Using Concept Maps for Information Conceptualization and Schematization in Technical Reading and Writing Courses: A Case Study for Computer Science Majors in Japan

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Abstract

In this article, we argue for the importance of using concept maps in an advanced technical reading class offered for computer science students. This article presents a strong argument that use of concept maps should be integrated effectively with traditional document conceptualization and production techniques. Assignments based on designing concept maps in a technical reading classroom should address the use of knowledge models like concept maps and should be integrated effectively with technical writing assignments. This study reports that readers think concept maps and the associated software are effective tools for comprehending technical details, and they prefer to use various strategies (when they are part of the class design) to dissect the technical text to be used in concept maps. Readers' self-reports also suggested that readers used concept maps for a variety of reasons.

Keywords: *Concept maps, Knowledge models, CMAPTools, technical writing, procedures.*

Introduction

We often need visualization tools to represent complex information in logical and simple ways. Concept mapping is one such technique. However, its optimal use in a variety of contexts, like language and information processing ability of the user, needs more research. A concept map is a constructivist technique to demonstrate the relationship between different concepts. A concept map is not only a learning tool but also an evaluation tool, thus encouraging students to use meaningful-mode learning patterns [1].

In this article, we discuss a specific learning context. For a production-oriented class like technical writing for computer science, there is not much research to indicate the use of concept maps for schematic visualization techniques demonstrating logical concepts that relate to explaining programming languages, relationships within and between databases, logistics of circuit design, etc. On a simpler level, concept maps often are used for general brainstorming purposes, initial conceptual framing, collaborative knowledge modeling, communicating complex ideas and arguments, and examining the symmetry of complex ideas and arguments related to networked topics.

In order to understand how concept mapping might aid the process of mastering technical writing skills for computer science majors, it is important to understand that technical writing does not deal only with the process of simplifying technical documents for end users (e.g., user manuals, quick guides, help files, etc).

A sub-genre of technical writing also caters to professionals in the field (e.g., user manuals for hardware technicians, software manuals for programmers who will develop the next version of the software, etc). Computer Science majors most often would be interested in writing programs, schematics, hardware designs, etc., for fellow professionals in a way that records not only the core of the argument itself but a logical and sequential flow in its argumentative presentation whereby the readers are able to see and scan through the inter-relationships among different elements in the design and/or the argument. This presentation is not about simplifying complex arguments for end users where by information might conveniently be censored based on end-user analysis but rather simplifying the presentation in a way such that the most complex information surfaces in the most convenient way for it to be used appropriately. However, do EFL readers have the expertise to process technical text or language in English for document production activities using concept maps? In order to answer this question, we first need to explore whether EFL readers have the expertise to process information by reception, e.g., to be able to process information from technical text.

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In order to achieve this goal, this article discusses results from a specific study in which concept maps have been used in technical reading classes with students in computer science to find out whether readers have the expertise to process and analyze logically information types in Computer Science using concept maps. For this study, readers were expected to be able to dissect textual information in specific ways, in addition to understanding the specific topic in computer science.

The technical reading class acts as a sort of prerequisite for the technical writing class. For the above-mentioned reasons, the current design of the curriculum in the technical reading class used concept maps before students could use them efficiently in technical writing classes. When English is a foreign language for students, it is important for readers to be able to read and process complex technical information accurately before they can produce the content as well as the schematics of the concept map. As part of the technical reading class, students do not produce the content of the topic; they only produce the concept map in a logical sequence. For the technical reading class under discussion in this paper, concept maps have been used extensively with a variety of computer science topics.

Before we delve into how concept maps are used in a technical reading class, it is important to discuss the cognitive framework in engineering education, how concept maps are used for learning, information representation, and assessment, and the scope of using concept maps in technical writing classes, so that it is easier to understand how concept maps can be used logically in the context. This discussion will make it easier to understand how students can be graduated from technical reading to a technical writing class in a second-language (EFL) context.

Literature Review

The development of procedural knowledge in students, i.e., the ability to solve domain problems effectively, is a major goal of instructional designers in engineering education. Recent initiatives in engineering education have adopted a cognitive framework for designing and implementing studies of student learning behaviors and outcomes. Cognitive theorists are of the opinion that acquiring and using declarative knowledge is essential for effective performance in skilled problem solving,. However, problem solving largely is procedural, i.e., action-oriented knowledge, and draws on a distinct form of memory that stores procedural knowledge. Litzenger et al. [2] have stressed the structured nature of setting up, solving, and checking the equations involved in problem solving. Researchers assert that skill is the result of declarative knowledge being integrated and transformed into procedures in a continuous process of refinement over time, as the result of deliberate practice on the part of the learner [3]. Our primary question for this article concerns how graphic knowledge models can be used systematically for procedural information visualization. In order to understand the different applications of graphics oriented knowledge models in demonstrating both declarative and procedural knowledge, it is important to understand what knowledge models represent and the common practice for developing cognitive framework through information visualization.

Concept Maps in Science

A model is an intellectual construct in artifact form that provides an abstract, highly formalized, often visual, and simplified representation of a phenomenon and its interactions [4, 5]. There are three types of models: mathematical models, descriptive models, and graphic models [6]. Graphic models use diagrams and symbols to illustrate simple and complex relationships. Often, graphic knowledge models are represented as a set of concept maps and associated resources about a particular domain of knowledge. Concept maps are a result of Novak and Gowin's [7] research into human learning and knowledge construction.

