Third Misconceptions Seminar Proceedings (1993)

Paper Title: **Explicit Signaling of Causal Relationships: A Text-Based Organizational Strategy to Help Elementary Teachers Understand Science Demonstrations**

Author: Gates, Rosalyn H.

Abstract: The purpose of this paper is to describe a text-based organizational strategy called explicit causal signaling and to demonstrate how it can be applied to create clear and understandable text explanations of science demonstrations for readers who do not possess extensive science background knowledge, namely, elementary preservice and inservice teachers. The strategy was used in the author's doctoral research in restructuring science text (Gates, 1992) and is supported by research-based practice in the areas of reading instruction and text comprehension (Beck, 1989; Cooper, 1993; McNeil, 1987; Vacca & Vacca, 1993). The theoretical framework that underlies the strategy comes from the writings and research of educational psychologist, Richard Mayer (Loman & Mayer, 1983; Mayer, 1987; Mayer, 1984; Mayer & Greeno, 1972), and will also be described.

The paper is organized into four major sections and a summary. The first section defines and describes expository text structure and the organizational strategy of signaling in text. The next section establishes the importance of clear text organization as an aid to comprehension. The third section provides some examples of causal explanations for an air pressure demonstration that lack text clarity and consequently make comprehension difficult, especially for elementary school teachers. The last section explains, step by step, how to apply the strategy of explicit causal signaling to clarify text explanation and thus improve reader comprehension. The paper then concludes with a brief summary of the major points established in the discussion.

Keywords: Educational Methods,Teacher Education,Concept Formation,Learning Strategies,Comprehension,Cognitive Processes,Teacher Educators,Teaching Methods,Teachers
General School Subject: Physics
Specific School Subject: Mechanics
Students: Education majors

Macintosh File Name: Gates - Signaling
Release Date: 6-24-94 G, 11-10-1994 I

Publisher: Misconceptions Trust

Publisher Location: Ithaca, NY
Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics
Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

----- -----

Explicit Signaling of Causal Relationships: A Text-Based Organizational Strategy to Help Elementary Teachers Understand Science Demonstrations

Rosalyn H. Gates
Indiana University of Pennsylvania
Indiana, Pennsylvania, U. S. A.

INTRODUCTION

The purpose of this paper is to describe a text-based organizational strategy called explicit causal signaling and to demonstrate how it can be applied to create clear and understandable text explanations of science demonstrations for readers who do not possess extensive science background knowledge, namely, elementary preservice and inservice teachers. The strategy was used in the author's doctoral research in restructuring science text (Gates, 1992) and is supported by research-based practice in the areas of reading instruction and text comprehension (Beck, 1989; Cooper, 1993; McNeil, 1987; Vacca & Vacca, 1993). The theoretical framework that underlies the strategy comes from the writings and research of educational psychologist, Richard Mayer (Loman & Mayer, 1983; Mayer, 1987; Mayer, 1984; Mayer & Greeno, 1972), and will also be described.

The paper is organized into four major sections and a summary. The first section defines and describes expository text structure and the organizational strategy of signaling in text. The next section establishes the importance of clear text organization as an aid to comprehension. The third section provides some examples of causal explanations for an air pressure demonstration that lack text clarity and consequently make comprehension difficult, especially for elementary school teachers. The last section explains, step by step, how to apply the strategy of explicit causal signaling to clarify text explanation and thus improve reader comprehension. The paper then concludes with a brief summary of the major points established in the discussion.

EXPOSITORY TEXT STRUCTURE AND THE ORGANIZATIONAL STRATEGY OF SIGNALING

Expository text is prose that is designed to inform, describe, or explain. Most science textbooks are written in expository prose. How the author organizes the prose to communicate to the reader the important ideas and concepts written in the paragraphs and the precise relationships between those ideas and concepts is referred to as text structure.

More specifically, text structure refers to the *pattern* used by the author to arrange the ideas and concepts and to the nature of the relationships connecting the ideas and concepts (Anderson & Armbruster, 1984).

