

**THE EFFECTS OF FLOW DIAGRAMS AND TEXTS WITH
INSTRUCTIVE QUESTIONS ON LEARNING VERBAL CHAINS**

by
Robert C. Branch

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APPROVED:

David M. Moore (Chair)

Thomas M. Sherman

John K. Burton

James W. Garrison

J. Thomas Head

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Chair: David M. Moore
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(ABSTRACT)

This study examined the ways in which diagrams and texts were used to teach verbal chains and other forms of cyclical information. One hundred twenty-nine college students were randomly assigned to one of four stimulus treatments and a comprehension test. The four treatments conditions were: Text Only (Control), Diagram Only, Text with Instructive Questions, and Diagram with Instructive Questions. Flow diagrams were more effective than texts as a presentation type when teaching cyclical information. The groups that studied diagrams scored significantly higher on the comprehension test than the groups that studied texts $F(1,125) = 22.44, p < .05$. However, instructive questions used as prompts or as study organizers did not enhance the instructional effectiveness of diagrams or texts. The groups that received instructive questions as an adjunct to the presentation mode scored significantly lower on the comprehension test than the groups that did not receive the adjunct questions $F(1,125) = 8.14, p < .05$. Further analysis indicated no interaction among the independent variables. It was concluded that flow diagrams are more effective than text when teaching verbal chains.

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**By the grace of God,
the wisdom of my parents,
and family support;
with the guidance of faculty,
the teamwork of colleagues,
and the encouragement of special friends;
there go I.**

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CHAPTER 1

Introduction

A summary of flow diagram research suggests single flow diagrams (e.g., a flow diagram used in teaching biological cycles and showing elements as pictures or labels) constitute an effective medium when teaching verbal chains. Verbal chains are stimuli that serve as cues or clues to assist the learner to form long sequences of associations (Gropper, 1970). In addition, similar evidence is available supporting the use of instructive questions as prompts or as organizers for information presented in either flow diagrams (Holliday, 1981, 1983) or texts (Burton, Niles, Lalik, & Reed, 1986). However, the evidence is inconclusive and both bodies of research recommend further inquiry into the use of flow diagrams and texts with instructive questions when teaching verbal chaining. This study was a partial replication of a study conducted by Holliday (1976) in which he investigated the differences between using diagrammatic representations and sentential representations when teaching verbal chains. He concluded that single flow diagrams were more effective when teaching verbal chains than texts of parallel information. He also predicted that learning verbal chains would be enhanced if instructive questions were added to diagrammatic representations and sentential representations. The theses of this study are that flow diagrams are a more effective presentation type for cyclical information than texts, and that each presentation type, when used in conjunction with instructive questions, will enhance the learning of verbal chains. The purpose of this study, therefore, was to evaluate the potential of flow diagrams and texts to teach verbal chains, and the ability of instructive questions to act as prompts or as information organizers.

Holliday (1976) noted that the basic difference between flow diagrams and textual descriptions was the manner of linking the sequential chains together. In flow diagrams, the connecting words which provide structural coherence among concepts in a text are replaced with a condensed and spatially integrated display of line drawings or block figures and design elements, thereby increasing the opportunity of mental linkage formation among verbal labels. The prompting or organizing effects of instructive questions in diagrammatic presentations was examined in this study.

According to Larkin and Simon (1987), people distinguish diagrammatic from sentential [texts] representations of information by developing alternative models of information-processing systems that are informationally equivalent and that can be characterized as sentential or diagrammatic. *Sentential* representations are sequential, like the propositions in texts. *Diagrammatic* representations are indexed by location in a plane (see Figures 1 and 2).

Can logical relationships that have been clearly established in textual terms be presented equivalently in diagrams? If so, what is the effect on student comprehension or a learners ability to remember sequences (verbal chains) when diagram technology is employed together with instructive questions?

The Hydrologic Cycle

The movement of water in a cycle is called the hydrologic cycle, or water cycle. The hydrologic cycle is the movement of the water from the oceans and fresh water sources to the air and land, and then back to the oceans. Three main steps make up the hydrologic cycle: evaporation, condensation and precipitation.

Evaporation is water vapor that comes from animals, the soil and plants, and is carried by wind over the land and the oceans. Condensation is when the water vapor changes back into a liquid and the droplets of water to form clouds. Precipitation is when the water is returned to the earth in the form of rain, snow, sleet or hail.

After the water falls to the earth by this process, some of the water returns to the atmosphere through evaporation. Then the cycle begins again.

Figure 1. Sentential Representation of Information.

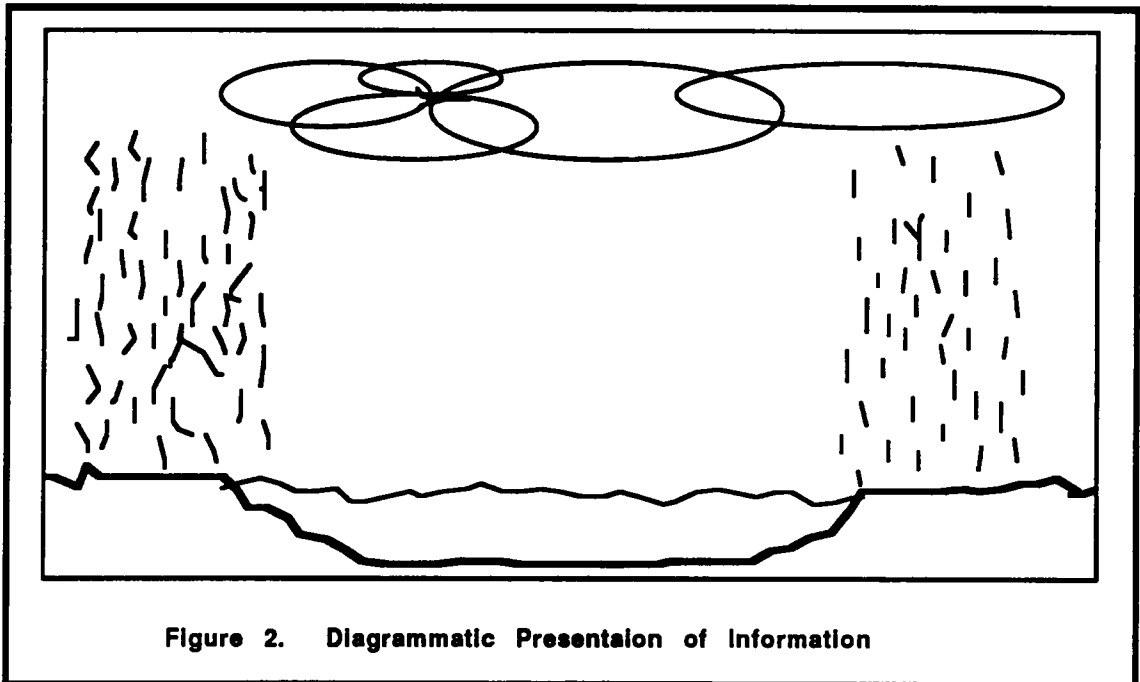


Figure 2. Diagrammatic Presentation of Information

Need for the Study

Research on diagrams is important for two reasons. First, most of the messages transmitted by electronic media are print oriented (Jonassen, 1982). For example, two of the primary instructional applications of computers are word processing and text presentation in the tutorial mode. Second, there is a resurgence of interest in print materials, based upon the increasing importance of cost effectiveness as a selection criterion for instructional materials. Thus, instructional technology is refocusing its concerns on the internal structure and design of instructional materials, rather than the medium of transmission (Clark, 1983; Jonassen, 1982).

A problem is that the effectiveness of visual materials as a component of a meaningful learning strategy is said to be obscured due to a need for standardization among visual materials (Clark, 1983; Clark & Angert, 1980; Dwyer, 1978; Heinich, 1984). The concept of standardization among visual materials can be realized once educators are able to select visual materials based on their attributes. The attributes of diagrammatic presentations are relatively well defined and the benefits of using instructive questions is also outlined rather implicitly in research literature.

However, no categorical recommendation about the use of flow diagrams can be made at this time because of the lack of diagram theory development and subsequent research in this area. Further, research should help clarify the potential utility of flow-diagram-based instruction. According to Holliday (1976), "if the terminal behavior includes concept attainment, the placement of a flow diagram with questions before or after a verbal discussion of the concepts might prove to constitute an effective instructional package" (p. 75). Therefore, it is recommended that instructional designers more seriously consider and investigate the use of flow diagrams with instructive questions.

Visual communication occupies an increasingly prominent place in the inventory of skills that citizens will need in the 21st century. Workers at all levels will be using charts, graphs and diagrams to communicate in a variety of environments. The advent of computer graphics in most school and business operations is an integral part of the routine workday (Armistead, Vogler & Branch, 1987). Although we live in an age of visual media, few people learn graphic techniques that apply graphically-literate layout strategies to instruction. Overhead transparencies, page layouts and bulletin boards usually present a flow of words down the page in straight texts or outline form. We need to research questions that describe and measure flow diagrams in a way that allows instructional designers, as well as classroom practitioners, to develop and use flow diagrams to increase the learning potential of the student. This means more practice with enlightened visual strategies in the classroom during the presentation of new concepts, abstract ideas or notions that are spatially oriented.

Charts, graphs, and diagrams comprise a family of graphic forms that have in common the attributes of abstraction and the exploitation of space. Charts illustrate relationships among categorical variables; graphs show relationships between individual variables; and diagrams describe whole processes often at levels of greater complexity than charts or graphs (Winn, 1987).

Media-related researchers typically have arranged the abstractness of instructional graphics on a continuum. Realistic pictures lie at one end while written language is located at the other (Dale, 1946; Knowlton, 1966; Levie & Dickie, 1973; Fleming & Levie, 1978). The basic rationale is that pictures resemble what they stand for while words are arbitrary (Doblin, 1980; Knowlton, 1966). Graphics (i.e., charts, graphs, and diagrams), lie at the center of this continuum. From words, graphics inherit the attribute of abstraction; but like pictures they exploit spatial layout in a meaningful way. The abstract

nature of diagrams makes them well suited for how learning processes work where realistic pictures would fail (Winn, 1980a).

Pictures are valuable in visual media because they facilitate learning by supplementing experience (Wendt, 1967). Learning is most efficient when information is presented beginning in the the concrete domain and progressing to the abstract domain (Gagne, 1977). Concrete personal experiences provide the cognitive building blocks for the student and facilitate the development of the pupil's knowledge acquisition process. Pictures can alleviate the need for some concrete personal experiences by illustrating relevant content information through the integration of pictures into the instructional event. Wendt (1967) goes so far as to suggest that "pictures are...surrogates for experience."

