therefore, landmark search performance is considerably affected by at least four cognitive factors, abstract reasoning ability, small scale spatial abilities, large scale environmental cognition and prior knowledge about the landmark. We established the following research questions:

1. How well do junior high school students perform landmark searches using Google Earth?

2. Do statistically significant correlations exist between landmark searches and the following factors: mental rotation, abstract reasoning, environmental cognition (landmark representation, intersection representation, and frame of reference), and prior geography knowledge?

3. What is the order of predictive power among mental rotation, abstract reasoning, landmark representation, intersection representation, frame of reference, and prior geography knowledge regarding the ability to successfully perform landmark searches using Google Earth?

6.2. Spatial ability

In this project we abided by Reber's (1985) broad description of spatial abilities as cognitive functions that support human mental rotation, visual spatial tasks, and object orientation in space. In their meta-analysis of related studies published between 1974 and 1982, Linn and Petersen (1985) found three categories of spatial tests: spatial perception (the ability to determine mental rotation in spite of distracting information), spatial visualization (the ability to manipulate complex spatial information when several stages are needed to produce a correct solution), and mental rotation (the ability to mentally rotate 2D or 3D imagery without the assistance of external tools). However, challenges arise when a factor analytical approach is used to group and define spatial abilities, the most important being that doing so does not necessarily produce converging definitions. The lack of a universally accepted definition of spatial ability may also be explained by the variety of psychometric tests used to analyze the term, as well as the lack of reliability of factor structures produced by multiple tests (Voyer, Voyer, & Bryden, 1995).

Psychometric approaches frequently entail the use of such tasks as the mental rotation of shapes, solving mazes, and finding hidden figures to measure spatial abilities (Carroll, 1993; Eliot & Smith, 1983; Lohman, 1979; McGee, 1979)—in other words, imagining the manipulation of visual forms in small-scale spaces relative to the body rather than the individual's own changing location and orientation in large-scale spaces. Mental rotation is very likely to be correlated with required cognitive functions for manipulating GIS-based tools such as Google Earth (e.g., performing landmark searches and finding/reading maps). These functions include the construction of internal representations of global and geographic information, maintaining high-quality internal representations, and performing spatial transformations to make inferences. Users may orient, reposition, and rotate internal representations before and as they spin a globe on a monitor, zoom in or out from an image, or otherwise use their cursors to manipulate globes or e-maps.

Correctly searching for landmarks with the help of a GIS tool also requires abstract reasoning, a non-verbal reasoning ability that is highly correlated with general ability (Pellegrino & Hunt, 1991). When searching for landmarks, users must form hypotheses, make explorations, and make reasonable guesses based on limited information. In this study, we assumed that performing searches with help of a GIS tool is dependent on both mental rotation and abstract reasoning capabilities.

6.3. Environmental cognition

Examples of everyday tasks requiring environmental cognition are finding one's way between two points and learning the layout of a building or city (Evans, 1980). Environmental space is large in scale relative to the body; individuals are said to be contained within such space. According to Siegel and White (1975), environmental cognition is developed in three phases: (a) landmark recognition; (b) constructing access to route knowledge, during which routes between landmarks and path intersections are established, eventually forming clusters that are linked to each other via topological relationships; and (c) developing coordinated frames of reference within and across clusters, thereby forming survey knowledge.

Hart and Moore (1973) used Piaget's studies of perspective taking to study spatial orientation in children, and traced the gradual development of increasingly accurate and complex spatial relationship memories of real environments. According to Hart and Moore, the frame of reference aspect of spatial relationships also has three developmental stages. The first, egocentric orientation frame of reference, young children organize objects spatially primarily in terms of personal mobility experiences—in other words, they orient all objects in their environment to their own central position and disregard rotation. The second, fixed frame of reference occurs during early concrete operational stages, when children move away from egocentric orientation and toward the fixed location of a specific object, usually one that they are most familiar with. Rotation is comprehended, but children in this phase still have difficulty coordinating multiple referents. The third, coordinated frame of reference, children are capable of perceiving all possible routes to the locations of known objects. Locations are no longer oriented in terms of relationships to their body positions in space or the relationships among proximate landmarks, but in respect to broader areas and expressed using abstract cardinal directions.

Assessing environmental cognition include recognizing scenes from a learned environment, retracing previously taken routes, estimating route distance, pointing to non-visible landmarks, and sketching real-world maps (Evans, 1980; Liben, Patterson & Newcombe, 1981; Spencer, Blades & Morsley, 1989). When geologists study relationships between the environment and human beings, they often utilize map sketches to show how human beings absorb, organize, save, memorize, and handle spatial knowledge and concepts (Downs & Stea, 1977; Golledge & Stimson, 1987; Ouyang, 1981). Consequently, cognitive maps are viewed as tools for understanding cognitive processes involved in the acquisition, representation, and processing of information about actual environments (Best, 1989; Golledge, 1999; Shih & Su, 1992; Thomas & Willinsky, 1999; Tverksy, 2004).