There are several different structural patterns used by authors for writing expository text. Common patterns are description, sequence, cause-effect, problem/solution, and compare/contrast (Cooper, 1993). The author's purpose for writing determines which pattern the author chooses to use. For example, a cause-effect structural pattern would be used for the purpose of explaining how facts or events (effects) come into being as a result of other facts or events (causes). Vacca & Vacca (1993) provide the following text as an example of this pattern:

> The fire was started by sparks from a campfire left by a careless camper. Thousands of acres of important watershed burned before the fire was brought under control. As a result of the fire, trees and the grasslands of the slopes of the valley were gone. Smoking black stumps were all that remained of tall pine trees. (p. 41)

Here is another example. This time the pattern is description. The purpose for using this structural pattern is to present facts, characteristics, traits, or features about a topic, event, object, person, or idea. In the example, the author describes a tiger stalking its prey.

> The tiger is the master of the Indian jungle. It stalks its prey in deadly silence. For half an hour or more, it carefully watches and then slowly, placing one foot softly in front of the other, closes in. (Cooper, 1993, p. 119)

Expository prose can be very complex. Although a single structural pattern usually predominates, authors may embed other patterns within the text in order to fully develop the intended communication. Recognizing this complexity and the need for readers to follow the writer's thoughts, authors use an organizational strategy within the text, called signaling, to clue the reader as to which structural pattern is being used and when. The technique involves the placement in text of noncontent words that serve to showcase the conceptual structure or organization of the text and identify specific relationships between ideas (Loman & Mayer, 1983). Some examples of signal words are: *therefore, since, however, finally, in contrast, after, most important,* and *for instance*. Linguists call these words connectives because they connect ideas and help the reader follow the writer's thoughts.

Different signal words are associated with specific structural patterns in text. Recognizing the type of signal words being used helps the reader to identify which pattern the author is using to organize the text information. For instance, signal words such as *similarly, however, although, in contrast, in comparison,* and *unlike* clue the reader that the text is structured in a compare/contrast pattern of organization. Signal words such as *because, since, as a result of, thus,* and *cause* would indicate to the reader that the author has written a cause-effect text and that the ideas within the text have causal relationships. For an example of this from actual text, refer back to the paragraph on the forest fire. The writer used the signal words *as a result of* to indicate to the reader a cause-effect organizational pattern and what events are to be related causally.

The strategy presented in this paper focuses on cause-effect structured text and takes the general strategy of signaling one step further by limiting the signal word to the word *cause* for causal relationships *most important* to recognize in order to understand what is being explained. Other signal words are used for the less important causal events. In order to appreciate how this strategy works, it is necessary to understand the theoretical connection between text organization and reader comprehension, which is established in the next section.

TEXT ORGANIZATION AND READER COMPREHENSION

Just as expository text authors structure information as they write, so do readers restructure in their minds that same information as they read. The restructuring process, often referred to as constructing meaning, involves mentally connecting ideas within the text to other ideas within the text and then integrating the information with prior knowledge (Cooper, 1993; Mayer, 1987). Ideally, the connections made between ideas and the relationships established by the reader are the ones intended by the author. In fact, the degree to which the reader relates and connects the important ideas or concepts as the author intended is the degree to which it can be said that the reader has comprehended what the author intended (Beck, 1989; Cooper, 1993; Glynn, 1989; Vacca & Vacca, 1993). Thus, comprehension of text requires that the reader be able to make appropriate and relevant connections and relationships among and between ideas or concepts within the text as well as between the text and the reader's prior knowledge.

Given this requirement for text comprehension, how does the structural organization of the text aid the reader's comprehension? Research indicates that the more clear the text

organization and the relationship of ideas involved, the more readily readers recognize the relevant connections and relationships most essential for comprehending the text; thus, text clarity facilitates the reader's mental construction of what the author is communicating (Anderson & Armbruster, 1984; Anderson, Armbruster, & Kantor (1980); Beck, McKeown, Omanson, & Pople (1984); Pearson, 1974-75; Trabasso, Secco, & van den Broek (1984). This is especially true for readers who possess only minimal background knowledge about the text topic, since what a reader is able to infer is dependent upon the wealth of prior knowledge brought to the comprehension task (Anderson & Armbruster, 1984; Anderson, Armbruster & Kantor, 1980; Pearson, 1974-75). In other words, the connections and conclusions that are *obvious* to a reader who already knows *a lot* about the text topic are *not obvious* to a reader who knows *little* about the text topic - so the author compensates for the reader's minimal background knowledge by making relevant connections obviously clear in the text.

