Empirical Evaluation of Concept Mapping: A Job Performance Aid for Writers

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SUMMARY

The usefulness of concept mapping as a job performance aid for writers of technical documents was examined. Thirty-four writers were randomly assigned to one of two groups. The experimental group received 2 hours of training in the use of concept mapping. Both groups revised the same chapter from a computer manual, and an experienced technical editor blindly evaluated each revision.

In part two of the study, revised texts were given to two groups of users. One group received a concept-mapped revision, while the other group received a text revised by a writer who had used conventional revision techniques. Readers' comprehension was tested and compared.

Revision time was not significantly different between groups, and the editor's ratings of quality were not different. However, readers' comprehension was significantly higher with the concept-mapped versions.

These results suggest that concept mapping is a useful revision tool for writers.

INTRODUCTION

Technical writers are often in the difficult position of being either too familiar or not familiar enough with their subject matter. When very familiar with the material, they may take for granted relationships among ideas that are less than obvious to their readers. When not familiar enough, they may not fully understand the existing relationships among the concepts. What is useful, then, is a technique to fully identify the important concepts, topics, and ideas, and to clearly indicate the interrelationships among them. This technique should be useful in both writing situations, by helping subject matter experts become aware of the relations they presume, and by helping novices identify the disconnected concepts that need

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further clarification by subject matter experts. Concept mapping has been proposed as such a technique (Novak and Gowen 1984).

**Concept Mapping**

A concept map is a picture of the ideas or topics in the information and the ways these ideas or topics are related to each other. It is a visual summary that shows the structure of the material the writer will describe. Figure 1 is an example of what the beginning stages of a concept map about fishing might look like.

![Concept Map of Fishing](image)

**Figure 1. A concept map about fishing.**

In the concept map in Figure 1, ideas and topics are enclosed in boxes. Lines show relationships that exist among the ideas. Words next to the lines present the relation that links the ideas. Examples (such as earthworm, salmon, and minnow) are included to prompt the writer’s memory; they are not enclosed in boxes.

The concept map depicts hierarchical relationships by presenting the most general, all-encompassing topic at the top of a tree-like figure, and showing more specific ideas lower down in the tree (under the ideas to which they are related). The examples are the most detailed ideas, and they appear at the bottom.

Although hierarchical relationships are the most common types of relationships depicted by concept maps, these writing aids may depict other relationships. For example, the relationship of equality among ideas is shown by placing the ideas on the same level of the tree. The notion of similarity between ideas (perhaps through metaphorical association), is shown by lines that run across the tree, like ribbons tied from one branch to another. These are cross-links. A detailed concept map could look like a network structure, but a writer will most likely have to choose a central beginning point and build into the material the prerequisite links for understanding the target concepts.

Concept mapping has been demonstrated to be an effective teaching and learning tool in traditional classroom settings (Nussbaum and Novak 1976; Novak, Gowen, and Johansen 1983). The purpose of the study described in this paper was to determine whether concept mapping is also useful in other environments, particularly in assisting those involved in the preparation of technical manuals.

**Background from Psycholinguistics**

To prepare effective computer manuals, technical writers must know a little about how people learn and store knowledge in memory. Research on the structure of memory points to the good possibility that knowledge is stored in a network (Collins and Loftus 1975) or hierarchy (Smith, Shoben, and Rips 1974) of linked relations. Learning, or the integration of new knowledge into existing memory, consists of two phases (Clark and Clark 1977). In the construction phase, we take a linear arrangement of constituents (words, for example) and translate them into meaning, into a hierarchical arrangement of propositions—a text base.

In forming this meaning, this text base, we first check for referential coherence, achieved through overlapping arguments—common relationships—
among propositions (Kintsch and van Dijk 1978). Next we fill in gaps in coherence by adding propositions, making bridging inferences. In this way we construct a network, or hierarchy, of propositions. In a map, nodes represent propositions, whereas the connecting lines represent shared referents. Exact wording is purged from our working memory, whereas the gist, this global representation of the text base, is retained.