Concept maps are a graphic two-dimensional display of concepts, connected by directed arcs encoding brief relationships between pairs of concepts forming propositions [8]. Abstract Concept mapping has been applied in a variety of fields, including instruction, learning, curriculum development, and assessment (Chang, Sun, Chen, 2001). Concept maps can be represented using *CmapTools*.

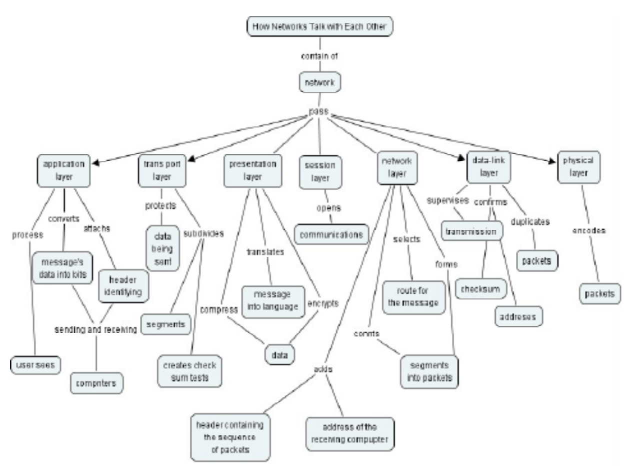

Figure 1. Example of a concept map

CmapTools provide a rich collection of features that help users easily construct Knowledge Models and publish and share them through servers or the worldwide Web [9]. Figure 1 shows an example of a concept map used in my technical reading class.

CmapTools are important applications in the engineering curriculum because of their focus on procedural knowledge and product interface design. Overall patterns in concept maps were found to be indicative of cognitive status. However, many other concept-based graphic tools are conceptually identical but differ in the way they focus on object identities, relationships between objects, and their structural and functional roles.

Assessment with Concept Maps

Ruiz Primo and Shavelson [10] examined the validity of claims that concept maps measure an important aspect of students' knowledge structures. Rice et al. [11] conducted an important study on assessing the use of concept maps. The results of the study suggest that a concept map might be used in assessing declarative and procedural knowledge, both of which have a place in the science classroom. One important implication of these results is that a science curriculum and its corresponding assessment need not be dichotomized into knowledge/comprehension versus higher-order outcomes. Research by Ruiz Primo and others [12] has reported the results of a study that compared two concept-mapping techniques, one high-directed, fill-in-the-map, and one low-directed, construct-a-map-from-scratch. High-directed and low-directed maps led to different interpretations about students' knowledge structure. Whereas scores obtained under the high-directed technique indicated that students' performance was close to the maximum possible, the scores obtained with the low-directed technique revealed that students' knowledge was incomplete compared to a criterion map. They concluded that the construct-a-map technique better reflected differences among students' knowledge structures.

Research [13] indicates that more teachers are inclined towards the potential to implement student-centered, inquiry-based approaches to learning. Assessing what each student knows in a broad subject area, such as science, is difficult. To meet the challenge, the authors chose to assess student learning using an open-ended concept map activity combined with a rubric that extracts quantitative information about the quality of understanding from each map. Research by Chularut and DeBacker [14] investigated the effectiveness of concept mapping used as a learning strategy with students in English as Second Language classrooms. Results indicated that there is significant influence of concept mapping on achievement, self-regulation, and self-efficacy in students.

Training with Concept Maps

Concept mapping without training is very difficult for beginners [15]. Without adequate training, students might not be able to structure and integrate the information in a proper way. Training is a key factor in producing a favorable outcome. Research [16] also has shown that students who worked with concept maps, after correcting mistakes in a worked out concept map example, produced better results with text comprehension than students who constructed concept maps with or without training. Results indicate that worked out examples showed positive effects on learning outcome.

Concept Maps for Text Analysis

Traditional research [17] has emphasized how the presence of signals like titles, headings, previews, overviews, summaries, typographical cues, recall sentences, number signals, importance indicators, and summary indicators in technical text affects subsequent memory for the text. Virtually all types of signals produce better memory for information they cue in a text, whereas memory for unsignaled information often is unaffected. Research [18] also has indicated that top-level rhetorical organization of expository texts and culturally familiar context in text significantly increases the amount of information that EFL students can recall and their overall good reading comprehension. So, is it possible for concept maps to facilitate the process of high-level rhetorical organization of the text?

A study by Anderson and Huang [19] examined the feasibility of using concept maps as a measure of content achievement; and whether these measures were sensitive to knowledge learned after reading expository text. Subjects were taught a mapping technique that required them to analyze ideas into propositions and then arrange them into concept maps. Results showed that most students from all ability groups learned to use the mapping technique.

Research [20] indicates that little is known about the specific cognitive processes that are responsible for concept mapping effects when technical text is read. Effective learners showed much effort in planning their mapping process and constructing a coherent concept map. These strategies were more evident in students with prior concept-mapping experience ("advanced beginners") than in those who had not used this learning strategy before ("successful beginners"). Based on the present findings, suggestions were developed for a direct training approach (i.e., strategy training with worked-out examples) and an indirect training approach (i.e., supporting the learners with strategy prompts).