For this project, participants were asked to create cognitive maps of their school neighborhood; we analyzed their maps in terms of landmark representation, path intersection representation, and frame of reference, testing our hypothesis that these three indicators of environmental cognition are all significantly correlated with landmark searches via the GIS-based Google Earth. Since the search task specifically requires the use of three cognitive functions (positioning, rotating, and orienting within a movable e-map/global screen) to locate landmarks, search outcomes were assumed to be dependent on path intersection representation, frame of reference quality and landmark representation quantity.

6.4. Prior knowledge

Prior knowledge holds a central position in the three most influential learning theories of the past half-century: schema (Anderson, 1977), mental models (Johnson-Laird, 1983), and constructivism (Roth & Roychoudhury, 1992; Von Glasersfeld, 1989). From misconception research, there is a common agreement that learners construct concepts from prior knowledge (Novak, 1990). Previous research also used expert-novice comparison paradigm to reveal the impact of science prior knowledge on learning process and resulting knowledge structure. Chi, Feltovich, and Glaser (1981), for example, found that experts have extensive domain knowledge and are more able to attend and remember the core principles represented by a graphic. In other words, they concentrate more on the relevant parts of incoming messages for the construction of a coherent schema or effective mental model. Though many of previous misconception and novice-expert studies focused on the domains of Physics and Chemistry, their findings are applicable to geographic learning. Various usages of visual representations by experts and novices can be attributed to different size of prior knowledge and different coherent degree of how prior knowledge stored in cognitive structure (Cook, 2006). Information-processing theorists suggest that people have a limited working memory, and when working memory is overloaded, learning does not happen. Prior knowledge largely determines the limitation for working memory.

Currently, mixed results have emerged from empirical studies of the effects of prior knowledge on various learning outcomes (comprehension or problem solving) in several domains including geography (see, for example, Dochy, Segers & Buehl, 1999; Hoz, Bowman & Kozminsky, 2001; O'Reilly & McNamara, 2007).

In this study we used grades in previous geography classes as the primary indicator of prior knowledge, acknowledging that such grades reflect success in the passive learning (memorization) of geography facts. Therefore, landmark searches as the outcome of active construction is somehow correlated with prior knowledge and we also assumed that prior knowledge learned through passive manner is a less successful predictor compared with mental rotation and environmental cognition.

6.5. Participants

Study participants were 153 seventh graders (73 boys, 80 girls) from a junior high school located in central Taiwan. According to prior performance records for the national senior high school entrance examination, the school population was well below the top 15% of all junior high schools in Taiwan. The sample consisted of student from five classes that were randomly chosen from the school’s 21 classes. In Taiwan, the government stipulated junior high school students must attend schools in their neighborhood school district. If adolescent population outnumbers student size that all schools in a district can take in, they have to queue in the descent order of the years their family live in the school district. For the participants, the average number of years living in this school district was 10.23 (SD=4.26, range from 3.93 to 14); this number suggests that all participants lived more than 3 years in this school district and we assume they are familiar with the neighborhood enough to sketch a map of the school district as a required of this study. All students in the sample were familiar with basic computer applications but had never used the Google Earth website.

6.6. Measures

6.6.1. Mental rotation

Our mental rotation measure was adopted from Lu, Ou, and Lu's (1994) Multiple Dimension Aptitude Test Battery (MDATB), a commonly used standardized aptitude test in Taiwan that consists of eight subscales. Test reliability and validity were acceptable according to its manual and the norms were developed for junior high school and high school students. In the subtest of mental rotation, participants are presented a target figure and four test figures, and are instructed to select the test figure that best represents a rotation of the target figure. Participants were given six minutes to respond to 32 items.

The reliability and validity of MDTB was provided by Lu, Ou and Lu's (1994). For the mental rotation scale, they found the internal consistency coefficient (Cronbach's alpha) in a sample of ninth grade boys was .80 and in eleventh grade girls .76; the test-retest reliability in a sample of ninth grade boys was .68, in tenth grade boys .80, in tenth grade girls .70. The concurrent validity for mental rotation scale was found between MDATB and a previous well established Differential Aptitude Test (Lu, Gien, & Chen, 1988) for tenth grade boys (r = .58, p< .01).

6.6.2. Abstract reasoning

Our abstract (non-verbal) reasoning measure was also adopted from the MDATB. Each item consists of five figures that form a series with a specific embedded logic. Participants are required to select from another set of four figures the one best representing the subsequent item in the series. Participants were given 15 minutes to complete this 32-item scale. For, the reliability test, Lu, Ou, and Lu's (1994) found the internal consistency coefficient in a sample of ninth grade boys was .82 and in eleventh grade girls .73. The test-retest reliability in ninth grade boys was .70, in tenth grade boys .83, and in tenth graders students .62. An acceptable concurrent validity was found between MDATB and DAT in tenth grade boys (r = .37, p< .01).

6.6.3. Map sketch

We used map drawings of a familiar real world setting as our environmental cognition measure. Participants were asked to sketch maps of the area immediately surrounding their junior high school. No restrictions were placed on the area to be covered in their maps, but they were required to include streets and facilities (e.g., stores, buildings, parks, and open spaces) and to place them accurately.

