A COMPARATIVE ANALYSIS OF HOLISTIC AND SERIALISTIC PEDAGOGICAL METHODOLOGY FOR BIOGEOCHEMISTRY

By

MARK D. WEBER

Bachelor of Arts
University of South Florida
Tampa, Florida
1975

Master of Arts
Oral Roberts University
Tulsa, Oklahoma
1985

Doctor of Education
Oklahoma State University
Stillwater, Oklahoma
1988

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Thesis Approved:

Thomas Ozman
Thesis Adviser

Robert L. Lochmiller

Nelson J. Ehrlich

T. Mills

Thomas C. Collins
Dean of the Graduate College

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CHAPTER I

THE RESEARCH PROBLEM

Introduction

The challenge for the professor of undergraduate college science classes is to teach sufficient amounts of scientific terminology, experimental techniques, and the concepts which undergird the techniques in a given period of time, without patronizing students or cheating them out of the opportunity for developing creative, independent and critical thinking. To enhance the development of creativity and critical analysis, the student must be first shown integrated generalizations among related concepts and then shown how to apply appropriate methods for developing these interrelationships. This is followed with limited guidance and encouragement to visualize accurate generalizations which can display the necessary integration, application and utilization of knowledge in realistic and contemporary problem-solving situations. Finally, the student should be encouraged to work toward formalizing organizational skills within independent research projects. A cross-disciplinary science course plays a integral role in facilitating this transitional learning process i.e., encouraging the student to move from the memorization of information through creative and critical thinking to the application of knowledge. Reorganization of curricular material in a cross-disciplinary manner is evidence that the professor is keeping the substance of education at pace with problems facing students in a rapidly evolving world (Ericksen, 1985).

Knowledge is obtained from all of the individual branches of the sciences, and there is a need for each discipline to "establish the mutual relations and to effect the intercommunion of one and all" (Newman, 1959). Such intercommunication may be organized into interdisciplinary courses. The information and educational material conveyed within the science course is as important as the structure of curriculum and arrangement of selected courses.

An example of such complexity may be taken from the first International Environmental Conference organized by the United Nations, where it was determined that long-term environmental considerations must be incorporated into any societal policy-making program of a governing body (Brown, 1978). Societal policies affect nearly every aspect of resource flow from primary possession to implementation to final processing and disposal of waste.

An integral strategy for the dissemination of information about environmental considerations, education is an invaluable and functional tool for societal decision-making, problem-solving, and policy-making. Environmental education is a multi-disciplinary approach which addresses the social awareness of and concern for critical issues and problems in the environment. It involves the research, knowledge, attitudes, abilities and skills needed to manage and effectively solve these problems and prevent the development of new ones (Brown, 1978).

One such critical environmental issue, human intrusions of biogeochemical cycles, receives much of its attention as it relates to education through bench and clinical research. At the heart of this research is a curriculum which is designed to meet the changing parameters of the earth's biologically determined survival system (McInnis, 1975). From an integrated curriculum designed to understand the aberrant influences of cyclical patterns, as well as the stimulants and determinants of such patterns, one can better understand and explore the strategies necessary to prevent disruption of local and global equilibrium within an ecosystem.

Description of the Problem

The development of an effective educational program which will equip the student with knowledge of the various environmental science concepts and problem-solving skills for application plays a critical role in the development of a global population which is increasingly aware of and concerned with the environment and its associated problems. The education program should provide the knowledge base, operational skills, attitudes, motivation, and commitments to individually and collectively resolve current problems and prevent new ones from arising.

The effectiveness of an integrated environmental science curriculum may be predicated upon the selection of courses (i.e., cohesiveness united by recurrent themes), course content, and method of presentation within the individual courses. By emphasizing course content and effective pedagogical practices, one may enhance effective communication of information, understanding of the critical nature of environmentalism, and generation of the values needed for resolving environmental issues.

Instruction of science through concepts, on which one can hang a number of facts, both depends upon and stresses the importance of developing the foundation for higher intellectual processes and cognitive skills. Comprehending concepts develops cognitive skills: discriminating, remembering, imagining, inferring, creating, elaborating, reorganizing, generalizing, speculating, and abstracting (Ericksen, 1985). These behavioral indicators imply successful achievement of the thought processes described by Bloom (1956) as comprehension, application, analysis, synthesis, and problem-solving. Students who are successful in designing and conducting experiments in science are operating at the higher levels of the cognitive domain.

Instruction which utilizes the inherent avenues for encoding information (i.e., the student's learning styles) can increase the degree of effectiveness in the learning process. Employing pedagogical practices which begin by introducing the environmental science topics with sturdy generalizations and build upon the conceptual framework through continual reinforcement of the inter-relationships with other intra- and extradisciplinary concepts enhance the student's comprehension and scope of each topic. The extensive breadth or scope of the presentation uses the framework and understanding of existing science concepts and avenues for information processing (i.e., developed learning styles).

Statement of the Problem

Quality environmental science education programs dramatically enhance knowledge, social awareness, concern, and generation of commitment toward resolving environmental problems. The effectiveness of a program is directly related to the design and method of presentation (McKeachie, 1986).

This study reviews the effectiveness of two teaching methodologies implemented for the dissemination of information on the topic of biogeochemistry to holistic and serialistic learners. Specifically, the following research questions will be considered:

1. Will field independent learners achieve higher scores (net gain = posttest minus pretest) through holistic instruction than with serialistic instruction?

2. Will field dependent learners achieve higher scores (net gain = posttest minus pretest) through holistic instruction than with serialistic instruction?

3. Will field independent learners show a greater positive affect (more interest) with serialistic instruction than with a blend of serialistic and holistic instruction?

4. Will field independent learners show a greater positive affect (more interest) with holistic instruction than with a blend of serialistic and holistic instruction?

5. Will field dependent learners show a greater positive affect (more interest) with serialistic instruction than with a blend of serialistic and holistic instruction?

6. Will field dependent learners show a greater positive affect (more interest) with holistic instruction than with a blend of serialistic and holistic instruction?

These questions can be rewritten as null hypotheses. The following hypotheses will be examined in this study.

Ho1. There is no significant difference in achievement (net gain = posttest minus pretest) as measured by a t test with field independent learners when exposed to serialistic instruction or holistic instruction.

Ho2. There is no significant difference in achievement (net gain = posttest minus pretest) as measured by a t test with field dependent learners when exposed to serialistic instruction or holistic instruction.

Ho3. There is no significant difference in interest as measured by a comparison of z scores with field independent learners when exposed to serialistic instruction versus a blend of serialistic and holistic instruction.

Ho4. There is no significant difference in interest as measured by a comparison of z scores with field independent learners when exposed to holistic instruction versus a blend of serialistic and holistic instruction.

Ho5. There is no significant difference in interest as measured by a comparison of z scores with field dependent learners when exposed to serialistic instruction versus a blend of serialistic and holistic instruction.

Ho6. There is no significant difference in interest as measured by a comparison of z scores with field dependent learners when exposed to holistic instruction versus a blend of serialistic and holistic instruction.

Purpose

The study attempts to determine the differences in achievement (assessed by a comparison of the means of posttest minus pretest scores) when exposed to two different pedagogical styles (e.g., holistic and serialistic) for a presentation on biogeochemical cycles to field dependent and field independent learners in two undergraduate ecology classes. The comparison may provide information which will be useful in developing instructional approaches for environmental science programs.

Definition of Terms

Although learning and teaching styles are parallel and the descriptive terminology used by researchers varies, for the purposes of this study holistic and serialistic will be used to describe teaching and field dependent and field independent will be used to describe learning styles.

The following definitions will be used for the purpose of this research study:

Environmentalism is the sum total of a series of organic and complementary reactions and interrelationships between the natural order and the human developed order as defined by growth of population, patterns and nature of resource and space use, and such factors as societal goals, socioeconomic structure, institutions and lifestyles (Brown, 1978). Ecosystem is an ecological system

> involving living and nonliving components, their interrelationships, all participating energy patterns and flow of matter (Schoenfeld, 1981).

Biogeochemical cycles are the cycling of chemical elements through the Earth's atmosphere, oceans, and sediments. The elements are affected by various constituents of the geological, biological and water cycles (Botkin and Keller, 1982). The most common elements referred to in the environment's biogeochemical cycles include oxygen, nitrogen, carbon, sulfur, phosphorus, and hydrogen.

Conceptual teaching is the process used by the instructors to "recognize" the shared features of otherwise discrete ideas or events, to "comprehend" their interrelationships and to present sturdy generalizations which can be used to establish the internal structure of abstract ideas. By teaching these generalizations to the learner so he/she begins to understand the constructs necessary to categorize and classify ideas or events through an identification of common features and determination of connections (Carnine, 1990; Ericksen, 1985).

Holistic presentations involve a flexible format in which several anecdotes, illustrations, analogies and subtopics can be incorporated or integrated. The initial steps include broad global descriptions encouraging visualization of the scope and comprehensive nature of the concept. Vacillation between the 'real world' and the abstract through the use of analogies brings new insights regarding the internal structure and boundaries of the concept (Entwistle and Ramsden, 1986). Closing steps include demonstration of, guidance toward, and encouragement to form generalizations of new material. This is followed with an application which presents concepts in new settings and integrates them with related cross-disciplinary concepts.

Serialist presentations follow a rigid and logical sequence of material connecting the 'real world' with the abstract only when necessary, with the majority of the information dealing with subtopic details, the 'big picture' or broad perspective is not realized until very late in the lesson (Entwistle and Ramsden, 1986). The student is offered little support in formalizing sturdy generalizations which integrate presented concepts with cross-disciplinary concepts. A blend of serialistic and holistic presentations contains some characteristics of each style. The professor used a step-by-step presentation of information and intermittently used diagrams and illustrations. Integration and generalizations were essentially absent from the presentation.

Field dependent learners are described as being a global thinkers because of the inherent preference to view the 'big picture' first and then attend to the details. This type of learner prefers guidance in systematically processing bits of information, in organizing the information, and in visualizing relative constructs following leads provided by the instructor (Witkin, 1977).

Field independent learners possess an inherent analytic ability to progress systematically through a series of tasks or bits of information, organize the information, and visualize relative constructs independent of an instructor (Witkin, 1977).

Limitations and Assumptions

An assumption of this study involves the consideration that the limited population (n = 57) is in fact a representation of the "real world." The possibility of biased results exist since the sample was purposefully selected rather than being drawn randomly. The data will be affected by the perceptions, terminology and experiences, especially for the affective assessment of the presentations, of the respondents. It is assumed that there is no significant difference in the percentage of the course text read between the two groups.

Prior to initiating the experiment, the resource information and presentations were examined and reviewed by a learning specialist (Dr. Karen Merz) in order to establish the criteria and categorize the material in the presentation as holistic or serialistic. The specialist has a doctorate in education and has done extensive work in areas of pedagogical practices (e.g., instructional work-shops, practical experience, and teaching educational courses) and learning styles. All possible steps were taken to insure the presentations were holistic and serialistic in nature.

Organization of the Study

This study is divided into five chapters and the appendixes. Chapter I includes an introduction, the description of the problem, statement of the problem, significance of the study, purpose of the study, definition of terms, limitations and assumptions of the study, and organization of the study. Chapter II reviews the literature regarding presentation of science concepts, student learning, teaching strategies, teaching styles, application of effective methodologies, criticism of science teaching, advantages of serialistic and holistic teaching and biogeochemical cycles. Chapter III presents the design of the study and procedures employed. The analysis of the data will be presented in Chapter IV. Chapter V will provide a summary of the research effort, conclusions, and recommendations for further study. A list of references follows Chapter V. The appendixes contain the notes for the (1) lectures notes for the holistic and serialistic presentations made to the undergraduate ecology classes (2) biographical information, and (3) reference and data tables.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

The review of the literature is divided into five sections. The first section focuses on presentation of science concepts with consideration to related topics (e.g., teaching effectiveness, lecture goals and objectives, lecture versus discussion, purpose, design and organization of lectures). Student learning, the second section, includes patterns of learning styles. Section three examines various teaching strategies and styles involved in conceptual presentations. The fourth section includes a discussion of the literature reviewed with related problems and application of effective methodology, criticisms of science teaching and advantages of holistic teaching, and a brief presentation and conceptual example topic--biogeochemical cycles--of what some researchers propose as an effective methodology. A summary of the chapter follows the fifth section.