The relationship between words and pictures is described as a verbal/visual image relationship (Wileman, 1980). Wileman identifies seven types of verbal/visual image relationships: Type 1, Pure Verbal; Type 2, Emphasized Verbal; Type 3, Verbal with Visual Cues; Type 4, Balanced Verbal/Visual; Type 5, Visual with Verbal Cues; Type 6, Emphasized Visual; and Type 7, Pure Visual. The practice of incorporating pictures during instruction is intended to complement both oral presentations of content material and printed forms of information (Holliday & Benson, 1981).

It has been commonly accepted that pictures inserted in prose facilitate verbal learning, however, an analysis of the research literature during the early 1970's provided little support for this generalization (Holliday, 1973a). In fact, Weintraub (1970) found that pictures which are not carefully arranged in prose can actually interfere with learning in certain situations. Samuels (1970) reviewed research on the general effects of pictures on verbal comprehension and concluded that "there was almost unanimous agreement that pictures, when used as adjuncts to the printed text, do not facilitate comprehension (p. 405)." In this context verbal comprehension is defined in relatively broad terms.

One of the most comprehensive empirical evaluations of two-dimensional visuals to date was performed by Dwyer (1972a). By then, Dwyer had reported some 32 investigations in which he used similar instructional treatments, experimental designs, statistical analyses, and evaluative criteria (Holliday, 1973b). Today that number has more than doubled. Dwyer's popular treatment materials were concerned with the structure and function of the human heart. Dwyer (1967, 1970, 1972b) found that instructional pictures of various types were effective cues and reinforcers, when subjects were asked to recall the location of pictured or drawn heart structures on the criterion set. However, no significant differences between the verbal and the verbal-picture treatment groups were generally found in his studies when the subjects were verbally asked to identify those structure function relationships more commonly taught in high school and college biology classes. Dwyer concluded in these cases that instructional materials without visuals were most effective in terms of "effectiveness, economy and/or simplicity of production." But the results of an experiment by Holliday (1975a) did not support this hypothesis that pictures don't help nor did it confirm the antithesis.

This present study was undertaken based on the results of previous research, and the need to answer questions regarding the effects of flow diagrams and texts with instructive questions on learning verbal chains. What follows is a review of relevant literature that describes previous research of the variables under investigation in this study: *Presentation Type* and the *Presence of Instructive Questions* as adjuncts to flow diagrams and texts, and *Verbal Chaining* as an indicator of correct response probability.

Literature Review

The scientific study of human responses to pictures is a relatively recent development, however, a substantial body of literature devoted to the area has already been accumulated (Levie, 1987). Most studies concerned with determining the

relationship between the use of visuals and the presentation of instructional materials have manipulated the visuals (Dwyer, 1967, 1970, 1972b; Holliday & Harvey, 1976; Spangenberg, 1971). During these experiments, researchers would either vary the amount of detail in the visual or they would vary the information contained in the visual. The experiment described in this study focuses on varying the information contained outside the visual.

Nugent (1982) presented various combinations of visuals, print and audio, to school children in elementary grades, beginning with a nonverbal film about the life of a cheetah. Although Nugent's (1982) investigation did not propose a way to describe and measure the information in visuals on an absolute scale, it did provide interesting contrasts between various combinations such as visual alone, visual with texts, and visual with audio. Questions regarding variations in format or presentation formation is routinely investigated in media-related research.

The question of format or presentation modality is often answered by determining whether the encoding-decoding process is primarily prose or picture. According to Sless (1981): "the printed word, paintings, drawings, sculpture, photography, cartography, charts, diagrams, graphs, film and television are all visual forms of communication and they depend centrally on the complex process of visual cognition" (p. 23).

The more we examine our questions regarding the effectiveness of pictures as a medium of communication in instruction, the more complex the question becomes. Basing instructional decisions concerning the inclusion or quality of pictures upon intuition is to disregard what empirical evidence has been generated to date. An additional caution should be directed toward those who generalize from verbal learning theory and research to the world of pictorial instruction. For example, Haber (1970) has accumulated considerable empirical evidence supporting the hypothesis for separate

kinds of linguistic and pictorial memory systems. Paivio (1968) has also investigated the instructional relationship between pictures and words and also claims that humans possess a dual coding system. It is possible that verbal concept formation and problem solving studies are not transferable to the pictorial medium. Apparently, instructional pictures have many unique advantages, and limitations, yet to be uncovered. Hsia (1968) generally discusses the comparative effectiveness of audio (verbal) and visual channels and criticizes the simplistic explanations offered by some media people. In contrasting the two sensory channel types, he summarizes the qualities of pictorial stimuli as having "more dimensionality, with more cues and clues, and... a greater amount of uncertainty than do printed worlds" (p. 248). While the variables under investigation here do not address contrasting sensory channel types, it does examine the instructional benefits of a verbal channel type (instructive questions) with the use of a visual channel type (flow diagrams).

The idea that whenever possible, students should be presented the whole picture rather than discrete parts had its beginnings in the Gestalt theory of perception. Research generally supports the use of flow diagrams which make use of pathways or cyclic schema to condense descriptive material into more "intellectually manageable" visual displays (Spangenberg, 1971). For example, labels of chlorophyll and ATP can be linked by arrows, forming part of a more complex system of diagrams, such as energy relationships in plant life.

A review of the literature regarding topics relevant to this study is discussed below. The three main topics reviewed are the efficacy of single flow diagrams and the structure of diagram technology for instructional purposes. The second topic reviewed addresses the use of instructive questions as facilitators or inhibitors of various information presentation types. The final topic reviewed discusses the comprehension of verbal chains that represent specific response associations.

Flow Diagrams

A Flow Diagram is a graphic design, composed of descriptive texts, or pictures, or both. Flow diagrams present sequence, identify relations, such as parts to a whole, and explain, rather than represent. A diagram is defined here as evidence of an idea being structured -- it is not *the idea* but a model of it, intended to clarify characteristics of features of that idea. A diagram is a form of communication which increases the pace of development, or allows an idea to function and develop for the thinker while offering the possibility of transfer of an idea or triggering of notions: through appropriate structuring, it may generate different notions and states of mind in the viewer (Dwyer & Dwyer, 1989).

Hartman (1988) introduced an appropriate structure of diagram technology while discussing methods of teaching visual literacy. Three major elements associated with Hartman's diagram technology are *Entities*, *Connectors*, and *Layout*. *Entities* are the graphic elements in a diagram that represent objects, events and/or concepts in an information network; the nodes in the diagram. *Connectors* are the design devices that describe relationships between the entities in a diagram (directional; or by proximity). *Layout* is the graphic arrangement of entities and connectors in a diagram that describes the nature of its logical relationships.

Holliday (1975b) suggested that flow diagrams are especially helpful for recalling components of a pathway or a cyclic schema and for getting the "big picture" at a glance. A chain of words in the texts (detailing for instance the steps in a metabolic pathway) can also provide the basis for such recall. Holliday hypothesized that a single flow diagram can teach more effectively than either a text description or combination of texts and diagram.

In 1976, Holliday published the results of a study of teaching verbal chains using flow diagrams and texts. The example described by Holliday (1976) states that a

psychological principle could be presented in text (e.g., "antecedents can determine behaviors and behaviors can determine consequences") and a single flow diagram (e.g., "antecedent ----> behaviors ----> consequences") could be used to draw the learners attention to critical parts of the chain and to provide subsequent learning practice. The learning of sequential chains of verbal labels constitutes either the terminal performance or a framework on which the labeled concepts included within the chain are more fully explained in the text. Holliday's (1976) study evaluated the use of single flow diagrams and texts in terms of the more immediate goal of verbal chaining, that is, the discriminated recall of sequential chains of verbal labels.

Holliday compared the teaching effectiveness of a flow diagram to the effectiveness of texts (diagram versus text hypothesis). Holliday adapted the block word diagram used in Gropper's (1970) "big-picture" verbal diagram, and adapted the picture word flow diagram from Spangenberg's (1971) coherent diagram. Previous research suggested "that a single flow diagram alone with instructive questions constitutes the most effective presentation" (Holliday, 1976, p. 64). Results from Gropper (1970) and Spangenberg's (1971) studies indirectly support the diagram versus text hypothesis; that is, a flow diagram represents a more effective instructional medium than a text description explaining the same verbal chains. Holliday (1976) contends that:

a textual description of verbal chains can provide the basis for recall. In fact, school textbooks usually use this technique while often adding a flow diagram adjacent to the texts. However, an instructional package consisting of a single flow diagram allows the learner easier and more immediate access to all critical chains and the interrelationships among these chains. This form of instructional condensation into a single 'manageable' display also allows the learner to view the total or 'big' picture at a glance (p. 64).

Gropper (1970) found that a variety of verbal diagrams (which contained verbal labels, short phrases, block figures and arrowed lines) with instructive questions was a better learning achievement package than an undefined conventional instruction based on the same objective. Terminal performance in his study consisted mainly of verbal chain production. Gropper concluded that single page diagrams should be used more frequently in response-oriented programs (i. e., those containing instructive questions) because this display type with questions seems to facilitate discrimination among stimuli, generalizations across stimuli, and associations between stimuli.

Spangenberg (1971) examined the effects of three different levels of structural coherence within verbal and pictorial displays. Spangenberg defined structural coherence as a display characteristic which describes the degree to which elements of a display appear to be integrated. The three levels of structural coherence are distinguished as:

Minimal -- No apparent integration of items is cued.

Subgrouped -- Subgroups of approximately five items each are cued.

Overall -- The display forms a single unit.

Six displays were created, each containing matching information, presented in either pictorial or textual format. Initial learning results indicated significant superiority of pictorial display groups over textual display groups. The results of his study show that subgrouped structural coherence level displays did not demonstrate as much transfer as overall structural coherence levels. In a more broad sense Spangenberg (1971) contends that "this research demonstrates a learning consequence attributable to the apparent degree of integration of an initial learning display" (p. 518).

Instructive Questions

Instructive Questions are questions that are designed to facilitate information organization and serve as adjuncts to presentation types. Two of the four treatment groups in this present study received instructive questions to answer as they studied the presentation material. The instructive questions serve as prompts or information organizers for the content to be learned from the diagram or the texts.

Winn and Holliday (1981, 1982) discussed learning from diagrams where the theoretical and instructional considerations on the use of diagrams were two-fold. First, to identify some of the relationships that exist between the unique properties of diagrams and various aspects of cognitive processes and learning. Second, to derive principles from these relationships that would direct the design and use of diagrams in the classroom. The unique properties of diagrams can be discussed in four different contexts, and these studies examined hypotheses developed within all four contexts. The conclusions from these studies are summarized as follows: (1) diagrams help learners because they direct attention to the important information, replacing critical verbal information with graphic devices such as lines and arrows; (2) diagrams help low-verbal learners overcome some of their difficulty with language by providing information in a form they can handle more easily; (3) through the use of normal (left-right, top-bottom layout, arrows, etc.) graphic devices, diagrams can teach sequences of events effectively; (4) the addition of study questions to diagrams help learners by directing their attention to critical information; (5) prompting can be useful in helping learners.