Concept Maps for Technical Writing

Research [21] indicates that writing achievement and creativity are linked and that writing achievement and concept mapping connectivity are linked. However, there is no conclusive evidence for linking concept-mapping connectivity with creativity. Findings show that concept mapping components increase post-test and that concept mapping ability can be evaluated using a connectivity index that may have some predictive value in assessing writing achievement. In this context, it would be useful to see how technical writing assignments are used in conjunction with concept mapping techniques.

Increasingly, technical writing is seen as an integral part of science, engineering, and computer science curricula. An integrated approach to teaching technical writing in the computer science classroom requires improving student writing, student motivation, appropriate writing assignments, strong evaluation standards, and productive instruction techniques. Effective technical writing has certain distinguishing qualities: a clearly defined audience and purpose, careful organization and development of ideas, and a concise and accurate style [22]. Students can develop these qualities best (for example in a computer science environment) when writing assignments are discussed logically and instructions are presented in the realistic context of problem solving. It is my contention that combinations of individual and collaborative thinking and design for procedural assignments based on knowledge models are efficacious ways to develop students' understanding of the logical structure in the document.

Lessons and activities in a technical writing class generally include business and communicative English, besides instructional design issues (organization, formatting, typography, layout, visual design, etc.) for end-user documentation. In a typical technical writing classroom, a majority of the time is spent on designing instructional manuals, help files, quick guides, documenting general or laboratory-based reports, proposals, letters, and resumes. These are essential components in a general technical writing class. However, when technical writing is offered as part of a support curriculum for engineering and computer science majors, research findings suggest that there should be more emphasis on document design strategies that helps conceptualize, visualize, represent, and solve problems for complex procedural tasks. If the purpose is for computer scientists to process and create software or hardware documentation to be used by other computer scientists, more emphasis should be placed on the modeling of concepts and procedures for documentation purposes. I suggest that the traditional document design techniques (used in a traditional technical writing class) can be integrated effectively with information conceptualization and visualization strategies to create effective instructional materials for engineering and computer science majors.

Knowledge engineers typically make use of a number of ways of representing concepts when acquiring knowledge from experts. This paper discusses how the techniques for representing knowledge can be used effectively in a technical writing classroom for the conceptual understanding of a problem and as a visualization strategy for complex technical documents. The motivation behind using the knowledge models for an engineering/computer science-based technical writing class is based on the importance of understanding different knowledge representations in an engineering/computer science document and the fact that the ease of solving such a problem is determined almost completely by the way in which the problem is conceptualized and represented.

Using knowledge models to support the conceptual understanding of the document context can be referred to as the hybrid approach because a technical writing class generally is considered a production-based class (authoring documents) but reception (reading and comprehending technical documents systematically inside a logical structural representation) often is overlooked. This article argues that knowledge models provide a framework wherein both production and reception activities can and should be integrated within the scope of a technical writing course offered in engineering and computer science schools.

The focus of a technical writing class is structured mostly on documentation. However, when a technical writing course is offered as part of the engineering discipline, technical writing teachers also should focus on knowledge models to facilitate both local and global conceptualization and spatial understanding of the information. When a technical writing course is offered as part of a science or engineering curriculum, there should be adequate focus on logical and conceptual understanding and representation of procedural knowledge. In other words, students in an engineering oriented technical writing class also should learn the techniques of text analysis.

Researchers have claimed that concept maps provide a measure of structural knowledge. Concept maps have been used widely in education as pedagogical tools and as assessment devices. In education, teachers often use concept maps as tools to identify those specific areas within the curriculum that should be modified and perhaps re-authored in order to facilitate a better understanding of the subject matter. Human visual/spatial problem solving often requires both global and local information to be processed. But the relationship between those two kinds of information and the way in which they interact with one another during problem solving has not been discussed thoroughly [23]. The limitation of the current practice seems to be that concept maps most often are used to focus on declarative knowledge. However, research suggests that procedural knowledge also is structured in a way that can be represented by networks [24]. The type of concept map depends on how students understand the text and procedure/design. If students understand the design process as a series of phases, they will adopt a linear pattern in presentation to describe the sequence of events. However, the limitation of such an approach is that students will not cover the iterative and complex nature of the process; neither will they understand the richness of the association between nodes [24]. However, if students understand the richness of the text and the complexity of the process, they will be in a position to judge the nature of concept map to use in order to explain the concepts. But it often might be a better strategy to use varieties of concept maps as learning tools to point out the complexity of the text and association between different key players in the text. This not only will help students to build up a structured mental orientation for any given text, but they also will be able to analyze any text conceptually and end up with a more complete analysis. Using concept maps with a wider role (combining local and global perspectives) and using the declarative and procedural elements of the text can help students see how the declarative and procedural knowledge can coexist in the way the content is presented and understood. The focus is on designing the technical writing assignments using various knowledge models (concept maps) in such a way that students can comprehend the content of the text better. This is a relatively new area of application in a technical writing class.

