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Using Concept Map to Evaluate Learning by Searching

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Abstract

We defined learning while searching and browsing on the Web as "learning by searching." We used concept map to evaluate how users' knowledge structure changed as a result of their learning by searching. The influence of different topics and different scenarios was also investigated. In the experiment, participants were divided into divergent and convergent scenario groups. They were asked to assume the role of a journal editor and search for information to be presented at an editorial meeting. They performed two tasks within the topics of environment and travel. We compared the two concept maps drawn by the participants before and after the search and analyzed the web pages browsed by the participants during the tasks. The results showed that the participants' knowledge representation dynamically changed through learning as a result of searching, and the topics and scenarios influenced their processes and changed their conceptual structures before and after searching.

Keywords: Concept Map; Knowledge Structure; Information Seeking on the Web; Learning by Searching

Introduction

Searching on the Web is more than just a tool for information retrieval; it has used a tool for investigating, learning, and decision making. For instance, when people buy a new digital camera, they often search and browse many digital camera sites. During these activities, they learn and acquire knowledge about digital cameras (i.e., function, structure, price, design, and size). We define this learning through searching and browsing on the Web as "Learning by Searching."

Learning by searching is considered a type of discovery learning. Discovery learning is inquiry-based, constructivist learning. The learner discover facts and relationships and new truths on their own (Bruner, 1967). Discovery learning facilitates the learner's spontaneous motivation and encourages discovery, as compared with learning by teacher instruction only. However, discovery learning is difficult for learners and research suggests that the effects of discovery learning are influenced by learning processes and the learner's skill or motivation. Learning by searching is considered to have the same benefits and problems as the discovery learning, but the factors that affect learning by searching have not been investigated. In this study, we focus on search topics and problem

contexts, and investigate how people acquire knowledge during their search and what influence search topics and situations have on their knowledge.

We used concept maps to evaluate the knowledge acquired by the users and how their knowledge structure changed as a result of their searching for information on the Web. The concept map is a graphical representation that allows people to explicitly represent their knowledge (Novak & Gowin, 1984). The concept map consists of concept words, arrows that connect the concept words, and linking words (link labels on the arrows.)

Concept maps have been used as measures to assess learners' knowledge and understanding. Meagher (2009) reported that the graph structures of concept maps became more complex from the first class in a course through the final exam. Rebich and Gautier (2005) also showed that the total number of useful items on post-course maps increased, while the total number of weak items and misconceptions decreased. Concept maps are also used to compare expert knowledge structures with novice knowledge structures. Chi, Feltovich, and Glaser (1981) compared the categories used by experts and novices and their explanations about the problems to examine the relationship between categorization and representation of physics problems. They drew concept maps to compare expert explanations with novice explanations.

Some research on information seeking behaviors has used concept maps as a means of measuring the change in a learner's knowledge. Vakkari and Pennanen (2003) explored how a student's conceptual structure is related to search tactics and search success. They reported that, between the beginning and end of the overall task, different features of the student's conceptual structures were connected to search success in terms of the useful documents they found. Cole, Lin, Leide, Large, and Beheshti (2007) focused on how students' mental model diagrams for a topic were represented in an early exploration stage of the information-seeking process and they suggested a 12-category classification schema of the mental models. Our previous researches also have studied



Figure 1: Concept map drawn by a participant for the environment topic in the divergent scenario.

how a user’s concept map differs before and after a search (Egusa et al., 2010). A comparative analysis of the pre- and post-search concept maps indicated that users significantly changed their knowledge structures on a topic through learning by searching. However, there has been little research using concept maps as a measurement of how the user’s knowledge has changed through the search process. Our final goal is to explore what and how people learn through searching and how their search processes influenced their learning.

Methods

Experimental Design

In the experiment, we focused on the influences of the topics (environment and travel) and scenarios (divergent and convergent). The participants were assigned to a factorial experiment that included two topics as within-subjects factors and two scenarios as between-subjects factors. The two within-subjects factors were counter-balanced.