Overprompting students by providing them with strong hints to the answers of questions can do learners more instructional harm than good (Anderson, 1970, 1972; Holliday, 1981). Anderson and Faust (1967), Faust and Anderson (1967), and Anderson, Faust, and Roderick (1968), using classroom prose materials, investigated a

strong prompting procedure employed in some self-instructional programs to assist students in locating correct answers before responding to programmed verbatim questions.

The overprompting theory was supported more recently by Holliday (1983) who investigated the hypothesis that students presented with strong prompts or hints to the answers of comprehension questions (adjunct to a flow diagram) would comprehend less than students provided with a no-prompt condition. Furthermore, a flow diagram-only (no adjunct questions) treatment group was hypothesized to outperform the strongly prompted treatment. In addition, all treatment groups were hypothesized to outperform a placebo-control group. Students provided with adjunct questions in this study were permitted to review the information presented in the flow diagram, a condition consistent with classroom practice and inconsistent with most experiments exploring other cognitive process issues dealing with shaping students' behaviors (Ellis, Wulfeck, & Montague, 1980). Holliday's (1983) results indicated the heavily prompted version was less effective than the unprompted version. It is apparent that instructive questions that are not regarded as overprompting have not been systematically investigated as adjuncts to flow diagrams when teaching verbal chains.

Verbal Chains

Verbal Chains are specific response associations (Stimulus-Response). Verbal chaining is contingent upon three conditions: "(a) the number of inputs are limited and the stimulus is presented under conditions commanding attention, (b) the response required of the learner is contiguous in time, and (c) the reinforcement as to the correctness or incorrectness of the response is immediate, and correctness procedures are implemented immediately if the initial response is incorrect" (Dwyer & Dwyer, 1989, p. 1). Under these conditions visualization is useful in assisting learners to acquire the basic data-units

of information processing -- facts. Gropper invented the term verbal chaining in his 1970 study on diagram types to describe how the probability of responding is increased. Holliday (1976) adopted the term verbal chaining to compare the teaching effectiveness between flow diagrams and texts.

A learner may be given verbal or visual examples of logical sequences and then be asked to state simple relationships between non-adjacent entities. For example, a learner may be given a verbal or visual example of what happens to solids, liquids, or gasses when heat is applied to them and may then be asked to state how heat affects matter. These varying types of cues are a second class of stimuli which find their way into practice opportunities to assist the learner in responding to the first class, the criterion stimuli. Gropper (1970) used two-dimensional blocks (Block Word Diagrams) in order to permit the spatial arrangement of verbal or pictorial stimulus material. The enclosure of material within a square permits that material to be compared distinctly with or related arbitrarily, logically, sequentially, or causally to material in other squares. The amount of material within any one square is usually held to the minimum necessary so that observing responses can be facilitated and reading time kept short. Relating stimulus material in one square with that in others is the basis for learning simple associations or complex chains. Gropper concluded that the spatial ordering of materials can facilitate the acquisition of long chains -- cyclical information.

Summary

Past visual experiments varied the information contained within the visual, however, this present study varied the information outside the visual. Because the question of the effectiveness of pictures as a medium of communication in instruction is complex, only one factor of pictorial display (flow diagram) was investigated in this study. Flow diagrams are especially helpful for recalling components of a pathway or a

cyclic schema and for getting the "big picture" at a glance (Holliday, 1975b). Flow diagrams with instructive questions are an effective instructional medium as suggested by Holliday (1976). Although Gropper (1970) and Spangenberg (1971) indirectly support Holliday's (1976) flow diagram with instructive texts theory, and further contend that a flow diagram represents a more effective instructional medium than a text description explaining the same verbal chains, the evidence is inconclusive. Gropper (1970) found that a variety of diagrams with instructive questions was a better learning achievement package than an undefined conventional instruction based on the same objective. Therefore, by utilizing identical information, but, in a textual format, we should be able to more clearly define the attributes associated with pictorial displays. Spangenberg (1971) found that pictorial display groups in controlled experiments performed better than textual display groups due to the degree of integration attributable to pictorial displays. Thus, presenting the main issue that this current study seeks to resolve, that is, are diagrams better than text descriptions when learning verbal chains.

The results of Holliday's (1976) study did not demonstrate that flow diagrams are better than text descriptions. He concluded that an alternative variable such as the use of instructive questions could produce significant differences in the use of flow diagrams when learning verbal chains. Therefore, it is reasonable to assume that a flow diagram of verbal chains can be an effective instructional medium in terms of verbal chaining behaviors related to instructive questions.

Reviewing the results of Holliday's (1976) study and subsequent investigations by Holliday and others regarding the effects of flow diagrams and texts on the ability to learn verbal chains, it is apparent that further questions need to be considered. Considering the use of instructive questions as prompts to flow diagrams is important and is examined in this study through the research questions given below.

Research Questions

The three major questions are: (1) What is the effect of presentation type (diagram or text) on verbal chain learning?, (2) What is the effect of instructive questions as an adjunct to the presentation type on learning verbal chains? and (3) Do interactions occur across presentation type (Diagram and Text) with the use of instructive questions?

Based on these questions and the review of the literature regarding the effectiveness of flow diagrams with instructive questions as prompts or information organizers, the following secondary research questions were developed: (4) Are flow diagrams with instructive questions more effective than flow diagrams without instructive questions when presenting cyclical information? and (5) Are texts with instructive questions more effective than texts without instructive questions when presenting cyclical information?

The following hypotheses were formulated based upon the research questions and the review of the literature:

- H #1 Diagrams are more effective than texts when presenting cyclical information.
- H #2 Instructive questions enhance learning effectiveness of the presentation type (diagram or text).
- H #3 There is interaction across presentation type and the use of instructive questions with diagrams being the most effective treatment and text only being the least effective treatment.
- H #4 Flow diagrams with instructive questions are more effective than flow diagrams without instructive questions.
- H #5 Texts with instructive questions are more effective than texts without instructive questions.

Additional comparisons were also statistically evaluated. Are flow diagrams with instructive questions more effective than texts with instructive questions when

presenting cyclical information? Are flow diagrams without instructive questions more effective than texts without instructive questions when presenting cyclical information? Are flow diagrams with instructive questions more effective than texts without instructive questions when presenting cyclical information? Are texts with instructive questions more effective than flow diagrams without instructive questions when presenting cyclical information?

Organization of the study

This study is divided into four chapters. Chapter 1, the Introduction, presented the need for the study, and a review of the literature relative to flow diagrams, instructive questions and verbal chaining. Chapter 1 also includes the research questions, and the organization of the study.

Chapter 2, the Methodology, describes the procedures for the study. This includes a description of the subjects, the instruments, the research procedures, the pilot study, the experiment and the research design.

Chapter 3, the Results, presents the findings of the study. It presents the statistical analysis of the comprehension test scores of the participants. Summary tables are also provided for review.

Chapter 4, the Discussion, presents the summary of the findings, and the conclusions. It also suggests recommendations for instructional designers on the use of diagrams with instructive questions and the implications for future research in this area.

These chapters are followed by a list of the literature cited and appendixes. The appendixes include copies of the treatment stimuli, the list of instructive questions, the multiple-choice comprehension test, the participant consent form, moderator scripts, instructions to the participants, selected demographic characteristics of the participants, and summary tables of additional comparisons.

CHAPTER 2

Methodology

The purpose of this study was to evaluate the potential of flow diagrams and texts to teach verbal chains, and the ability of instructive questions to act as prompts or as information organizers. This was a partial replication of a study conducted by Holliday (1976) in which the results indicated that there were differences between using diagrammatic representations and sentential representations when teaching verbal chains if instructive questions were added. Holliday (1976) noted that the basic difference between flow diagrams and textual descriptions was the manner of linking sequential chains together. In text, the connecting words which provide structural coherence among concepts are replaced in flow diagrams with a condensed and spatially integrated display of line drawings or block figures and design elements thus increasing the theoretical opportunity of mental linkage formation among verbal labels. The prompting or organizing effects of instructive questions in diagrammatic presentations were also examined in this study.

A review of the literature revealed a need for systematic investigation regarding the effects of diagrams and texts on the ability to learn verbal chains. Research that considered the use of instructive questions as prompts or as organizers for differing information types was recommended for study. The basis of this study was formed by the following research questions: (1) Which presentation mode is more effective (diagram or text) when teaching cyclical information?, (2) Does the use of instructive questions as an adjunct to the presentation mode enhance the learning effectiveness when teaching cyclical information? and (3) Is there any interaction across presentation type (Diagram and Text) with the use of instructive questions?

Participants

The participants in this experiment consisted of 129 college students enrolled in professional education classes at a large, mid-atlantic, land-grant university. The gender distribution was 102 females and 26 males, and the median age was 21 years old. The participants were from intact classes and were randomly assigned to one of the four treatment groups.

Instruments

There were two instruments used in this study: a flow diagram depicting biogeochemical cycles and a three-page-text passage with parallel information on biogeochemical cycles as in the flow diagram. In addition, there was a list of twenty instructive questions that requested the participants to provide a written response and a twenty-four item multiple-choice comprehension test (the dependent variable) which includes demographic information.

The flow diagram used in this study was a replica of the flow diagram used in previous studies by Holliday (1976, 1981, 1983). The content of the instruments used in this study were validated by a panel of four experts who have taught in the field of Earth Science. The individuals on the panel represented a cumulative teaching experience of 67 years at either high school or college level. The comprehension test (dependent variable) produced a Kuder-Richardson reliability coefficient of 0.531. Each of the two instruments and the additional experimental materials are described below.

The *flow diagram* used in this study described four, related, scientific pathways or cyclical schemes (see Appendix A). Specifically, these are oxygen, carbon dioxide, nitrogen, and water cycles. These cycles were selected because the content was appropriate for instruction by a diagram. The diagram also contained color and was stylized by line drawings illustrating concrete objects (e.g., "deer"). The more abstract

technical concepts (e.g., "the nitrogen cycle") were placed in a logical position similar to their occurrence in nature. For example, the "nitrifying bacteria" label was spatially placed below ground level. The diagram (similar yet more complex than those found in some Biological Science Curriculum Study (1973a, 1973b) learning materials) used in this study, presented cycles by syntactically condensing prose passages presented in science textbooks. The flow diagram used in this present study contained conceptual labels, such as "nitrifying bacteria" and "nitrate." These conceptual labels were spatially linked in the display by arrowed lines, which indicated a part of the nitrogen cycle. Arrowed lines, separation, adjacency, two-dimensional positioning, ordering of words and referent drawings constituted the spatial or diagrammatic techniques used to facilitate information processing of conceptual relationships in a way not possible in a typical science texts (Holliday, 1976). Recently, Winn (1980b, 1982) empirically and theoretically supported the learning effectiveness of such science diagrams.