Presentation of Science Concepts

Teaching Effectiveness

The "variable degree of influence" and "long term impact" a teacher has on students relates to the development of values, learning, memory, problem solving, decision making and critical thinking processes. The existence of such a relationship provides ample reason for course and curriculum design to be founded on the constructive goal of enhancing the student's potential for integration and understanding for future application.

All too often, students perceive their undergraduate science education as training at the expense of true education (Tobias, 1990). This would not be the case if the science teacher would do more than teach students "how much" and "when." Teachers need to encourage interactions and discussions which answer the questions of "why" and "what happens if" and thus "lead students to encode and integrate the information in memorable form, ensure competence in the procedure" of a particular field of science, encourage critical analysis and "promote learning how to learn independently" (Ericksen, 1985). Clearly, the teacher's selection, organization, and delivery of subject matter is directly related to the degree of immediate influence, and ultimate effectiveness, on the "impartation" of knowledge to the student body.

The effectiveness of teaching science is of particular importance when considering the dramatic attrition rate (40%) of college freshmen who originally intended on majoring in some field of science but changed degree plans after their first taste of college science (National Science Foundation, 1987). The major reason reported for students switching out of science did not deal with the difficulty in course work or potentially better job prospects, rather it was because the students found other fields more interesting. Consequently, the focus becomes one of retention of those originally indicating interest in science and improving the perception and commitment of those dedicated toward the pursuit of a career in science.

If it is stipulated that effectiveness should be a consideration, then it follows that teaching styles should which employ techniques for presenting course material that blend mastery of craft (i.e., the mechanics of problem solving) and creativity and finesse. The latter is instrumental in the development of critical thinking, integration and application. There is some difficulty associated with identifying how much one can reasonably expect academically from each student and then determining the degree to which that student achieved the course goals. The difficulty in accurately assessing effectiveness is compounded by the variability in each student's ability, experience, and exposure to content in science prerequisites. All are known determinants in the student's achievement. Additionally, it would be important to determine what other teachers of the same course have accomplished with comparable groups (McKeachie, 1986).

Goals and Objectives

The broad and general educational statements regarding the course's content, organization and preferred references (texts) are characteristically known as goals. The statements indicate the instructor's expectations and project intended behavior acquisition upon completion of the course (Minter, 1986). The following statements are examples of goals.

- To develop a wholesome self-concept
- To develop critical thinking and decision-making processes
- To develop vocational skills so that each student can find work in a particular field of science (Hannah and Michaelis, 1977, pp. 21).

Often the goals, whether long or short term gains the students are to obtain, are almost impossible to assess. Thus, there is a need to determine measurable functional connections between goals and grades. Goals need to broken down to operational statements, objectives, which depict the learning and understanding expected to take place as a result of the course. Diversity within these objectives assures the additional measure of meeting the collective minds of different individuals.

Throughout behavioristic educational literature there are various adjectives used to categorize objectives. Whether known as "instructional objectives," "behavioral objectives," "performance objectives," "developmental objectives," or "terminal objectives," objectives should be written in a manner in which evidence of achievement clearly is reflected in methods of assessment and testing. For the sake of simplicity in this paper, the author will use the representative synonym "instructional objectives" when referring to objectives as a principle part of the operational definition of goals.

Regardless of the specific style, instructional objectives are usually prepared with three common characteristics:

1. (the) statement of an observable behavior of performance on the part of the learner.
2. (a description of) . . . the condition under which learner behavior or performance is to occur.

3. (the statement) . . . of a minimally acceptable performance on the part of the learner (Orlich, et.al. 1985, pp. 37).

Additionally, the course objectives invariably should answer two questions:

1. At what time in the future will the significance of a given segment of knowledge pass its inflection point and start downhill toward obsolescence?
2. Is it stepping-stone information or something to be learned for its own long-term value? (Ericksen, 1985, pp. 110).

The goals and objectives help set the stage for the course, structure the learning process, and establish the student's responsibilities. One final aspect determined by the instructional objectives is the type of instruction. Some objectives can be met through orthodox or traditional lecture presentations. Other objectives are better served through the implementation of discussions or small groups (McKeachie, 1986).

Because the level of thinking is directly related to the instructional behavior and learning activity the instructor often dictates his methodology by the design of instructional objectives. The design reflects projected thought process and the level of desired behavior obtained through implementation of specific learning activities. The specific sequence of instructional objectives and arrangement of course content determines at least in part the "vehicle" used by the instructor for delivering the subject matter.

Methodology: Lecture vs. Discussion

Most college professors choose one of the two principal formats for delivering the subject matter, the lecture or the discussion. More often than not, most science courses are taught with the lecture format which involves a verbal exposition by the instructor at the front of the class. Communication is usually unidirectional and may include audio and visual aids (e.g., slide presentations, films or demonstration of charts, models, reactions). The instructor actively presents information by utilizing techniques which reflect his/her accumulated wisdom and innate talents to a passively participating constituency. McKeachie (1986) notes that "effective lecturers combine the talents of scholar, writer, producer, comedian, showman, and teacher in ways that contribute to student learning."

There are several advantages to this method of delivery. A few are listed below:

1. It is a very efficient method for communicating facts, concepts, and principles. It is economic use of faculty time, permitting the instructor to cover large amounts of material in a given time frame.
2. The instructor is permitted to use his/her experience and knowledge in an organized and systematic presentation and thus provide information not readily found in texts or obtained from other sources.
3. It is amenable to recording (audio, video, film) and transcription.
4. It can be effective with large or small numbers of students.
5. It provides the students with the opportunity to develop the ability to listen accurately.
6. It can be stimulating and can enhance students's desire to learn the subject matter.
7. It requires little or no special instructional equipment or materials (Yelon, 1978, pp. 1).

Notably, there are also some limitations to the lecture method of instruction. Several limitations are listed below:

1. The lecture method makes it difficult for the teacher to accommodate student's individual differences in background or rate of comprehension.
2. It places heavy reliance on students' listening, memory, and note-taking skills.
3. It demands sustained student concentration.
4. It provides limited opportunity for active student participation.
5. It provides limited opportunity for judging audience understanding or reaction accurately.
6. It is inadequate for developing high-level intellectual skills, (e.g., problem solving) (Alexander and Davis, 1977; Yelon, 1978, pp. 2-3)

With skillful preparation and presentation of the subject matter, the lecturer can overcome many of these limitations. The following strategies could be implemented to overcome innate limitations of the traditional lecture.

The lecturer could augment the verbal exposition with a variety of visual aids, question and answer interludes, and short assessments (quizzing) to reduce student passivity, monotony, and fatigue while increasing or maintaining attention.

Including concrete illustrations and ancillary materials after the essential points have been clearly articulated at a moderate pace will reinforce the concepts.

Most undergraduate science classes consist of heterogeneous groups. Individuals differ in speed of comprehension, prerequisite knowledge, skills, note-taking abilities, and learning styles. It is suggested that prepared notes, study guides, and other handouts given to the student prior to lecture can reduce the amount of student anxiety and frustration. Implementation of these techniques will allow for greater continuity within the formal lecture because of the reduced number of questions and interruptions.

Those instructional goals designed for the promotion and development of decision making and problem solving abilities are linked with methods which extend beyond the traditional lecture format. A complementary or alternative instructional method to the traditional lecture would be a discussion. In this case the instructional objectives are achieved through the cooperative interaction and exchange of ideas, facts, and opinions by a group of people. The following advantages are noticeably different from those of the lecture:

1. The discussion permits students to become directly and actively involved in the learning process.
2. It avoids monotony and maintains student interest.
3. It provides opportunity to share information and experiences from which new insights might emerge.
4. It provides opportunity to practice and learn such intellectual skills as organizing facts, asking discerning questions, presenting a coherent argument, and thinking independently while reflecting on one's own ideas and those of others.
5. It provides opportunity to practice and learn inter-personal communication and cooperation skills such as social sensitivity, listening, role-flexibility, and leadership.
6. It provides immediate feedback to the instructor on student progress and understanding (Yelon, 1978, pp. 2-3).

Though there are distinct advantages the discussion has over the lecture, it is not without its limitations. The following statements outline some of the limitations.

1. The discussion method does not function well unless participants have a common background of knowledge, level of maturity, and vested interest (motivation) in success of this methodology.
2. It consumes much more time than the lecture.

3. It depends upon the learner's capacity and mood for active participation and the instructor's preparation for the discussion.
4. It depends upon all participants having previously learned the discussion skills required to enhance effective participation.
5. It requires a teacher who is willing and able to relinquish control to the students (Alexander and Davis, 1977; Yelon, 1978, pp. 3-4).

Basically the instructional objectives established should suggest the need for a large percentage of active participation from the students. To spark discussions, the instructor should have designed the objectives so that critical thinking, problem solving, analysis, synthesis and application to take place. Although discussions maintain the potential of promoting these desired student achievements, they also hold the potential of producing negative feedback, criticism, and chaos. Unwanted behavior can be avoided through proper preparation of subject matter, usually through stimulating (e.g., divergent and evaluative) questions.

Several studies have compared the effectiveness of lectures with discussions. When assessing students at the knowledge level, lectures prove to be equal to or more efficient than discussions. Alternately, experiments considering measures of application of knowledge, retention of information, problem solving, critical thinking, and affective changes (attitude and motivation), the results indicate the discussion as a more efficient method of achieving instructional objectives.

Barnard (1942) compared the effectiveness of a lecture-demonstration instructional method with that of a problem-solving developmental discussion method in a college science course. In an assessment of specific knowledge, the lecture-demonstration method proved more efficient. When measuring problem solving and affective results (attitude and motivation), the discussion method proved more efficient. Other experiments (Beardslee, Birney, and McKeachie, 1951; Casey and Weaver, 1956) in college courses outside the science field showed little or no difference in knowledge of content between lecture and discussion, but a superiority in attitudinal outcomes favored small discussions over a lecture format. Further investigation into the specific nature of the lectures or discussions in these experiments reveal that the conclusions fail to disclose other discriminating factors, in particular the deliberate design of each method. For example, an instructional method designed to promote development of problem solving ability should have a greater likelihood of yielding those desired results as compared to a method not designed to do so.

The crux of the matter in the choice of methodology lies in the desired outcome (instructional goals and objectives) and the strategies and delivery utilized to obtain these outcomes. Yelon (1978) points out one other factor influential in choosing instructional method, the number of students. Often the teacher responsible for large college science classes must be well prepared and organized in such a way as to obtain the desired outcome and overcome any negative influence of larger class size. Although there are distinct advantages for both lecture and discussion, the organization of the material for each session and complete course is more important than the method of presentation. Thus, the internal design and organization of the lecture or discussion remains as the key to the effectiveness of the knowledge of content, retention of information, problem solving and critical thinking.

Interestingly enough, many of the national entrance and science proficiency exams predominantly test specific knowledge rather than application or set of values embraced by learner. This emphasis coupled with multiple choice or "objective" instruments for evaluation and assessment of knowledge would encourage some teachers to favor methodologies for dissemination of information (emphasis on content knowledge) and evaluation which would be of a similar nature or design in order to promote the student learning being tested and development of test-taking skills for greater proficiency on that type of exam. Additionally, these teachers would be trained by example to be specialists in conveying and evaluating subject matter in a manner which will be a positive reflection on their abilities.

The Purpose and Design of Lectures

Typically, lectures strive to present a systematic and succinct summary of the information appropriated for a particular class period. The summary or "conclusion oriented" approach develops from a process of abstracting texts and encyclopedia, but seldom teaches the students to learn and think independently (McKeachie, 1986; Chang, Crombag, vander Drift, and Moonen, 1983). The lecture should emphasize cognitive activity rather than cognitive results

(McKeachie, 1986). The lecture should encourage the student to manipulate and process the information through a sequence of steps which promote the development of independent thinking. It should encourage the student to analyze situations, formulate and succinctly articulate the problems, develop the hypotheses, consider all possible solutions, implement and test, and finally critically evaluate results and limitations of process before developing the conclusions and recommendations. The manner in which students process the lecturer's verbal discourse will not only dictate the efficiency for processing greater amounts of subject matter but also gives them an understanding of the methods and conventions used to discriminate the interrelationships of interdisciplinary factors. Therefore, the lecture design which employs strategies to encourage development of the student's ability to process, integrate and apply (i.e., cognitive activities) the information contained within the verbal discourse should prove to be more effective than the lecture design which primarily emphasizes the absorption of facts, ideas and events (cognitive results).