In the second stage of comprehension, the utilization phase, we retrieve information from long-term memory and compare it with the new information in working memory. The comparison results in adding the new information to memory (appending to or modifying the old information), rejecting the new information, or holding it in working memory for another round of processing. If new information has been presented in an optimum manner, relating each bit of new information to a bit already within the reader’s memory, the utilization phase will proceed smoothly and quickly (Clark and Clark 1977). If there is no match between given and new, according to the Congruence Principle, it will take extra processing time to either reject the information or construct the bridging inferences.

Based on this background of theory, three principles of learning become evident:

- First, all learning depends on prior knowledge. Learners try to link new information to what they already know. They actively try to incorporate new information into existing knowledge frameworks and thus make the new information understandable (Resnick 1983).
- Second, understanding means knowing relationships. Human knowledge is stored in clusters and organized into frameworks that people use both to interpret familiar situations and to reason about new ones. Pieces of information that are isolated from such frameworks are the “stuff” of rote learning. Such pieces are not recognized as meaningful and are usually soon forgotten.
- Third, learners do not merely receive or even discover information. They actively construct meaning by searching for it, trying to find regularity and order in what they see, hear, read, or otherwise perceive. As they proceed, learners construct explanations for what they are learning. In the beginning, or when the information is incomplete, they may construct naive explanations. However, these explanations may be revised, and they can become much more sophisticated as the learning process proceeds.

Based on these considerations of how people learn, technical writers should do two things. First, we must take into account what our intended audience already knows. Only by careful consideration of what is already known can we be successful in making the link to the new information, and only by making that link can we make that new information meaningful.

First, we must take into account what our intended audience already knows.

Second, we must focus on the interrelationships among ideas.

Information that has been presented in a meaningful manner, elaborating its relationship to known information, has been shown to be understood better and remembered longer than less meaningfully presented information (Bransford 1979).

**Research Method**

A two-part study was conducted to determine whether concept mapping could be useful as a job performance aid for technical writers. In the first part of the study, 34 IBM Information Developers (mostly writers) were randomly assigned to one of two groups. The experimental group received 2 hours of training and practice in the use of concept mapping as a revision tool. The control group participated in a 2-hour workshop discussing the cognitive style of potential readers. Both groups then revised the same chapter from a computer technical manual. The experimental group was told to use the new, concept mapping approach. The control group was told to use their conventional revision techniques. (Most people used outlines.)

Measures were taken of revision time and attitude. Amount of scrap paper produced (an indication of the number of false starts) was monitored informally. After finishing the revision task, the groups completed an attitude questionnaire regarding their experience with the revision task. The experimental group answered two additional questions about concept mapping’s usefulness.

Next, the revised texts produced by both writers’ groups were sent to an IBM editor who “blindly”
evaluated all of them for accuracy and comprehensibility. That is, this independent evaluator did not know whether a particular text had been prepared by a control group or an experimental group writer. Following the blind evaluation of the revised texts, one representative text (from among those having the modal rating score, which was equal between the groups) was chosen to represent their group. Thus, one representative text was obtained from the control group, and another was obtained from the experimental group.

In the second part of the study, 56 undergraduate computer science students at Broome Community College (Binghamton, NY) were randomly assigned to read one of the representative revised texts from the first part of the study. Half of the users received the text revised by a writer using concept mapping, while the other half received the text revised by a writer using conventional revision techniques. The readers were asked to read the revised texts, and when they finished, the texts were removed, and they were asked to answer a set of questions about the text. The questions were designed to measure comprehension of the text, as well as the users' attitudes toward the text.

Thus, the utility of concept mapping was evaluated in terms of the following:

1. Writer productivity (time)
2. Writer false starts (waste paper)
3. Writer attitudes toward concept mapping
4. Editor judgments of quality
5. Reader comprehension
6. Reader attitude

**Hypotheses**

1. We expected that writers who used concept mapping for the first time would take longer to produce their revisions.
2. We expected that writers who used concept mapping for the first time would experience more false starts (because they would not be proficient with this new method after only 2 hours of training).
3. We anticipated that despite the frustrations mentioned above, writers who used concept mapping would have a positive attitude toward this new tool.
4. We expected that the quality of the revisions done using concept mapping would be judged higher than those done using other methods.
5. We expected that users would find the revision produced using concept mapping easier to understand than the revision produced using the other techniques—mostly outlining.

**Results**

The data from the two phases of the study were analyzed using a variety of statistical methods.