The *text passage* contained the same information as presented in the diagram. A textual description of the same linkages was typically restricted to the use of nouns, verbs and modifiers and presented in sentence form. The text passage used in this present study featured words in boldface type to indicate concrete concepts. The more abstract concepts were phrased in sentences where the boldface word began the sentence (see Appendix B)

The *list of instructive questions* (see Appendix C) used in two of the four treatments was of the "fill-in-the-blank" variety and served as an adjunct or prompt to the diagram or text presentations. Anderson (1972) recommended that comprehension questions used to explore research hypotheses be operationally definable in terms of each other and in terms of treatment learning materials. Accordingly, two types of study questions (ten each) were developed for this study and covered all criterion information. Students were instructed to write concept labels associated with a given concept

displayed in the diagram or text. Specifically, Type I questions begin with the word "What" and requested students to write a single component of a two-concept pair linked by an arrowed line presented in the diagram or text. For example, "What thing makes oxygen?" Type II questions begin with the word "List" and requested students to write two to six components independently linked by arrowed lines to a central or common concept presented in the diagram or text. For example, "List four things that need oxygen." These two question types were placed in a random presentation order independent of the question type. Such an arrangement permitted a sample-question treatment with no chance of a randomly selected question dependent in some manner on an adjacent unselected question from the pool of 20 study questions. Finally, the responses to the instructive questions written by the participants were not scored, neither were the participants provided feedback regarding their answers to the instructive questions. This is consistent with Anderson (1970).

The *comprehension test* (dependent variable) consisted of 24, four-choice items and constituted a content synthesis of two or more of the units displayed in the diagram or presented in the texts (see Appendix D). An example was, "Trees can: (1) add oxygen to the air, (2) remove carbon dioxide from the air, (3) remove oxygen from the air, or (4) all of the above." A paraphrasing technique adapted from Anderson and Biddle (1975) was used to increase the chances of measuring learner comprehension of the diagrammatic information. Specifically, the verbs and modifiers differed in the instructive and comprehension test questions and were not used in the diagram or text. The nouns used in the comprehension test questions and diagram are identical because of the lack of reasonable substitutes, as is often the case (Anderson, 1972; Holliday, 1983). The use of such paraphrasing techniques minimized the overlap of substantive words throughout the experiment. This increased the likelihood of the questions which could measure semantic encoding and comprehension and not just verbatim perceptual or

acoustical encoding or surface information, such as the learning of meaningless strings of word shapes and speech sounds, as described by Anderson and Biddle (1975), and Bormuth (1976).

The 24 multiple-choice, prose form (i.e., non-diagrammatic) comprehension test questions required the participants to answer discriminated recall questions. These questions were developed from the rephrased and recombined instructive questions presented in two of the treatments. For example, an instructive question from the treatment materials ("Nitrogen-fixing bacteria change nitrogen of the air to _____") formed the basis for a comprehension test question ("The bacteria that change nitrogen in the air to nitrates are the: a) denitrifying bacteria, b) nitrate bacteria, c) [*] nitrogen-fixing bacteria, d) bacteria of decay").

Procedures

The following procedures were patterned after Holliday (1976, 1981, 1983). These procedures were confirmed by W. G. Holliday (personal communication by telephone, January 25, 1989; in person, February 13, 1989).

For the experimental task, the students were randomly assigned to one of the four treatment conditions. The first treatment condition (Text Only) required the participants to read a passage composed only of prose which described verbal chains of information. The second treatment condition (Diagram Only) required the participants to study a flow diagram presenting the same verbal chains as the text only condition. The third treatment condition (Text with Instructive Questions) required the participants to answer the instructive questions as they read the textual passage. The fourth treatment condition (Diagram with Instructive Questions) required the participants to answer instructive questions as they studied the flow diagram. After receiving one of the four treatment conditions, each student completed the same 24 item multiple-choice comprehension test.

Pilot Study

A pilot study was conducted with nineteen college students. There were nine female and ten male participants, ranging in age from eighteen to thirty; the median age was nineteen. Eighty-nine percent of the participants were undergraduate students. The rest of the students were graduate students.

As a result of the pilot study, several procedural modifications were made to increase the control of extraneous variables and to increase instrument reliability. These modifications included adding more detail to the moderator scripts, and instructions to the moderator that these scripts are to be read to the participants verbatim. A stopwatch was substituted for a wall clock to record treatment times more accurately. A title was added to the color flow diagram identical to the title for the text passage to enhance construct validity. The spacing and character style of the text passage was changed to reflect that which is most common in general science textbooks. The amount of time allocated for treatment and testing was reduced from 15 minutes to ten minutes respectively so as to reduce boredom among the participants.

The Experiment

For this study each student entered the classroom and was seated with equal spacing between the other students. All students were then requested to complete the Human Subjects Consent Form (see Appendix E).

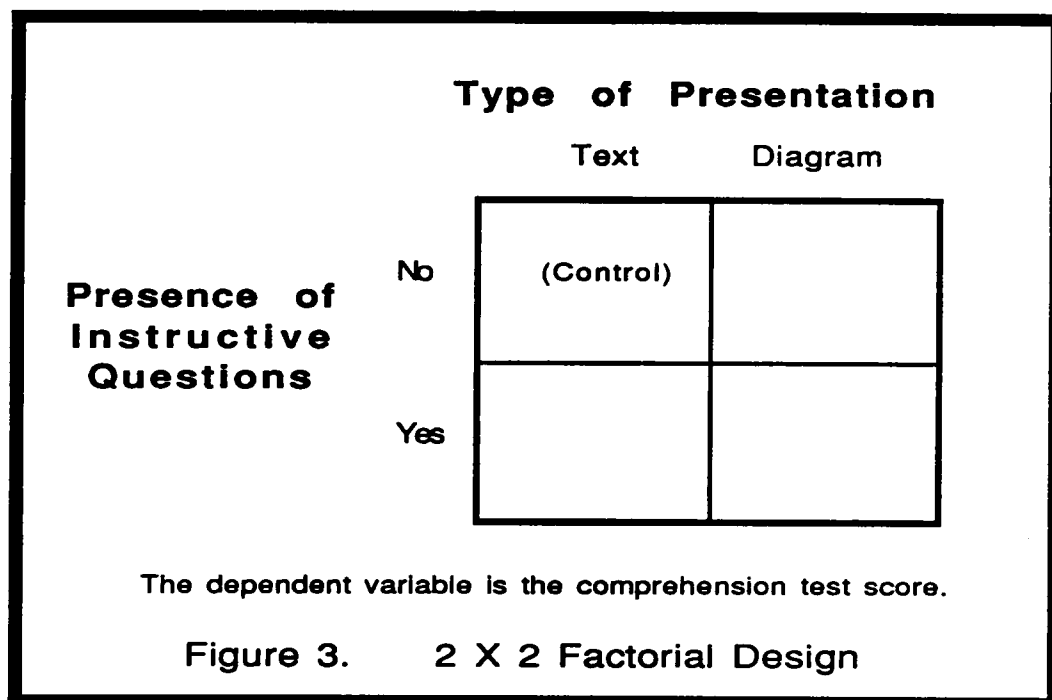
A script was read which included general instructions to the participants (see Appendix F). The specific instructions and directions related to the experiment were written on the cover sheet of the individual treatment materials packets (see Appendix G). The participants were instructed to study the presented material individually. The participants were also told that the packet of materials they received was different from

the person next to them and that they should work individually. Before the packets are distributed, the participants were informed that a comprehension test would be administered at the end of the experimental period. The form of the test was described as a multiple-choice test containing only words, and that it would be a good indicator of their ability to comprehend the science information. The participants were provided with a number two pencil to record their answers on an optical scan sheet which also contained the test questions (see Appendix D). The participants were given ten minutes to complete Part I of the comprehension test, i.e., the multiple-choice questions. The participants were requested in Part II to provide additional demographic information (not used in this study), and were not timed (see Appendix D). The placement and order of the demographic information section was carefully considered. Potentially sensitive personal information was placed last on the test so as not to affect the performance of the participants on criteria items. This is consistent with Dillman's (1978) guidelines on telephone and mail survey construction. The entire experimental process lasted approximately thirty minutes.

Research Design

This experiment used two independent variables: (1) *Presentation Type*, and (2) *the Presence of Instructive Questions*. The dependent variable was the mean score received on the comprehension test. There were four treatment conditions: Text Only, Diagram Only, Text with Instructive Questions, and Diagram with Instructive Questions. The four treatment conditions in this study contained identical information (content) presented diagrammatically or sententially either with or without instructive questions. Because text is the most common form of information presentation in formal educational environs, the participants assigned to the first treatment condition (Text Only) was regarded as the control group.

This experiment used a posttest-only equivalent group design. The data collected from the participants was analyzed using a 2 X 2 factorial analysis design. An Analysis of Variance (ANOVA) was used to determine statistical significance [$\text{Alpha} = .05$]. Figure 3 illustrates the research design. Research questions 4 and 5 were considered in a secondary analysis. Additional statistical comparisons were also included as noted earlier. Statistical significance between the means of various groups was determined by a series of one-way ANOVA's. The following chapter is a report of the results of the procedures described above.



Summary

The experimental task in this study required the participants to study a flow diagram or a text passage, with or without instructive questions, and to take a comprehension test on its contents. One group studied the text passage only. A second group studied the flow diagram only. A third group studied the text passage with the aid of the instructive questions. The fourth group studied the flow diagram with the aid of the instructive questions. The text passage was the same for groups one and three. The flow diagram was the same for groups two and four. The list of instructive questions was the same for groups three and four. All four groups received the same comprehension test following the treatments. Based on the results from the pilot study, the two instruments, the list of instructive questions and the comprehension test were judged to be of appropriate difficulty to meet the needs of the study.

CHAPTER 3

Results

The primary purpose of this study was to determine whether students studying cyclical information presented in a diagram or text, and with or without the use of instructive questions would achieve significantly different test scores. Analysis included a statistical comparison of the variance of the treatment groups. The hypotheses were tested with data collected from the study participants. A 2 X 2 factorial analysis design was employed to interpret the data. Analysis of Variance (ANOVA) was used to determine statistical significance [alpha set at .05] of the main effects (Research questions 1 - 3). A secondary analysis was conducted to test the significance of research question 4 and 5. For these questions a one-way analysis of variance [alpha set at .05] was used to determine significance.