These teaching strategies should maintain flexibility and spontaneity for answering questions without losing track of the interrelationships among interdisciplinary factors, lecture organization, and contributions from the questions (Day, 1980).

Active participation by the student in the lecture can be achieved through classroom drama, creative imagery techniques, demonstrations, applicable questions, and discussion. Regardless of the technique used in the presentation, once the new concept has been introduced, the reinforcement of the mental image needs to be incorporated by providing situations and scenarios for application.

Developing a lecture involves more than the arrangement of the content of the particular subject matter in a logical structure, whether sequential or building in a comprehensive manner allowing for the derivation of specifics from general principles. For example, the manner in which a particular subject develops can implicate a preferred method of arranging the content and thus presenting the lecture material. The importance of issue becomes especially notable when considering explosion of information in nearly every field of science.

Lieth (1977) suggests that different subjects progress in different ways. The same is true for the various fields of science. Some subjects organized in a linear or hierarchical fashion (one concept builds on the preceding one) require the learner to follow a particular sequence in order to reach a more sophisticated level. Others need the accumulation of several interrelated bits of information before progressing to the next stages of development. Still others are loosely arranged in networks of information which allows for one to start at any one of several points of the network and proceed in various directions from that point (McKeachie, 1986).

The development and organization of a subject relates to the manner in which the subject matter can be presented i.e., a specific methodology to facilitate understanding of information. In application, it calls for the lecturer to be familiar with the existing cognitive structures in the student's mind through an understanding of the prerequisite science course contents.

Organization of Lectures

Three principal parts exist in most lectures - the introduction, body, and conclusion or closure. The amount of time and material covered depends upon the design and instructional objectives.

The introduction of a lecture could identify direction, destination and expectation of the current session or identify the objective of the last lecture coupled with a brief review of the material covered (Eble, 1971). These introductions might clarify plan and organization while building confidence and reducing anxiety. This type of introduction is befitting of subject matter which is best organized in a linear, sequential or hierarchical manner. Another type of lecture introduction is organized to address or is built around what are suspected gaps in the student's knowledge. Understanding where the student is coming from remains critical in bridging those gaps. Finally, introducing the lecture with a question regarding existing or traditional constructs and methods of organization of the subject would raise curiosity and increase intrinsic motivation.

A consensus exists among learning theorists regarding the importance of content organization, but the most effective means of organization has yet to be established (Healy, 1989). Creating a framework in the student's cognitive structure by which new information may be categorized, integrated, and later applied through the introduction of an expository or comparative organizer proves to be more effective in learning new information than without any content organization (Kozlow & White, 1979). Organization of the content, especially in science courses, remains at the discretion of the instructor and is greatly influenced by the nature and structure of learning resources available and prerequisites.

Effectiveness in transmitting information through lectures, and therefore learning, has been shown to depend upon the instructor's ability to illustrate concretely abstract concepts such as biological cycles (Winn, 1988; Holliday, 1976). Mediating factors, such as a student's ability to organize information within a concept or learn information from a diagram or illustration, are also inherently relevant to effectiveness of instruction (Winn, 1988; Rego, Salgado, Fernandez, and Sonnier 1986).

Perhaps, the most critical structure for achieving the instructional objectives exists within the organization of the body. McKeachie (1986) points out the most common error is that of trying to include too much material for the given time frame. This is especially true of subjects such as science, in which there is a tremendous amount of material to be conveyed in any given course. Regardless of the amount of material presented, some students will benefit much more than others because of the style of lecture. Styles which employ principles covering a sequence of generalizations first, then followed by drill and practice of the sequence will produce a greater understanding in some students more than in others. The same is true for a group of students who prefer specifics which lead to generalizations (Larkin, Heller, and Greeno, 1980). Some of the various principles employed in organizing lectures are: cause to effect; time sequence (e.g., stories); parallel organization such as phenomena to theory to evidence; problem to solution; pro versus con to resolution; familiar to unfamiliar; and concept to application (McKeachie, 1986). Periodic summaries throughout the body of the lecture clarify transitions on topics, reinforces and solidifies material, and allows time for the students to catch up.

The conclusion maintains cohesiveness within the lecture and continuity within the course. Facilitating understanding through integration of material from an individual session with existing cognitive structures and insightful questions reinforces student confidence and increases motivation.

Of the principles employed in the organization of a science lecture listed above, the concept to application is most significant for this paper. The remainder of the paper will concentrate on the importance of presenting the material conceptually, the increased understanding of the information through application and the relationship this principle has with student learning.

Student Learning

Patterns of Thinking: Localizations vs. Loops

Theories regarding localization of brain functions have been the dominant explanation for understanding information processing within the cerebrum - perception, recognition, memory and learning. These theories have strongly influenced educators and the development of instructional methods throughout the 1960s and 1970s.

Development of specific localizations in the brain which are associated with certain functions (e.g., visual, somesthetic, language, olfactory, auditory, gustatory, etc.) is directly related to an individual's "strength" or "weakness" in processing incoming stimuli (Carnine, 1990). Educators choosing to maximize learning through previously developed avenues select methods which utilize an individual's strength for receiving and processing information. These highly accepted theories of localization of brain functions and dependent pedagogy are being challenged by research from Nobel laureate, Gerald Edelman (1987), who suggests neural pathways are determined as a function of ordering, categorizing, and recategorizing in terms of other stimuli.

Although many of the brain functions have been determined as being localized in relatively specific locations within the cerebral hemispheres, evidence suggests that these centers contain only portions of neural loops employed for processing specific types of information. A neural loop consists of an integrated network of neurons within the brain, usually limited to the diencephalon and cerebrum. The pathway for transmission of impulses employed for the interpretation of information through an encoding, decoding and categorizing of stimuli for perception, recognition and memory depends upon the specific type of stimuli and its relationship to other stimuli previously processed. Thus, neural loops employed for transmission of information of a specific stimuli and categorization of a particular topic are not necessarily the same, or portions of the same, loops employed for processing other impulses or recategorization of the same topic.

Rosenfield (1988) capsulized Edelman's theory of categorization and recategorization into three operations.

1. How we perceive stimuli depends on how they are categorized, how they are organized in terms of other stimuli, not on their absolute structure.

2. Recognition of an object requires its categorization. And categories are created by coupling, or correlating different samplings of the stimuli.

3. We do not simply store images or bits but become more richly endowed with the capacity to categorize in connected ways.

Thus, processing information becomes a function of categorizing and recategorizing stimuli within various locations of the brain. Carnine (1990) contended the "cornerstone of the capacity to categorize is the learner's ability to note instances of sameness." Being able to perceive connections and integrations among what might first appear as unrelated ideas or events becomes the principle focus for understanding the meaning of concepts and comprehending the scope for application of those concepts. Individuals with the ability to impose structure, organization, and analytically encode new information demonstrate a better recall of information when given nonacquisition recall cues than those individuals without this ability. Those with this innate encoding ability store the information in a more versatile manner (Goodenough, 1982). These inherent and acquired abilities have important implications for instruction.

Lectures or discussions designed to display specific connections or interrelationships are not equally effective for each student. One cannot always predict what constitutes information for a learner and which combination of incoming stimuli will be selected in an attempt to understand the meaning of ideas or for relating them to other ideas (Rosenfield, 1988). Therefore, although the presentation of material may intend to show specific connections between new ideas and existing cognitive structures, the professor's ability, first, to select and control specific stimuli, which are consciously or unconsciously attractive to the student, and, second, to communicate effectively the interrelationships often dictates the learning process.

Sometimes the student will acquire an unintended connection from the material presented, which produces mistakes--perhaps trivial, perhaps significant. Extensive research has shown that the more the objects and symbols share visual and auditory "samenesses," the more likely students will be to confuse them (Carnine, 1990). Similarly, the more concepts share facts, ideas or events, the more likely the student will form misconceptions. Carnine (1990, pp. 373-374) encouraged educators to adopt the goal "to develop activities that help students learn important samenesses" and keep them from "learning inappropriate . . . and unintended samenesses." He suggests implementation of "multistep procedures" and "unifying principles" to achieve the objectives related to this goal, particularly for the science classes.

Regarding categorization and recategorization, Edelman, Rosenfield, and Carnine suggested that instructional methods employing strategies which display intended connections and interrelationships through illustrations, analogies, and integrations with past subject matter are more favorable in assisting the student to develop an understanding of accurate meanings of concepts and more appropriate applications, in contrast to methods which delineate facts, ideas or events without displaying interrelationships. Additionally, systematic reviews with deliberate introduction of discrepant events or inappropriate connections help to identify the true internal structure, boundaries and meaning of a concept and thus militate against the formation of misconceptions. With a greater understanding of the material and parameters of concepts, frustration and anxiety decrease and the sense of accomplishment, enjoyment, appreciation and motivation for further study tend to increase.

Learning Styles

Today's students are a diverse group in terms of background, experience, learning styles, availability of educational resources, and socioeconomic status, all of which influence the development of individual learning styles (Douglass, 1979; Rabianski-Carriuolo, 1989). Given the diversity of human intelligence and the ways such intellectual abilities are manifested, the task of the educator is to facilitate their expression (Rabianski-Carriuolo, 1989) by accepting responsibility for what is learned, not for what is taught. A learning style is simply a collection of characteristic ways of responding to various learning situations. Messick (1977) described an individual's learning or cognitive style as the "characteristic way of functioning, revealed through each of his/her own way of perceiving as expressed in intellectual activities." Concurring, Kogan, (as cited in Rego, Salgado, Fernandez, and Sonnier 1986, p. 282), stated that "individual differences in perceiving, remembering, and thinking are as distinctly different as ways of learning, storing, transferring, and using information."

The instructor's method for presenting information often dictates the frequency of effective transmission and travel along the students' particular avenues. Kolb (1985) distinguished differences in learning styles based upon the student's preferred method of gathering information (e.g., concrete experience or feeling; reflective observation or watching and listening; abstract conceptualization or thinking logically: and active experimentation or doing through a practical approach). He described the four learning activities associated with gathering new information as parts of a cycle. Classification of a particular learning style is determined by the student's learning strengths, and preferences dictate the preferred method of gathering information.

Sims, Veres, and Shake (1989) provided a strong argument questioning the validity and internal reliability of Kolb's Learning Style Inventory II as an accurate measurement and true indicator of an individual's learning style. Although student behavior patterns, modes of perception, and preferred methods of gathering information are important considerations in developing effective teaching methods, they are mere extremities of expression for styles of processing information. For example, a student's performance on Witkin's (1977) Group Embedded Figure Test clearly reflects a relationship between their visual perceptual talents and thinking style. Test scores reflect the learner's ability to overcome distractions by the surroundings and structure the incoming information. As the score increases, so does the person's analytical ability and field independence. From the review of the literature, the crux and focus of the learning style remains the learner's method of processing new information (Douglass, 1979; Rego, Salgado, Fernandez, and Sonnier, 1986; McKeachie, 1986; Harris and Bell, 1986; Sims, Veres, and Shake, 1989).

Researchers have identified 'serialist' and 'holist' learners. Serialistic or analytic (field independent) learners prefer to have information presented one step at a time in a linear or serial form. Holistic or global (field dependent) learners prefer to see the 'big picture' first and then attend to rearranging and recategorizing the details in a pattern which makes sense to them (Harris and Bell, 1986; Dunn and Dunn, 1987; Rego, Salgado, Fernandez, and Sonnier, 1986).

Dunn and Dunn (1987) argue that effectively teaching holistic/ field dependent learners does not require clearly stated objectives strictly followed by detailed, step-by-step, sequential explanations, for holistic learners grasp large concepts presented in a manner which does not adhere to the lesson plan built on detailed sequential expositions. Given the choice between a series of 'abstract' topics and a parallel series of 'real world' tasks, the holist may vacillate between the 'real world' and the 'abstract,' looking for analogies, connections, and deeper meanings (Rego, Salgado, Fernandez, and Sonnier, 1986). After concentrating on understanding the complexity and comprehensive nature of the concept (the 'big picture'), the holist then attends to the factual details related to the concept (Dunn and Dunn, 1987; Harris and Bell, 1986; Rego, Salgado, Fernandez, and Sonnier, 1986; Entwistle and Ramsden, 1983). These intense and efficient learners are extrinsically motivated and field dependent. Expressing a greater interest in people than their serialistic counterpart, these individuals are more motivated to acquire skills for service related professions and thus are predominantly found in the humanities and social sciences (Entwistle and Ramsden, 1986; Gayle, 1981).