Mayer (1987), in his textbook *Educational Psychology, A Cognitive Approach*, and in previous writing (Loman & Mayer, 1983; Mayer, 1984; Mayer & Greeno, 1972), has offered a theoretical explanation for why text-based strategies, such as signaling, aid comprehension. The explanation is based on an information-processing model of cognition and is summarized in Figure 1.

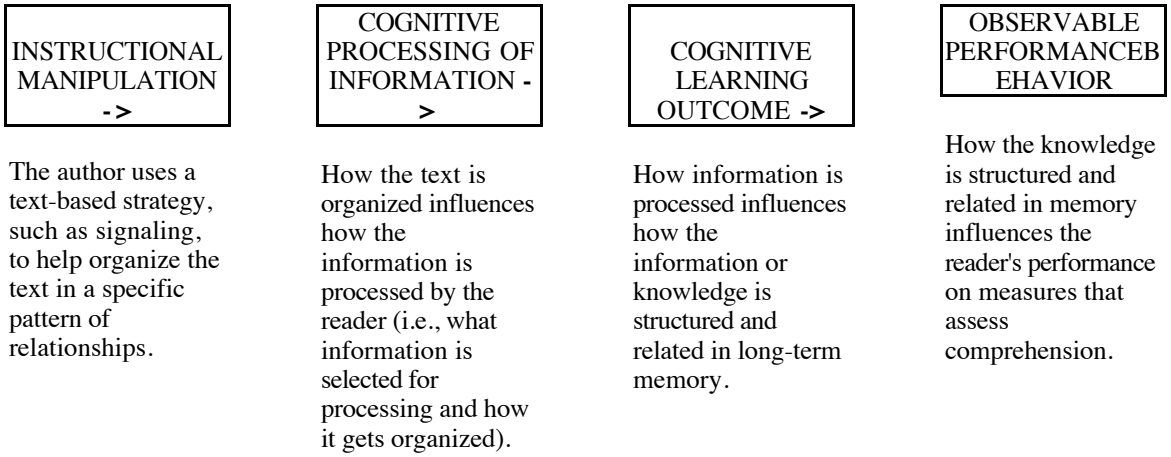

Figure 1. Theoretical Explanation for the Effect of Text Organization on Reader Comprehension. Based on Loman & Mayer (1983), Mayer (1987), Mayer (1984), and Mayer & Greeno (1972).

Mayer's theory explains the effect of text-based strategies on reader comprehension in terms of the effect strategies have on guiding the reader's cognitive processes of *selecting* text information, *organizing* the selected information into a network of concepts and relationships, and *integrating* the network in relevant ways into prior knowledge for storage in long-term memory. The resulting knowledge structure that represents the processed text information is called the reader's cognitive learning outcome. It is from this knowledge structure that the reader retrieves information to respond to measures of text comprehension. Ideally, text should be organized so that the reader will process, structure, and store the information in a form compatible with performance goals in order to facilitate retrieval.

Since clarity of text structure is such a critical factor in text comprehension, researchers in this area have examined the different text-based organizational strategies to determine each one's precise role and effectiveness as a comprehension aid (Mayer, 1984). Those who have investigated the strategy of signaling have, in general, concluded that signals have a significant effect on "directing the reader's attention toward conceptual information" and encouraging the reader to "organize the material around conceptual information, which is useful for creative problem solving"(Mayer, 1987, p. 132) (Loman & Mayer, 1983; Meyer, Brandt & Bluth, 1981; Meyer & Rice, 1984). Thus, the role of signals in text comprehension is to "provide a conceptual framework for the reader to use in

selecting [italics added] relevant information and in *organizing* [italics added] the information into a coherent representation" (Mayer, 1987, p. 128). As an organizational strategy, signals aid the reader to process and structure in memory the information from the text in a pattern similar to the author's in order to more completely comprehend the author's communication as the author intended.