Analysis of the Data

Table 1 provides a summary of the mean scores, standard deviations and number of subjects across all treatment groups. Table 2 contains the summary of the 2 X 2 factorial analysis of variance. Selected demographic characteristics are reported in Appendix H.

Table 1**Summary Table of Means and Standard Deviations by Main Effects**

N = 129

 $\bar{X} = 16.74$

Group	n	Mean	SD
Presentation Type			
Diagram	64	17.81	2.81
Text	65	15.69	2.43
Instructive Questions			
With	64	16.11	2.66
Without	65	17.37	2.86
Text Only	33	16.06	2.09
Diagram Only	32	18.72	2.86
Text with Instructive Questions	32	15.31	2.65
Diagram with Instructive Questions	32	16.91	2.36

Note: Maximum possible score = 24.

Table 2**Summary ANOVA Table of Presentation Type and Presence of Instructive Questions**

	DF	SS	MS	F	p
Presentation Type	1	145.73	145.73	22.436	.0001**
Instructive Questions	1	52.85	52.85	8.137	.0051*
Interaction	1	9.13	9.13	1.406	.2380
Error	125	811.94	6.50		

* $p < .01$

** $p < .001$

Research Question #1: Which presentation type is more effective (Diagram or Text) when teaching cyclical information? (Hypothesis #1: Diagrams are more effective than texts when presenting cyclical information.)

The analysis of variance summarized in Table 2 indicates that the main effects of presentation type (Diagram or Text) was significant, $F(1,125) = 22.44, p < .05$. Mean test scores from Table 1 indicated that flow diagrams ($\bar{x} = 17.81$) are more effective than texts ($\bar{x} = 15.69$) as a presentation method when presenting cyclical information. Both groups that studied diagrams scored higher on the comprehension test than the two groups that studied texts. The hypothesis was confirmed.

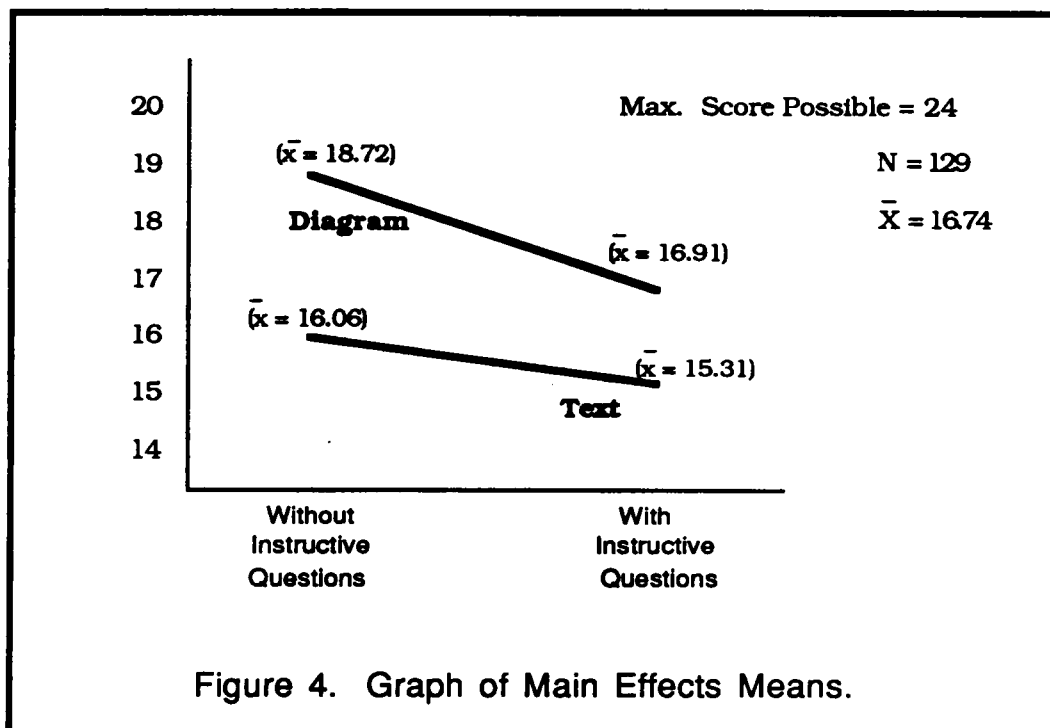
Research Question #2: Does the use of instructive questions as an adjunct to the presentation mode enhance the learning effectiveness when teaching cyclical information? (Hypothesis #2: Instructive questions enhance learning effectiveness of presentation type, diagram or texts.)

The results from the analysis of variance (Table 2) indicate that the F-ratio for the main effect of the use of instructive questions was also significant, $F(1,125) = 8.14, p < .05$. Contrary to the prediction, however, the two groups that received instructive questions as an adjunct to the diagram or text ($\bar{x} = 16.11$) scored lower on the comprehension test than the two groups that did not have the use of instructive questions ($\bar{x} = 17.37$). The hypothesis was not accepted.

Research Question #3: Is there any interaction across presentation type (Diagram and Text) with the use of instructive questions? (Hypothesis #3:

There is interaction across presentation type and the use of instructive questions with diagrams being the most effective treatment and text only being the least.)

The summary table of the analysis of variance for main effects (Table 2) indicates that there was no significant interaction, $F(1,125) = 1.41, p > .05$. In both cases the presentation type without the use of instructive questions was the most effective, i.e., Diagram with Instructive Questions ($\bar{x} = 16.91$), Diagram without Instructive Questions ($\bar{x} = 18.72$), Text with Instructive Questions ($\bar{x} = 15.31$) and Text without Instructive Questions ($\bar{x} = 16.06$). There was no interaction, therefore the hypothesis was not confirmed. Figure 4 is a graphical representation of the mean scores for each of the treatment groups.



The following two research questions (Question #4 and Question #5) were considered in the secondary analysis of variance to test the significance between each of the two groups compared, that is, flow diagrams with and without instructive questions, and text with and without instructive questions.

Research Question #4: Are flow diagrams with instructive questions more effective than flow diagrams without instructive questions when presenting cyclical information? (Hypothesis #4: Flow diagrams with instructive questions are more effective than diagrams without instructive questions.)

The summary of the analysis of variance (Table 3) indicates that there is a significant difference in the mean scores of flow diagrams with the use of instructive questions ($\bar{x} = 16.91$) and the diagrams without the use of instructive questions ($\bar{x} = 18.72$). Flow diagrams with instructive questions were, therefore, less effective than flow diagrams without instructive questions when presenting cyclical information, $F(10,31) = 2.46$, $p < .05$. The hypothesis was rejected.

Table 3
Summary ANOVA for
Diagrams with Instructive Questions and Diagrams Without Instructive Questions

Source	DF	SS	MS	F	p
Between	10	142.683	14.268	2.46	.0395*
Within	21	121.786	5.799		
Total	31	264.469			

* $p < .05$

Research Question #5: Are texts with instructive questions more effective than texts without instructive questions when presenting cyclical information? (Hypothesis #5: Texts with instructive questions are more effective than texts without instructive questions.)

Results from Table 4 indicate that there is no significant difference, $F(8,31) = .395$, $p = .9118$ between the use of texts ($\bar{x} = 15.31$) with and without instructive questions ($\bar{x} = 16.06$). The hypothesis was not accepted.

Table 4

Summary ANOVA for

Texts with instructive questions and Texts without instructive questions

Source	DF	SS	MS	F	p
Between	8	27.18	3.397	.395	.9118
Within	23	197.695	8.595		
Total	31	224.875			

Additional statistical comparisons were made and are summarized in Table 5. Summary ANOVA tables for these comparisons are found in Appendix I.

Table 5**Summary of Additional Research Comparisons of One-Way Analysis of Variance**

Table	Comparison	p
7	Diagram with questions versus text with questions.	.7599
8	Diagram without questions versus text without questions.	.7082
9	Diagram with questions ($\bar{x} = 16.91$) versus text without questions ($\bar{x} = 16.06$).	.0100*
10	Text with questions ($\bar{x} = 15.31$) versus diagram without questions ($\bar{x} = 18.72$).	.0001**

* $p < .05$.

** $p < .001$.

Note: Additional tables found in Appendix I.

This chapter presented the results of the study examining the effects of flow diagrams and texts with instructive questions on learning verbal chains. The results of the analyses indicated the following:

1. Diagrams are a more effective presentation type than texts.
2. Instructive questions do not enhance learning effectiveness as an adjunct to the two presentation types.
3. There was no differential advantage between presentation type and the use of instructive questions.

The summary of the research, discussion and recommendations are presented next in Chapter 4.

CHAPTER 4

Discussion

The present study investigated the relationship between presentation type (diagram versus text), and instructive questions with performance on verbal chain learning. Past research which dealt with educational applications of presentation types and instructive questions produced findings which were inconclusive. These inconclusive results may have been due to the fact that these earlier studies did not account for the control of parallel information contained in both presentation types, or the isolation of presentation type accompanied by adjunct questions, prior to administering the comprehension test.

The results of this study strongly support Holliday's (1976) study of flow diagrams as an effective medium when teaching verbal chains. The first hypothesis of the present study, that flow diagrams are more effective than texts when presenting cyclical information, is accepted. An explanation for this occurrence is that flow diagrams have as a primary attribute the ability to present spatial relationships of entities which reinforce a predicted response (Dwyer & Dwyer, 1989). "We know visualization is capable of: stimulating curiosity, facilitating organization, illustrating data, focusing attention, clarifying information, stimulating interest, raising questions, spanning linguistic barriers, facilitating retention of information, increasing communication reliability, isolating learning cues, facilitating discrimination, introducing new information and initiating discussion" (Dwyer & Dwyer, 1989, p. 2).

Texts may be capable of achieving the same ability to present spatial relationships of entities which reinforce a predicted response, however, diagrams apparently do this more efficiently. Support for the claim is evidenced in this study by the fact that the Diagram-Only group outperformed the other three groups on the comprehension test (see Table 1). Further support for such a claim that diagrams are more efficient than text at presenting certain types of information is observed in the difference between the number of instructive questions answered during the study period of the treatment for the two groups that received the instructive questions.

The two experimental groups that received the list of instructive questions (Text with Instructive Questions and Diagram with Instructive Questions) differed markedly in the number of instructive questions they answered during the treatment period. Group three: Text with Instructive Questions ($n = 31$), averaged a 41% completion rate of the instructive questions while Group four: Diagram with Instructive Questions ($n = 30$), managed an average completion rate of 87% of the instructive questions. This strongly suggests that it was easier for the group studying the diagram to complete the instructive questions during the treatment period than it was for the group studying the text during the treatment period. Perhaps the groups exposed to the instructive questions required longer reading time. Generalization is limited in this case because the scores of correctly completed instructive questions were not recorded, therefore, it is unknown whether those completing more instructive questions did so accurately, or that they scored higher on the comprehension test than those who did not complete as many instructive questions.