Using the modified system described by Ouyang (1982), Matthews (1984), and Su and Huang (2005), sketch maps were scored based on the three above-mentioned environmental cognition features, landmark representation quantity, intersection representation quality, and frame of reference quality.

Higher scores represented more sophisticated knowledge of spatial layout—that is, correct and precise positioning of landmarks, correct alignment of streets, and proper coordination of map elements according to a clear frame of reference.

Our landmark representation scoring procedure is to count the number of identifiable objects in a sketched map. The purpose for this scoring item is to evaluate whether participants observe and pay attention to any objects around their school and how many objects they can save and memorize in their mind. The importance of all objects is the same, therefore every tangible object (e.g., streets and facilities) or each intangible indicator of geographic directions or traffic flow in a map gains one point.

Our intersection representation scoring procedure focuses on path intersection pattern quality. We identified three types of intersections described by Ouyang (1982): (a) orthogonal intersections (Figure 9, map A) with a majority of paths in perpendicular positions, considered the lowest quality; (b) orthogonal and oblique intersections (map B); and (c) orthogonal, oblique, and curved intersections (map C) representing precise and flexible combinations of all intersections pattern types, which are considered higher quality.

Our frame of reference scoring procedure is based on Hart and Moore's (1973) categories. In maps reflecting an egocentric frame of reference (Figure 9, map D), scenes and paths are centered solely on the participants' standing perspective; anything outside of the participant's physical view is excluded. These maps often show less elaborated manner containing merely self-relevant landmarks such as the student's home, school, or route between the two points. Wrong locations of landmarks are common. These self-centered maps were viewed as representative of lower spatial capabilities. Fixed frame of reference maps (map E) contained fixed positions or landmarks that serve as centers for all scenes and paths. In coordinated frame of reference maps (map F), all scenes and paths are aligned in an abstract and coordinated fashion, and identifiable landmarks are located in correct positions and with accurate orientations.

