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ABSTRACT

A study investigated the relationships among prior topic knowledge. information in elementary science text, and the construction of visual representation of key text ideas. Eight preservice elementary teachers were first interviewed on two topics in science ("how plants get their food" and "air and weather"); then they read elementary textbook selection on these topics; and finally they constructed an idea map to represent key text ideas. Analysis of the data showed that 18% of the ideas represented in the idea maps were inaccurate with respect to text information. Analysis of topic-knowledge assessments and videotaped map constructions showed that misconceptions and task constraints contributed to the misrepresentation of scientific concepts in the idea maps made by seven of the preservice teachers. Findings suggest that preservice teachers could benefit from acquiring a sound knowledge base in science topics, developing a systematic way to examine their own knowledge of science topics, and having extensive practice in constructing idea maps, which have a research base as an instructional tool. (Contains 32 references, as well as one table and three figures of data. An appendix presents four statements and claims of partial knowledge.) (Author/RS)

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Abstract

A study investigated the relationships among prior topic knowledge, information in elementary science text, and the construction of a visual representation of key text ideas. Eight preservice elementary teachers were interviewed on two topics in science ("how plants get their food" and "air and weather"), then they read elementary textbook selections on these topics, and finally they constructed an idea map to represent key text ideas. Analysis of the data showed that 18% of the ideas represented in the idea maps were inaccurate with respect to text information. Analysis of topic-knowledge assessments and videotaped map constructions showed that misconceptions and task constraints contributed to the misrepresentation of scientific concepts in the idea maps made by seven of the preservice teachers. These results suggest that preservice teachers could benefit from acquiring a sound knowledge base in science topics, developing a systematic way to examine their own knowledge of science topics, and having extensive practice in constructing idea maps, which have a research base as an instructional tool.

PRIOR KNOWLEDGE, TEXT FEATURES, AND IDEA MAPS

The effects of prior knowledge on text comprehension have been discussed theoretically (Anderson & Pearson, 1984; Rumelhart, 1980) and demonstrated empirically (for review and commentary see Prawat, 1989; Roller, 1990). Readers with high amounts of prior knowledge about a topic have recalled significantly more text ideas than have readers with low amounts of topic knowledge (Chiesi, Spilich, & Voss, 1979; Pearson, Hansen, & Gordon, 1979; Spilich, Vesonder, Chiesi, & Voss, 1979). Furthermore, prior topic knowledge that is consistent with text information may facilitate comprehension, but prior topic knowledge that is incompatible with text information may interfere with comprehension (Alvermann, Smith, & Readence, 1985; Anderson & Smith, 1984; Dole & Smith, 1989; Eaton, Anderson, & Smith, 1984; Marshall, 1989; Vosniadou, 1991). In other words, the reader's misconceptions may override text information, resulting in a misinterpretation or misrepresentation of text concepts (for a discussion of distinctions among various kinds of misconceptions, see Guzzetti, Snyder, Glass, & Gamas, 1993).

The reader's awareness of text features (such as the overall organizational pattern, transitional markers, topic sentences, and the hierarchy of content ideas) also influences comprehension. Research evidence supporting the effects of text structure on reading comprehension has been mixed (Roller, 1990), but Roller suggested that the interaction of prior topic knowledge and text structure had not been adequately studied and might have accounted for the mixed results. In their review of comprehension instruction, however, Pearson and Fielding (1991) found

> incredibly positive support for just about any approach to text structure instruction for expository text. It appears that any sort of systematic attention to clues that reveal how authors attempt to impose structure upon a text, especially in some sort of visual representation of the relationships among key ideas, facilitates comprehension. (p. 832)

As readers learn from text, visual representations aid readers in selecting and organizing important information (Armbruster, Anderson, & Meyer, 1991; Mayer, 1989).

In general, visual representations of text structure use unique spatial arrangements of words to represent the key text ideas and the relationships among them. Visual representations of text include charts (Gallagher & Pearson, 1989), flow charts (Geva, 1983), frames (Armbruster et al., 1991; Armbruster, Anderson, & Ostertag, 1987), graphic organizers (Bean, Singer, Sorter, & Frazee, 1986), networks (Dansereau et al., 1979), concept maps (Novak & Gowin, 1984), knowledge maps (Dansereau & Cross, 1990), and idea maps (Barman et al., 1989). By making explicit the ideas and conceptual relationships of text, visual representations of text aid students in identifying key ideas and in understanding the relationships connecting them.

Comprehending major ideas of informational text was identified in the 1992 NAEP *Reading Report Card* (Mullis, Campbell, & Farstrup, 1993) as an appropriate performance standard for fourth graders at the Proficient achievement level and for eighth and twelfth graders at the Basic achievement level. According to the 1992 NAEP study, 75% of the fourth graders, 31% of the eighth graders, and 25% of the twelfth graders who participated in the study did not perform at these achievement levels. The use of visual representations of text addresses the need suggested by the results of the NAEP report for students to develop the ability for comprehending the key ideas of informational text. Evidence from classroom research studies indicates that instruction involving visual representations of informational text structure led to the improved learning of key text ideas by elementary students (Armbruster et al., 1991; Armbruster et al., 1987; Berkowitz, 1986; Gallagher & Pearson, 1989).

The construction of visual representations of text can be challenging and time-consuming (Armstrong, Armbruster, & Anderson, 1991; Goetz, 1984; Richardson & Morgan, 1990). Some of the challenges involve selecting key text ideas, understanding their interrelationships, and expressing these ideas and relationships in the syntax of the visual format. In the studies previously cited, the instructional materials were developed by the researchers (Armbruster et al., 1987; Gallagher & Pearson, 1989) or by the researchers and classroom teachers (Armbruster et al., 1991; Berkowitz, 1986). To what extent are classroom teachers prepared to develop visual representations of text for instructional use? They are recommended as instructional strategies in textbooks developed for content area reading instruction (e.g., see textbooks by McKenna & Robinson, 1993; Readence, Bean, & Baldwin, 1992; Richardson & Morgan, 1990; Tierney, Readence, & Dishner, 1990). In a study of visual representations (frames) of text made by 27 upper elementary teachers, Armstrong et al. (1991) found that the teacher-made frames varied considerably in accuracy and completeness of representing text concepts and in explicit use of text terms.