Applying the theoretical reasoning just described to the strategy of explicit causal signaling, which will be described in more detail in the next sections, the explanation of how the strategy works would be as follows: The inclusion in text of the explicit signal word cause to connect the most important causal events with their related effects would "force" the reader to select and attend primarily to these cause-effect relationships and encode them in a causal organization into memory. The resulting cognitive learning outcome, which mentally represents the explanation text just read, would then be structured as a network of concepts of causes and related effects, linked by causal relations. A mental representation such as this should aid the reader in generating a reasonably accurate explanation for what was just read for the purpose of comprehension assessment. The apparent success of this strategy has been documented in the research of Loman & Mayer (1983) and in the author's doctoral research (Gates, 1992).

The remaining sections of this paper focus on causal explanations in text that explain classroom demonstrations of science phenomena and the need for these explanations to be clearly written, especially when the reader audience is one of limited science background knowledge. The strategy of explicit causal signaling is then presented as a way to improve the clarity of demonstration explanations in science text.

CAUSAL EXPLANATIONS IN SCIENCE TEXT

One of the foremost objectives in science is explanation. One type of scientific explanation, from the philosophy of science, is the causal conception. According to Kourany (1987), the causal conception of scientific explanation provides the most basic form of explanation in that it "exhibits the underlying causal processes by which the phenomenon-to-be-explained was brought about" (p. 25). To explain an event causally means to give an account of how something occurred and that involves exposing explicitly a simple chain or a more complex network of causal events and their related effects. For example, the explanation for the bending of a bimetallic rod held over a Bunsen burner

would involve laying bare the causal relationships connected with the process of heating and the expansion of metals at different rates.

Since causal explanations are considered very basic explanations, they are often used in school science textbooks and teachers' resource materials to explain how classroom demonstrations of science phenomena work as they do. Although not every science demonstration or activity lends itself readily to this type of explanation, many do, especially those that demonstrate the working of physical laws in nature.

Since the purpose of this paper is to present and describe a text-based, organizational strategy to facilitate elementary teachers' understanding of science demonstrations, let's focus on the elementary school teacher as the science text reader. More likely than not, the elementary teacher does not have extensive background knowledge in science as would a high school or college science teacher; therefore, the text to be read must be written for a reader possessing minimal prior knowledge of the science involved in the text topic. In addition, it would be advantageous for the demonstration explanation to be written in a cause-effect text pattern, if possible, since the causal explanation is considered to be the most basic form of explanation. From the discussion in previous sections, it would also be advantageous for authors to use causal signals in the explanation to help the reader focus on and select cause and effect events and mentally organize them into a network of causal relationships that would serve to represent in the reader's memory the demonstration being explained.

How carefully are demonstration explanations written in science textbooks and teachers' resource materials? Are they written for readers who possess only minimal science background knowledge and therefore must depend on the author to make explicitly clear the connections and relationships within the text that are relevant and essential for reader comprehension of the demonstration being explained? Or are the explanations written with the assumption that the reader has the background knowledge to make the inferential leaps necessary to comprehend the demonstration and therefore the author does not need to make the essential cause-effect connections explicit in the text? It has been the experience of this author, a former elementary school teacher, that demonstration explanations in science resource text materials for elementary teachers are generally *not* written for readers who possess only minimal science background knowledge. This is unfortunate because the reader audience for which the explanations have been written is one that depends on the author's clarity and completeness in order to understand the particular demonstration being explained.

Four examples of text explanations given for a classroom demonstration involving air pressure are offered to illustrate the general lack of causal clarity in written explanations for teachers. The explanations all come from different resource materials and textbooks for elementary teachers. The demonstration being explained is the same for each and is the one in which a glass is inverted over a lit candle standing vertical in 1/2 inch of water in a pie plate. As the flame extinguishes, water rises inside the glass.

Example 1:

> The burning of the candle needs oxygen and is therefore taking away all the oxygen under the cup. The flame is extinguished as soon as all the oxygen is used up. As the space under the cup does not contain any oxygen any more, it is exerting less pressure compared to the atmospheric air. The water is therefore pushed into the space under the cup.
>
> Another major factor contributing to the decrease of pressure inside the cup, is the fact that the heat of the flame expanded the air under the cup, just before it hit the water. At that moment air escaped from under the cup. After the flame extinguished, the remaining air cooled off and contracted and in so doing it sucked up the water (Liem, 1987, p. 38).