The results for this study also favor the overprompting theory (Anderson, 1970, 1972; Anderson & Faust, 1967; Anderson, Faust & Roderick, 1968; Faust and Anderson, 1967; Holliday, 1981,1983) which basically states that providing students with strong hints to the answers of questions can do more harm than good. The second

hypothesis of the present study which states instructive questions enhance learning effectiveness of the presentation type (diagram or text) is rejected. The data in this study indicated that student comprehension of verbal chains is inhibited when diagrams are employed together with instructive questions. From the results of the present study, consistent with Holliday's (1981) findings, it is recommended that researchers and teachers be cognizant of the fact that encouraging students to focus selective attention on a sampling of criterial information can result in inadequate processing of such specialized instructional materials as flow diagrams. The use of adjunct questions with flow diagrams is worthy of further investigation with regard to how adjunct questions can be incorporated into instructional methods without interfering with the way students generally study content information.

For example, the relationship between comprehension test scores and the absence of student note taking during the study period of the treatment requires further examination. Post-experiment interviews revealed that the participants desired to write study notes on the self-instructional materials, but, did not do so because the instructions to participants were not explicit in this direction (see Appendix G) and because the materials seemed so "neat," "clean," "formal," "organized" and "just too pretty to write on." Future investigations of this nature should address this issue. Another example of how adjunct questions could be better incorporated into instructional methods is to provide additional time for those required to study the diagram or text and write in the answers to the instructive questions.

In addition to the above, three variables are recommended for further research. First, additional performance verbs should be included the experimental text passage that will explicitly describe procedural entities. This will increase the reading time for the text passage, however, more directive verbal cues will enhance the parallelism of the text passage with the flow diagram. It should also be noted here that the Text Only group

was consistently observed completing their treatment ahead of two of the three other groups, which sometime added a dimension of boredom. Second, the participants in the study should be directed to take notes while studying the instructional materials during the study period (treatment). This will better simulate student classroom study activity. Third, the items on the comprehension test should be revised to increase the reliability ($K-R_{20} > .531$) and content validity. This should increase generalizability of the results from the test scores.

Conclusions

Logical relationships that have been clearly established in textual terms can be equivalently expressed in visual terms. Indeed, facilitating organization through spatial relationships and isolating learning cues with pictures may lend themselves more to teaching special kinds of information than do texts. The use of instructive questions as prompts or study organizers under experimental conditions did not enhance the ability of learners to comprehend verbal chains when added to sentential or diagrammatic representations (see Figure 4).

These findings bring into question certain aspects of the present study. Does the assignment of the text-only treatment meet the conditions of a control group? Does the concept undergirding the arrangement of the list of instructive questions satisfy the constructs of mathemagenic procedures? Does the absence of student note taking during the treatment condition violate the norms of the classroom environment?

The text-only group in the present study was considered a treatment (not a typical control) and was included to evaluate the hypothetical advantage of an uncued flow diagram. Future research dealing with instructive questions should evaluate treatment data in terms of control data because such information helps establish evidence that

experimental questions are adjunct facilitators or inhibitors of learning, according to Faw and Waller (1976), McConkie, (1977), and Rickards (1979).

The presentation order in the list of instructive questions was randomized independent of question type (Type I questions; beginning with the word "What" or Type II questions; beginning with the word "List"). Such an arrangement permitted a sample-question treatment with no chance of a randomly selected question dependent in some manner on an adjacent unselected question from the pool of 20 study questions. The possibility did exist, however, that the lack of relationship between the order of the instructive questions and the content information presented in the presentation treatments may have contributed to lower scores on the comprehension test. This is especially plausible with group three: Text with Instructive Questions where the participants were required to scan several pages of texts as they searched for the answers, unlike group four: Diagram with Instructive Questions, whose content information was presented in a single flow diagram on one page (see Table 7). Subsequent studies of this nature should consider ordering the list of instructive questions to match the order in which the information is presented in the treatment stimuli. This is particularly true with regard to the text passage where patterns of semantic coding may be affected.

Future research in the area of flow diagrams as an instructional medium should consider two additional independent variables. First, a treatment condition should be considered that presents a flow diagram accompanied by a text passage with the same information, and this should be treated as a single independent variable. This diagram with text variable can then be compared with diagram-only or text-only variables on various dependent variables. Second, prior content knowledge should be considered as an independent variable (Joseph & Dwyer, 1987). It is conceivable that college students majoring in Life Sciences, e.g., biology, would score higher as a group on an Earth Science comprehension test than non-Life Science majors.

Summary

Media-related researchers need to continue to develop the "broad picture" of flow diagram use in instruction. Diagram type, such as picture-word diagrams (Spangenberg, 1971) or block-word diagrams (Gropper, 1970), diagram complexity, such as word-picture ratio, and diagram resolution are considerations for future research on diagrams.

While we live in an age of visual media, few people learn graphic techniques that apply graphically literate layout strategies. Overhead transparencies, page layouts and bulletin boards usually present a flow of words down the page in straight text or outline form. There is a need to practice more enlightened visual strategies in the classroom by maximizing the use of diagrams (Weisberg, 1970).

Despite the widespread and increasing use of instructional graphics empirical support is needed that will enable diagrams to be effective as a medium on the basis of their instructional qualities rather than on their decorative qualities (Bates, 1981). Flow diagrams have generally been designed to supplement visually the information presented in texts. We must begin to interpret flow diagrams as an integrated component of a total learning strategy. More evaluation and analysis is still required on how verbal-visual relationships and prior knowledge affect diagram effectiveness. A more informed theoretical understanding of how learners with different levels of prior knowledge relate to varying amounts of descriptive text in diagrams will assist media-related researchers in forming clear criteria for designing efficient diagrams.

Visual thinking occupies an increasingly prominent place in the inventory of skills that citizens will need in the 21st century. Workers at all levels will be using charts, graphs, and diagrams to communicate all types of information. Continued diagram theory development and subsequent research such as this study will aid in the development of categorical recommendations about the use of flow diagrams as a component of a meaningful learning strategy.

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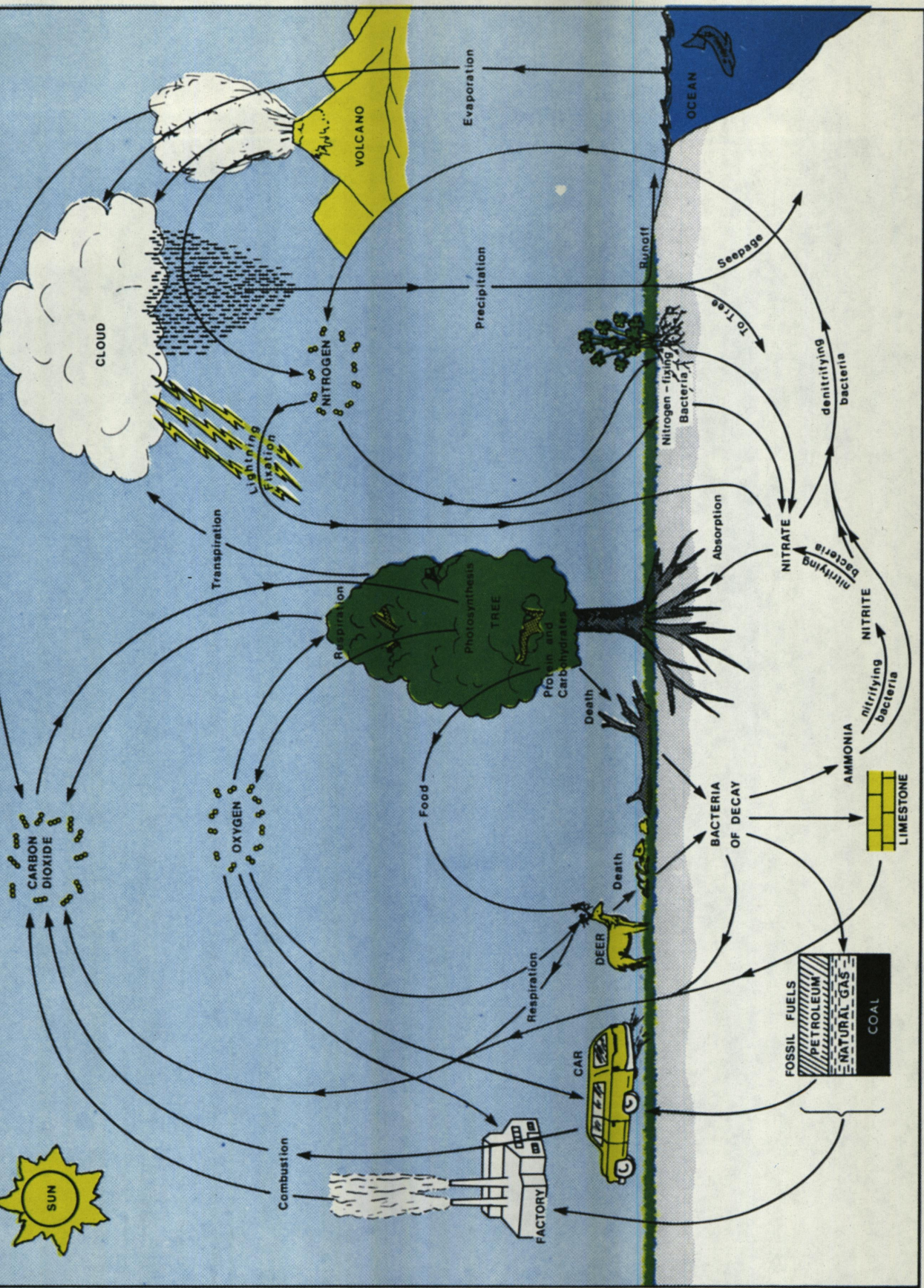
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Appendix A

Treatment Stimulus: Color Flow Diagram



Biogeochemical Cycles

Appendix B

Treatment Stimulus: Text Passage

Biogeochemical Cycles

The **sun** provides radiant energy that enables green plants to grow and to make food. Directly, and indirectly, green plants are the source of food for all living things. An indirect source of coal, petroleum, and natural gas was indirectly provided by the sun. These materials were formed by the death and decay of ancient green plants, and recycling carbon from the air. Energy from the sun permits all of the biogeochemical cycles to operate.