On the other hand, the serialist learner follows a rational progression or series of facts that eventually leads to a concept (Douglass, 1979; Dunn and Dunn, 1987; Entwistle and Ramsden, 1983; Trautman, 1979). Given a collection of parallel series of 'abstract' topics and 'real world' tasks, the serialist does not vacillate between the 'abstract' and 'real world' but rather operates in a sequential pattern, moving through one at a time. This type of learner is much more efficient under intrinsically motivated circumstances and more field independent (Witkin, 1977; Rego, Salgado, Fernandez, and Sonnier, 1986). Found predominantly in the math and science fields, field independent individuals are still capable of success in other areas of study (Gayle, 1981; Entwistle and Ramsden, 1986).

Researchers disagree on whether or to what degree students can shift between the two styles (Harris and Bell, 1986; Rabian-ski-Carriuolo, 1989). However, most will agree on two of the most influential factors determining the style--motivation toward people and subject matter. Students constantly exhibit recurring idiosyncratic behavior patterns, reflective of the student's relationship to the external environment, thus the likelihood of altering learning styles is greatly diminished (Rabianski-Carriuolo, 1989).

Goodenough (1982, pp. 44-45) offers several generalizations between field independent and field dependent learners which reflect innate differences in performance on attention tasks.

1. Field dependent subjects make greater errors than field independent subjects in both visual and auditory modes when they are asked to attend to a relevant stimulus in the presence of a competing, irrelevant stimulus (Avolio, Alexander, Barrett & Sterns, 1981).

2. Field dependent subjects need a longer time to pick up information and are less flexible in eye movement patterns when the visual display is changing. That is, the field dependent individuals tend to confine their fixations to a smaller region within the total visual field (Shinar, McDowell, Rackoff, & Rockwell, 1978).

3. Field dependent subjects tend to be less effective in signal detection accuracy when the demands of the task are high (Forbes & Barrett, 1978).

4. Field dependent subjects have larger and a greater number of eye movements during the Rod and Frame Test performance. This finding suggests that part of the field dependent subjects deficit in performance on the rod and frame test is related to selective attention,

and that field dependent subjects scan more of the visual field but are unable to selectively attend to the relevant part of the visual field (Blowers & O'Conner, 1978).

5. Field dependent subjects tend to prefer a slower pace of stimulus presentation in auditory and visual selective attention tasks (Avolio, Alexander, Barrett & Sterns, 1979).

Witkin (1977) noted that field dependent (extrinsically motivated) students, preferring a spectator approach to concept attainment, need greater assistance through a lesson to assist them in analytical short-comings and that--therefore--the lecture should be more structured. Field independent learners preferred an hypothesis-testing approach.

In summary, field independent individuals maintain superior abilities in selective attention, encoding, and long term memory processes (Witkin and Goodenough, 1981: Goodenough, 1982). The serialist prefers to be allowed to impose organization, structure and develop their own generalizations for assimilation of concepts. Whereas, field dependent individuals prefer, and thus are more motivated by, a passive responding teaching approach, more teacher-imposed organization, salient cues and people-oriented subjects.

Other characteristics and constructs used for distinguishing differences in learning styles include behavior patterns, modes of perception, and preferred methods of gathering information. Guild (1989) suggested that learners were generalists (takes the necessary steps to obtain overview), explorers (active, hands on), team players (emphasis on social interaction), verbalizers (needs 'sounding board'), and structured types (needs rules for learning structure). Learning styles determined by the avenue of perception can be differentiated into visual, auditory, and kinesthetic (or tactile) categories (Esfahani, 1989).

Finally, two other learning styles are closely related to the characteristic categories of holistic and serialistic learners--conceptual and rote or linear learning styles. Conceptual learning is the process of recognizing the shared features of otherwise discrete ideas or events and comprehending their interrelationships. Comprehending the meaning of a concrete or abstract concept, the learner scans details in search of sturdy generalizations or formulates hypotheses which once tested and proven can be used to establish the internal structure of abstract ideas. The resulting process of categorizing and classifying allows the learner to identify common features and determine connections among what first appears as somewhat unrelated ideas or events (Carnine, 1990; Ericksen, 1985). Rote learners prefer to be given the basic information in a sequential linear fashion. For the learner, processing the information consists of memorization through rehearsal of facts, ideas, and practice of events. The increase in understanding and comprehension of the material comes as a result of coincidence in terminology and congruence in definition (Thune and Ericksen, 1960; Ericksen, 1985; McKeachie, 1986).

The process of comprehending a concept through formal instruction is much more time consuming and difficult to learn and test than verbal learning or rote memorization. Simply <u>knowing</u> something is achieved much faster and easier than <u>understanding</u> what it is that is known. The difficulty in understanding abstract concepts stems from two principal characteristics, evolving boundaries and functional application. The original, rather amorphous, collection of interrelated facts or ideas undergoes constant revision and recategorization with the addition of new information. As the learner becomes more fully cognizant of the new meanings for individual ideas or events, the integration and application into known and unknown domains increases. Without comprehending the deeper meaning of concepts, the learner uses hollow terms and labels and thus is limited to a mere shell of descriptors.

Although learning concepts is more time consuming and more difficult to process for some students than rote memorization, there exists a distinct advantage in retention of information and transference to different models (Thune and Ericksen, 1960; Ericksen, 1962). Ericksen (1985) noted that conceptual learners carry essential features of one concept into relatively novel testing situations much more readily than rote learners. Stanners and Brown (1982) delineated direct relationships between theories of personality and pervasive nature of grouping concepts together while learning. The more abstract the concept, the more difficulty the learner has developing boundaries and understanding the expanse of the concept's meaning and application.

Identifying and understanding of the students' learning styles can be extremely helpful in determining the best method for instruction. Depending upon the instructional objectives, the method of instruction could be designed to utilize the strengths of the students' learning style. The professor should be aware first, that there are different style of teaching and learning, and second, that different goals are better reached through carefully selected means.

Conceptual Presentations

<u>Teaching Strategy: Concept to Application</u>

The manipulation and management of knowledge proves far more beneficial because of the connections and synergistic networking made possible by those interrelationships than the accumulation of the individual bits of knowledge. "Knowledge of things is not produced in us through knowledge of signs, but through knowledge of things more certain, namely, principles . . . For knowledge of principles produces in us knowledge of conclusions; knowledge of signs does not" (Thomas Aquinas, The Teacher, cited in Erickson, 1985, pp. 53).

Instruction which utilizes the teaching of science through concepts, on which one can hang a number of facts, stresses the importance of developing the foundation for higher intellectual processes and cognitive skills. Comprehending concepts develops cognitive skills: discriminating, remembering, imagining, inferring, creating, elaborating, reorganizing, generalizing, speculating, and abstracting (Ericksen, 1985). These behavioral indicators imply successful achievement of thought processes described by Bloom (1956) as understanding, application, analysis and synthesis. With the technical and intellectual skills developed, the student can progress through Bloom's hierarchy of thought processes by designing and conducting experiments which uncover new information in science.

Conceptual teaching involves the process of recognizing and presenting the shared features of otherwise discrete ideas or events and comprehending their interrelationships. Comprehending the meaning of a concrete or abstract concept, the instructor reviews the details of a topic, looking for sturdy generalizations which can be used to establish the internal structure of abstract ideas. By offering these generalizations, the learner begins to understand the constructs necessary to categorize and classify ideas or events through an identification of common features and determination of connections (Carnine, 1990; Ericksen, 1985).

Teaching Style: Presenting the Concept

The context within which a new concept is presented dramatically influences its meaning and related perceptions of its internal structure. Presentation of a particular concept at one time entailed describing the rule or framework, the target concept, followed by numerous examples for application. When tested for understanding of the concept, all too often the instrument for evaluation could have obtained the right answer but either for the wrong reason or no reason (Ericksen, 1985; McKeachie, 1986; Entwistle and Ramsden, 1983). More recently, the real test of understanding of a concept involves verbalization of the relationships. Some dialogue or exchange between the learner and instructor is needed to assure comprehension of the concept.

The concept can be presented in an expository or inquiry (discovery) manner, or a combination of the two. The teacher-centered verbal exposition includes definition(s), clarification of boundaries, and examples to illustrate the depth of the meaning involved in a concrete or abstract concept. Inquiry instruction extrinsically encourages and guides the students to identify the problem, form a hypothesis, gather and analyze data, and finally form their own conclusion. The combination of these methods includes the verbal exposition (definition(s), clarification of boundaries, and some illustrations of integration existing cognitive constructs) followed by intense questioning which will promote application, independent thinking, and the development of skills for critical thinking, evaluation, and judgement regarding the particular concept. Kauchak (1989) identifies the main categories of questions as knowledge centered (i.e., for testing recall, comprehension, and application), inquiry-skilled centered (i.e., for formulation and testing hypotheses), and value-attitude centered (i.e., for evaluation of input for determination of individual attitudes).

Joseph Hesse (1989) suggested presenting a challenging concept with a discrepant event as a variation to the above options. The students' naive conceptions are confronted and refuted by the presentation of an event that runs counter to predictions based on illogical or unscientific concepts. Following the science demonstration, the plausible and intelligible presentation of the correct explanation illuminates any errors in the original hypotheses, generalizations, or theories held by the students.

Recent thrusts in science education have promoted the concept of cross-disciplinary courses with interdisciplinary content. Reorganizing of curriculum in a cross-disciplinary manner will help meet the growing demands for future scientists to be well versed in areas outside traditional boundaries. Although seldom implemented within a course, presenting interrelationships and connections of topics or ideas from various disciplines clearly indicates the professor is concerned with integrative ties between subjects and thereby broadening the scope of a concept for understanding and application. Such an approach also indicates the professor is keeping pace with the types of complex issues facing today's students in a rapidly changing world.

Finally, there are teaching styles which reflect characteristics of the two principle patterns for processing information -- holistic and serialistic. The holistic presentations involve numerous anecdotes, illustrations, and analogies (Entwistle and Ramsden, 1986). Because of the learner's wide focus of attention, the lecture design maintains a flexible format in which several subtopics can be integrated. Vacillating between 'real world' and abstract through, using analogies brings new insight to the internal structure and boundaries of the concept. The serialist presentation follows a rigid and logical sequence of material connecting the 'real world' with the abstract only when necessary. With the majority of the lecture dealing with sub-topic details, the 'big picture' or broad perspective is not realized until very late in the lesson.

Some researchers suggest matching learning and teaching styles, or at least tailoring the presentation style to inherent strengths and preferences students display both in cognitive and affective domains (Pask, 1977; Entwistle and Ramsden, 1986). When facing the extremely serialistic student at one end of the spectrum and the extremely holistic student at the other end, it would be difficult, if not impossible, to offer opposite methods for presenting material at the same time.

Some researchers suggest using instruction which displays a marriage of both styles to increase the understanding of both global and analytic learners (Bireley and Hoehn, 1987; Dunn and Dunn, 1987; Entwistle and Ramsden, 1983; Ericksen, 1985) and to encourage learners to try alternative styles (Harris and Bell, 1986). Others, recognizing time is inadequate to employ both, suggest employing the holistic-oriented mode. Rego, Salgado, Fernandez, and Sonnier (1986) concluded the holistic teaching strategy is superior to the serialistic style for heterogeneous groups of students displaying different cognitive styles. They suggested that the holistic style "must be used to enrich a majority of students, each through his/her own thinking-learning mode." Witkin (1977) suggests an advantage to having a serialist/field independent teacher present an inherent amount of organization and salient cues to holist/field dependent learners but notes that these learners are likely to find the teaching impersonal in nature and oriented toward the more cognitive aspects of teaching. Conversely, the holistic/field dependent teacher favors situations that allows for greater interaction with learners and less emphasis on the cognitive aspects but this is not preferred by the serialistic/field independent learner (Entwistle and Rams den, 1983; Ericksen, 1985).