Example 2:

> As the candle burns, the oxygen part of the air in the jar combines with the carbon from the melted candle wax. The product of the reaction is carbon dioxide gas. Oxygen molecules are lighter and faster than are carbon dioxide molecules. The carbon dioxide gas does not exert as much pressure as did the oxygen, so the air outside pushes the colored water into the jar (VanCleave, 1985, p. 28).

Example 3:

> ...air expands when heated and contracts when cooled. The candle flame heats the air inside the bottle, forcing it to bubble out. In fact, if you listen, you can hear it bubble out during the first few seconds after the bottle is inverted. It happens so quickly, however, that many people are not aware of what is happening.

Later, after the fire goes out, the air contracts. Now the air tries to get back inside. Since it cannot get in any other way, it pushes the water into the bottle to replace the air that was originally pushed out (Friedl, 1986, p. 132).

Example 4:

Fires need oxygen in order to burn. The burning candle used up the oxygen contained in the air in the glass and then went out. Because of the missing oxygen, the air inside the glass became lighter than the air outside the glass. The air outside, therefore, pressed down on the water in the basin more strongly than did the air inside the glass. As a result, it pushed the water up into the glass in proportion to the difference in pressure (Mullin, 1968, pp. 30-31).

Remember that the purpose of the examples is to examine text clarity, not to pass judgment on their accuracy or completeness, although both are factors to be considered.

All four examples use cause-effect text structure. Sometimes the causal event and its effect are connected by a causal signal word or phrase, such as *therefore, as, so since, because* and *as a result*. Other times the causal relation is indicated by the use of a causal verb which is usually connected with the event that is the effect. Some examples of causal verbs are *expands, forces, heats*, and *contracts*. And sometimes no signal word is used at all.

Since these examples are all structured causally, one would expect that the causal events and the related effects would be clearly indicated. However, an initial impression suggests that the text examples are not as clear as what they could be, especially for a reader who is dependent upon the text author to clarify the network of essential causal relationships that are critical for the reader to recognize in order to mentally construct an adequate representation in memory of this demonstration.

Let's go back to some portions of text from Examples 1 and 2 and examine the causal clarity more closely.

Example 1: ....As the space under the cup does not contain any oxygen any more, it is exerting less pressure compared to the atmospheric air. The water is therefore pushed into the space under the cup....

The word *therefore* indicates a causal relationship in which water movement is the effect, but what causes the water to move? The reader who does not know beforehand that a situation of pressure difference causes movement and the movement causes a resulting situation of pressure stability will not readily recognize the cause of the water movement. The text does not make these causal relationships clear to the reader.

Example 2: ....The carbon dioxide gas does not exert as much pressure as did the oxygen, so the air outside pushes the colored water into the jar.

The word *so* indicates a causal relationship, but what are the cause and effect events that are related? Again, like the previous example, the reader who possesses only a minimal understanding of the role of pressure in this demonstration would not realize from this statement what is actually happening that causes the water to rise inside the jar. The text is unclear.

These two examples illustrate the need for authors to write clearer explanations for demonstrations in science, especially when the reader audience is one that depends upon the text clarity to aid the reader in recognizing the causal events and related effects that are critical to understanding the demonstration. And, not surprisingly, as the text clarity improves, the factors of accuracy and completeness, which were mentioned earlier, get dealt with also.

The final section in this paper describes how the explanation for the air pressure demonstration can be clarified by utilizing the organizational strategy of explicit causal signaling to facilitate comprehension for readers with minimal science background knowledge.

THE STRATEGY OF EXPLICIT CAUSAL SIGNALING

The text-based organizational strategy of explicit causal signaling that is detailed in this section was created for and used in the author's doctoral research (Gates, 1992). The strategy was applied to write an explanation text for the air pressure demonstration described in the last section. In the research study, preservice elementary teachers observed the demonstration, read either the version of explanation text that was made clear by explicit signaling or the version that was not made clear, then wrote their explanation for the demonstration. (This is an over-simplification of the actual methodology used, but it will

suffice for the purpose of this paper.) The teachers who read the explicit text generated significantly higher quality explanations, as defined in the study, than did teachers who read the non-explicit text. The conclusion made was that explicitness of causal relationships in science text is a significant factor in reader comprehension.