Thus, visual representations of text structure appear to be powerful instructional tools for teachers to use in guiding students to learn from informational text, but teachers may not be well prepared to develop them. The results of research in learning from text also lead to questions about the development and instructional use of visual text representations. How does prior topic knowledge interact with the text information in the construction of a visual representation of text? In particular, do teachers or preservice teachers have misconceptions that override conflicting information in elementary science textbooks and then appear in a visual representation of text? The purpose of the present study was to understand the relationships among preservice teachers' prior knowledge of two topics in science (photosynthesis and the air and weather), the features of elementary science texts, and a visual representation of text ideas that the preservice teachers developed for instructional use.

Method

Participants

The participants were eight students enrolled in a university elementary teacher certification program. Seven women and one man were randomly selected from a pool of volunteers, who were enrolled in a reading education course. Names used in this report are not the students' real names. Student participants were paid at the rate of six dollars per hour.

Materials

I developed materials for mapping instruction, think-aloud procedures, topic-knowledge assessment, and independent mapping. I also developed a pencil-and-paper background survey for participants to complete by listing the teaching methods courses and college science and history courses that they had completed or in which they were currently enrolled.

The instructional materials included idea maps (Barman et al., 1989) and sample texts that exemplified overall organizational patterns of informational text (Armbruster, 1984): simple listing, comparison/contrast, temporal sequence, cause-effect, and problem-solution. An idea map was defined as a visual representation of key text concepts and the relationships between them. In idea maps, text concepts (names of objects or events) are arranged hierarchically in nodes. Nodes are joined by links, typically verbs, as in this example:

Mollusks ----- are -----> soft-bodied animals.

Thus, each linked pair of nodes is an idea (usually a clause or proposition) and was referred to as a Linked Concept Pair (LCP). Link arrows indicate the direction of the relationship expressed in the LCP. (See Figure 2 for an example of a complete idea map.) Instructional materials also included a set of eight Standard Links (modified from Dansereau & Cross, 1990): *is, includes, has, is part of, is* *like, leads to, influences,* and *precedes*. A ninth "supplemental link" was an unnamed Other Link and could be *any word* used to join concepts (modified from Novak & Gowin, 1984). Practice exercises provided students with opportunities to use and to invent links for mapping practice texts, which ranged in length from single sentences to passages of 200 words. (For detailed description and examples of instructional materials, see Armstrong, 1993a, 1993b.)

A similar set of passages was used for practicing a think-aloud procedure (Ericsson & Simon, 1984). The guidelines asked students to express their thoughts aloud while mapping.

For assessing students' knowledge of the two topics in science, "how green plants get food" and "air and weather," two paper-and-pencil instruments and one interview instrument were developed. The paper-and-pencil instruments were modeled on those reported in other research (Bishop, Roth, & Anderson, 1986; Crawley & Arditzoglou, 1988; Stepans & Kuehn, 1985) and included questions about concepts associated with commonly reported misconceptions.

One paper-and-pencil instrument consisted of open-ended questions on each topic: (a) Explain how green plants get their food; (b) How would a scientist describe air? and (c) What causes weather? The second paper-and-pencil instrument was a series of "short answer items" (multiple choice questions and questions requiring recall of previously learned information). For example, "Do green plants need water? Why or why not?" or "What is air made of?" The interview instrument consisted of probes that asked for clarification, additional information, or further explanation of the students' written responses. Interviews were recorded on audiotape. Complete copies of topic-knowledge assessment instruments are available elsewhere (Armstrong, 1993b).

Materials for independent student mapping included two texts, the student's instructional mapping materials, an unrestricted supply of 8 1/2 x 11" paper, and felt pens. The texts were photocopies of "Plants Make Food" (Barman et al., 1991, hereafter "the photosynthesis text"), which is 847 words long, and "Weather and the Atmosphere" (Mallinson et al., 1991, hereafter "the weather text"), which is 680 words long. Both texts are intended for use at the fifth-grade level. These texts did not contain any explicit refutation of common misconceptions associated with knowledge about the phenomenon. Independent mapping sessions were recorded on videotape.

Prior to the study, materials were pilot tested with three students from the same population as the students in the full study. Based on the pilot work and an independent review by two professors of reading education and two professors of science education, I modified the instructional materials for the full study. The texts for independent mapping sessions (Barman et al., 1991; Mallinson et al., 1991) were not modified.

Procedure

Students individually completed one instructional session with me and two independent work sessions.

Instructional Session

First, the survey of academic background was completed by students. Next, I guided students through the following sequence of instruction: presentation of model texts (of about 200 words) and idea maps, introduction of idea mapping with Standard and Other Links, and mapping practice texts ranging from single sentences to paragraphs of 200 words. I emphasized that the goal in mapping the longer texts was to construct an idea map of 10 to 15 concepts representing the main text ideas. Untimed instructional sessions lasted about three hours each.

Independent Work Sessions

The two independent work sessions for each student included think-aloud practice, topic-knowledge assessment, reading a text, and idea mapping of the text corresponding to the topic of the knowledge assessment. Each student completed sessions on the two topics, photosynthesis and the air and weather, which were counterbalanced for order.

I administered the topic-knowledge assessment and operated the recording equipment. For each topic students completed the instruments of the knowledge assessment in this sequence: information inventory, short-answer items, and interview.

Upon completing the topic-knowledge interview, students were directed to read the corresponding text. They were permitted to read the text silently once. Students were then asked express their thoughts aloud as they developed an idea map of 10 to 15 concepts for use with an "average class" of fifth graders and to read aloud if they referred back to the text, the mapping instructional materials, or earlier drafts of their own idea maps. If students stopped thinking aloud during mapping sessions, then I prompted them to "keep talking."