Integrating Knowledge Models with Technical Writing

Mostly, a technical writing class housed in an engineering or computer science school is expected to be production oriented (generally true of any technical writing course) whereby students author a technical manual, a technical business proposal, laboratory report, etc. However, in EFL environments, before moving into direct authorship, it often makes sense to conceptually and logically understand how a document is authored. Is there any structured and universally acceptable way to do it within the scope of a technical writing class? The answer is NO. In other words, technical writing teachers in EFL-based environment first should spend a reasonable amount of time helping students to dissect a technical text in various analytical ways.

Knowledge models, if properly valued and used, can provide one such analytic tool. Generally, the idea is to start comprehending and analyzing a document (an example) first, using knowledge models, as a receptive activity, and then move into the production of a similar document. Students might be handed examples of a laboratory report, a technical business proposal, and a technical manual and given several questions to answer for each type. Each type of document can be a separate project. Each project is developed into two stages.

1. ***Reception Activity***: Students analyze an already authored example of technical document using knowledge models.

A. Study the variety of knowledge models.
B. Read through the example of technical document handed out.
C. Decide on the set of knowledge models to use for analyzing the document logically.
D. Complete an analysis of the text using the knowledge models.

2. ***Production Activity***: Students author a technical document from scratch based on their experience of understanding a similar example using knowledge models.

A. Students start authoring a technical document from scratch.
B. As a first step, students brainstorm and storyboard the core idea of the document as a knowledge model. In this step, authors not only storyboard the content and represent it visually as knowledge models, but also use flow charts (visualization techniques) to storyboard the overall layout of the document in the correct sequence.
C. Students author the content and decide to use knowledge models as sound visualization techniques for concept representation.

It now is important to see some of the current practice of using knowledge models.

Concept Maps for Technical Reading

Research results [25] have indicated that teachers place high value on reading as an important strategy to promote learning in science and that they generally accept responsibility for teaching content reading skills to science students. Results also indicated that science teachers generally reject the text-driven model of reading, but they usually do not have well-formulated alternative models to guide their teaching practices. Teachers have intuitive beliefs about science reading that partially agree with many research findings, but their beliefs are fragmented and particularly sketchy in regard to the cognitive and meta-cognitive skills required by readers to learn from science texts. In this context, it is important to explore whether concept maps help readers with logical schematization and comprehension of technical information.

Major Hypotheses

The following hypotheses are designed on the basis of the research mentioned above.

1. Students in EFL Computer Science environments can use concept maps effectively for dissecting technical text.
2. Readers adopt several specific reading strategies and prefer some level of preparation when developing concept maps.
3. Readers understand the design and purpose of the concept map assignment.

The Study

I ran a study with 24 junior-level students in Computer Science to explore the extent to which they found the concept map to be a useful tool for logical understanding and subsequent visual representation of topics in Computer Science. The students all are part of a technical reading class and are in the age group of 19–21. These students all have taken introductory courses in topics related to Computer Science and also can process information logically to a certain extent. However, their English skill is moderate at best; specifically, their reception skills (reading English) are better than their production skills (writing English).

Methods

In the current study, students in the technical reading class were exposed repeatedly to the concept maps over the semester before they participated in the study. Before explaining the design of the study, it is important for readers to understand the design of assignments.

During the semester, students used concept maps using the IHMC concept map software both as part of an individual assignment and as part of a group assignment. Let us explain how the individual and group CMAP assignments were organized. First, the entire class was divided into teams with four members.

Individual CMAP Assignment: Each person in a group has been assigned a different color. There are four colors so each person in a group will have a different color. Each color corresponds to an individual section of the textbook. So, for example, everyone in the class who has been assigned the color *RED* will all be reading the same section from the textbook. However, the members of his/her own group will have different colors, and hence will have been assigned different parts of the textbook to work with in class.

Group CMAP Assignment: As part of this assignment, every member in the group works on the same section from the textbook. Each group member has a role—these roles are self-selected and must be rotated. The roles are:

1. Vocabulary developer (key terms + definitions are added to final CMAP)
2. Designer (draws cmap/poster on paper in class)
3. Question maker (creates five questions that can be answered from the CMAP/poster. These questions are listed under the final CMAP/poster)
4. Submitter (uses CmapTools/html editor to complete the final version and submits it to Moodle)

Sample: As part of this study, 24 students in a technical reading class participated in an online survey in which they were asked about their experience with concept maps for the variety of technical topics that they dissected and analyzed over the course of the semester. Students handled two specific topics every week, one for an individual concept map assignment and another topic for a group concept map assignment, as mentioned above. In total, students handled 24 topics for 12 weeks during the semester. In other words, students participated in developing 24 concept maps over the semester. However, it also is important to remember that each student also developed questions and key terms for the group topic, besides participating in the concept map itself.

Major Questions in Survey: The online survey was designed to address a number of key questions.

1. The extent to which readers think of the concept map as an effective learning tool.

2. Do they understand the purpose of the assignment and how concept maps are used?
3. What kinds of strategies do readers adopt when reading technical text and representing the information as a concept map?

The survey that participants handled can be considered as a post-test analysis of their learning and comprehension over the semester. This survey was handed out as a homework assignment and participants were not timed; neither were they observed or identified individually when participating in this survey. The purpose of this assignment was not to measure individual reaction times as this survey did not measure any performance. Rather, the purpose was to measure self-reports on the questions asked previously.