Discussion of the Literature Reviewed:
Problems and Application

The following section considers the research reviewed above as it relates to the state of science education at the college level and proposes possible trends for future instruction. The question remains: Does understanding improve significantly with a matching of styles or with a mismatching of styles? Or more appropriately, does one style of teaching improve understanding for both field dependent and field independent learners?

Criticisms of Science Instruction

Often science classes are criticized for being passive experiences. Lack of interaction contributes to the lack of community, isolation which leads to competitiveness, boredom, and finally dissent.

Considering the vast amount of course material presented in many science classes, the inherent bias of the system favors those students who need less time to organize and process information and concepts. The presentation of facts and mechanics of problem solving often meets the requirements for accurately mimicking the keeper of information, but it needs to be complemented with interpretive information and conceptual teaching (Tobias, 1990). Time committed to memorizing facts, formulas, and problem-solving techniques should be balanced with real world ramifications of theory and practical applications of concepts which include the integration of at least the dominant functional components.

Pathologies associated with the two main styles of teaching must also be considered. Holists tend to be sporadic, over-eager to generalize and not always prone to show adequate connections among the topics covered; serialists fail to incorporate analogies and demonstrations integrating the various topics, which weakens an understanding of the important interrelation-ships of those topics and comprehension of the subject matter as a whole (Entwistle and Ramsden, 1986).

Advantages of Holistic Conceptual Methodology

There are several advantages of presenting information through a conceptual and holistic approach. Conceptual teaching emphasizes shared values within a group of ideas or events, interrelationships, integration, and application. Holistic teaching emphasizes the broad perspective through the employment of diagrams, illustrations, anecdotes, and analogies.

Several advantages accrue through conceptual teaching. The professor experiences a feeling of professional growth because of the increased familiarity and greater understanding of the content of lectures. Student learning increases through the clarification of scientific concepts and illumination of misconceptions and stumbling blocks through constant feedback and discussion following an activity or demonstration (Hesse, 1989). The additional care and concern demonstrated through healthy, thought-provoking presentations and follow-up questions clearly indicates the teacher's desire to improve the student's analytical and critical thinking. Students perceive the teacher as a mentor they can relate to and interact with, thus improving student-teacher relationships. In addition, research indicates that such teaching results in greater retention of information and greater transference into different models.

Holistic methodologies also meet the needs of heterogeneous student groups and therefore reduce anxiety and frustration. They encourage students accustomed to sequential teaching styles to try alternative styles which enhance comprehension and application. They provide the teacher with the flexibility necessary to offer large amounts of information in an entertaining, integrative fashion, without being bogged down with tedious details that add to the meaning of some specific aspect or subtopic but take away from the big picture. The holistic style allows the instructor to demonstrate with much greater freedom not only where the presentation is coming from or going to but sometimes more importantly the relationships with other topics in the same subject matter.

Biogeochemical Cycles: A Conceptual Presentation

Given that most students prefer some background discussion regarding the laws of nature, their development, and their interactions rather than just being presented with the finished product, the emphasis the science class should establish is a foundation for facts. The questions scientists ask are couched in theory, and the derived answers are interpreted within a theoretical framework (Rigden and Tobias, 1991). The student needs to be introduced to a genuine dialogue, formalized and theory-laden, reflective and representative of reality. Once introduced to this dialogue, the subsequent investigations between these future scientists and nature, which brings new mysteries, insights, and global syntheses, will not be nearly as incomprehensible or intimidating. Understanding nature, its current trends and future problems associated with aberrations, can be facilitated through conceptually structured conversations which make science exciting and dynamic.

The task itself can be stated simply, the accomplishment of the task can be a rather enormous struggle. The professor delineates and attends to overarching, intra- and interdisciplinary goals which illuminate the integration of new concepts with those reviewed in the past. The professor's conceptual presentations should be a balance between lecture and discussion questions whose resolution would provide a raison d'etre for a course. No concept is isolated. Unity and integration are stressed. Socratic dialogue and Aristolean logic guide the joint-venture toward the conceptual transition and thus optimal, rather than just adequate, application of information.

For example, the seasoned science educator who is already conversant with the facts of the subject might introduce a series of presentations regarding biogeochemistry in the following manner. The introduction begins with an outline of the umbrella of integrated concepts and works toward the development and description of the related topics.

The living world is dependent upon and integrated into the flow of energy and cycling of nutrients through ecosystems. Both influence the populations of organisms, their metabolic rates, and the complexity of the interrelationships between and within the populations of an ecosystem, with naturally occurring nutrients cycling from biotic to abiotic components and back again. Plants and animals obtain their nutrients from these perpetual cycles.

A short discussion and definition of terms should preempt any presentation regarding the specifics of each cycle (e.g., reservoir, sink, residence time, steady state, flow, turnover rate, recipient and donor controlled flow, macronutrients and micronutrients, intrusions, etc.).

Next the educator might note there are two principal types of biogeochemical cycles: gaseous (e.g., oxygen, carbon, and nitrogen cycles) and sedimentary (e.g., phosphorus and sulfur). These cycles contain main reservoirs for gaseous cycles, the atmosphere and ocean; for sedimentary cycles, the earth's crust. The constituents within these two types of cycles are interactive and interdependent.

That in turn could lead to focusing specifically on oxygen and stress that it has a complex cycle involving oxidative reactions with several minerals of the earth's crust and organic constituents of the various components of the ecosystem (i.e., hydrosphere, biosphere, and stratosphere). Plants and animals are dependent on the role oxygen plays (i.e., photosynthesis and aerobic respiration) on the energy cycles, involving conversions of kinetic to potential energy.

Oxygen would be followed by ozone, since it is an important component of the atmospheric reservoir of oxygen, plays a vital role in blocking solar ultraviolet radiation. The latter function of ozone is guaranteed to snag the attention of those students interested in their tans. Under normal conditions, a balance exists between the formation and destruction of ozone. Because of the relatively extensive percentage of the atmosphere available, diurnal fluctuations are minimal, but annual oxygen curves reflect its seasonal interaction with other natural cycles as well as with human intrusion (i.e., human made disruptions, such as chemicals which alter the naturally occurring processes within a cycle).

Carbon, which students may regard as more concrete than oxygen or ozone, is intimately involved with the flow of energy and plays integral roles in plant respiration and photosynthesis, consumption and degradation of carbohydrates (i.e., cellular respiration), mineralization of wood, soil respiration, accumulation in biomass, and carbonification into long term reserves. Students may not know that the majority of carbon is found in a gaseous state as carbon dioxide; to a lesser degree it is tied up in organic and inorganic compounds of the biosphere. Because of its relatively low percentage in the atmosphere, diurnal and annual fluctuations of carbon dioxide are reflective of plant respiration patterns and rapid injections of large quantities of carbon dioxide through burning of fossil fuels.

Students also need to know that the nitrogen cycle involves processes of ammonification, nitrification, and denitrification by constituents of the biosphere. Atmospheric nitrogen is assimilated by nitrogen-fixing organisms (e.g., bacteria in the root nodules of leguminous plants and blue-green bacteria) and is released through denitrification by other bacteria. Diurnal and annual fluctuations are linked to interactions with other cycles and human intrusions.

The process for actively involving students does not need to be restricted to the gaseous cycles for it works equally well when one considers sedimentary cycles, which involves weathering, making minerals available from the earth's crust, mobilization through entry into the water cycle as a salt solution, and return back to the earth's crust through sedimentation. The phosphorus cycle, strictly sedimentary in nature, involves mobilization from its primary reservoir in phosphate rock. As a fertilizer, most of it is immobilized by the soil. The cycle is broken as large quantities are lost through its involvement as a waste carried by sewage effluents.

Sulfur, inherently both gaseous and sedimentary in nature, has reservoirs in both the atmosphere and earth's crust. It is released in the sedimentary phase by weathering and decomposition and is then acquired by aquatic and terrestrial organisms. A considerable portion of the earth's sulfur is found in the atmospheric reservoir. Entering the gaseous state as a result of combustion of fossil fuels or of volcanic eruptions and as gases released during decomposition reactions or from the surface of lakes and ocean, sulfur is rapidly oxidized to sulfur dioxide. Being soluble in water, it can reenter the hydrosphere as a weak acid. As a gas or liquid, sulfur is incorporated into sulfur-bearing amino acids. The sulfur cycle and its annual fluctuations are dramatically influenced by the injection of large quantities of sulfur dioxide, a pollutant, into the atmosphere through the burning of fossil fuels.

Human intrusions disrupt the flow and steady state balance within the ecosystem by releasing pollutants into the atmosphere (e.g., nitrogen dioxide, nitrogen monoxide, chloroflurocarbons, nitrogen fertilizers, and sewage effluents). With each one of these disruptions exists the propensity of disturbing or destroying the multiple naturally occurring phases within several cycles.

In an effort to encourage the visualization of interrelationships, the professor might ask the student a question which beckons the student to consider the effect of a single emission or hazardous waste effluent on a main reservoir and all integrated cycles. The question might be along the lines of, "What would happen on a local scale if abnormally high amounts of carbon dioxide or methane enter the atmosphere?" This question would act as a springboard for a discussion which would illuminate the parameters of each concept and display the interrelationships for the student.

The next step would be to encourage, nurture, and develop the student's analytical ability by asking questions which require one to impose organization upon related bits of information and go through the process of forming generalizations which link these concepts. For example the professor might ask, "What would happen if abnormally high amounts of nitrogen oxides or sulfur dioxides enter the atmoshpere?" Follow-up questions that guide the linkage of related concepts might be along the lines of, "How would these affect the biotic community and/or concentration of metals (e.g., aluminum) in the soil?" This type of question calls for the student to develop and organize thoughts regarding both types of reservoirs and at least two types of nutrient cycles as they relate to a convergent arena, in this case the biotic community.

The student might be asked to recognize, if not clarify, his/her value system by bringing the subject matter home with a personal question such as, "What effect would these oxides have on concentrations of toxins (e.g., dioxin) in the atmosphere?" and

"What are the effects of dioxin on the human body?" Once the student has grasped the importance of such an issue by understanding the direct impact it will have on him or her personally, the ensuing development of an interest, intrinsic motivation, and quite possibly a proactive commitment begins to be formalized.

Finally, the professor concludes the transition process by offering the proper stimulation for self-organization by the student. In this case, one might ask a question of broader scope and allow the student to develop a succession of questions regarding the relationship of subtopics. For example, a question such as, "How does the destruction of the ozone layer relate to global warming and acid rain?" might lead to a series of questions such as, "What are the causes of acid rain? How are these causes related to the destruction of the ozone? What effect would global warming have on the biosphere and hydrosphere which indirectly support the industry which generates the causes of ozone destruction?" The follow-up questions for this stage of development would call for an understanding not of cause-and-effect, but rather of conservation-minded solutions for the cause. This concept might be introduced by guiding the student to see the connection and possible correction by asking "How might it be possible to . . ." or "What if it were possible to . . .?"

Knowledge of interrelationship per se is not adequate, for the purpose of integrated science education is to enable the person to bridge the natural sciences and man's dominion in order to create a productive coexistence. That is, man should be encouraged to take a proactive position rather than abdicating his role in preservation and conservation. By nurturing develop-mental and conservative activities and discouraging destructive steps, man avoids the awkward predicament of generating legislation to save himself and the environment he lives in.

If one is to emphasize the political and legislative ramifications of environmental science, the professor needs to engender among the students a concern about integrated education. Toward that end, the professor might ask a question which emphasizes the transformation of biological and/or chemical carcinogens, the long distance transfer of a chemical within a medium or across media, the transmittance of specific pollutants or substances which are potentially carcinogenic, and finally the accumulation and magnification of toxic substances (usually stored in adipose tissue) in organisms at higher levels in the food chain. This would lead to questions which ask the student to propose ideas for developing regulatory legislation which is cross-media and emphasizes the highly integrated nature of the ecosystem.

Finally, the professor must prove the importance of pedagogical practices in which subject matter is steeped in theory and laden with questions which encourage the development and formalization of integrated concepts. The proof in this case lies in the pudding, the evaluation of acquired knowledge and understanding of the concepts--the exams. The exam questions must demand explanations/ discussions of conceptual interactions and interrelationships through short answer/essay type inquiry. The request for "comment on . . ." or "explain the relationship between . . ." or "discuss the effects of the following aberrations on . . ." assures the student of the professed importance of problem-oriented approaches by developing analytical ability and critical thinking through an investment in time and energy.