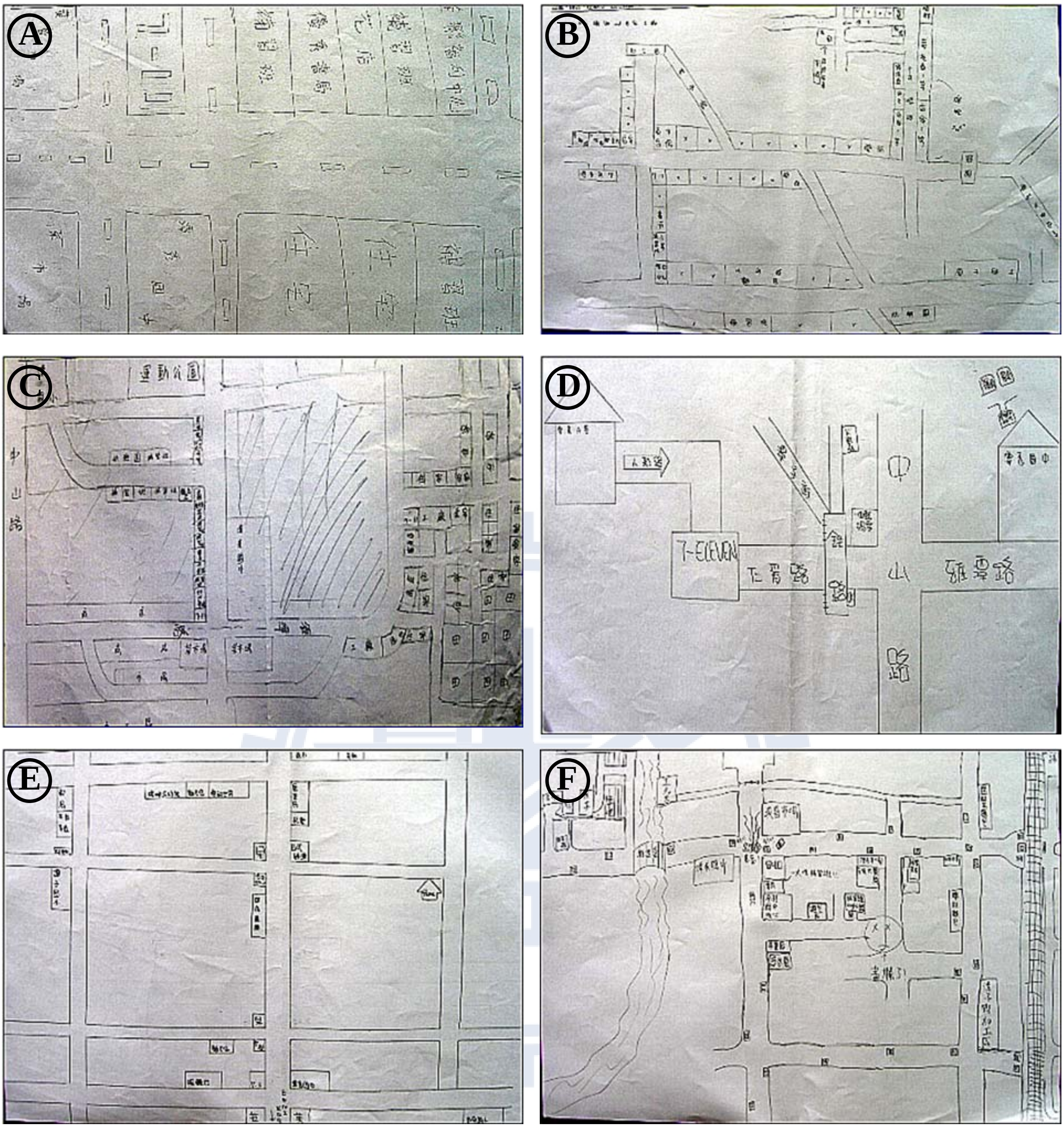

Figure 9. Some exemplifications of sketch maps (A: orthogonal intersections; B: orthogonal and oblique intersections; C: orthogonal, oblique, and curved intersections; D: egocentric frame of reference; E: fixed frame of reference; F: coordinated frame of reference).

Two teachers from the junior high school used in this study devised a scheme for scoring the quality of intersection representation and frame of reference, then separately rated all 153 maps. A Kappa coefficient of agreement was used to examine consistency between the two raters. Results for two quality indicators of environmental cognition indicated high inter-rater reliability for intersection representation ($K = .75$, $p < .001$) and frame of reference ($K = .60$, $p < .001$).

Scoring results for landmark representation, intersection representation, and frame of reference are shown in Table 9. The average number of illustrated objects in the student maps was 26. More than one-half of the participants (80, or 52.3%) sketched simple orthogonal intersections. Just under one-quarter (34, or 22.2%) illustrated both orthogonal and oblique intersections, and the rest (39, or 25.5%) displayed flexible patterns of orthogonal, oblique, and curved intersections. In terms of frame of reference, just over one-third (55, or 35.9%) drew egocentric maps, less that one-third (45, or 29.4%) drew fixed frame maps, and the rest (53, or 34.6%) drew high-quality coordinated frame of reference maps, which are considered appropriate to the developmental stage of this age group.

Table 9. Descriptive statistics of mental rotation, abstract reasoning, prior knowledge, landmark search and environmental cognition.

Variables			n	M	SD	%
Mental rotation			153	22.29	5.064	-
Abstract reasoning			153	22.01	6.156	-
Prior knowledge			153	76.53	15.50	-
Landmark search			153	41.20	13.19	-
Environmental cognition: Landmark representation			153	26.61	15.20	-
Environmental cognition	Intersection representation	Simple orthogonal	80	-	-	52.3%
		Orthogonal and oblique	34	-	-	22.2%
		Flexible patterns of orthogonal, oblique, and curved	39	-	-	25.5%
	Frame of reference	Ego centric	55	-	-	35.9%
		Fixed	45	-	-	29.4%
		Coordinated	53	-	-	34.6%

6.6.4. Related functionality of Google Earth

Google Earth adopts many pictures of common areas, aerial photos that have received permission, pictures of KeyHole spy satellite and many other pictures of towns and cities via satellite (Wikipedia, retrieved December 7, 2008). Type in keywords of the landmarks you're looking for then Google Earth takes you up to the air as if you're watching the landmarks from a helicopter (Butler, 2006). Google Earth also allows image search. It adds zoom in/out function to GIS, transforming the originally 2-D searching platform to 3-D. It provides not only free of charge information regarding 3-D aerial photos but also integrates a lot of geographical data, such as data of streets, hotels, restaurants, well-renowned landmarks, routes, borders, and time related to the destination completely and accurately (Butler, 2006; Trimbath, 2006).

Our decision to use Google Earth Free was based on its features, which were considered adequate for the purposes of the study and for the needs of the participating teachers and students. As shown in Figure 10, the Google Earth interface consists of (a) a 3D Viewer for viewing global and terrain images (Figure 10, circle 1); (b) a sidebar for overlaying landmarks, polygons, paths, and images (circle 2); (c) navigation controls, including tilting, zooming and pulling out, and moving around within an image (circle 3); (d) a layers panel to display points of interest (circle 4); (e) a places panel to locate, save, organize, and revisit landmarks (circle 5); (f) a search panel to find places and directions and to manage search results (circle 6) (Wikipedia, retrieved December 7, 2008).

The term "layers" refers to the high or low resolution of system landmarks. For example, Mississippi River contours have lower resolution (upper layers on an e-map) than the Statue of Liberty. We divided landmark layers into seven levels according to degree of resolution: Level 1 shows the entire globe (lowest resolution); Level 2 continents and oceans; Level 3 countries; Level 4 capitals, cities and counties; Level 5 villages, towns, mountains, and rivers; Level 6 streets; and Level 7 buildings (highest resolution). The landmarks that the study participants searched for had various levels; the zoom-in zoom-out feature allowed for adjustments to be made to resolution levels.