Participants

Thirty-two undergraduate students aged 20 to 23 years participated in this study (sixteen male and sixteen female). Partic-

ipants were recruited from various departments and universities in the Tokyo area. We selected participants who didn’t have much experience and knowledge on the topics based on their responses to a pretest questionnaire. They were divided into two scenarios equivalent as to age, sex and major.

Topics

The participants were instructed to assume the role of a magazine editor and to gather information on the Web in preparation for a regular magazine series on environmental and travel topics. The environment topic required the participants to introduce various environmental issues, while the travel topic asked them to present various destinations for one-day trips from Tokyo.

Scenarios

There were two scenarios, divergent and convergent. In the divergent scenario, the participants were required to gather web pages for a series of articles to be a regular feature of the magazine. In the convergent scenario, they were required to gather pages for a single article of the regular feature. We prepared tasks for each scenario of the two topics.

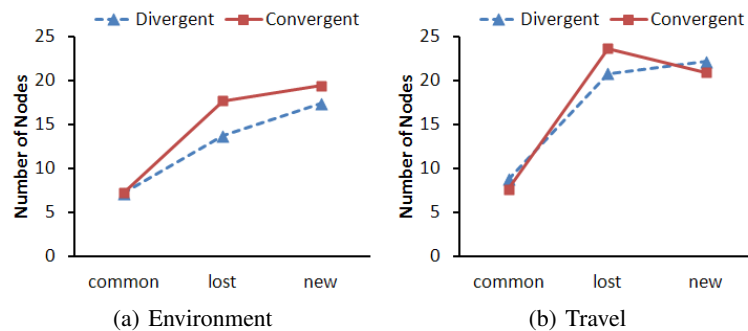


Figure 2: The average number of common, lost, and new nodes in each task.

The instruction sets for the environment topic using the divergent scenario and the travel topic using the convergent scenario are shown in Appendix A and Appendix B, respectively.

Procedures

The participants answered questions about their experience using web search engines and the Internet on a search-experience questionnaire. They were instructed on how to create the concept maps and were given time to practice. They then received their task instructions and drew a concept map for the assigned topic with a 10-minute time limit. A blank sheet of paper with a single node of the topic, either environmental issues or one-day trips from Tokyo, was provided for drawing the concept map.

After drawing the concept map, the participants conducted a 15-minute search task. While performing the search task, the log data were recorded using a plug-in software developed by our group. After completing each search task, the participants were required to again draw a concept map about the assigned topic and to answer questions about their prior knowledge of the task, their interest in the topic, the difficulty of the task, and the difficulty gathering information. They were also asked to provide comments on the task. They then repeated the task for the other topic, from the instruction stage to answering the questionnaire.

After the two main tasks were completed, the participants answered questions comparing the two tasks and the changes in their knowledge after completing the task, and then were asked to comment on how they felt about the changes between the two concept maps, i.e., before and after the web search.

In the final session, the participants were asked to check whether the same concept could be found on both concept maps and, if such corresponding concepts were found, they were assigned the same number.

Results

We analyzed the two (before and after search) concept maps drawn by the participants to examine whether their knowledge representation of the topic changed. We also analyzed the web pages browsed by the participants during the tasks to

investigate the relationship between the participants' conceptual changes and their search behaviors.

Numbers of Common, Lost, and New Nodes

Figure 1 shows the concept map drawn by a participant for the environment topic in the divergent scenario. The node enclosed in a double line show the center node. The nodes enclosed in a dotted line with the same number show that the participant checked these nodes as having the same meaning in the final session.

We defined three types of change between the participants' pre and post-search concept maps. The nodes that participants identified as having the same meaning in the pre and post-search maps were defined as common nodes, nodes existing only in the pre-search map were defined as lost nodes, and nodes first appearing in the post-search map were defined as new nodes. We then analyzed the number of common nodes, new nodes, and lost nodes. For instance, Figure 1(a) has four common nodes, 13 lost nodes, and 22 new nodes.