Text Materials

Each week, the topics were arranged based on difference in content and not in terms of increasing order of complexity. Rather, the text for the topic was decided by keeping in mind that the length of the text, individual paragraphs, number of ideas introduced, and the numbers of key terms are more or less similar across the text types used for different weeks. Each week, readers were given two pages to read on a specific topic in computer science for the individual CMAP assignment. Students were observed when they completed the assignment. The text had pictures explaining specific procedures or sometimes showing a very general illustration, which does not necessarily explain the specific procedure discussed in the text. The text was written in short paragraphs with considerable white space in between. For each task (e.g., individual CMAP assignment, group CMAP assignment, etc.) readers were allotted 30 minutes to accommodate the different types of assignments scheduled for each week. It often was observed that readers did not finish the task within the stipulated time period and completed the assignment at a different time. Readers were told categorically that they should revise and read each sentence twice before deciding on the type of nodes that should go into the concept map. Readers also were given a demonstration of how a typical concept map looks for a similar topic that they handle every week. Students familiarized themselves with the example provided. I also mentioned the word choice to the students and said that they should not try to include every word in the sentence as part of the concept map. A very simple strategy that was explained and adopted was to dissect the text on the basis of noun-verb-noun. For example, the plug is connected to the wall.

Pilot Testing (Observational study): In reality, the students dealt with more complex types of sentences; pilot testing then suggested that they tried to follow the same strategy by dividing the text into two separate sentences and then drawing two nodes from the same noun or verb. To avoid being distracted with unnecessary words used in the sentences, they often scratched out the words in the text and then concentrated on the nouns and verbs that they eventually used. Students asked questions for the first two weeks but after that they could handle the text with greater ease, and self-efficacy improved. Students designed the concept maps in class as a rough sketch. They completed the assignment, revised it, and then posted it in the learning management system called Moodle as a JPEG or a PDF file. For the group CMAP assignments, students also familiarized themselves with the content of the text by asking important questions that represented the crux of the argument in the text, identifying key words and then finally designing the CMAP as a group activity.

These activities were not identified as isolated text-reading strategies. Rather, this group assignment was explained to the students in terms of these strategies been used as a build-up toward the concept map activity. This led to increased collaboration between students and higher level of discussion.

The questions in the survey were organized mostly as a likert scale, with the participants being able to choose only one option for the question (e.g., extent of use, rating concept map, etc.). However, there were a few questions were readers could click and choose multiple answers for the same question (e.g., concept map is used as).

Findings

After 15 weeks of using concept maps for individual and group activities, readers were asked whether they understood the design of the technical reading class. The question could have mentioned directly whether they understood the design of concept maps. However, if the class structure is not clear in the students' mind, it is difficult for them to complete the assignment successfully and post them in Moodle. This is because they need to collaborate each week with group members in specific ways, and complete the individual concept map activity based on colors, timings for posting the assignments, where and how to post it, etc. Figure 1 shows that almost all students understood the design of the class.

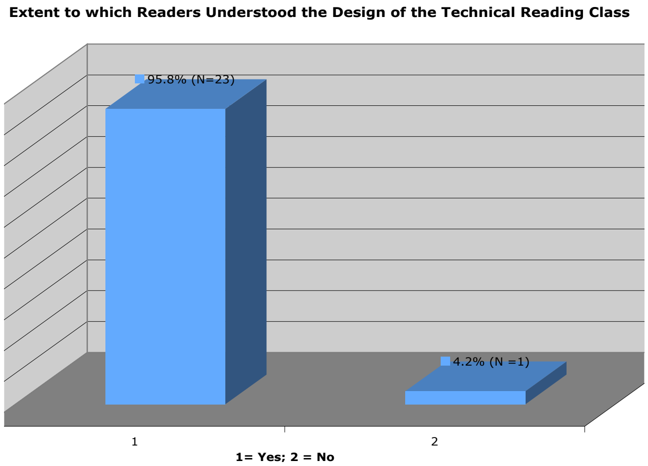

Figure 1. Extent to which readers understood the design of technical reading class

Conceptual Understanding and Language Skills

For drawing the concept maps electronically, readers used the IHMC CMAP software.

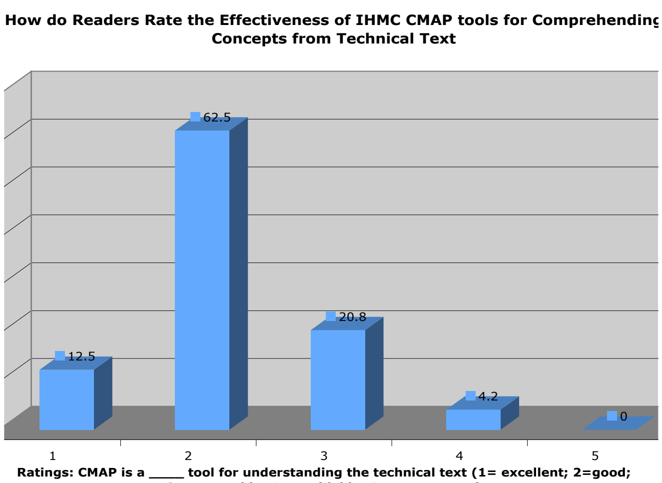

Figure 2. Effectiveness of IHMC CMAP tool for understanding concepts from technical text

Readers were asked how they rate this software for understanding concepts from technical text that they used throughout the semester. Figure 2 demonstrates that CMAP is favored for understanding the concepts in technical text. Figure 3 show that readers consider concept mapping a good technique for understanding technical text and developing reading skills.