Google Earth allows users to key in addresses (for a limited number of countries) or coordinates to browse locations. We purposefully disabled this function—as well as the layers, places, and search panels (circle 4, 5, and 6 in Figure 10)—in order to emphasize map-searching behaviors among the students. In other words, participants did not have access to keyword searches, but were required to use the zoom-in and zoom-out features for navigation.

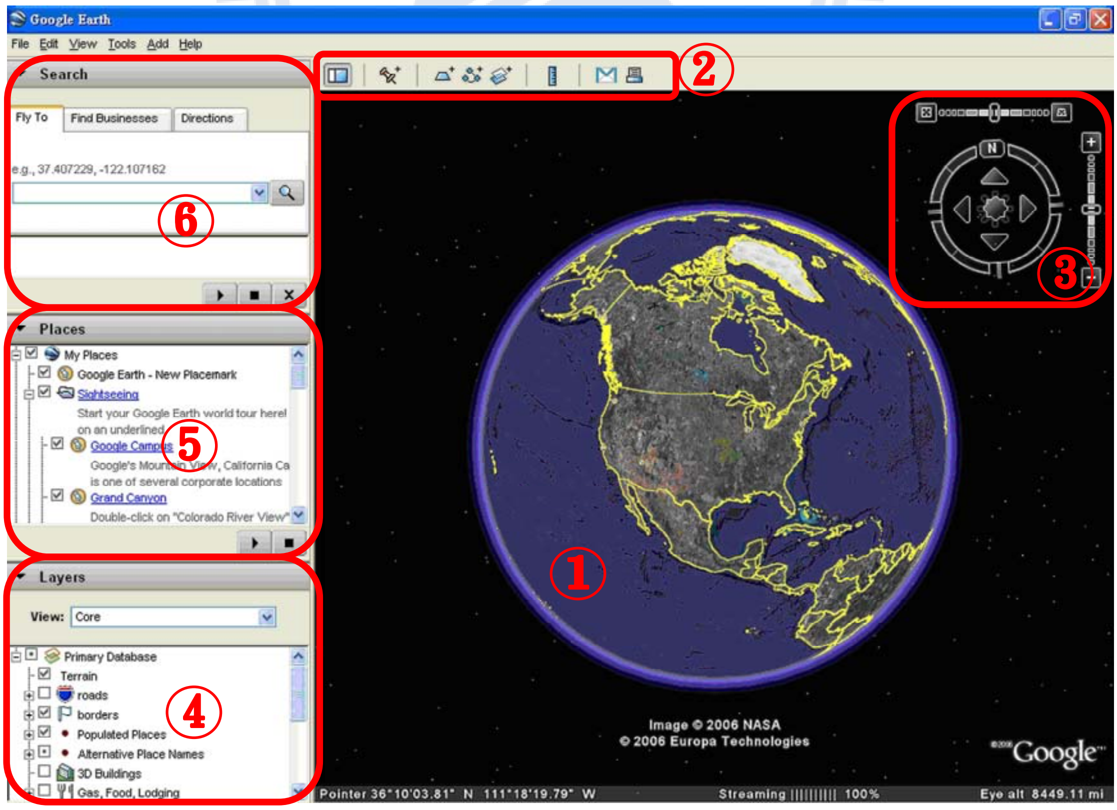

Figure 10. The user interface of Google Earth.

6.6.5. Landmark search worksheets

Students were instructed to complete "landmark search worksheets," each containing the same 16 search tasks selected by three geography teachers. Landmark resolution levels ranged from 1 to 7, with at least two tasks for each level—one for a familiar landmark and another for an unfamiliar location as determined by the three experienced teachers. For example, at level 3 the familiar-to-unfamiliar tasks were "Taiwan Island" and "Madagascar Island." The four level 7 tasks were the Taipei 101 building (the tallest inhabited building in the world, judged as familiar), the participants' school (familiar), the Statue of Liberty in the United States (relatively unfamiliar), and the US Pentagon (unfamiliar). The description of each task included a printed landmark illustration and a short description. Students were given 50 minutes to complete the 16 search tasks and to upload pictures that they found during the session.

Students were given a maximum of 5 points for each correct uploaded picture that was identical in direction, distance, and level to the corresponding illustration on the worksheet, for a maximum score of 80. Fewer points were awarded for pictures that did not precisely match the illustration. For example, 5 points were awarded for a picture of the Taipei 101 building that had the same level 7 and orientation as the illustration, 4 points if the building direction or angle was different, 3 points if the picture was of Taipei City but not the building, 2 points for downloading a picture of Taiwan Island, and 1 point for downloading a picture of Asia. No points were awarded for pictures of other continents or if a student couldn't find a picture.

Landmark search results were scored by the three independent raters. A

Kendall's coefficient of concordance was used to examine consistency among the three coders; our results indicated a high level of inter-rater reliability ($W=.98$, $p < .001$).