Figure 2 shows the average number of common, lost, and new nodes in each scenario of the two tasks. A 3-way mixed ANOVA (analysis of variance) with scenario as a between-subjects factor and topic and type of change as within-subjects factors revealed that there is significant interaction between topic and type of change ($F(2,60)=6.56, p < .01$). The number of lost and new nodes in the travel topic were more than those in the environment topic (lost: $F(2,60)=21.98, p < .01$; new: $F(2,60)=8.81, p < .01$). There also were differences among the three types of change. In the environment topic, the number of new nodes was more than the other two types of nodes and the number of common nodes was less than the other two types of nodes ($F(2,60)=41.21, p < .01$). In the travel topic, the number of common nodes was less than the other two types of nodes ($F(2,60)=49.93, p < .01$).

In total, there were few common nodes and a relatively large number of lost and new nodes. These results suggest that the concept maps changed greatly after the web searches were conducted.

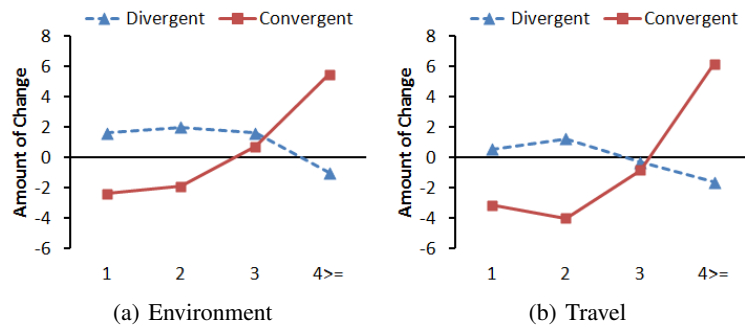


Figure 3: The differences from pre to post-search in the number of nodes at each distance.

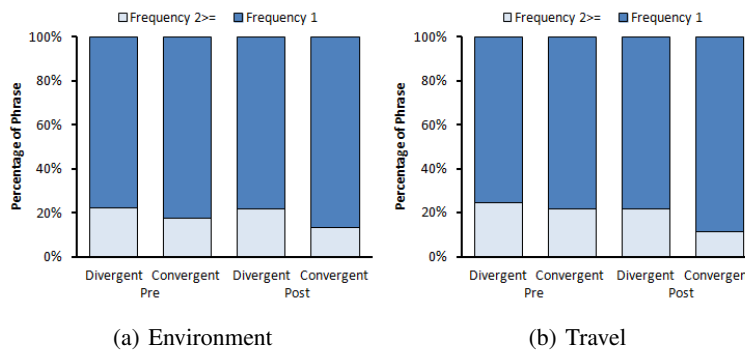


Figure 4: The percentage of phrases with a frequency of 1 or more than 2 for each topic.

Number of Nodes at Each Distance from the Center Node

Regardless of the scenarios and topics, the participants' maps changed dynamically before and after searching. Next, we examined whether or not there were any differences in the position of each node in the map between scenarios and topics.

To analyze differences in the position of each node, we defined distance in each node. Distance in each node is measured by the number of arrows following the center. Nodes that were linked to more than two nodes and had more than two distances were counted at each distance. We counted the number of nodes at each distance from the center node, that is, the node placed at the center of the concept map. Nodes at distance 4 or higher were counted as in the same category. Moreover, to clear the differences between scenarios and topics, we calculated the amount of change for each distance from the pre to post-search maps by subtracting the number of nodes at each distance in the post-search map from those in the pre-search map. If the number of nodes in the post-search map at distance n was more than that in the pre-search map, the amount of change at distance n was considered a positive value.

Figure 3 shows the amount of change at distances 1, 2, 3, and 4 or more for the two topics in each scenario. A 3-way mixed ANOVA with topic and distance as within-subjects factors and the scenario as a between-subjects fac-

tor revealed significant interaction between scenario and distance ($F(3,90)=14.40, p < .01$). The amount of change at distances 1 and 2 in the divergent scenario occurred more than those in the convergent scenario (distance 1: $F(3,90)=27.90, p < .01$; distance 2: $F(3,90)=14.23, p < .01$). Differences were also found for each distance in the convergent scenario. The amount of change at distance 4 or more was more than the other distances ($F(3,90)=16.80, p < .01$).