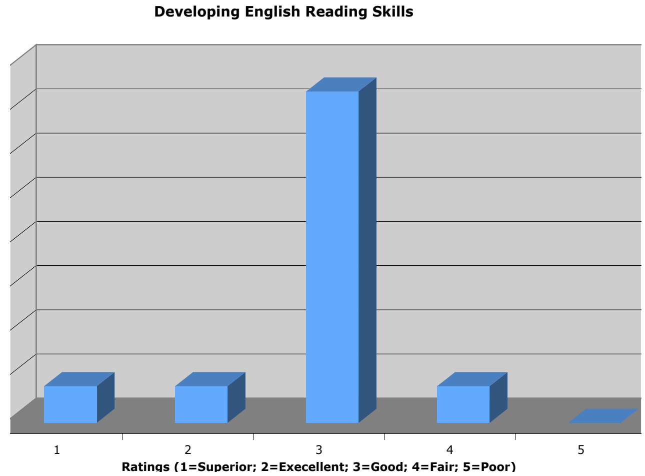

Figure 3. Concept Mapping to improve language skills

Readers then were asked about the purpose for which they think concept maps can be used. Figures 4 and 5 show the data.

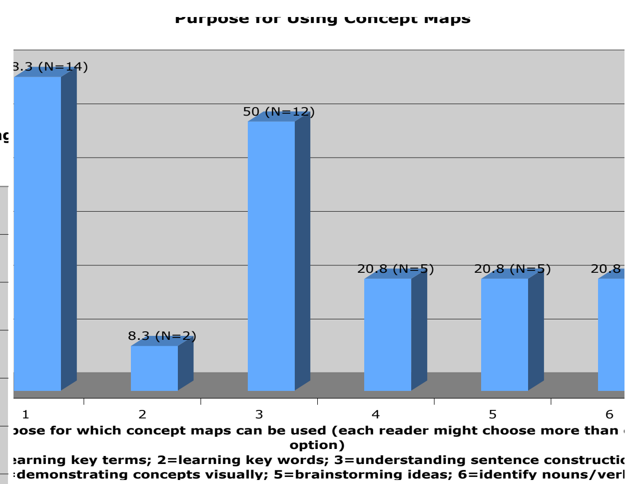

Figure 4. Purpose for using concept maps

The choices included all the options for which concept maps were used during the semester. Each reader could click all the options they think to be appropriate. Data in Figures 2, 3, 4, and 5 suggest that readers are quite clear about the purpose for which concept mapping is used and they think it to be a reasonably good tool for understanding concepts, the language in technical text, and developing English reading skills. From the data, it appears that most of the time, readers might have used the concept maps to identify words, nouns, verbs, organizing ideas, etc. In other words, a large percentage of readers have used concept maps for both micro- and macro-level analysis of the text.

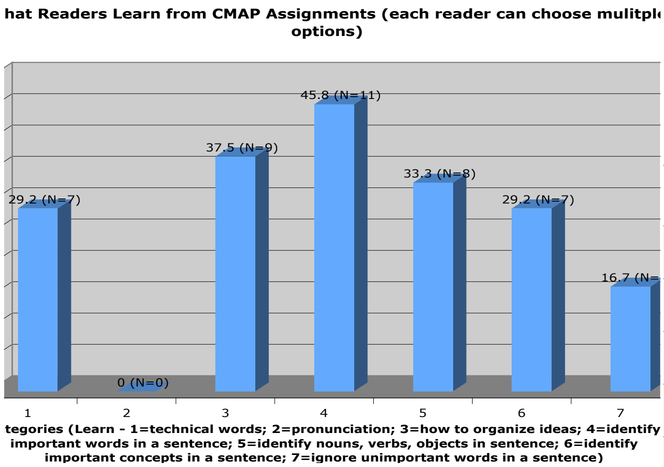

Figure 5. What readers learn from concept map assignments?

Strategy for Understanding Concept Maps:

It always is important for readers to have a thorough understanding of the text before starting to design concept maps. Figure 5 demonstrates whether any level of preparation actually helps or whether readers just analyze the text using one sentence at a time, without trying to get an overall feel of the entire topic first.

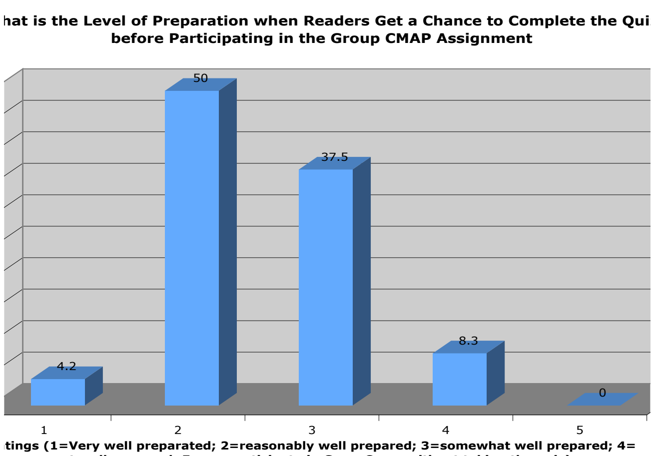

Figure 6. Readers' level of preparation when they take quiz ahead of Group CMAP

Data shows that it does help, but there still are questions that remain unanswered.