Clouds form when moisture in the air condenses on small particles of dust or other solid particles in the air. Moisture from trees and other plant (**transpiration**) form the clouds. Water vapor that condenses and forms clouds often falls to the earth in the form of rain, sleet, snow, or hail. Water that falls from the atmosphere to the earth is called **precipitation**. Some water that falls to the earth goes into the ocean through **runoff**. Some water goes into the ground as **seepage**. Trees and other forms of plant life use the water.

Oceans play an important part in the hydrologic cycle. During this cycle, the sun's rays heat the surface of the ocean, causing the water to enter the atmosphere as water vapor (**evaporation**). Seepage and runoff replenish the water of the ocean.

Trees and other plant life play a central role in the biogeochemical cycles of the earth. Through respiration and photosynthesis oxygen and carbon dioxide are exchanged into the air. Trees provide a source of food such as **protein and carbohydrates**. Bacterial decay are formed by the death of trees.

Photosynthesis is the process by which plants make food. Carbon dioxide is removed from the atmosphere by photosynthesis of plants. Carbon dioxide is returned to the atmosphere by the **respiration** of plants and animals. The amount of carbon dioxide used by plants is equal to the amount returned to the atmosphere by respiration, decay, and other natural processes. In addition to these processes, trees (plant life) absorb nitrates from the soil. Trees also contribute to cloud formation through **transpiration**.

Bacteria of decay contributes to the formation of fossil fuels, limestone (and other minerals), and ammonia (and other chemicals). Bacteria of decay absorb plants and animal, and returns carbon dioxide to the air. **Limestone**, and other minerals in the soil, are given off by bacterial decay, and add carbon dioxide to the air. **Deer** (and other animal life) add carbon dioxide to the air through respiration. In exchange, the death of animal life adds to food for bacteria of decay.

Fossil fuels are formed by the death and decay of ancient green plants under high pressure and temperature. The three basic types of fossil fuels are: **petroleum**, **natural gas** and **coal**. The burning of fossil fuels by cars and factories adds carbon dioxide to the atmosphere. **Cars**, and similar machines, operate on fossil fuels and oxygen. They add carbon dioxide to the air through **combustion**. **Factories**, and similar industrial facilities, also operate on fossil fuels and oxygen. Factories also add carbon dioxide to the air through combustion.

Oxygen in the air contributes to the functioning of trees (plant life), and deer (animal life), through respiration, and by cars (machinery) and factories (industry) through combustion. Plant life provides the main source of oxygen in the air through the process of photosynthesis. While oxygen contributes to the functioning of trees, deer, cars and factories, these same things add **carbon dioxide** to the air. Carbon dioxide is absorbed by trees and other plant life during photosynthesis.

Denitrifying bacteria take nitrates or nitrites and produce **nitrogen**. **Nitrogen-fixing bacteria** are microorganisms which live in the soil. Some live on the roots of plants. These nitrogen-fixing bacteria use the nitrogen of the air and combine to form nitrates, a nitrogen compound usable by plants. Since the nitrogen is no longer free it is said to be fixed. **Volcanoes** emit carbon dioxide and nitrogen into the air. The small solid particles in volcanic emissions also contribute to cloud formation.

Another phenomenon often associated with clouds is lightning. Lightning is an electrical discharge often from one cloud to another, or to the ground. **Lightning fixation** contributes to nitrogen in the soil by causing atmospheric nitrogen to form nitrates.

Ammonia, and other chemicals in the soil, are changed to nitrites by nitrifying bacteria. **Nitrite** in the soil is changed to either nitrogen in the air or nitrate in the soil. Nitrite is changed to nitrogen in the air by denitrifying bacteria. Nitrite is changed to nitrate in the soil by **nitrifying bacteria**. **Nitrate** in the soil is absorbed by trees (plant life). Nitrate is changed to nitrogen in the air by denitrifying bacteria.

Appendix C

Instructive Questions

Instructive Questions

Answer these questions as you study the self-instructional material.

1. What thing makes oxygen? _____
2. What two things use fossil fuels? _____
3. What three things form clouds? _____
4. List six things that give off carbon dioxide.

5. What thing absorbs carbon dioxide? _____
6. What thing produces nitrogen from both nitrifying bacteria and denitrifying bacteria?

7. What thing absorbs nitrate? _____
8. What three things are produced by the volcano? _____
9. What thing produces nitrite from nitrifying bacteria? _____
10. List two things that form bacteria of decay. _____
11. What thing produces nitrate from nitrifying bacteria? _____
12. List four things that use bacteria of decay. _____
13. List three destinations of precipitation. _____
14. List the three things that contribute to cloud formation. _____
15. List two things that produce combustion. _____
16. List the three basic fossil fuels. _____
17. List four things that need oxygen. _____
18. List two things absorbed by nitrogen through denitrifying bacteria. _____
19. What thing absorbs nitrogen through nitrogen-fixing bacteria? _____
20. List four things that benefit from the tree. _____


Instructive Questions

(With Answers)

1. What thing makes oxygen? Tree
2. What two things use fossil fuels? Car Factory
3. What three things form clouds? Evaporation Volcano Transpiration
4. List six things that give off carbon dioxide.
Factory Car Tree Volcano Limestone Bacteria of Decay
5. What thing absorbs carbon dioxide? Tree
6. What thing produces nitrogen from both nitrifying bacteria and denitrifying bacteria? Ammonia
7. What thing absorbs nitrate? Tree
8. What three things are produced by the volcano? Cloud Carbon Dioxide Oxygen
9. What thing produces nitrite from nitrifying bacteria? Ammonia
10. List two things that form bacteria of decay. Deer Tree
11. What thing produces nitrate from nitrifying bacteria? Nitrite
12. List four things that use bacteria of decay.
Ammonia Limestone Fossil Fuels Carbon Dioxide
13. List three destinations of precipitation. Ocean Seepage Tree
14. List the three things that contribute to cloud formation. Ocean Volcano Tree
15. List two things that produce combustion. Car Factory
16. List the three basic fossil fuels. Petroleum Natural Gas Coal
17. List four things that need oxygen. Tree Car Factory Deer
18. List two things absorbed by nitrogen through denitrifying bacteria. Nitrate Ammonia
19. What thing absorbs nitrogen through nitrogen-fixing bacteria? Nitrate
20. List four things that benefit from the tree.
Bacteria of Decay Deer Oxygen Carbon Dioxide

Appendix D

**Comprehension Test
(scored)**

INCORRECT MARKS

LEAVE BLANK

CORRECT MARKS


USE NO. 2 PENCIL

NAME

COURSE

DATE

ID NUMBER										FORM	SEAT NO.			GROUP
LEAVE	BLANK													
0	0	0	0	0	0	0	0	0	0	A	0	0	0	1
1	1	1	1	1	1	1	1	1	1	B	1	1	1	2
2	2	2	2	2	2	2	2	2	2	C	2	2	2	3
3	3	3	3	3	3	3	3	3	3	D	3	3	3	4
4	4	4	4	4	4	4	4	4	4	E	4	4	4	5
5	5	5	5	5	5	5	5	5	5	F	5	5	5	6
6	6	6	6	6	6	6	6	6	6	G	6	6	6	7
7	7	7	7	7	7	7	7	7	7	H	7	7	7	8
8	8	8	8	8	8	8	8	8	8	I	8	8	8	9
9	9	9	9	9	9	9	9	9	9		9	9	9	10

PART I: Take 10 minutes to complete Part I.

- Trees can
 - add oxygen to the air.
 - remove carbon dioxide from the air.
 - remove oxygen from the air.
 - All of the above
- Nitrogen uses nitrifying bacteria and denitrifying bacteria to produce
 - limestone.
 - nitrate.
 - nitrite.
 - Ammonia.
- Volcano residue combines with evaporation and transpiration
 - to form fossil fuels.
 - to form clouds.
 - as combustion.
 - as carbon dioxide.
- Nitrite produces
 - oxygen from denitrifying bacteria.
 - oxygen from nitrifying bacteria.
 - nitrate from denitrifying bacteria.
 - nitrate from nitrifying bacteria.
- Petroleum and coal are
 - bacteria of decay.
 - limestone.
 - fossil fuels.
 - None of the above
- Cars
 - add oxygen to the air.
 - add carbon dioxide to the air.
 - remove carbon dioxide from the air.
 - All of the above
- Limestone is formed from
 - nitrifying bacteria.
 - denitrifying bacteria.
 - bacteria of decay.
 - nitrogen-fixing bacteria.
- Which uses fossil fuels?
 - Cars and factories.
 - Trees and clouds.
 - The Sun.
 - The ocean.
- Volcanoes add
 - carbon dioxide to the air.
 - nitrogen to the air.
 - Both
 - Neither
- Trees absorb
 - nitrogen from the air.
 - nitrate from the air.
 - nitrogen from the ground.
 - nitrate from the ground.
- Ammonia produces nitrate from
 - bacteria of decay.
 - denitrifying bacteria.
 - nitrogen-fixing bacteria.
 - nitrifying bacteria.
- Factories
 - add oxygen to the air.
 - removes oxygen from the air.
 - add carbon dioxide to the air.
 - removes carbon dioxide from the air.
- Deer need
 - bacteria and ammonia.
 - oxygen and trees.
 - nitrogen and carbon dioxide.
 - None of the above
- The bacteria that changes nitrogen in the air to nitrates is
 - nitrate bacteria.
 - nitrogen-fixing bacteria.
 - denitrifying bacteria.
 - bacteria of decay.
- Cars operate on
 - nitrates.
 - carbon dioxide.
 - transpiration.
 - fossil fuels and oxygen.
- Deer, oxygen, carbon dioxide and bacteria of decay
 - use combustion.
 - benefit from the tree.
 - add nitrogen to the air.
 - None of the above
- Deer and trees die and form
 - clouds.
 - limestone.
 - bacteria of decay.
 - the ocean.
- Bacteria of decay contribute to formations of
 - ammonia.
 - limestone.
 - fossil fuels.
 - All of the above
- The ocean adds
 - carbon dioxide to the air.
 - to clouds.
 - oxygen to the air.
 - to fossil fuels.
- Carbon dioxide can
 - be absorbed by deer.
 - be absorbed by trees.
 - add to nitrogen in the air.
 - add oxygen to the air.
- Oxygen and carbon dioxide can
 - add to combustion.
 - be absorbed by trees.
 - Both.
 - Neither.
- Bacteria of decay can add to
 - the ocean level through runoff.
 - clouds.
 - fossil fuel production.
 - carbon dioxide in the air.
- Volcanoes can
 - remove nitrogen from the air.
 - add nitrogen to the air.
 - remove oxygen from the air.
 - add oxygen to the air.
- Nitrogen-fixing bacteria forms
 - oxygen.
 - nitrogen.
 - nitrite.
 - nitrate.