Summary of Biogeochemical Cycles:
A Conceptual Approach

The holistic presentation, heavy laden with integrated concepts, began with the delineation of overarching goals. The subsequent attention to those goals involves an introduction of the subject matter and is followed by a progressive succession of three basic series of presentations. Each series is organized and structured from a question-oriented investigation of the material. The design allows time for the students to make the transition from previous "requests" (i.e., to follow traditional and common serialistic descriptions of factual information) to a self-motivated holistic investigation of nature.

The first series of questions is intended simply to illuminate the interrelationships and integration of the various concepts for the student. The second series guides the student toward the development of generalizations which include characteristics of one or more concepts and which encourage a personalized imposition of values, delineation of conceptual parameters or boundaries, and understanding of the subject. The third series of questions attempts to crystalize the breadth of a concept through questions which depict discrepant events and aberrations (i.e., "What if?").

Although extremely brief and over simplified, the gaseous and sedimentary cycles outlined above display recurrent similarities and interrelationships which enhance the understanding of each chemical separately and holistically. The presentation follows a systematic approach, delineating a series of steps in each cycle, relationship with the biosphere in particular, and diurnal and annual fluctuations due to human intrusions.

With the adoption and implementation of "unifying principles" as the main theme or the effective teaching strategy, this presentation centers on changes in quantities in the biosphere, stratosphere, and hydrosphere and on the relationship of such changes to metabolic rates. On a larger scale, the principle of naturally occurring cycles versus aberrations through injections into reservoirs through human intrusion threads and unifies each of the other concepts regarding chemical cycles. This strategy affords the lecturer the flexibility to insert analogies, anecdotes, illustrations, and practical examples in order to enhance the reliance and understanding of foundational principles and terminology and to demonstrate the connection of the various subtopics, each an abstract concept, to the real world. Although the professor may explore momentary tangents and questions for immediate application in environmental science or ecology and human anatomy and physiology (e.g., pathology or pharmacology), the retaining theme allows for a smooth return to the original lesson plans.

Not shown above is the constant referencing of interrelated subtopics. For example, the professor can recall for the student the biochemical and physiological relationships which the aberrant substances (e.g., toxins, chemicals disrupting naturally occurring cycles) or the aberrant quantities of naturally occurring substances (e.g., carbon dioxide and methane) have with normal cell metabolism such as growth patterns and cytological behavior, perpetuation of imbalance disrupting the local and global equilibrium, and homeostatic tendencies.

Additionally, the student views the characteristics as a series of events within a meaningful process instead of as a collection of isolated features. By enhancing and facilitating the visualization of the interrelationships and interdependency of each characteristic, the professor beckons the students to experience the cohesiveness of physiological activity. The future application of related ideas becomes noticeably easier because the recalled relationships encourage the student to see the characteristics not as independent features of a cycle but as an integral part within a series of interrelated cycles which lead to structural and functional change associated with each constituent of that cycle.

Summary of Effective Teaching Methods and Strategies

The holistic conceptual lecture style clearly surpasses alternative methods for presenting science concepts within a given framework of time. It meets the demands for introducing and processing large amounts of material in a short period of time while offering the necessary framework for integration, application, and interaction with the students. Teaching concepts in both a disciplinary and cross-disciplinary manner allows even greater insight to the breadth of a topic and develops the necessary framework for creative and critical thinking. The holistic conceptual lecture style of material which is both disciplinary and cross-disciplinary increases the opportunity for development of the intellectual abilities necessary for solving the types of problems facing today's students.

From understanding some of the parameters, connections, interrelationships, and rules of thumb, application in a particular research experiment or theoretically based setting becomes much more feasible, manageable, accurate, and usable (Carnine, 1990; Douglass, 1979; Ericksen, 1985). Many of the details or specifics of a particular concept are much easier to understand and integrate. In addition, a presentation with this type of format affords the learner an understanding of the internal and external network of ideas associated with the concepts and the foundational steps needed for creative, independent and critical thinking.

CHAPTER III

RESEARCH METHODOLOGY

An experiment was designed to consider the preferences learners have regarding two different pedagogical methods--serialistic and holistic. The experiment considered the learners' preference for instruction by using complementary or noncomplementary styles. The study attempted to determine the differences in learners' achievement (assessed by a comparison of means of posttest minus pretest scores) and interest (affective domain) when exposed to two different pedagogical styles for a presentation on biogeochemical cycles.

Learners were identified as field dependent or field independent according to their analytical preference. Determination of the individual's analytical ability was based upon their scores on the Group Embedded Figures Test (Witkin, 1977).

The two different pedagogical styles employed for the study, holistic and serialistic, reflect characteristics of the two principal patterns for processing information. The serialist presentations followed a rigid and logical sequence of material. No efforts were made to link connections between the 'real world' and the abstract. With the majority of the presentations dealing with the progressive succession of subtopic details, the 'big picture' or broad perspective was not realized until very late in the lesson.

On the other hand, the holistic presentations contained numerous anecdotes, diagrams, illustrations, analogies, global descriptions, integrations, and applications. Because of the wide focus, the presentations were designed to maintain a flexible format in which several subtopics could be incorporated or integrated. By moving between 'real world' and abstract and by using analogies, the instruction was designed to bring new insight to the internal structure and boundaries of the concept.

The serialistic presentation, by following a sequential didactic method, was expected to favor the field independent learner (Entwistle and Ramsden, 1986). The holistic presentation, by following a modified deductive sequence, was expected to favor the field dependent learner (Rego, Salgado, Fernandez, and Sonnier, 1986).

Criteria for serialistic and holistic presentations were referenced from resource articles and texts (Pask, 1977; Entwistle and Ramsden, 1986; Rego, Salgado, Fernandez, and Sonnier, 1986) and established in conjunction with a learning specialist and faculty development coordinator. Information presented serialistically was introduced in a sequential linear progression with analysis of specific characteristics of a particular topics augmented with detailed examples. General conclusions and interrelationships with other concepts were to be drawn from the presentation by the learner. Holistic presentations were introduced with generalizations, an organized analysis, and a broad picture perspective of a particular topic. These were supported by general characteristics and interrelationships which strengthened continuity and comprehensiveness of the issue. Details and examples were offered to support the generalizations of the concept.

Hypotheses

This study assessed the effect of two teaching methodologies implemented for the dissemination of information on the topic of biogeochemistry to field dependent or field independent learners. The following hypotheses will be examined in this study.

Ho1. There is no significant difference in achievement (net gain = posttest minus pretest) as measured by a t test with field independent learners when exposed to serialistic instruction or holistic instruction.

Ho2. There is no significant difference in achievement (net gain = posttest minus pretest) as measured by a t test with field dependent learners when exposed to serialistic instruction or holistic instruction.

Ho3. There is no significant difference in interest as measured by a comparison of z scores with field independent learners when exposed to serialistic instruction versus a blend of serialistic and holistic instruction.

Ho4. There is no significant difference in interest as measured by a comparison of z scores with field independent learners when exposed to holistic instruction versus a blend of serialistic and holistic instruction.

Ho5. There is no significant difference in interest as measured by a comparison of z scores with field dependent learners when exposed to serialistic instruction versus a blend of serialistic and holistic instruction.

Ho6. There is no significant difference in interest as measured by a comparison of z scores with field dependent learners when exposed to holistic instruction versus a blend of serialistic and holistic instruction.

Overview of Research Design

The subjects (n=57) were members of two senior level ecology classes at a private university. The two classes were taught in two successive semesters by the same professor. One class (n=31) was exposed to a serialistic teaching method which employed a modified inductive sequence of information for a period of three weeks (See Appendix A). The other class (n=26) was exposed to holistic teaching which employed a modified deductive sequence of information for the same period of time (See Appendix B).

Prior to the exposure of the particular subject matter, biogeochemical cycles, the learners were first given the Group Embedded Figures Test (GEFT), Shipley Institute of Living Scale (SILS), and an ecology pretest on biogeochemical cycles.

The individual's analytical preference as a function of cognitive learning style was measured by the scores of the GEFT (Witkin, 1974). The ecology students were divided into two groups based upon their individual performance on the GEFT. Those individuals who obtained a score of 16 or above were described as being field independent. Those individuals with scores of 15 or below were described as being field dependent. A high mean was expected and reflective of those individuals entering the field of science (Witkin, 1977).

Assessment of general intellectual ability was established by the scores of the Shipley Institute of Living Scale. The Wechsler Adult Intelligence Scale served as the basic criterion measure for validating the use of the SILS in predicting individual IQ scores. The instrument was used to determine homogeneity between the two populations, each exposed to a different teaching style.

The ecology pretest consisted of 24 general ecology questions varying in level of difficulty and depth of conceptual understanding (see Appendix C). General ecology texts and the Graduate Record Exam were the two main sources for the exam questions for this particular topic.

An exam similar in style, questions, and levels of difficulty was constructed and administered as a posttest after the presentations covering biogeochemistry were completed (See Appendix D). Participants' individual performance scores were determined by subtracting pretest percentage scores from posttest percentages.

In addition, the students were asked to identify their relative interest in the material based upon the pedagogical style. A question designed to address the affective domain can be found at the end of the posttest (See Appendix D). The question attempted to determine the student's perception regarding interest for the particular section of the course and interest derived from a particular lecture style.

Sampling Procedure

The experiment was limited to the presentation of information to two different senior level ecology classes in successive semesters--a convenient cluster sample. The students had taken the four introductory or basic science courses as a part of the established curriculum. Very few students had taken more than four. The majority of the students had some inherent interest in a particular field of science, although it was not necessarily limited to ecology. No empirical data were obtained to assure similarity of professional interest and course application between the two classes.

Those students completing the SILS, GEFT, and pretest exam were included in the study. One student dropped the course prior to completion of presentation and therefore was dropped from the sample population.

Instruments

A teaching assistant administered the GEFT, SILS, and pretest one week prior to the teaching on biogeochemistry. The Group Embedded Figures Test (Consulting Psychologists Press) was used to determine analytical preference. The instrument has a high positive correlation with Piagetian tests but takes significantly less time--12 minutes (Witkin, 1977). The students were identified as being field independent (a numerical score above 15) or field dependent (a numerical score of 15 or below) depending upon their performance.

The Shipley Living Scale was used to assess the general intelligence of the students (20 min). It was designed to measure the student's facility in reasoning and in dealing abstractly with verbal, symbolic, and figural content. It has a high correlation with the WASC (Zachary, Paulson, and Gorsuch, 1985).

The ecology pretest was designed by the instructor and experimenter to assess the initial knowledge regarding the special topic biogeochemistry. Questions were derived from the Graduate Record Exam and suggested questions from the text.

Implementation and Statistical Procedures

The t test for significance was chosen because of the strength and reliability (i.e., parametric versus nonparametric) in displaying a relationship between two variables (i.e., cognitive learning style and method of presentation). As well, the experiment could easily meet the two assumptions of the test. The data could be measured on a continuous scale, and normality of underlying distribution (reviewed by a comparison of means with in the classes) was exhibited. For simplicity, a numerical scale, which was previously devised for each instrument, was used to assess intelligence, analytical ability, and acquired knowledge. It was accepted that normality for intelligence existed within the group.

Parametric t tests for significance were used to examine the relationship between the GEFT, SILS, and pretest scores between the two groups. This examination was to assure homogeneity in analytical ability, level of intelligence, and previous knowledge of biogeochemistry between the two classes.

Individuals were categorized into one of two groups, field dependent or field independent learners, for each of the two classes. With each class being exposed to a different type of teaching methodology, all of the students participating would fall into one of four categories (see Table I).

TABLE I

CATEGORIZATION OF LEARNING STYLES

Teaching Method	GEFT Scores 0-15	16-18
Serialistic	Field Dependent	Field Independent
Holistic	Field Dependent	Field Independent

The mean score of each group, a composite of individual net scores (posttests minus pretests) was used to determine knowledge acquired primarily from the method of presentation. T tests for significance were used to examine the differences in the means of the two groups of field independent learners, a comparison of performance of those exposed to the serialistic presentation with those exposed to the holistic presentation. The same tests for significance were used to examine the differences in means of the two groups of field dependent learners. This information was used to determine the affect pedagogical methodology had on comprehension of the material for field independent and field dependent learners. The sample size needed to conduct a test with significance level α and probability of $1-\beta$ of detecting a significant difference is

$$N = \frac{\sigma^2 (z_{1-\beta} + z_{1-\alpha})^2}{(\mu_0 - \mu_1)^2},$$

where μ equates the mean, σ^2 equates the known variance, and n equales sample size.