Reading Strategy when participating in CMAP assignment: Readers were asked how they handle the text as they go about designing the concept map. Figure 6 shows that readers most often handle one sentence at a time and then make a node for the concept map before moving on to the next sentence. However, a sizable percentage also has said that they read the entire text first before starting to design the concept map.

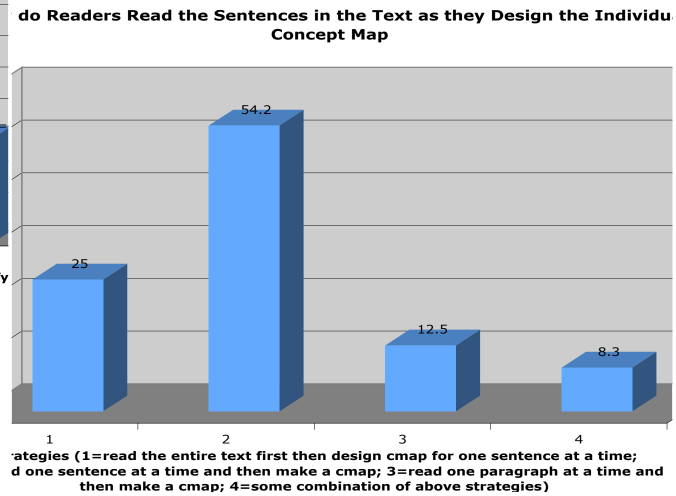

Figure 7. Strategies for reading sentences in the text as they design the individual concept map

Readers then were asked how they read the words in a sentence as they design the individual concept map assignment.

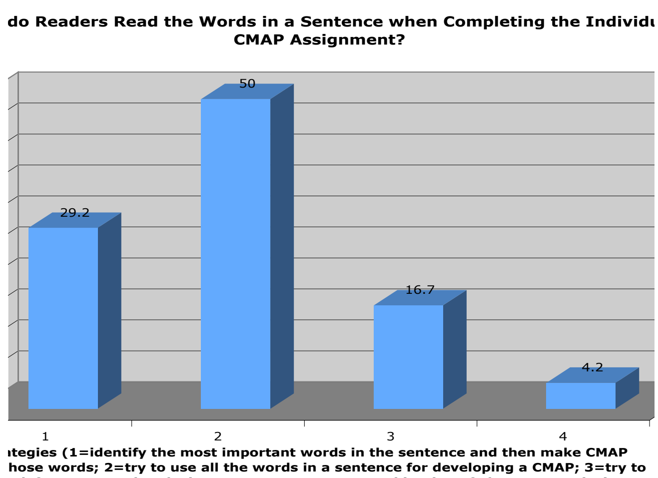

Figure 8. Strategies for using words in a sentence when completing the individual CMAP assignment

Data in Figure 7 suggest that readers most often try to use all the words in a sentence for developing the CMAP. However, a large percentage also agreed that they used only the most important words in a sentence for CMAP purposes.

Associated strategies for strengthening the conceptual foundation of a CMAP assignment: For the group CMAP assignment, readers were asked what they think to be the purpose of writing definitions and key terms based on the technical text, besides designing the concept map. Figure 8 shows that a major portion thinks that these strategies are used so readers can understand the major issues in text and also major words in text.

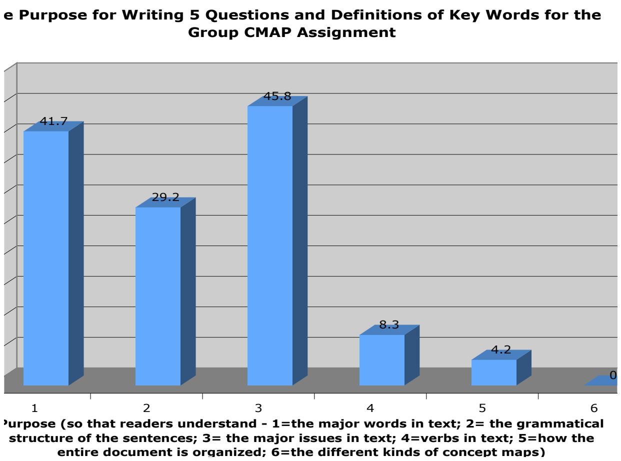

Figure 9. Associated strategies for better use of concept maps

Interestingly, only a small percentage of students think that these strategies actually can help readers identify verbs in text or learn how the entire document is organized.