I also provided some assistance or scaffolding (Wood, Bruner, & Ross, 1976) to students after they had worked for at least 40 minutes on their own. A 40-minute period was chosen because that was the time in which 27 inservice teachers had completed their frames (Armstrong et al., 1991). After 40 minutes if the students hadn't worked out the "big picture" (the superordinate concept and its relationship to key subordinate concepts), then I offered assistance. Later I offered assistance if students requested it. Scaffolding occurred when I asked students what they were trying to do or where they were stuck. In every case, I tried to leave the student with the decision of what concepts to map and how to map them.

Sessions ended when students said that their maps were completed. The mean number of map drafts produced by students was 6.00 (SD = 2.65) on the photosynthesis text and 4.75 (SD = 1.09) on the weather text. The mean length of sessions on the photosynthesis text was 65.13 minutes (SD = 24.76) and on the weather text was 58.25 minutes (SD 14.45). No student completed more than one session per day, and the total span of involvement for each student in all three sessions ranged from 9 to 17 days.

Data Sources and Analysis

The data sources included instructional materials, the survey of academic background, completed knowledge assessment instruments (including audiotape transcriptions), each student's copy of "the photosynthesis text" and "the weather text" (some students annotated their copies), each student's map drafts of these texts, and the videotapes and transcripts of independent mapping sessions. In the first three steps of analysis, data were categorized, and frequency counts were used to describe the overall correspondences among students' knowledge claims, the text information, and student-made idea maps. The fourth step of analysis involved qualitative descriptions of moment-by-moment constructions of selected LCPs (Linked Concept Pairs) in the student-made maps and identification of instances of scaffolding.

1. Topic Knowledge and Corresponding Text Statements

I examined the topic-knowledge assessment instruments of each student and then matched the knowledge claims to the content of the sentences appearing in the corresponding text. A knowledge claim was an expression of what Chinn and Brewer (1993) define as a *belief*, a piece of knowledge in the knowledge base. A knowledge claim was expressed in response to an assessment item and usually consisted of one to several sentences, depending on the complexity of the topic and the amount of knowledge the students expressed. For example, statements of equivalence (definition of terms) usually consisted of one-sentence responses, but explanations of processes (such as photosynthesis or the causes of weather) usually consisted of several sentences.

The following Incomplete Knowledge categories emerged from the data: No Knowledge, Partial Knowledge, and Correct Knowledge with Uncertainty Expressed. Claims of No Knowledge included comments such as "I don't know if sugar is made inside the plant" (Ginny's claim), or "I don't know what air pressure is" (Carrie's claim). Claims of Partial Knowledge are discussed in detail in the next paragraph. Claims of Correct Knowledge with Uncertainty Expressed were included as a distinct category because I theorized that if the students explicitly stated that they were uncertain of a piece of knowledge, then it might be less stable than correct claims about which they expressed no uncertainty. Examples of Correct Knowledge with Uncertainty Expressed included Flora's claim, "I think that sugar or glucose is the food that has the energy, but I just can't remember exactly" and Eddie's claim, "Maybe I would define weather as a change in the current conditions of the air. I don't know." In all, I initially categorized 128 knowledge claims: 27 No Knowledge, 89 Partial Knowledge, and 12 Correct Knowledge with Uncertainty Expressed. Initially, I did not categorize knowledge claims that were fully correct because the emphasis in the study was to understand how knowledge that was incomplete (in particular, knowledge that was inaccurate with respect to text information) corresponded to the reader's visual representation of text ideas.

After further examination of the data, I divided the 89 Partial Knowledge claims into four categories: 31 Conflict claims (claims incompatible with text), 20 Basic claims (claims basically accurate and nearly complete in terms of text, but showing some confusion), 32 General claims (vague claims, lacking details or explanation), and 6 Other claims (claims not corresponding to text or claim fitting more than one category). Please see the Appendix for examples of Partial Knowledge claims and corresponding text statements.

Three independent raters categorized 25% of the data, resulting in an interrater reliability of .91 (ranging from .88 to .94) for the three Incomplete Knowledge categories and .71 (ranging from .67 to .78) for the four categories of Partial Knowledge. Disagreements among raters were resolved through discussion.

2. Map LCPs and Corresponding Text Statements

In the eight maps representing the photosynthesis text, the number of LCPs ranged from 11 to 27 (M = 16.88, SD = 4.78). In the eight maps representing the weather text, the number of LCPs ranged from 12 to 27 (M = 17.87, SD = 4.14).

Each LCP unit in each student's final map draft was checked for accuracy with respect to text statements. Of the 278 LCPs in the 16 student-made idea maps, 274 LCPs could be verified with respect to text statements. Verifiable LCPs were judged to be correct or faulty. Of the 274 verifiable LCPs, 48 (18%) were found to be faulty with respect to text information. Examples of faulty LCPs are presented in the Results and Discussion section. Three independent raters judged the accuracy of the LCP units in 4 (25%) of the maps; the interrater reliability was .95 (with a range of .94 to .98). Disagreements among raters were resolved through discussion.

3. Correspondences among Map LCPs, Text Statements, and Knowledge Claims

I determined whether or not the LCPs in the maps made by the students corresponded to their knowledge claims. There were not always one-to-one correspondences between map LCPs and knowledge claims. That is, several map LCPs could correspond to one knowledge claim because each map LCP consisted of two linked concepts (in other words, the core of a clause) but the knowledge claims ranged from one to several sentences in length and contained as many as a half-dozen concepts and their linking words. However, these discrepancies did not present any problems in data analysis. Each faulty map LCP was matched to the corresponding linked concepts within the related knowledge claim.

The emphasis of the study was on the correspondences between faulty map information (i.e., faulty map LCPs), text information, and faulty prior knowledge (i.e., Partial Knowledge claims). However, as I analyzed the idea maps and knowledge assessment protocols, I discovered that some faulty map information corresponded to knowledge claims that were correct (with no uncertainty expressed in the claims). These correspondences are reported here, too.