This formula indicates that as the n decreases, z decreases, and appropriate α levels increase. For example, if n=100, the sample size has the potential to show significance at α = .01, but when n=20 it does not s how significance. It may only be able to detect a significant difference at α = .1 (Rosner, 1982). Due to the limited number of individuals in each group (i.e., field independent and field dependent exposed to each teaching style), a level of confidence of .1 was selected. This selection was supported in a personal conversation between William D. Warde, professor of statistics, and Thomas A. Karman, August 26, 1991.

A comparison of z scores for each group was used to determine the significance of the exposure each teaching methodology had in the affective domain. The z test displays a value of a proportion, showing it to be greater or less than .50).

Each class was given the following question and asked to choose one of the five possible answers.

How did my lecture style (not topic) on biogeochemistry compare with my other lectures? (Be honest; this question will not be graded.)

a. much worse; dull
b. less interesting
c. about the same
d. more interesting
e. much better; motivating

With each group being exposed to the introductory ecology material through a teaching method that could be described as a blend of modified serialistic and holistic methods prior to the section on biogeochemical cycles, the students' answers to the question above would be based upon a comparison to this blend which preceded their exposure to either the serialistic or holistic teaching method. The responses were used to divide the population into six groups of students for each of the two types of presentation. These groups were of primary interest determining the significance and acceptance of research hypotheses three through six. Because of the manner in which null hypotheses three through six were written, the affective domain for each type of learner was divided into three areas (i.e., more interested, about the same, and less intrested). These divisions would better enable the determination of rejection or nonrejection of each hypothesis. The six groups of students exposed to the serialistic method are field independent students indicating the lectures were more interesting by answering choices d or e; field independent students indicating the lectures were about the same by answering c; field independent students indicating the lectures were less interesting by answering a or b; field dependent students indicating the lectures were more interesting by answering d or e; field dependent students indicating the lectures were about the same by answering c; and field dependent students indicating the lectures were less interesting by answering a or b (see Table II). The six groups of students exposed to the holistic method were field independent students indicating the

TABLE II

AFFECTIVE DOMAIN FOR SERIALISTIC PRESENTATION

	Indication of Interest		
Type of Learner	More Interested	About the Same	Less Interested
Field Independent	d or e	c	a or b
Field Dependent	d or e	c	a or b

lectures were more interesting by answering choices d or e; field independent students indicating the lectures were about the same by answering c; field independent students indicating the lectures were less interesting by answering a or b; field dependent students indicating the lectures were more interesting by answering d or e; field dependent students indicating the lectures were about the same by answering c; and field dependent students indicating the lectures were less interesting by answering a or b (see Table III).

TABLE III

AFFECTIVE DOMAIN FOR HOLISTIC PRESENTATION

	Indication of Interest		
Type of Learner	More Interested	About the Same	Less Interested
Field Independent	d or e	c	a or b
Field Dependent	d or e	c	a or b

The results of these statistical procedures are reported in the following chapter. Chapter V contains the interpretation of the data and conclusions.

CHAPTER IV

ANALYSIS OF THE DATA

Introduction

This chapter reports the results of the study with respect to the relationships between analytical ability, as determined by the Group Embedded Figures Test (GEFT), and teaching methods (serialistic or holistic). Hypotheses one and two were tested by means of a t test. Hypotheses three and four were tested by a comparison of z scores. The sample of 58 students produced 57 useable sets of responses. One set of responses was lacking vital information (i.e., pretest scores) and was omitted from the study.

Determination of Homogeneity

After the GEFT, SILS, and pretest had been scored, the means of the two classes, one class exposed to the serialistic teaching and the other to holistic teaching, were determined (see Table IV). The comparison of means was used to determine the similarity in analytical ability and intelligence, as defined by the GEFT and SILS scores respectively, between the two student groups. The comparison of means of the pretest score was used to determine the similarity in background knowledge of biogeochemistry.

TABLE IV

MEANS OF EACH CLASS IDENTIFIED BY THE METHOD OF TEACHING

	N	MEAN	MEDIAN	TRMEAN	STDEV
GEFT-S	31	14.35	16.00	14.78	3.88
GEFT-H	26	15.08	17.00	15.21	3.24
SILS-S	31	116.90	119.00	117.70	6.72
SILS-H	26	116.73	117.50	116.96	5.84
PRE-S	31	53.32	52.00	53.41	10.10
PRE-H	26	51.27	50.00	51.54	13.15

S indicates being exposed to the serialistic presentation.
H indicates being exposed to the holistic presentation.

A t test for significance was used to compare statistically the GEFT, SILS and Pretest means for analytical preference, estimated intelligence quotients, and previous knowledge of biogeochemistry for the two classes, respectively. Based upon the information acquired from the instruments described above, no significant difference was found between the two groups in analytical ability (t= -0.77, P=.45, DF= 54), in intellectual level (t= 0.10, P= .92, DF= 54), or in previous knowledge of biogeochemistry (t= 0.65, P= 0.52, DF= 46).

Evaluation of Achievement Scores

Consideration is given to each of the hypotheses.

Ho1. There is no significant difference in achievement (net gain = posttest minus pretest) with field independent learners when exposed to serialistic instruction or holistic instruction.

Null hypothesis one was not rejected. There was no evidence that field independent learners differed in achievement (posttest minus pretest) when exposed to serialistic or holistic instruction (see Table V). A statistical comparison of the means of the differences (posttest minus pretest) from each class yielded a t value of -0.25 with P= 0.40 and DF= 23.

TABLE V

FIELD INDEPENDENT LEARNERS

	N	MEAN	STDEV
Serialistic Presentation	18	11.4	11.4
Holistic Presentation	15	12.7	17.3

Ho2. There is no significant difference in achievement (net gain = posttest minus pretest) with field dependent learners when exposed to serialistic instruction or holistic instruction.

Null hypothesis two was rejected. A significant difference was found between field dependent learners' performance when exposed to serialistic teaching style versus holistic teaching style (see Table

VI). The statistical comparison of the means of the differences (posttest minus pretest) from each class showed t= - 1.55, P= 0.069, and DF= 21.

TABLE VI

FIELD DEPENDENT LEARNERS

	N	MEAN	STDEV
Serialistic Presentation	13	9.3	15.8
Holistic Presentation	11	18.7	14.1

Ho3. There is no significant difference in appreciation (interest) with field independent learners when exposed to serialistic instruction versus a blend of serialistic and holistic instruction.

Null hypothesis three was not rejected. Eleven percent of the field independent learners said that serialistic instruction was more interesting than what they were previous exposed to, significantly less than fifty percent (z= -3.31, P= .0004). Forty-four percent of field independent learners said that serialistic instruction was less interesting, not significantly less than fifty percent (z=-.51, P=.305). Forty-four percent of the students indicated that the teaching style was about the same as what they were previously exposed to (see Table VII).

TABLE VII

FIELD INDEPENDENT LEARNERS

	L	A	M
Exposed to Seralistic <u>Teaching Style</u>			
Number of responses	8	8	2
Percentages	44	44	11
z scores	-.51	-.51	-3.31
Probability	.305	.305	.0004
<u>Exposed to Holistic Teaching Style</u>			
Number of responses	10	4	1
Percentages	67	27	7
z scores	1.10	-2.01	-3.33
Probability	.08	.0228	.0004

Responses to the question regarding affective domain on the posttest
L indicates responses of "less interesting" or "much worse"
A indicates responses of "about the same"
M indicates responses of "more interesting" or "much better"

Ho4. There is no significant difference in appreciation (interest) with field independent learners when exposed to holistic instruction versus a blend of serialistic and holistic instruction.

Null hypothesis four was rejected. Seven percent of field independent learners said that holistic instruction was "more interesting" than what they were previous exposed to, a blend between serialistic and holistic teaching styles. That number was significantly less than fifty percent (z=-3.33, P=.0004). Sixty-seven percent of field independent learners said holistic instruction was "less interesting" than what they were previous exposed to, which was significantly greater than fifty percent (z=1.10, P=.08). Twenty seven percent of the students indicated that the teaching style was "about the same" as what they were previously exposed to.

Ho5. There is no significant difference in appreciation (interest) with field dependent learners when exposed to serialistic instruction versus a blend of serialistic and holistic instruction.

Null hypothesis five was not rejected. Thirty-one percent of field dependent learners said that serialistic instruction was more interesting than what they were previous exposed to, a blend between serialistic and holistic teaching styles, significantly less than fifty percent (z= -1.48, P=0.069). Approximately eight percent of the field dependent learners said that serialistic instruction was less interesting. This number was significantly less than fifty percent (z=-5.72, P=0.00). Sixty two percent of the students indicated that the teaching style was about the same as what they were previously exposed to (see Table VIII).

Ho6. There is no significant difference in appreciation (interest) with field dependent learners when exposed to holistic instruction versus a blend of serialistic and holistic instruction.

TABLE VIII

FIELD DEPENDENT LEARNERS

	L	A	M
Exposed to Serialistic Teaching Style			
Number of responses	1	8	4
Percentages	7.7	62	31
z scores	-5.72	.89	-1.48
Probability	.0001	.187	.069
Exposed to Holistic Teaching Style			
Number of responses	5	5	1
Percentages	45	45	9
z scores	-.33	-.33	-2.72
Probability	.37	.37	.0033

Responses to the question regarding affective domain on the posttest
L indicates responses of "less interesting" or "much worse"
A indicates responses of "about the same"
M indicates responses of "more interesting" or "much better"

Null hypothesis six was not rejected. Nine percent of field dependent learners said that holistic instruction was more interesting than what they were previous exposed to. This number was significantly less than fifty percent (z=-2.72, P=.0033). Forty-five percent of field dependent learners said that holistic instruction was less interesting than a what they were previous exposed to, not significantly less than fifty percent (z=-.33, P=.37). Forty-five percent of the students indicated that the teaching style was about the same as what they were previously exposed to.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter is composed of three sections. A summary of the study is presented first. The conclusions and recommendations for further research follow.

Summary

The purpose of the study was to determine if there were differences in achievement (assessed by a comparison of the means of posttest minus pretest scores) when field dependent and field independent learners in two undergraduate ecology classes were exposed to two different pedagogical styles (i.e., holistic and serialistic) for a presentation on biogeochemical cycles.

The subjects (n=57) were members of two upper division undergraduate ecology classes at a private university. The two classes were taught in two successive semesters by the same professor. One class (n=31) was exposed to a serialistic teaching method which employed a modified inductive sequence of information for a period of three weeks (See Appendix A). The other class (n=26) was exposed to holistic teaching which employed a modified deductive sequence of information for the same length of time (See Appendix B).

The experiment was limited to the presentation of information to two different classes in successive semesters--a convenient cluster sample. The students had taken the four introductory or basic science courses as a part of the established curriculum. Very few students had taken more than four. The majority of the students had some inherent interest in a particular field of science, although it was not necessarily limited to ecology. No empirical data were obtained to assure similarity of professional interest and course application between the two different classes. Prior to the exposure of the particular subject matter, biogeochemical cycles, the learners were first given the Group Embedded Figures Test (GEFT), Shipley Institute of Living Scale (SILS), and an ecology pretest on biogeochemical cycles.

The individual's analytical ability as a function of cognitive learning style was measured by the scores of the GEFT (Witkin, 1974). The ecology students were divided into two groups based upon their individual performance on the GEFT. Those individuals who obtained a score of 16 or above were described as being field independent. Those individuals with scores of 15 or below were described as being field dependent. A high mean was expected and reflective of those individuals entering the field of science (Witkin, 1977).

Assessment of general intellectual ability was established by the scores of the SILS. The Wechsler Adult Intelligence Scale served as the basic criterion measure for validating the use of the SILS in predicting individual IQ scores. The instrument was used to determine homogeneity between the two populations, each exposed to a different teaching style.

The ecology pretest consisted of 24 general ecology questions varying in level of difficulty and depth of conceptual understanding (See Appendix C). General ecology texts and the Graduate Record Exam were the two main sources for the exam questions for this particular topic.