Since the research yielded significant results, the strategy is being shared through this paper. Perhaps other researchers in science learning/teaching will utilize it in their research, applying the strategy to write explanations for science demonstrations other than the one already used.

The strategy basically repeats the steps listed below until the writer is satisfied with the end product. To clarify steps 1-4, an example using the air pressure demonstration is given to illustrate how each step is applied in the creation of a causally explicit text, like the one used in the author's doctoral research. In that text, the air pressure explanation included 16 major causal relations, made explicit by the form "a causes b", and 14 less important causal relations that were signaled by the use of less explicit signal words or phrases, as described in Step 3. Neither the entire list of causal relations, nor the entire text, is included in this paper; however, the complete graphic representation, Step 4, is shown in Figure 2.

STEPS FOR CONSTRUCTING AN EXPLANATION TEXT UTILIZING THE STRATEGY OF EXPLICIT CAUSAL SIGNALING

STEP 1. Determine the major causal relations that form the backbone of the explanation. List these in the form "a causes b" and in the order that they become important to include as you explain the demonstration. Note that this list is not necessarily written in the order of event occurrence, since many demonstrations cannot be explained in a linear causal chain; but the list is written in the order that the relationships need to be mentioned for both the explanation and demonstration to make sense to the reader.

Application: The first two causal relations on the Backbone List for the air pressure demonstration where the water rose inside the glass were determined to be...

HEAT/HEATING AIR CAUSES AIR TO EXPAND
EXPANSION OF AIR CAUSES AIR TO ESCAPE FROM THE GLASS

STEP 2. Using this backbone list as your guide, construct an explanation text in paragraph form that maintains the form "a causes b" for each of the major causal relations. The verb *cause* is your signal word that explicitly connects the major causal events with their related effects.

Application: The constructed text began as follows...(The above two causal relations appear in capital letters for the purpose of illustration only.)...

In the demonstration, the flame from the candle is a source of heat. HEAT from the flame causes the AIR surrounding the flame TO EXPAND. The heated air is expanding as the glass is lowered over the candle. The EXPANSION OF AIR CAUSES some of the AIR from inside the glass TO ESCAPE to the outside before the glass touches the water...

STEP 3. Reread the written explanation and note any additional causal relations that are implied in the text, but were not included in the backbone list. The act of transforming the list to paragraph form seems to "uncover" these additional causal relationships that were not obvious at first. These additional causal relations may be converted to the explicit form "a causes b" or they may be written in a less explicit form, utilizing various other causal signal words, such as *therefore*, *as*, or *when* or other causal verbs such as *forces* or *expands*. In general, the most important causal relations should be written in the "a causes b" form and the less important causal relations can be written using less explicit signal words.

Application: When the text was reread, the following two less important causal relations were discovered at the very beginning of the prose. It was decided to leave the writing as it was and not explicitly signal these two new relationships...

Candle burning (combustion process) causes heat to be produced.
Heat from candle burning causes surrounding air to be heated.
HEAT/HEATING AIR CAUSES AIR TO EXPAND.
EXPANSION OF AIR CAUSES AIR TO ESCAPE FROM THE GLASS.

STEP 4. Create a graphic representation of the demonstration explanation with boxes for cause and effect events and lines between boxes to indicate causal relationships. Space your boxes and connecting lines in such a way that your representation flows from left to right and reflects any causal chains that occur simultaneously. Use this to clarify the network of relationships and as a check to see that all the essential causal relations are included in the written explanation.

Application: See Figure 2 for the graphic representation created for the air pressure demonstration. Each connecting line is a causal link between a causal event and its effect. The arrows point to the effects.

STEP 5. Repeat any of the above steps as needed until you are satisfied that the explanation you have written is both accurate and complete to the degree of preciseness that fits your intended audience.