6.7. Procedure

The study was conducted over four weeks (one hour per week). Mental rotation and abstract reasoning data were collected during week 1, maps of the school and surrounding community were drawn and collected during week 2, Google Earth features and methods were taught during week 3, and the search tasks were completed during a 50-minute session in week 4.

6.8. Result

6.8.1. Landmark search performance

Our data indicate that the large majority of the study participants successfully learned how to find images using the GIS-based Google Earth, but the success rate for completing search tasks decreased as the required resolution level increased. For example, in the unfamiliar landmark category, the number of students earning between 1 and 5 points was 152 for locating the African continent (level 2), 143 for Madagascar Island (level 3), 118 for Tokyo (level 4), 58 for Fuji Mountain (level 5), 51 for Athens Olympic Stadium (level 6), and 44 for the Statue of Liberty (level 7). The author also observed that for those who could complete the searching tasks, they could control and operate the Google Earth searching system. That is, it is impossible to find the target landmarks accidentally.

Our results suggest that prior knowledge accounted for a considerable amount of success in landmark search performance. Participants earned considerably higher scores on searches for Taiwan Island, Yu Shan Mountain (Taiwan's tallest), Wuchi Port (a commercial port near the participants' home city), the Taipei 101 Building, and their junior high school than the unfamiliar landmarks in the same level. For example, the numbers of students earning between 1 and 5 points for the Taipei 101 Building (familiar), their school (familiar), the Statue of Liberty (unfamiliar), and the Pentagon (very unfamiliar) (all level 7) were 93, 60, 44, and 13, respectively. In sum, more students successfully searched the target landmarks if they were familiar with the landmarks.

6.8.2. Correlations between spatial ability, environmental cognition, prior geographic knowledge, and landmark search

Results for data pertaining to the second research question are shown in Table 10. A statistically significant correlation was found between mental rotation and abstract reasoning ($r = .351$, $p < .01$); a possible explanation for this result is consistency in test item format in terms of information processing of small-scale figures. No correlation was found between small-scale spatial abilities and well-learned large-scale environment indicators, which conflicts with Evans' (1980) description of a conceptual association between mental rotation and the qualitative development of frame of reference. In addition, this finding is only partly in agreement with Hegarty et al.'s (2006) observations for a group of American college students that measures of small scale spatial abilities have weak or no correlations with information processing measures of newly learned environmental settings. Finally, low correlations were found between landmark representation and intersection representation (r = .391, p< .01), landmark representation and frame of reference (r = .275, p< .01), and medium correlations was found between intersection representation and frame of reference (r = .685, p< .01).

Table 10. The coefficient of correlation of mental rotation, abstract reasoning, environmental cognition, prior knowledge and landmark searching.

Test items	Mental rotation	Abstract reasoning	Landmark representation	Intersection representation	Frame of reference	Prior knowledge	Landmark searching
Abstract reasoning	.351**	1					
Landmark representation	.004	.069	1				
Intersection representation	.122	.043	.391**	1			
Frame of reference	.081	.093	.275**	.685**	1		
Prior knowledge	.131	.302**	.176*	.116	.056	1	.
Landmark searching	.293**	.256**	.354**	.500**	.367**	.260**	1

*：p<.05　**：p<.01　***：p<.001

A statistically significant correlation was found between abstract reasoning ability and prior geographic knowledge (r = .302, p <.01), but not between mental rotation ability and prior geographic knowledge. This suggests that learning geography is dependent on general intelligence but not on the ability to mentally rotate spatial representations. We also found a statistically significant correlation between landmark representation (an indicator of less complex spatial memory) and prior geographic knowledge (r = .176, p <.05), but not between prior geographic knowledge and two indicators of more complex environmental information processing—intersection representation and frame of reference. This strongly suggests that conceptual understanding accounts more about the outcomes of ordinary geographical learning than transformations of complex spatial information, which is more closely associated with hands-on experiences and knowledge construction.

6.8.3. Predictive effects of six factors on landmark search

We used a multiple regression analysis (stepwise method) to clarify the relative predictive powers of mental rotation, abstract reasoning, environmental cognition, and prior knowledge on successful landmark searches using Google Earth (Table 11). According to our results, a four-factor model accounted for 60% of the variance for landmark searches ($R^2 = .613$, $F = 22.298$, $p < .001$). The strongest predictor was frame of reference (beta = .401, t = 5.678, p< 001), followed by mental rotation (beta = .230, t = 3.499, p< .01), landmark representation (beta = .174, t = 2.445, p< .05), and prior geographic knowledge (beta = .161, t = 2.413, p< .05). Abstract reasoning ability and intersection representation did not account for landmark searches using Google Earth. Instead, success was more likely for students (a) with an advanced coordinated frame of reference, (b) with greater capacities for mental rotation, (c) who were more capable of sustaining real-life landmark knowledge in the form of spatial memory, and (d) who had acquired greater amounts of prior geographic knowledge.

Table 11. Regression analysis summary for mental rotation, abstract reasoning, environmental cognition, and prior knowledge predicting students' searching score.