As I analyzed the idea maps and knowledge assessments, I also found that some of the map LCPs that were faithful to the text corresponded to Partial Knowledge claims that had been incompatible with the text. Thus, I systematically analyzed the 31 Partial Knowledge claims in the Conflict category to learn how many of them corresponded to essentially correct information in the student-made idea maps.

To summarize the focus of this third step of analysis, I determined the correspondences between *faulty map LCPs* and the students' claims of No Knowledge, Partial Knowledge (including categories of Conflict, Basic, General, and Other), Correct Knowledge with Uncertainty Expressed, and Correct Knowledge. I also examined all of the "Conflict" claims (in the Partial Knowledge category) to see how many of these claims corresponded to *correct information in map LCPs*.

4. Construction of Selected Map LCPs

In the fourth step of analysis, I used the idea maps and videotapes (and transcripts) to analyze the moment-by-moment construction of the faulty LCP units that corresponded to the students' prior knowledge claims. A *construction* was considered to be the result of prior knowledge that is "brought to bear on a particular task within a particular situation" (Alexander, Schallert, & Hare, 1991, p. 323). This definition was applied to the current study: Each map LCP was viewed as the result of the students' prior knowledge of science concepts (from text and non-text sources) and idea mapping that was brought to bear on the building of each map component in the independent mapping session of the study.

I also analyzed the idea maps and videotapes for the presence of scaffolding provided to the students. Assisting a student with the development of the "big picture" (the relationship of the superordinate concept to key subordinate concepts) of an idea map was considered an instance of a major level of scaffolding. Assisting a student with rephrasing LCPs or with reorganizing subordinate map concepts was considered an instance of a minor level of scaffolding.

Results and Discussion

Scaffolding

I provided five students with scaffolding, three of them with major levels, one with minor levels, and one with both levels. Major levels of scaffolding occurred only in mapping sessions on the photosynthesis text. Minor levels of scaffolding occurred only in two sessions on the weather text. The number of sessions with major and minor scaffolding were evenly divided between students' first and second independent mapping sessions.

The overall organization of the photosynthesis text seemed to challenge the four students whom I provided major levels of scaffolding. In mapping the photosynthesis text, students had difficulty in determining the superordinate concept and its relationship to key subordinate concepts. The photosynthesis text is divided by headings according to the names of plant parts or plant processes (*Roots, Stems and Leaves, Foodmaking in the Leaf*, and *Storing Food*). In our "scaffolding dialogues" the four students referred to the divided emphasis of the photosynthesis text and to problems in mapping the parts and the processes of green plants. For example, Flora stated, "I'm trying to show how water's used in all of these, from the roots, to the stems to the photosynthesis."

Correspondences among Partial Knowledge Claims, Text Information, and Correct Information in Idea Maps

These results concern the incorrect prior-topic-knowledge claims that corresponded to *correct LCPs* in student-made maps. Of the 31 Partial Knowledge claims in the Conflict category (i.e., claims that were incompatible with text information), 16 of them corresponded to correct information in student-made maps. In all cases, the students' conflicting claims were directly addressed by factual information in the text. The students didn't usually reveal the process of correcting their prior knowledge, this process of construction perhaps occurring during their first reading, which they were permitted to do silently. For example, as Abby finished her first reading of the text, she remarked that she had mixed up the roles of oxygen and carbon dioxide in photosynthesis. This correction seemed to involve only the correction in the name of the gas and not a change in understanding of the photosynthetic process. This confusion of gas names was the most common incorrect knowledge claim that corresponded to correct information in idea maps, occurring in 5 of the 16 claims that were examined in the Conflict category.

Correspondences among Knowledge Claims, Text Information, and Faulty Information in Idea Maps

These results concern the correct and faulty knowledge claims that corresponded to *faulty LCPs* in the student-made maps. Of the 274 verifiable LCP units in the 16 student-made maps, 48 (18%) were judged to be faulty in terms of text. Only 3 of the 16 maps did not contain faulty information.

The faulty information included the use of imprecise links or incorrect information in the nodes. For example, in their maps two students used "produce" to link the materials and products of photosynthesis, as shown in the following node-link relationships (with nodes represented in parentheses and the link arrows omitted):

(water)(sunlight)(carbon dioxide) produce (oxygen) (sugar).

In contrast, the link "are used to produce" would have been considered precise and accurate. Faulty information also occurred in some nodes, such as in a map of the weather text:

(atmosphere) contains (gases) include (carbon).

According to the text the atmosphere contains carbon dioxide--not free carbon gas. Another example of faulty information in nodes occurred in another student's map:

(sunlight water air) contain (H_2O minerals).

This contains faulty information--sunlight does not contain water and minerals--and also shows a map syntax problem: Each node contains more than one concept. Thus, faulty mapping knowledge may have contributed to the construction of faulty map LCPs.

Of the 48 faulty LCP units in all 16 idea maps, 33 (69%) of the LCPs were represented in students' knowledge claims. (These 33 map LCPs corresponded to 21 knowledge claims.) The 33 LCPs were categorized in terms of Text Map (photosynthesis or air and weather) and type of knowledge claim:

No Knowledge, Partial Knowledge (Conflict, Basic, General, and Other), Correct Knowledge with Uncertainty Expressed, and Correct Knowledge. I found only one instance of a faulty map LCP corresponding to a knowledge claim in the category of Correct Knowledge with Uncertainty Expressed, so I decided to collapse this category and Correct Knowledge into a single category of Correct Knowledge. These data are displayed in Table 1.

[Insert Table 1 about here.]

Faulty LCPs Corresponding to No Prior Knowledge

The two instances in which a faulty map LCP corresponded to a claim of No Knowledge (see Table 1) occurred in the work of two students. Both cases involved the map of the air and weather text, one concerning an LCP on humidity and the other an LCP on air pressure. In general, there did not seem to be an important relationship between faulty map information and the absence of prior knowledge on the corresponding concepts.