After the explanation text has been written to the satisfaction of the writer, it is ready for its ultimate test - have someone from your intended reader audience read it and explain back to you the demonstration explanation. Do they understand what's happening in the demonstration? If it appears to you that they have an adequate mental representation of the causal relationships involved, then the strategy has been effective and the reader is ready for more elaborate discussion of the science principles involved in and related to the demonstration.

SUMMARY

A text-based organizational strategy, called explicit causal signaling, has been introduced in this paper, then described and applied to causally structured science text for

the purpose of increasing reader comprehension of a science demonstration explained in the text. The importance of clear, causal explanations has been established within Mayer's theoretical explanation of how text-based strategies aid reader comprehension. In addition, the need for explanations to be written for science demonstrations that are clear, complete, and understandable to readers with minimal science background knowledge has been illustrated and emphasized. It is the hope of this author that the strategy presented here will be researched further and become even more useful to improve the written explanations of science demonstrations found in science textbooks and teacher resource materials.

REFERENCES

Anderson, T.H. & Armbruster, B.B. (1984). Content area textbooks. In R.C. Anderson, J. Osborn, & R.J. Tierney (Eds.), Learning to read in American schools (pp. 193-226). Hillsdale, NJ: Lawrence Erlbaum Associates.

Anderson, T.H., Armbruster, B.B., & Kantor, R.N. (1980, August). How clearly written are children's textbooks? Or, of bladderworts and alfa (Reading Education Report No. 16). Urbana: University of Illinois, Center for the Study of Reading. (ERIC Document Reproduction Service No. ED 192 275)

Beck, I.L. (1989). Improving practice through understanding reading. In L.B. Resnick & L.E. Klopfer (Eds.), Toward a thinking curriculum: Current cognitive research (pp. 40-58). 1989 Yearbook of the Association for Supervision and Curriculum Development.

Beck, I.L., McKeown, M.G., Omanson, R.C. & Pople, M.T. (1984, Spring). Improving the comprehensibility of stories: The effects of revisions that improve coherence. Reading Research Quarterly, 19, 263-277.

Cooper, J.D. (1993). Literacy: Helping childen construct meaning (2nd ed.). Boston: Houghton-Mifflin Company.

Friedl, A.E. (1986). Teaching science to children, and integrated approach. New York: Random House.

Gates, R.H. (1992). The cognitive effects of causal explicitness in text on quality of written explanation and transfer performance. (Doctoral dissertation, The Pennsylvania State University, 1991). Dissertation Abstracts International, 52, 2804A-2805A.

Glynn, S.M. (1989). The teaching with analogies model. In D.K. Muth (Ed.), Children's comprehension of text (pp. 185-204). Newark, DE: International Reading Association.

Kourany, J.A. (1987). Scientific knowledge. Belmont, CA: Wadsworth Publishing Co.

Liem, T.L. (1987). Invitations to science inquiry. Lexington, MA: Ginn Press.

Loman, N.L. & Mayer, R.E. (1983). Signaling techniques that increase the understandability of expository prose. Journal of Educational Psychology, 75 (3), 402-412.

Mayer, R.E. (1987). Educational psychology, a cognitive approach. Boston: Little, Brown and Company.

Mayer, R.E. (1984). Aids to text comprehension. Education Psychologist, 19 (1), 30-42.

Mayer, R.E. & Greeno, J.G. (1972). Structural differences between learning outcomes produced by different instructional methods. Journal of Educational Psychology, 63 (2), 165-173.

Meyer, B.J.F., Brandt, D.M. &Bluth, G.J. (1980). Use of top level structure in text: Key for reading comprehension of ninth grade students. Reading Research Quarterly, (16), 72-103.

Meyer, B.J.F. & Rice, E. (1984). The structure of text. In P.D. Pearson (Ed.), Handbook of reading research (pp. 319-351). New York: Longman.

Trabasso, T., Secco, T., & van den Broek, P. (1984). Causal cohesion and story coherence. In J. Mandl, N.L. Stein, & Trabasso, T. (Eds.), Learning and comprehension of text. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Vacca, R.T. & Vacca J.L. (1993). Content area reading (4th ed.). New York: Harper-Collins.