Discussion

The findings suggest that students claim to have understood the design of the technical reading class. Figures 2, 3, 4, and 5 suggest that most readers correctly have identified the purpose for using the concept maps. Further, their self-report suggests that they think it to be a useful tool for understanding concepts from technical text, and also that it improves language skills. When readers were asked categorically to identify the reasons for using concept maps, data show that they mostly are in agreement with the fact that concept maps can be used to improve word level understanding and also the overall text. An interesting point here is that readers more often favor using concept maps for micro-level analysis of the text, like identifying key words, new words, nouns and verbs, sentence construction, etc., rather than focusing on how the concept map explains the global character of the text or the overall idea of the text. In other words, when using concept maps, readers are more comfortable dissecting a sentence in terms of its construction, key words, etc., rather than dissecting the idea behind a paragraph and making it into a simple concept map. This also might indicate that when similar sentences and ideas are mentioned in different words, readers create different nodes for the same or very similar information. This is because they are focusing on each sentence at a time rather than the idea behind the entire paragraph or text. It also is interesting to note that readers do not have a clear idea as to how concept maps can be used for brainstorming purposes. A possible way to use a concept map for brainstorming purposes might be to try to get an overall feel for the major argument in the technical text and then try to design a concept map that represents it. This concept map won't be based on dissecting the technical text but rather on what readers understand after having read the text and seeing how they can represent it in their own words.

Perhaps the above data are expected because most EFL students in Japan at the third year undergraduate level might not have enough expertise to process technical text globally. They might feel more comfortable analyzing one sentence at a time. This might not have anything to do with their ability to process complex information or their ability for logical reasoning. Rather, it might be a language-level issue.

Participants indicate towards the conclusion that some level of preparation with the text before starting to develop concept maps does help with material comprehension. However, results also indicate that it is not absolutely necessary and students perhaps can do without it, if that indeed is what the class structure advocates. It is possible that some readers feel this level of comfort with the text (e.g., starting to develop concept maps before taking part in the quiz) because readers in most cases always will start analyzing sentences, one at a time, before caring about what it means within the scope of the central argument in the text or the core of the information in the text. If that indeed is the case, then they can do without any preparation that leads them to material comprehension and information retention to be used in concept maps, directly or indirectly. The above argument clearly is supported by the findings in Figure 7 that suggests reader process one sentence at a time when designing concept maps.

However, some readers often can take this micro-level analysis to an extreme form by making attempts to use every word in a sentence, as suggested in Figure 8. Interesting data suggested in Figure 8 is that most readers clearly know what their approach is when they analyze the text and use it for concept maps; almost no one suggested that they use some combination of strategies, like making attempts to use every word, identifying the nouns and verbs, etc.

Data also suggested in Figure 9 that they are in favor of using associated strategies that help them identify the major words and the central idea in the text. An interesting issue here, as seen from Figure 9 and previous findings, is that readers prefer to use associated strategies that will help them get some grasp of the central argument in the text; yet, their approach most often is local and tends towards a micro-level analysis of the text, which is not much help when it comes to understanding the central argument. However, it also is true that in some text, the central argument might be mentioned first and then be explained in later sections. In that case, micro-level analysis is more acceptable and productive.

Recommendations for Future Research

There are multiple recommendations that teachers and researchers in technical writing and reading might consider for future teaching and research.

1. The current practice in the technical reading class, as discussed here, has been rated as structurally sound and has proven to be a successful practice that students in a computer science/engineering course can benefit from. However, within the scope of this course, based mainly on the students' level of expertise, it was not possible to use the CMAP software to introduce the full range of knowledge maps available. Students were exposed only to the variety called concept ladder. In a full-fledged and reasonably advanced technical writing class, it is possible to import this structure from the technical reading class, equip the structure with the full range of knowledge models available, and then finally apply it to conceptually develop and design traditional assignments in a technical writing class like Designing a User Manual or Writing a Feasibility Report.

2. It might be advisable for teachers of technical reading to find out if students can be made to read the entire text first, identify a few sentences that they consider the core argument in the text, and then design a concept map based on those sentences, instead of allowing them to use every sentence in the text. In other words, some controlled access and use of the text might drive EFL readers in computer science to think in specific ways that involve ability to extract the central argument, scan through the text efficiently, and present the information through concept maps more from the mind and as a logical argument rather than as noun-verb-noun connections. It is not easy to apply this strategy for EFL students who still are struggling with language issues. However, for production-based classes like technical writing, this strategy easily can be used in a small-scale and at a preliminary level.

3. Previous research has cited that "fill-in-the-nodes" concept maps might be a strategy that can be adopted for material comprehension. This should run simultaneously with fill-in-the-blanks in sentences. This will help strengthen readers' word level analysis. Readers can be asked to identify words that fill in the blanks in a sentence and then choose a similar word to fill in the blanks in the node that represent the sentence. This will help readers learn new words and applications simultaneously.

4. More advanced readers can be included in a similar experiment at a slightly different level. Readers might be given a paragraph pertaining to a topic in computer science and be asked to design a two- or maximum three-node concept map that represents all the major information in the paragraph. Conditions might be imposed that force readers to use all the key words in the paragraph. This will be a healthy exercise, as readers will have to learn to extract information efficiently and also represent it in a logical way. Readers will learn editing skills and scanning information from paragraphs and organization skills for information representation purposes.

Conclusion

This study indicates that EFL computer science students are capable of using concept maps efficiently. However, data suggest that they are more prone toward a micro-level analysis of the text, rather than using concept maps to get a feel for the global nature of the text. With some change in the nature of assignments and systematic use of text (based on student ability), readers will be more efficient with the language and also develop editing, scanning, and information organization skills. Further, concept maps can be used efficiently for both reception (technical reading) and production-based activities (technical writing), as discussed in this article.

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