Faulty LCPs Corresponding to Correct Prior Knowledge

There were 12 LCPs that corresponded to correct prior topic knowledge (see Table 1); these 12 LCPs corresponded to 8 knowledge claims. The videotaped map constructions revealed that text features and mapping constraints appeared to mediate the effects of prior knowledge on the mapping of text. That is, 8 of these 12 LCPs involved the construction of the superordinate terms in photosynthesis maps made by three students, two of whom were provided a major level of scaffolding.

Faulty LCPs with Incorrect Prior Topic Knowledge

As shown in Table 1, the 19 LCPs corresponding to faulty prior knowledge were nearly evenly divided between the photosynthesis maps (10) and the air and weather maps (9). These 19 LCPs corresponded to 11 Partial Knowledge claims.

The persistence of faulty prior knowledge during map construction may be understood in terms of an "entrenched theory" that contains "one or more deeply entrenched beliefs ... embedded in a network of other beliefs" (Chinn & Brewer, 1993, p. 15), with a *theory* defined as a "collection of beliefs that have explanatory force" (p. 39). The 12 faulty LCPs that corresponded to General (vague) knowledge claims, which lacked details or explanation, could not be understood well in terms of entrenched beliefs or theories. Other factors, such as text information and mapping constraints, along with insufficient knowledge appeared to contribute to the faulty map information.

The other seven LCPs in Table 1 are associated with "Conflict" or "Basic" claims. There was sufficient evidence in the knowledge assessment protocols to link five of these claims to students' entrenched theories about phenomena. Three of the five LCPs (and corresponding knowledge claims) involved the inclusion of minerals as an essential component of photosynthesis. These knowledge claims are consistent with the commonly occurring misconceptions about photosynthesis that were identified in other research (Bishop et al., 1986; Crawley & Arditzoglou, 1988). The five LCPs represent the knowledge and work of five of the eight students in the study. Two of these five LCP constructions are discussed in detail. In each instance the student's knowledge claim and the text information are presented as background for the corresponding map construction.

Minerals in photosynthesis: Eddie's map. Eddie was a master's level student in the first semester of his academic program. As an undergraduate he had completed two courses in physics and one in environmental biology. During his topic-knowledge interview Eddie remarked that he was trying to remember things from his high school biology course.

Eddie made two knowledge claims in conflict with the text information about the foodmaking in plants: "Green plants absorb their food through their roots," and "Soil minerals are part of the food that is taken in."

In contrast, the text (Barman et al., 1991) states, "Foodmaking usually occurs in the leaf cells of plants" (p. 66) and "Chloroplasts change the leaf's water into ... oxygen gas and hydrogen gas.... The hydrogen and carbon dioxide join to make sugar.... This sugar is the food of plants" (p. 71). However, the text also implies that minerals are involved in photosynthesis: "The things needed to make food must be transported to these leaf cells" (p. 66) and "the soil contains water and minerals the plant needs," (p. 67). These latter statements reinforced Eddie's claims that plants absorb food and that minerals are involved in foodmaking.

During his mapping session the earliest connection that Eddie made between minerals and the foodmaking process occurred in his third map draft. A detail from his third draft is presented in Figure 1. The map was redrawn from data revealed on the videotape because Eddie had crossed out several words, making the LCPs illegible.

[Insert Figure 1 about here.]

The following excerpt from Eddie's think-aloud protocol shows the construction of the LCP connecting *minerals* and *food* and corresponds to part of the information in Figure 1. In the excerpt, please note: "[M]" shows what he read from his idea map; what he wrote on his map is printed in italics.

> [Eddie glances at text diagram showing transportation of water, minerals and other materials, p. 69; looks back to map.] "[M] Leaves... [um] ... Leaves ... " *have connection to → soil*. "[M] Soil" *provides → minerals*. Now what does all that leave us? ... [Rereads several LCPs from map ...]. "[M] CO_2 minerals energy" unite [draws arrows connecting CO_2, minerals, energy]--What's my topic down here?--to make food *make → food*.

In essence, Eddie used the text to guide his construction of two LCPs showing that soil provides minerals to make food in plants.

In the final (ninth) draft of his idea map (see Figure 2), Eddie correctly stated that plants make food and that sugar is the food of plants. Several times during his mapping session, Eddie encountered text information that explicitly stated that "plants make food" (the title of the text passage!) and that sugar is the food of plants. Thus, this information overcame his prior knowledge claims that plants absorb minerals as part of their food.

[Insert Figure 2 about here.]

On the other hand, Eddie showed in his final draft that water provides minerals for photosynthesis. While mapping, Eddie encountered information that reinforced his prior knowledge that minerals are involved with photosynthesis, but he never explicitly encountered any information to challenge his inaccurate knowledge. That is, during the rest of his mapping session, Eddie never used the diagram of a chloroplast on page 71, the only place in the text stating that water provides hydrogen for photosynthesis. At one point he skimmed the diagram but never read aloud the word *hydrogen*. In sum, his entrenched belief about minerals in the foodmaking process was modified somewhat but not thoroughly changed by the text.

Carbon in the air: Abby's map. Abby was a graduating senior who had taken a science education methods course as well as college courses in astronomy, geology, and plant biology.

During her topic-knowledge assessment, Abby wrote that "air is made of molecules of different gases, including carbon, hydrogen, oxygen, and other gases." This claim was categorized as basically accurate (a "Basic" claim), but she wrote *carbon* instead of carbon dioxide. She also wrote *hydrogen*, but not water vapor. During the interview I asked Abby, "What form of carbon might be in air?" She replied, "Most likely combined with oxygen to form carbon dioxide." Abby also stated that "air can contain water, but that's a result of hydrogen and oxygen combining...." She added later, "... if it's warm, there's a greater percentage of [unintelligible word] like creating steam and water vapor, and molecules combine and cause rain." Thus, Abby seemed to have an entrenched theory that accounted for weather changes through the combining of elemental molecules of different gases.

The text discusses carbon dioxide in several paragraphs and includes it as a label in the diagram, "Gases in the atmosphere" (Mallinson et al., 1991, p. 307). Water vapor, but not hydrogen, is mentioned in several places in the text. The text never discusses what causes rain and other forms of precipitation.