VanCleave, J.P. (1985). Teaching the fun of physics, 101 acactivities to make science education easy and enjoyable. The Prentice-Hall Science Education Series. Englewood Cliffs, NJ: Prentice-Hall, Inc.

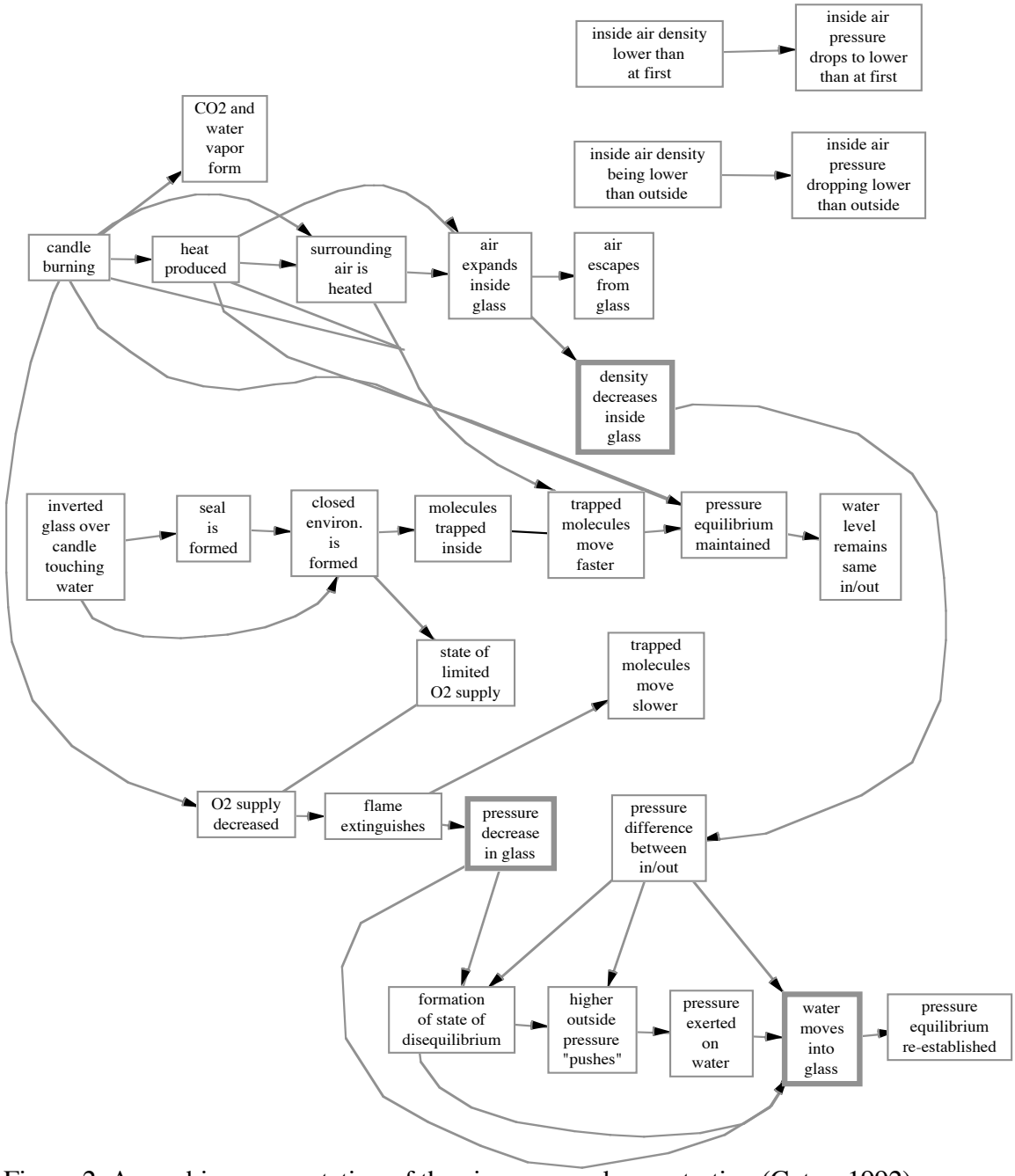

Figure 2. A graphic representation of the air pressure demonstration (Gates, 1992).