**Results from the First Part of the Study**

Descriptive statistics comparing the time spent revising for the experimental and control writers' groups are summarized in Figure 2.

<table>
<thead>
<tr>
<th></th>
<th>Experimental Writers (N = 17)</th>
<th>Control Writers (N = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>58.3</td>
<td>59.8</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>14.6</td>
<td>10.9</td>
</tr>
<tr>
<td>Minimum</td>
<td>21.6</td>
<td>43.5</td>
</tr>
<tr>
<td>Maximum</td>
<td>75.0</td>
<td>95.1</td>
</tr>
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</table>

*Figure 2. Time devoted to revision task (in minutes).*

The mean time spent in revision was lower for the experimental group than for the control group. A *t*-test revealed that this difference between groups in time on task was not significantly different, however (*t* = 0.33, *p* > 0.05). Thus, Hypothesis 1 was not supported because concept mapping was easier to use than we expected.

An informal record of the amount of scrap paper used during revision indicated that the experimental group used only about one sheet of scrap paper during revision (on which the concept map was drawn and from which the revised text was written directly), whereas the control group writers typically used three to four sheets of scrap paper. Hypothesis 2 was not supported: concept mapping proved easier to use than we expected.

In the questionnaire given the experimental writers to evaluate the usefulness of the concept mapping instructional materials, writers were asked to rate the technique of concept mapping in several categories using a 5-point Likert scale:

- Regarding how the use of concept mapping would affect the speed of writing, the mean rating of 3.13 indicated that the writers thought that using concept mapping would have little effect on writing speed (5 = greatly increased speed; 1 = greatly decreased speed).
- In the category of effect on writing accuracy,
however, the mean rating of 2.15 revealed that the writers perceived concept mapping to be useful in decreasing writing errors (5 = increased errors; 1 = decreased errors).

- In comparison to other writing job performance aids, the mean rating of 3.70 showed that the writers felt that concept mapping would be more helpful in facilitating the preparation and revision of technical materials (5 = greatly facilitated compared to other techniques; 1 = greatly interfered compared to other techniques).

- The writers judged concept mapping to be useful in improving their own writing effectiveness by giving the technique a mean rating in this category of 3.57 (5 = greatly improved effectiveness; 1 = greatly hindered effectiveness).

- Finally, a mean rating of 3.11 indicated that most writers would use concept mapping often in preparing and revising technical materials (5 = never; 4 = seldom; 3 = often; 2 = frequently; 1 = always).

Thus, Hypothesis 3 was supported: writers had a positive attitude toward this new tool.

The descriptive statistics comparing the ratings by the independent evaluator for the revisions produced by the experimental and control writers’ groups are summarized in Figure 3. The quality rating consisted of the evaluator’s response to six questions rated on a 5-point Likert scale (5 = good; 1 = poor). The lowest score possible, therefore, was 6, and the highest was 30. The evaluator did not rate the experimental and control writers’ groups as significantly different in quality. Thus, Hypothesis 4 was not supported.\(^1\) Other statistical analyses were performed to determine whether there were significant relationships among any variables. A series of Pearson Product-Moment correlations was performed but revealed no significant correlations among the following variables: evaluator’s rating of revision quality, years of experience as a writer, and time needed to complete the revision task.

<table>
<thead>
<tr>
<th>Experimental Writers (N = 17)</th>
<th>Control Writers (N = 17)</th>
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<tbody>
<tr>
<td>Mean</td>
<td>17.7</td>
</tr>
<tr>
<td>Mode</td>
<td>16.0</td>
</tr>
<tr>
<td>Median</td>
<td>17.0</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>3.9</td>
</tr>
<tr>
<td>Minimum</td>
<td>13.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>30.0</td>
</tr>
</tbody>
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**Figure 3. Independent evaluator (editor) ratings of revisions.**