Abby's idea map does not include hydrogen, but it does include carbon instead of carbon dioxide, as shown in Figure 3, which displays a detail excerpted from the first of two map drafts that Abby made of the weather text.

[Insert Figure 3 about here.]

The think-aloud protocol shows what Abby stated as she constructed the LCP involving carbon in Figure 3:

> "[Reads text] Carbon dioxide enters the air when it is given off--" Oh, this is carbon, not oxygen. Where's carbon? [Turns page to pie chart, then writes *C* on map] Carbon is really a small percentage, but I guess that should be on here [the map] too.

The pie chart in text shows that carbon dioxide makes up a small percentage of the gases in the air, but Abby read aloud "carbon" and wrote the symbol for the element carbon on her map. She continued to include the term *carbon* in the rest of her work, though the text used the term *carbon dioxide*. Thus, the difference between the two terms was more than just a difference in concept labels. Carbon appeared to be part of Abby's entrenched theories about the air and weather, and the text did not refute her theories by explaining how weather occurs.

Conclusion

Several conclusions seem warranted by this study. First, preservice teachers appear to have prior topic knowledge that overrides conflicting information in text if entrenched beliefs in their prior topic knowledge are not explicitly refuted by text information.

Second, the successful implementation in classrooms of visual representations of text structure may depend upon extensive teacher preparation through numerous opportunities for guided practice with a variety of text selections. The amount of scaffolding of student work in the present study indicated that one intensive instructional session was not sufficient to prepare students for independent mapping. The difficulty of mapping text structure appears to depend in part on prior knowledge of the text topic and the complexity of the structure of the particular text being mapped.

Third, the methods used to collect and analyze data on the correspondences among prior topic knowledge, text features, and idea mapping may be useful in future research on learning from text. Detailed descriptions of conceptual knowledge, text manipulations during learning, and text representations of learning from text (such as idea maps) may be necessary for researchers to understand the complex relationships among prior topic knowledge, text features, and task conditions that affect learning from text.

The findings in this study have implications for the preparation of preservice elementary teachers. Preservice elementary teachers could benefit from knowing what misconceptions they might bring to the preparation of lessons in science (e.g., see Crawley & Arditzoglou, 1988; Hynd, Alvermann, & Qian, 1993) and what misconceptions their future students are likely to have about the phenomena that they are studying. By extension, too, teacher educators need to be aware of commonly occurring content-specific misconceptions. Thus, teachers of science at all levels could benefit from access to refutational text, which contains explicit refutations of common misconceptions associated with explanations of phenomena (Guzzetti et al., 1993). Because it seems unlikely that textbook writers and teachers could anticipate the nature and depth of the non-scientific explanations that teachers and students might bring to their study of topics in science, teachers and teacher educators also could benefit from knowing how to recognize their own misconceptions and how to promote conceptual change in their students.

There is a growing body of research literature on the nature of conceptual change and how to promote it (Chinn & Brewer, 1993; Guzzetti et al., 1993; Hynd, Qian, Ridgeway, & Pickle, 1991; Pintrich, Marx, & Boyle, 1993; Strike & Posner, 1992). These instructional strategies could be made available to preservice and inservice teachers.

On the other hand, there seems to be little research evidence of how adults, including preservice and inservice teachers, can teach themselves to recognize their own misconceptions. The research and other scholarship on conceptual change, however, suggest that some of the components of this self-analytic process might include the following: (a) examining one's existing science topic knowledge through writing (Armbruster, 1991), (b) reading refutational text and reflecting upon scientific explanations and misconceptions (Guzzetti et al., 1993), (c) discussing scientific explanations, misconceptions, and conceptual change with peers and colleagues (Champagne, Klopfer, & Gunstone, 1982; Strike & Posner, 1992; Vosniadou & Brewer, 1987), and (d) developing visual representations of conceptual relationships in science text and of phenomena under scientific study (Mayer, 1989; Hynd et al., 1991). Investigations of the metacognition involved in teaching oneself conceptual change in science are needed to determine the appropriateness and usefulness of these four components and others that could be added to the list.

The generalizability and transferability of the findings from this study to the preparation of preservice teachers are limited by two conditions: (a) only eight preservice teachers, two science text selections from two topic areas, and one type of visual representation of text structure were used in the study, and (b) mapping did not occur within the context of a regular teacher education course or field experience.

In spite of these limitations, this study and others point to the need for current and future teachers to have access to informative refutational text, to methods for teaching for conceptual change, and to a systematic way for evaluating their own scientific knowledge. With this information, teachers can strengthen their knowledge base for teaching science. Teachers who develop a strong base of content knowledge and become skilled at using instructional tools, such as visual representations of key text ideas, can guide their students to successful learning.

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Appendix

Four Text Statements & Claims of Partial Knowledge

1. **Text:** "Weather is the condition of the atmosphere at a given time and place. The conditions that make up weather include air temperature, air pressure, wind, and water in the form of ice, water droplets, and water vapor" (Mallinson et al., 1991, p. 309).

General claim (Dixie): "Weather is what it is outside, including temperature and wind."

Claim Conflicting with text (Dixie): "Weather could be defined as the result of different amounts of carbon dioxide, oxygen, and water in the air."

2. **Text:** "The water vapor in the air is called humidity.... *Relative humidity* is the amount of water vapor that the air can hold at that temperature.... Relative humidity is expressed as a percent" (Mallinson et al., 1991, p. 309).

General claim (Carrie): "Humidity is moisture in the air."

Basically accurate claim (Abby): "Humidity is the percentage of water vapor in the air."

3. **Text:** "During photosynthesis, plants take in water from the soil and carbon dioxide from the air. They produce oxygen and sugar. This sugar is the food of plants" (Barman et al., 1991, p. 71).

Basically accurate claim (Becky): "Plants make food by taking in carbon dioxide, water, minerals, and nitrogen, and making carbohydrates, sugar."