Predictor variables	R	ΔR^2	ΔF	B	β	t
Step 1	.509	.259	52.708***			
Frame of reference				7.959	.509	7.260***
Step 2	.563	.059	12.914***			
Frame of reference				7.568	.484	7.132***
Mental rotation				.635	.244	3.594***
Step 3	.593	.034	7.808***			
Frame of reference				6.379	.408	5.688***
Mental rotation				.635	.251	3.778***
Landmark representation				.173	.199	2.794**
Step 4	.613	.025	5.822***			
Frame of reference				6.272	.401	5.678***
Mental rotation				.600	.230	3.499**
Landmark representation				.151	.174	2.445*
Prior knowledge				.137	.161	2.413*

* p<.05 ** p<.01 *** p<.001

6.9. Discussion

This project shows the results of several Taiwan teachers actively introducing new technology into their geography classes. In accordance with many students' perception that geography can be learned passively, evidences of this study confirm that geography grade is accounted for by abstract reasoning ability (general intelligence) and landmark representation (acquiring basic spatial information). Conceptual understanding seems gained much more emphasis in the previous geography examinations in Taiwan junior high schools.

The first result suggests that Google Earth landmark searches require complex cognitive processing in the form of conceptual understanding (landmark representations and prior geographic knowledge) processed by long term memory and spatial representation processing (using coordinated reference frames and mental rotation) controlled by working memory. Google Earth and other comparable tools can be used in such a manner as to support constructivist teacher activities—engaging students as they complete activities and posing questions to promote reasoning (DeVries, Zan, Hildebrandt, Edmiaston, & Sales, 2002). In order to fully engage and challenge learners, learning tasks must reflect the complexity of learning environments in a manner that gives them ownership of the learning process, problem-solving process, and of the problem itself (Derry, 1999). Our results indicate that Google Earth can facilitate this kind of learning in geography classrooms.

Another study contribution is its replication of previous findings showing weak or no correlations between small-scale spatial abilities and large-scale environmental cognition (Hegarty et al., 2006). Both small-scale spatial abilities and large-scale environmental cognition are important factors of individual differences in knowledge construction of geography.

According to Shih and Su (1992) and Lay (1999), the ways that students use maps are affected by their cognitive development, thus the ability to use maps is representative of an individual’s spatial cognition. We think that spatial cognition is developed by exploring in spatial environment. In landmark searching process, the recognition of all roads, buildings, and landforms, differentiating directions, proportion, distance, area, location, and sequence are closely related to environmental cognition. The use of Google Earth search system is similar to the encoding and saving of information in real environment. Therefore, people with better environmental cognition are better at manipulating software to find out landmarks.

Spatial ability refers to the ability to imagine object moving in the three-dimensional space or to manipulate the object imaginatively. People with better spatial ability could twist, transfer, or rotate the image to a new location in their brains. They are able to imagine the rotation of objects in their minds, the floor plan of objects on a flat surface or the folded three-D. They also have the ability to understand the change of objects' location in the space. Therefore, people with better spatial ability can imagine the differences between the simulated environments and authentic situations.

However, the predictor of geographical knowledge was not as good as previous expectations. For example, whereas most Taiwanese junior high students know that the Statue of Liberty is in New York, only a small number of participants in this study were capable of using Google Earth to locate the United States, the East coast of North America, the New York State, and the Liberty Island in New York Harbor step by step. The GIS-based tool required students to use prior knowledge or their reasoning skills to locate all of these landmarks. Accordingly, geographical knowledge did not remarkably affect the effectiveness of searching tasks.

GIS has been suggested as a supportive tool to develop students' spatial thinking and enquiry which is, in turn, an important competence underpinning a lot of science discoveries. However, our results indicate that a surprisingly large percentage of participants were in a spatial cognition developmental stage marked by an egocentric orientation frame of reference, explaining they had not enough skills in the creation and use of maps. This suggests (a) the learning of geographic knowledge among Taiwanese junior high school students can benefit greatly from direct exposure to either actual or virtual environments, and (b) presenting concepts such as distributional relationships among spatial phenomena in an active and vivid manner can enhance student interest in learning geography. It is our hope that this study will support the expanded use of 3D simulation software and GIS-based tools such as Google Earth in Taiwanese classrooms.

Chapter 7. Conclusion

In this study, we explored how human factors (including cognitive, affective, and skill factors) influence search behaviors, strategies and performance in a variety of multimedia search engines. The findings support the ideas that (a) students with different thinking style levels (an affective factor) perform various search strategies and behaviors and present different search performance in text search tasks, (b) successful image searches are strongly dependent on reading ability (a cognitive factor) rather than on Internet experience (a skill factor), (c) the strongest predictor of landmark search performance is environmental cognition (a cognitive factor) followed by spatial ability and geographical knowledge (two cognitive factors), and (d) metacognitive strategies (a cognitive factor) are important factors influencing video search success and learning effectiveness, but verbal-imagery cognitive style (an affective factor) does not exert a strong influence on video searches. Therefore, the development of cognitive abilities is very important for students to be able to search the web for information effectively.