Frequency of Phrases Used in Nodes

The position of the nodes in the map were different for the two scenarios. However, it is unclear whether or not these differences were also found in the phrasing used by the participants. We therefore compared the changes in the phrases used in the maps between the two scenarios and the two topics.

Before making our analysis, we extracted phrases included in nodes from the participants' concept map. These were phrases in both the pre and post-search maps put together with respect to each scenario and topic. Because these phrases were spelled in several different ways, we adjusted the differences based on the rules listed below. Finally, we counted the frequency of the phrases.

- phrases expressed in different forms, such as "東京", "とうきょう", and "トウキョウ" (These phrases all mean "Tokyo.").

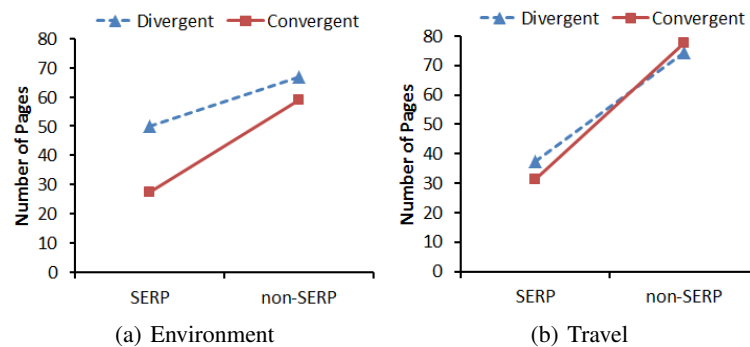


Figure 5: The number of SERP and nonSERP in each topic.

- phrases expressed with or without a particle, as in “海面の上昇” and “海面上昇”.
- phrases expressed in abbreviated form or not, such as “eco” and “ecology.”
- phrases with typographical errors.

Figure 4 shows the percentage of phrases used once and more than twice in each task. On the whole, 80 % of phrases were used only once. The results of the χ^2 test revealed significant differences between the two scenarios in the post-search map (Environment: $\chi^2(1)=6.810, p < .01$; Travel: $\chi^2(1)=13.181, p < .01$). The number of phrases occurring once in the convergent scenario was greater than those in the divergent scenario for the two topics and the number of phrases with a frequency of more than two in the convergent scenario was less than those in the divergent scenario for the two topics. There were no differences in the pre-search map.

Number of Web Pages Browsed

Finally, we examined the relationship between the participants’ conceptual changes and their search behaviors. We focused on the web pages browsed by the participants during the task because their conceptual changes would be most likely influenced by them. We extracted the web page URLs from the browser logs. These URLs were classified by a logging tool as a search engine result page (SERP) or some other page (nonSERP).

Figure 5 shows the average number of SERPs and nonSERPs for each topic. A 3-way mixed ANOVA with topic and page type as within-subjects factors and scenario as a between-subjects factor revealed a significant interaction between topic and scenario ($F(1,30)=7.08, p < .05$). In the environment topic, participants in the divergent scenario browsed more SERPs and nonSERPs than participants in the convergent scenario ($F(1,30)=10.27, p < .01$). In the convergent scenario, participants browsed more SERPs and nonSERPs for the travel topic than the environment topic ($F(1,30)=9.39, p < .01$). A significant interaction was also found between topic and page type ($F(1,30)=15.13, p < .01$). The participants browsed more nonSERPs for the travel topic than the environment topic ($F(1,30)=12.55, p < .01$). The number of SERPs

was more than those of nonSERPs for the two topics (Environment: $F(1,30)=18.16, p < .01$; Travel: $F(1,30)=42.20, p < .01$).