**Results from the Second Part of the Study**

The data from the second phase of the project were analyzed by comparing those users who received the experimental text revision with those who received the control text revision. A series of \(t\)-tests was conducted to compare these groups with respect to several measures of user understanding: recall of factual information, comprehension of relationships among ideas, and overall understanding of the text. Recall of factual information was tested via cloze procedures, open-ended responses, and multiple choice questions requiring the reader to supply exactly the same responses as those provided in the text. Comprehension of relationships among ideas was tested in the same way, requiring the reader to reason and draw inferences from the presented material rather than reiterate material. Overall understanding was a composite measure of these two factors. The descriptive statistics for each of these measures are summarized in Figures 4, 5, and 6. The \(t\)-tests revealed that the experimental group recalled more factual information than did the control group (\(t = 2.08, p = 0.067\)). The experimental group showed significantly greater comprehension of relationships among ideas (\(t = 5.08, p < 0.001\)), and significantly greater overall understanding of the text (\(t = 4.85, p < 0.001\)). Thus, Hypothesis 5 was supported: readers found the revision produced using concept mapping more comprehensible than the

<table>
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<th>Experimental Writers (N = 28)</th>
<th>Control Writers (N = 28)</th>
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<tbody>
<tr>
<td>Mean</td>
<td>9.8</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.6</td>
</tr>
<tr>
<td>Minimum</td>
<td>5.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>12.0</td>
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**Figure 4. User comprehension data, factual recall (max = 12.0).**

\(^1\) A Wald-Wolfowitz Runs test indicated that although the means and medians of the two groups were not significantly different, there was a statistically significant tendency for the experimental group ratings to be clustered in groupings that were higher than the clusterings of the ratings for the control group (\(z = 2.6124, p = 0.0045\)). Additionally, the highest text revision ratings were obtained by a writer in the experimental group. We drew no conclusions from this data, however.


**Experimental Writers (N = 17)**

<table>
<thead>
<tr>
<th></th>
<th>Control Writers (N = 17)</th>
</tr>
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<tbody>
<tr>
<td>Mean</td>
<td>3.1</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.6</td>
</tr>
</tbody>
</table>

**Figure 5. User comprehension data, comprehension of relationships (max = 5.0).**

<table>
<thead>
<tr>
<th></th>
<th>Control Writers (N = 28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>12.9</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.7</td>
</tr>
<tr>
<td>Minimum</td>
<td>9.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>16.0</td>
</tr>
</tbody>
</table>

**Figure 6. User comprehension data, overall understanding of text (max = 16.0).**

revision produced using the other techniques—mostly outlining.

**DISCUSSION**

The objective of this project was to determine the utility of concept mapping as a revision tool for technical writers and to field test a set of instructional materials for training writers to use this tool.

The results presented in the preceding section demonstrate that the technical text revised using concept mapping as a job performance aid was more successful in communicating information to users than was the same text when it was revised using traditional techniques such as outlining. Although the ratings by an independent evaluator of the comprehensibility of the text revisions failed to show that concept mapping was superior to other techniques, when the revised texts were subjected to a more practical test of their comprehensibility, the advantages and benefits of concept mapping were readily apparent. The user comprehension data clearly demonstrated the superiority of concept mapping over other techniques in increasing the level of understanding as well as the level of factual recall of information.

The writers who were trained in the use of concept mapping and who experienced the usefulness of the technique as a revision tool were distinctly favorable in their evaluations. They assessed the technique as beneficial in improving accuracy and helpful in the preparation and revision of materials, and indicated that they plan to use it often in their work. The fact that they were so favorable after only a short exposure to the technique further indicates its strong appeal.²

**CONCLUSION**

This study examined the usefulness of concept mapping as an aid to revising technical documentation. In addition to its usefulness as a revision tool, we believe that concept mapping could also aid in the initial composition or creation phase. Further study should examine this possibility.

Concept mapping may hold other promises as well for the design of information for new media, where straight linear presentation cannot be assumed. The challenges we face in linking ideas rationally and in structuring transitions and coherence into "less-ordered" information may require us to develop and use new methods of writing. For this reason, concept mapping may be a useful tool in structuring usable information for paperless media.

**REFERENCES**


²It may be worth noting that the 2-hour workshop for the control group addressing the cognitive style of readers may have actually served to mask the effects of the experimental treatment under study. That is, as practitioners we realize that a good mapping of the subject matter to the readers’ prior knowledge is important, and we would not argue for concept mapping versus audience analysis. Rather, the two enhance each other. Therefore, the results reported in this study may actually be conservative.
structured interviews.” *Science Education* 60, no. 4: 535–550.


**SUGGESTED READINGS**