1	1	2	3	4	5	6	7	8	9	10
2	1	2	3	4	5	6	7	8	9	10
3	1	2	3	4	5	6	7	8	9	10
4	1	2	3	4	5	6	7	8	9	10
5	1	2	3	4	5	6	7	8	9	10
6	1	2	3	4	5	6	7	8	9	10
7	1	2	3	4	5	6	7	8	9	10
8	1	2	3	4	5	6	7	8	9	10
9	1	2	3	4	5	6	7	8	9	10
10	1	2	3	4	5	6	7	8	9	10
11	1	2	3	4	5	6	7	8	9	10
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15	1	2	3	4	5	6	7	8	9	10
16	1	2	3	4	5	6	7	8	9	10
17	1	2	3	4	5	6	7	8	9	10
18	1	2	3	4	5	6	7	8	9	10
19	1	2	3	4	5	6	7	8	9	10
20	1	2	3	4	5	6	7	8	9	10
21	1	2	3	4	5	6	7	8	9	10
22	1	2	3	4	5	6	7	8	9	10
23	1	2	3	4	5	6	7	8	9	10
24	1	2	3	4	5	6	7	8	9	10

STOP HERE
End of Part I

Wait for the moderator to tell you to continue.

PART II: Background Information.

- Complete all of the remaining questions.
- Put the test in the folder on the desk when you are done.
- Upon completion of Part II, you may be excused quietly.

25. My age is
1. under 18 2. 18 3. 19 4. 20 5. 21 6. 22 7. 23 8. 24 - 30 9. 31 - 40 10. over 40

26. My gender is 1. female. 2. male.

27. According to the Registrar, my current class status is
1. Freshman. 2. Sophomore. 3. Junior. 4. Senior. 5. Graduate/ Masters. 6. Graduate/ Doctoral.

28. My QCA is above
1. 0.00 2. 0.50 3. 1.00 4. 1.50 5. 2.00 6. 2.50 7. 3.00 8. 3.50

29. My current major is in the college of

1. Agriculture and Life Sciences.
2. Architecture and Urban Studies
3. Arts and Sciences.
4. Business.
5. Education.
6. Engineering.
7. Human Resources.
8. Veterinary Medicine.

30. My academic major is _____

25	1	2	3	4	5	6	7	8	9	10
26	1	2	3	4	5	6	7	8	9	10
27	1	2	3	4	5	6	7	8	9	10
28	1	2	3	4	5	6	7	8	9	10
29	1	2	3	4	5	6	7	8	9	10
30	1	2	3	4	5	6	7	8	9	10
31	1	2	3	4	5	6	7	8	9	10
32	1	2	3	4	5	6	7	8	9	10
33	1	2	3	4	5	6	7	8	9	10
34	1	2	3	4	5	6	7	8	9	10
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40	1	2	3	4	5	6	7	8	9	10
41	1	2	3	4	5	6	7	8	9	10
42	1	2	3	4	5	6	7	8	9	10
43	1	2	3	4	5	6	7	8	9	10
44	1	2	3	4	5	6	7	8	9	10
45	1	2	3	4	5	6	7	8	9	10
46	1	2	3	4	5	6	7	8	9	10
47	1	2	3	4	5	6	7	8	9	10
48	1	2	3	4	5	6	7	8	9	10

DO NOT
WRITE
IN
THIS
SPACE

Appendix E

Participant Consent Form

Consent Form

1. This project involves studying some descriptive information about Earth Science and answering some questions on their content.
2. Completing these two parts will take approximately 30 minutes.
3. From this project we hope to learn if various types of information configurations convey different types of information.
4. As with all such studies you are free to withdraw from this project at any time without penalty or prejudice.
5. This project has been approved by the Human Subjects Committee and the Institutional Review Board. If you have questions you may call or visit Thomas M. Sherman (231-5598, room 307 War Memorial Hall).
6. I hereby agree to voluntarily participate in the research project described above and under the conditions described above.
7. _____
Signature ID Number
8. Thank you for your participation.

Appendix F

Moderator Scripts

Moderator Script for Directions to Participants

(Hand out the self-instructional materials, the tests in their individual file folders and pencils.

Then... Read these instructions to the participants *verbatim*)

We are ready to begin.

**You have two folders: one containing
self-instructional materials, and the other
containing a test.**

Put the test aside; that will come later.

**Read the instructions on the self-instructional
materials folder carefully.**

Do not start until you are instructed to do so.

(Wait until all the participants have read the instructions.)

Are there any questions about the consent form?

**Are there any questions about the instructions on
the folder?**

Please start.

Moderator Script for Posttest Instructions Part I

(After ten minutes, read these instructions to the participants *verbatim*)

Please stop.

Place your materials back into the folder and put it aside.

The test inside the other folder has two parts: Part one on the front, and Part two on the back.

Part I tests the information from the self-instructional materials.

Part II contains questions regarding background information, such as your academic major.

You will have ten minutes to complete Part I of the test.

Do not go on to Part II until you are instructed to do so.

Are there any questions.

Begin.

Moderator Script for Posttest Instructions Part II

(After ten minutes, read these instructions to the participants *verbatim*)

Please stop, Part I is over.

**Turn your test paper over and read the instructions
for Part II.**

Part II asks questions about your background.

Do not go back to Part I.

**After you have read the instructions for Part II,
you may begin.**

Appendix G

Instructions to Participants (by Group)

SELF-INSTRUCTIONAL MATERIAL

Instructions:

1. This packet contains self-instructional material in the form of a passage of text.
2. The material you receive is different from the person next to you, therefore, you should work independently.
3. You will be given 10 minutes to study and learn the self-instructional material before you.
4. After ten minutes, the study period will end and the entire class will be administered a 24 item multiple-choice test based on the passage of text you have just studied. The results will be a good indicator of your ability to understand science information.
5. Do not open the packet until the moderator tells you to begin.

SELF-INSTRUCTIONAL MATERIAL

Instructions:

1. This packet contains self-instructional material in the form of a diagram.
2. The material you receive is different from the person next to you, therefore, you should work independently.
3. You will be given 10 minutes to study and learn the self-instructional material before you.
4. After ten minutes, the study period will end and the entire class will be administered a 24 item multiple-choice test based on the diagram you have just studied. The results will be a good indicator of your ability to understand science information.
5. Do not open the packet until the moderator tells you to begin.

SELF-INSTRUCTIONAL MATERIALS

Instructions:

1. This packet contains self-instructional materials.

The materials include: (A) a passage of text, and
(B) a list of instructive questions.

2. The materials you receive are different from the person next to you, therefore, you should work independently.

3. You will be given 10 minutes to study and learn the self-instructional material before you.

4. *Answer the instructive questions in writing as you study.*

5. After ten minutes, the study period will end and the entire class will be administered a 24 item multiple-choice test based on the text passage and questions you have just studied. The results will be a good indicator of your ability to understand science information.

6. Do not open the packet until the moderator tells you to begin.

SELF-INSTRUCTIONAL MATERIALS

Instructions:

1. This packet contains self-instructional materials.

The materials include: (A) a diagram and
(B) a list of instructive questions.

2. The materials you receive are different from the person next to you, therefore, you should work independently.

3. You will be given 10 minutes to study and learn the self-instructional material before you.

4. *Answer the instructive questions in writing as you study.*

5. After ten minutes, the study period will end and the entire class will be administered a 24 item multiple-choice test based on the diagram and questions you have just studied. The results will be a good indicator of your ability to understand science information.

6. Do not open the packet until the moderator tells you to begin.

Appendix H

Selected Demographic Characteristics of the Participants

Table 6
Demographic Characteristics of Participants

N = 129

Characteristics	n	Percent
<u>Age</u>		
19 years	9	7%
20 years	42	33%
21 years	43	33%
22 years	20	16%
23 years	1	1%
24 - 30 years	4	3%
31 - 40 years	4	3%
Over 40 years	5	4%
<u>Gender</u>		
Female	102	79%
Male	26	21%
<u>Class Status</u>		
Freshman	0	0%
Sophomore	13	10%
Junior	83	64%
Senior	25	20%
Graduate/Masters	4	3%
Graduate/Doctoral	1	1%
Special Status	2	2%

Table 6 (continued)**Demographic Characteristics of Participants**

N = 129

Characteristics	n	Percent
<u>Grade Point Average</u>		
0.00 - 0.50	0	0%
0.51 - 1.00	2	2%
1.01 - 1.50	1	1%
1.51 - 2.00	4	5%
2.01 - 2.50	29	23%
2.51 - 3.00	57	44%
3.01 - 3.50	22	16%
3.51 - 4.00	11	9%
<u>College</u>		
Agriculture and Life Science	1	1%
Architecture and Urban Studies	0	0%
Arts and Sciences	21	15%
Business	2	2%
Education	82	66%
Engineering	0	0%
Human Resources	22	16%
Veterinary Medicine	0	0%

Table 6 (continued)**Demographic Characteristics of Participants**

N = 129

Characteristics	n	Percent
<u>Academic Major</u>		
Elementary Education	45	34%
Family and Child Development	22	16%
Health and Physical Recreation	7	5%
Marketing Education	6	5%
Math Education	5	4%
Agriculture Education	4	3%
Science Education	4	3%
Technology Education	4	3%
Instructional Technology	3	2%
Math	3	2%
Biology	2	2%
English	2	2%
History	2	2%
Accounting	1	1%
Communication	1	1%
Curriculum and Instruction	1	1%
Extension Education	1	1%
Fashion Merchandising	1	1%
Finance	1	1%
Industrial Forestry Operations	1	1%
Psychology	1	1%
Spanish	1	1%
Spanish Education	1	1%
Undecided	2	2%
Special Status	1	1%
Omitted	7	5%

Appendix I

Summary Tables for Additional Comparisons

Table 7**Summary ANOVA for****Diagrams with instructive questions and Texts with instructive questions**

Source	DF	SS	MS	F	p
Between	10	52.839	5.284	.625	.7599
Within	21	172.036	8.192		
Total	31	224.875			

Table 8**Summary ANOVA for****Diagrams without instructive questions and Texts without instructive questions**

Source	DF	SS	MS	F	p
Between	8	50.302	6.288	.675	.7082
Within	23	214.167	9.312		
Total	31	264.469			

Table 9**Summary ANOVA for****Diagrams with instructive questions and Texts without instructive questions**

Source	DF	SS	MS	F	p
Between	8	96.938	12.117	3.408	.0100*
Within	23	81.781	3.556		
Total	31	178.719			

* $p < .05$ **Table 10****Summary ANOVA for****Texts with instructive questions and Diagrams without instructive questions**

Source	DF	SS	MS	F	p
Between	8	188.63	23.58	1.081	.0001*
Within	23	489.34	21.28		
Total	31	677.97			

* $p < .001$

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