Discussion

We defined learning during searching and browsing on the Web as “learning by searching.” We investigated how searchers’ conceptual knowledge of topics changed by comparing their before search and after search concept maps. The influence of different topics and different scenarios was also investigated. In the experiment, participants were divided into divergent and convergent scenario groups. They were asked to assume the role of a journal editor and search for information to be presented at an editorial meeting. They also performed two tasks under the topics of environment and travel.

We analyzed the before and after search concept maps drawn by the participants to examine whether their knowledge representation of the topic changed during the search. The results show that their concept maps dynamically changed after the search regardless of the topics or scenarios. Egusa et al. (2010) also reported the same results. These results indicate that searching and browsing web pages strongly influences a searcher’s knowledge structure of a topic. Why did their conceptual structure change so dramatically? One likely reason is that the participants searched and browsed web pages that suited their interests, which allows them to easily build new knowledge onto their existing knowledge base. An alternate reason is that they had this knowledge already and they reconstructed their knowledge through learning by searching. However, these changes might be temporary and forgotten with the passage of time. We need to further examine the continuousness of learning by searching.

Results also demonstrated the influence of topics and scenarios. The number of lost and new nodes in the travel topic was greater than those in the environment topic. These results indicate that there are differences in the knowledge structures for the topics and that the concept map can represent these differences. Cole et al. (2007) also found the differences between the concept map drawn by history students and those by psychology students.

Differences between the scenarios were found in the node distances and phrase frequencies. In the divergent scenario, nodes placed near the center increased and nodes placed far from the center decreased. On the other hand, nodes placed far from the center increased in the convergent scenario. As can be seen from the examples in Figure 1, the node concepts changed from general to specific as distance from the center node increased. Therefore, the participants in the convergent scenario acquire specific knowledge while the participants in the divergent scenario acquire general knowledge. A similar tendency was seen in the analysis of the frequency of phrases used in the nodes. In the convergent scenario, the phrases used once increased and the phrases used more than twice decreased.

We also analyzed the web pages browsed by the participants during the tasks to investigate the relationship between the participants' conceptual changes and their search behaviors. Differences between the scenarios were only seen in the environment topic. The number of SERPs and nonSERPs in the divergent scenario was greater than those in the convergent scenario. This indicates that the participants in the divergent scenario searched and browsed quickly to gather a wide scope of information about the environment topic, while the participants in the convergent scenario browsed web pages more minutely to gather detailed information about the specific theme of the environment topic. We presume that these web page results relate to the above concept map results. However, with the travel topic, we could not find differences between the scenarios. We must analyze other process data to explicitly capture the relationship between the searchers' search processes and the changes in their knowledge representation.

Finally, we discuss on the significance of our study. In this study, we compared different scenarios about the same topic. We found that these differences of scenario influenced breadth and depth of searching and quality of knowledge acquisition. In the discovery learning, it is also important to explicit relationship between how students explored and what they learned for helping students learn and discover effectively.

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Appendix

A. Instructions for environment in divergent scenario

Please carry out this task as if you were in the following situation: You are working as an editor for a news magazine published by a national newspaper. Your chief has asked you to gather information to introduce various environmental issues for a regular series that will begin with the next issue. The chief will hold a meeting with other managers from several departments to discuss this regular series.

In the meeting, the chief would like to present an overall picture of each article for the series. For that purpose, you must gather various pieces of information that are sufficient for discussing which topic should be selected for each article of the series, rather than gathering detailed information for just a single article in the series.

Please choose the most interesting topics for the readers. You have just 15 minutes to search the Web and find the needed information. If you find a useful web page for the topic, add it to the bookmarks.

B. Instructions for travel in convergent scenario

You are working as an editor for a travel magazine published by a major publishing company. Your chief has asked you to gather information to introduce various one-day trips for a regular series that will begin with the next issue. The chief will hold a meeting with other managers from several departments to discuss this regular series.

In the meeting, the chief would like to present the specific contents for one article of the series. For that purpose, you must gather detailed information for a single article of the series rather than information for several trips.

Please choose the most interesting topics for the readers. You have just 15 minutes to search the Web and find the needed information. If you find a useful web page for the topic, add it to the bookmarks.