Claim conflicting with text (Ginny): "Through the process of photosynthesis, the plants convert minerals from the soil into 'food'--not food as we know it--but usable energy."

4. **Text:** "During photosynthesis, plants take in water from the soil and carbon dioxide from the air. They produce oxygen and sugar.... Chloroplasts use light energy to change the leaf's water into two parts: oxygen gas and hydrogen gas.... Chloroplasts use light energy to combine hydrogen and carbon dioxide. The hydrogen and carbon dioxide combine to make sugar" (Barman et al., 1991, p. 71).

General claim (Flora): I think that plants need water in photosynthesis, but I can't remember the actual process.

Basically accurate claim (Holly): Water is used in photosynthesis.... I'm assuming that the process has something to do with the chemical bond between water mixing with the carbon dioxide and then giving off glucose and then oxygen.

Table 1

Faulty Map LCPs Corresponding to Students' Prior Knowledge Claims

	All Idea Maps	Photosynthesis Maps	Air and Weather Maps
No Knowledge	2	0	2
Correct Knowledge	12	11	1
Partial Knowledge	19	10	9
Conflict[a]	3	2	1
Basic[b]	4	1	3
General[c]	12	7	5
Other[d]	0	0	0

[a]Claim incompatible with text

[b]Claim basically accurate in terms of text, but shows some confusion or is incomplete

[c]Vague claim lacking details or explanation

[d]Claim not fitting another category or not corresponding to text

Figure Captions

Figure 1. Detail (redrawn) from Eddie's third map draft of photosynthesis text

Figure 2. Eddie's final (ninth) map draft of photosynthesis text

Figure 3. Detail from Abby's first map draft of weather text

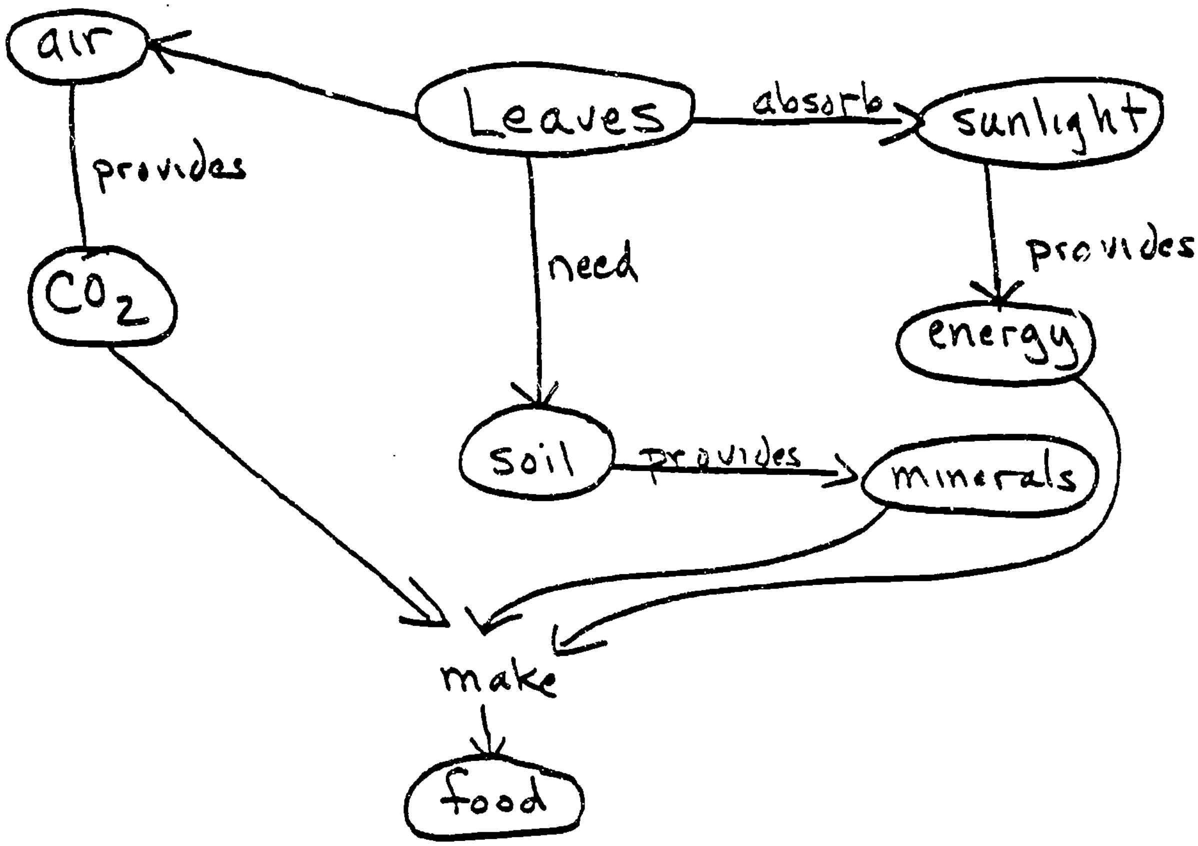
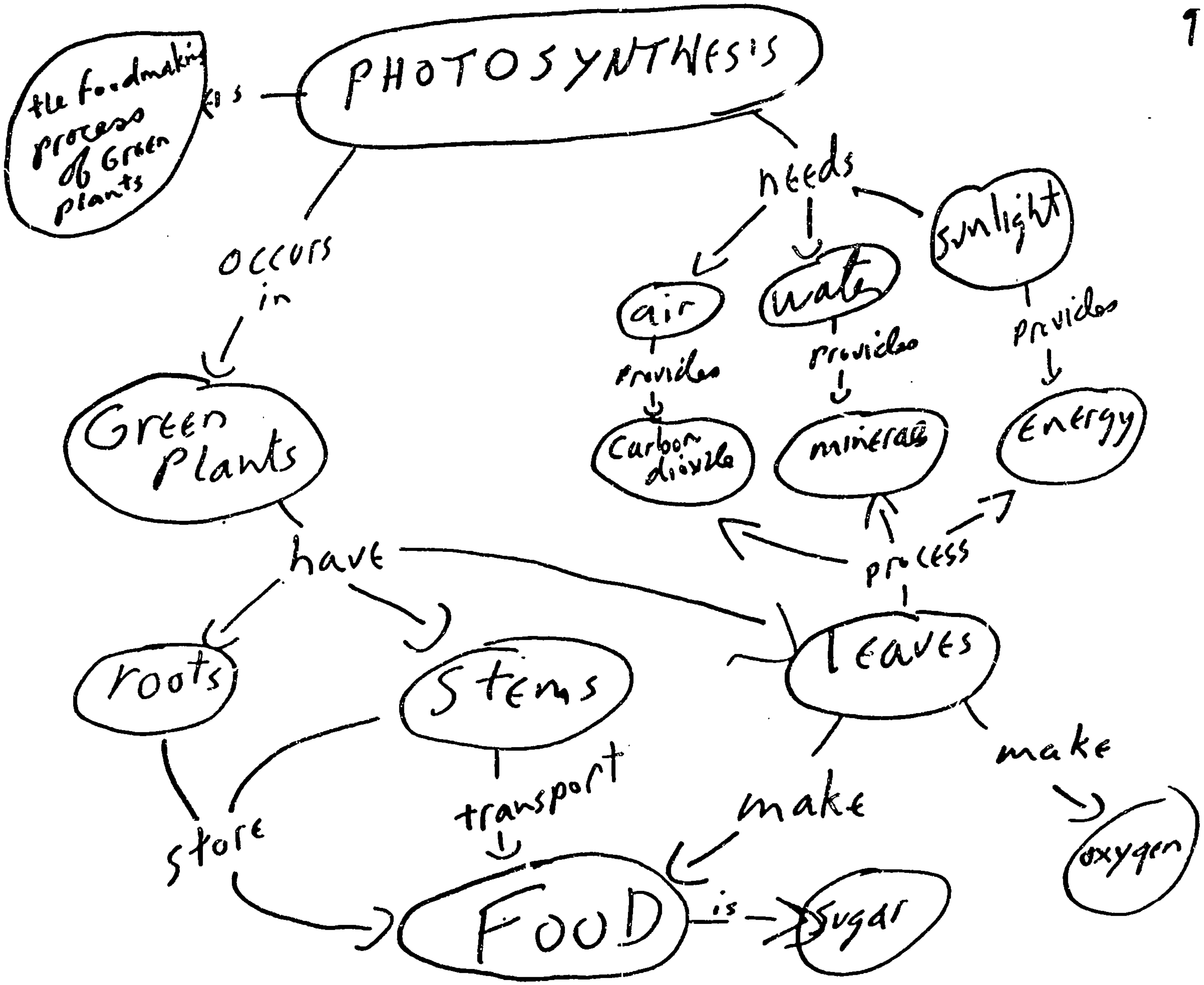