This study offered a summary of human factors, different types of search engines, and search behaviors and strategies that can serve as indicators of how students interact with and respond to search engine interfaces. The results indicate that a positive relationship was found between text search performance and the total number of keywords, while a negative relationship was found between video search performance and the total number of keywords. However, no relationship was found between image search performance and keyword-based behavior indicators, and positive relations were found between image search performance and two behavior indicators of search outcome evaluation. We believe that the differences lie in the distinction between text, image and video searches. Because text search makes it easy for users to make use of related ideas to formulate keywords, the users can broaden or narrow their search scopes by constantly changing the keywords. Moreover, text search has a huge database; therefore, it only takes a few searches to retrieve the correct documents or answers. However, given that images generally have abstract and complex concepts, it is hard for users to translate their visions into literal descriptions in order to formulate keywords. Therefore, the search engines may not always provide the corresponding images. Under this circumstance, it is vital for users to compare and evaluate the relevance between the images and the task description. This way, users can obtain better search performance if they are willing or competent enough to view more pages of image search results. As for video searches, videos, like images, are infused with complex concepts. Sometimes it is hard for people to describe the video content that they want with accurate keywords. In addition, not every topic is suitable to be made into a video. So, the database of videos is not as large as the image and text databases. If users fail to use accurate keywords, they will not be able to find relevant videos. Even though users change keywords frequently, it does not help much in resolving this issue.

The use of computer technologies for problem-solving is rapidly becoming a required daily life skill for students and non-students alike. This transformation is affecting education in terms of knowledge transfer and construction because students are increasingly required to take the initiative to seek and construct their own knowledge pools. Accordingly, learning effectiveness is increasingly impacted by information collection, analysis, assessment, and integration. Visual stimuli, in particular, promote learner interest and attention, support learner efforts to construct new knowledge, and facilitate memory. However, much of the information on websites is uploaded by Internet users, leading to poor quality. To achieve autonomous learning, educators can focus on teaching Internet search and website information assessment skills, as well as on helping students to acquire the knowledge contained in various types of search engines. For example, computer teachers can introduce how web search results can be ranked and remind students that the most useful/correct knowledge and quality information is not necessarily placed at the top. Moreover, teachers should provide different guidance to different students based on the students' individual differences and encourage them to leverage their characteristics and expertise to find good and readable information on the Internet in order to address all types of tasks and problems in real life.

Even though our four-phase search tasks may appear simple to execute, we observed sharp distinctions between students at various cognitive ability levels. For example, a lack of reading ability affects students' abilities to search for images effectively. Therefore, how to modify instructional approaches for students with specific characteristics, such as good versus poor reading skills, improve student's cognitive abilities (including reading, spatial, metacognitive abilities, etc.), and build up their visual literacy are all missions for teachers.

We found that most participants surfed the web following the sequence of search result lists and became bored or frustrated after viewing a small number of links. Only good readers were capable of selecting satisfactory materials when facing numerous retrieved outcomes; hence, the ranking and clustering functions of search engines seemingly need improvement. In particular, on meta search engines, the volume of search results is greater than other general search engines. The sequence and classification of search results can correspond to the individual differences of users even more. Otherwise, users may fail to find the information that they want when facing massive search results. The authors suggest that search engine designers create interfaces or algorithms that (a) present large bodies of search results in ways that are easier for users to comprehend by, for example, classifying search results according to correlation; (b) help users narrow their searches to reduce information complexity according to their individual information needs or cognitive abilities, for example, AI technologies can be used to differentiate individual abilities (e.g., reading, spatial or visual literacy) and Internet usage habits (e.g., viewing result pages and keyword usage), to provide appropriate auxiliaries; and (c) predict users' search intentions, for instance, after users have chosen their first keywords, instead of forcing them to filter large amounts of search results, search engines could be designed to recommend related information or search results.

Currently, search engines are trending towards hybrid or multimedia search engines. Thus, it is possible for users to input not only keywords but also images, videos and audio in order to search for information by comparing more sets of metadata. The search results are likely to be more diversiform, and the search processes of searchers may be different. Search engine designers need to consider how users construct mental representations when performing multimedia searches, how complex information negatively affects performance, and how to alleviate users’ working memory loads. For example, search engines can provide more personalized functions in terms of inquiry strategies, filtering techniques, and multiple media indexing or provide some functions that are enabled or disabled by users’ inclinations. However, it remains to be examined whether these new functions support greater search result accuracy or simply impose additional cognitive burdens. Future research can further investigate whether there are other cognitive abilities affecting the search performance of multimedia search engines, leveraging this research as a cornerstone.

This study acknowledges at least one study limitations. The author simply adopted the model driven methodology to explore search behaviors and performance in accordance with individual differences measured through various questionnaires. Future research can further adopt the data driven methodology to investigate individual characteristics in accordance with search behavior patterns collected through artificial intelligence technologies. Thus, the results of these two methods can be cross-referenced and it can enhance accuracy of this study.

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