air
Leaves
absorb
sunlight
provides
need
provides
CO2
energy
soil
provides
minerals
make
food

Figure 1



PHOTOSYNTHESIS
is
the foodmaking process of Green plants
occurs in
Green Plants
needs
air
water
sunlight
provides
carbon dioxide
minerals
Energy
have
roots
Stems
leaves
process
store
transport
make
FOOD
is
sugar
oxygen

Figure 2

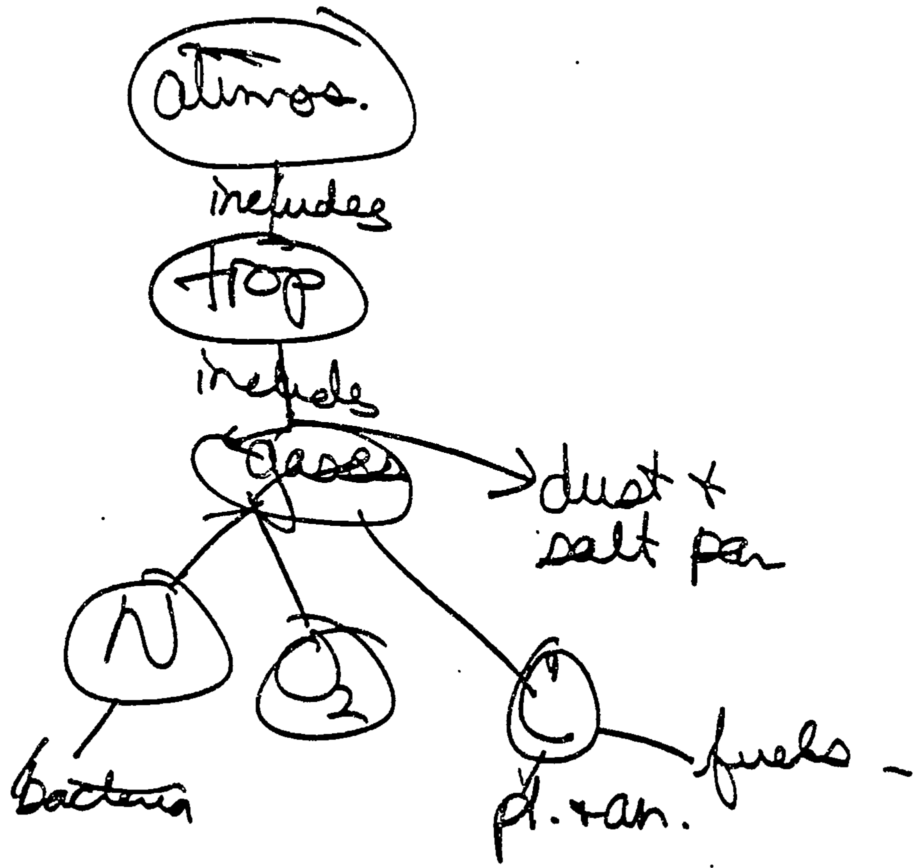

atmos.
includes
trop
includes
gases
dust + salt par
N
O2
C
bacteria
pl. + an.
fuels

Figure 3