The two teaching styles, which reflected characteristics of the two principal patterns for processing information (i.e., holistic and serialistic) were used by the same professor to present material to the ecology classes. The serialist presentation followed a rigid and logical sequence of material. No efforts were made to make connections between the 'real world' and the abstract. With the majority of the lecture dealing with the progressive succession of subtopic details, the 'big picture' or broad perspective was not realized until very late in the lesson. The holistic presentation contained numerous anecdotes, diagrams, illustrations, analogies, global descriptions, integrations, and applications. The lecture design maintained a flexible format in which several subtopics could be incorporated or integrated. Moving between the 'real world' and the abstract by using analogies, the instruction was designed to bring new insights to the internal structure and boundaries of the concept.

The serialistic presentation, following a sequential didactic method, was expected to favor the field independent learner (Entwistle and Ramsden, 1986). The holistic presentation, following a modified deductive sequence, was expected to favor the field dependent and not differentiate against the field independent (Rego, Salgado, Fernandez, and Sonnier, 1986).

An exam similar to the pretest in style, questions, and level of difficulty was constructed and administered as a post-test after the presentations covering biogeochemistry were completed (See Appendix D). The student's individual performance scores were determined by subtracting pretest percentage scores from posttest percentages. The means for the differences (post-test minus pretest) of each group were compared for statistical significance using t-tests.

Although the mean difference of field independent learners exposed to the holistic teaching style was higher than that of field independent learners exposed to the serialistic teaching style, the score was not significantly higher. The mean difference of field dependent learners exposed to the holistic teaching style was significantly higher than the mean difference of field dependent learners exposed to the serialistic teaching style.

In addition to testing the cognitive domain, the study explored the degree to which students were interested the style of instruction to which they were exposed. A question designed to address the affective domain can be found at the end of the posttest (See Appendix D). The question attempted to determine the student's perception regarding self-motivation and interest derived from a particular lecture style.

There was not a significant number of field independent students who indicated either that the serialistic or holistic teaching style was more interesting. There was a significant number of field independent students who indicated the holistic teaching style was less interesting. There was not a significant number of field independent students who indicated the serialistic teaching style was less interesting. There was not a significant number of field dependent students who indicated either the serialistic or holistic teaching style was either more or less interesting.

Conclusions

The purpose of the study was to determine the differences in achievement (assessed by a comparison of means of posttest minus pretest scores) when exposed to two different pedagogical styles (i.e., holistic and serialistic) for a presentation on biogeochemical cycles to field dependent and field independent learners. The findings of this study lead to the following conclusion with regard to research question number one (i.e., will field independent learners achieve higher scores [net gain = posttest minus pretest] through holistic instruction than with serialistic instruction?).

Although the mean of the difference (posttest minus pretest scores) for field independent learners was higher when taught through holistic instruction than with serialistic instruction, it wa significantly higher.

Contrary to most of the researchers cited in the review of the literature (i.e., matching styles--field independent learning with serialistic teaching--would result in higher achievement scores), the results of this study suggest that field independent learners perform better with holistic instruction. This agrees with the research of Rego, Salgado, Fernandez and Sonnier (1986) who concluded the holistic teaching style is superior to the serialistic style for heterogeneous groups.

The findings of this study lead to the following conclusion with regard to research question number two (i.e., will field dependent learners achieve higher scores [net gain = posttest minus pretest] through holistic instruction than with serialistic instruction?).

The mean of the differences (posttest minus pretest scores) for field dependent learners was significantly higher scores through holistic instruction versus serialistic instruction. In this case, a match in styles (i.e., holistic teaching and field dependent learning) was superior to a mismatch (i.e., serialistic teaching and field dependent). This indicates the presentations beginning with the broad perspective, use of analogies and illustrations, and multiple integrations were more conducive for processing information by this type of learner.

The findings of this study lead to the following conclusions with regard to research questions number three and four (i.e., Will field independent learners show a greater positive affect [more appreciation] for serialistic instruction than for a blend of serialistic and holistic instruction? and, Will field independent learners show a greater positive affect [more appreciation] with holistic instruction than with a blend of serialistic and holistic instruction?). Field independent learners did not indicate a greater appreciation for either serialistic or holistic instruction than with a blend of serialistic and holistic instruction.

With regard to research question number five and six (i.e., Will field dependent learners show a greater positive affect [more appreciation] with serialistic instruction than with a blend of serialistic and holistic instruction? and, Will field dependent learners show a greater positive affect [more appreciation] with holistic instruction than with a blend of serialistic and holistic instruction?), the findings lead to the following conclusions. Field dependent learners did not indicate a greater positive affect with serialistic or holistic instruction than with a blend of serialistic and holistic instruction. In this case, the majority of the field dependent learners perceived the serialistic and holistic instruction to be similar to the style of delivery used in previous presentations.

The results of the study concerned with the cognitive domain substantiate that holistic instruction produces greater learning for the heterogeneous group than the serialistic instruction. That is, both field dependent and field independent learners had higher achievement scores with holistic teaching.

The experimental results for the affective domain indicate neither field independent nor field dependent learners had greater appreciation for either the serialistic or holistic teaching style than a blend of holistic and serialistic styles. Whether it was perceived by the students as being different from that which was expected and predicted or from that which they were accustomed, the change in lecture style was unwelcome or at least not preferred. A contributing factor to the dissent might be credited to the professor's personality or traditional teaching style--self-acknowledged favoring of the serialistic style. Although the professor did a masterful job following the prescribed lecture design and presentation style, it might have been perceived by the students as being out of character (see recommendation number one below).

Recommendations

The purpose of this study evolved from an attempt to understand the differences in achievement (assessed by a comparison of the means of posttest minus pretest scores) of field independent and field dependent learners when exposed to two different pedagogical styles (e.g., serialistic and holistic). Although the purpose of this study was fulfilled in part and the significance of the study was established, there are many facets of the problem which lend themselves to further research.

(1) The study should be replicated using a professor who traditionally presents the subject in a holistic manner. This would assist in determining the effect that inadvertent tendencies generated from personal habits and traditional lecture styles have

on the affective domain of the learner. Carried one step further, the question is raised, is it more natural for a professor who traditionally lectures in a holistic manner to make a serialistic presentation than a professor who traditionally lectures in a serialistic manner to present material in a holistic fashion?

(2) The methods of this study should be replicated on a larger population for verification of the results. With a larger population, the verification of results should be conducted at a higher level of confidence. Similar results from a study involving a larger population would increase the strength of the conclusions.

(3) The methods employed in this study should be used on a broader heterogeneous population (e.g., majors versus non-majors and students from large state universities) to determine if the patterns of undergraduate science students differ from other college students. In addition, this would offer a greater number of possibilities for sampling the population. By using a sampling method other than the convenient cluster, the results of this type of experiment might be different.

(4) A study should be conducted to investigate the need for and affect of holistic instruction on such interdisciplinary courses as environmental science. If there is indication of greater learning and retention of subject matter with holistic instruction, as suggested by this study, then steps should be taken to encourage more holistic presentations of the environmental science topics.

(5) A determination of a stronger method for evaluation of the lecturer's adherence to presentation style, assessment of the

students' perception of the presentations, and evaluation of acquired knowledge and conceptual understanding should be made to strengthen the results of this study.

(6) This study should be complemented with a follow-up investigation of retention of the biogeochemical concepts by the students taught in this study. Considering the additional time involved to understand the concepts rather than just know the pertinent facts, a study investigating the retention of subject matter may reinforce the advantage of holistic presentations.

(7) It is recommended that research be done to determine the interaction between field independent and field dependent learners with lecturers exhibiting either serialistic and holistic styles. The quality and quantity of interaction, exchange of ideas, and learning generated by communication between the two types of learners, could possible affect the results of this type of experiment.

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APPENDIX

APPENDIX A

STATISTICAL PRESENTATION

SERIALISTIC PRESENTATION

BIOGEOCHEMICAL CYCLES

I. **INTRODUCTION**

A. TYPES OF BIOGEOCHEMICAL CYCLES

1. O_2
2. O_3
3. C-
4. N_2
5. sulphur
6. phosphorus

B. RESERVOIRS

1. atmosphere & ocean
2. earth's crust

C. COMPONENTS

1. biological agents
2. nonbiological agents

II. **CYCLES**

A. OXYGEN CYCLE

1. Major supply of free O_2 provided by 2 sources in the atmosphere
   a. photodissociation of water vapor
   b. photosynthesis
2. Major nonliving O_2 pool consists of molecular O_2, H_2O & CO_2.
3. O_2 reacts with reduced organic matter and minerals in the earth's crust.
4. Decaying trees replace oxygen consumed by oxidation of minerals.
5. O_2 is biologically exchangeable in such compounds as sulfates and nitrates, utilized by organisms that reduce them to ammonia and hydrogen sulfide.

B. THE OZONE LAYER

1. Most O_3 resides in stratosphere, where temperature increases with altitude.
2. Upper, thin layer absorbs most of the UV-radiation.
3. Downward flow of stratospheric air into troposphere with
4. O_3 necessary to initiate photochemical processes
5. O_3-layer is maintained by cyclic photolytic reaction of O_2:
   a. $O_2 + hv \rightarrow O + O$ h - Planck's constant v - freq. of light
   b. $O + O_2 \xrightarrow{\underline{M}} O_3$ (M being a catalyst)

6. "h" is Planck's constant, "v" is the frequency of light
   a. $O_3 + hv \rightarrow O + O_2$
   b. $O + O_3 \rightarrow 2O_2$
7. There is a balance between the rates of these O_3 reactions.
8. The chlorine from chlorofluorocarbons in spray propellants can be involved in the catalytic reactions of O_3:
   a. $Cl + O_3 \rightarrow ClO + O_2$
   b. $O_3 + hv \rightarrow O + O_2$
   c. $ClO + O \rightarrow Cl + O_2$

   Net reaction: $2O_3 + hv \rightarrow 3O_2$

C. THE CARBON CYCLE (C - cycle)
1. The main <u>sources</u> of carbon are the atmosphere and bodies of water.
2. The C-cycle is closely tied to <u>energy flow in ecosystem</u>:
   a. Plants convert CO_2 into glucose.
   b. From glucose, they synthesize fats and sugars and store them as plant tissue.
   c. Herbivores digest these compounds and synthesize them into other carbon compounds.
   d. Carnivores redigest and resynthesize these compounds into other forms.
   e. Some carbon is returned to the atmosphere in the form of CO_2 as a by-product of respiration, the remainder becomes incorporated in the biomass.
   f. Carbon in dead plant and animal tissues is freed up by decomposers.
3. Cycling takes place in <u>aquatic ecosystems</u>:
   a. Phytoplankton convert dissolved CO_2 into simple and complex sugars.
   b. Simple and complex sugars are ingested by fish.
   c. CO_2 from respiration is reutilized by the phytoplankton.
   d. Carbon bound as carbonates in the shells of mollusces and foraminiferans accumulate as sediments.
4. <u>Local Patterns</u>
   a. photosynthesis decreases during the night since plants stop photosynthesis in the absence of light.
   b. photosynthesis (light phase) increases with increases in light.
   c. measured by nocturnal accumulation in spring and summer the rate of CO_2 production by respiration may be two to three times higher than in winter months.

5. Global Patterns

The carbon pool involved in global carbon cycle amounts to an estimated 55,000 Gt (Gt is a gigaton, equal to 1 billion metric tons).

a. Oceans contain 93% of the carbon pool.

b. Most of the carbon in oceans are found as bicarbonate and carbonate ions.

c. CO_2 content in the atmosphere fluctuates according to the individual and corporate needs of plants.

d. 1650 Gt of carbon in dead organic matter in oceans
1456 Gt of carbon in dead organic matter in biosphere
826 Gt of carbon in living organic matter in biosphere

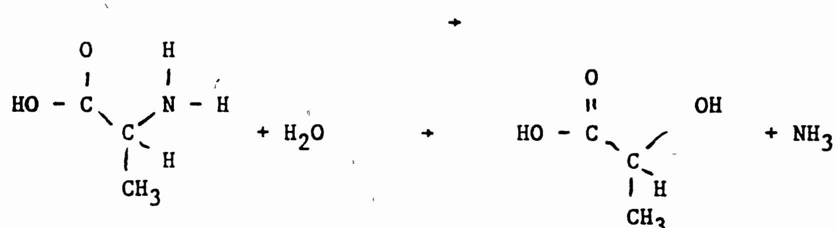
e. Ability of the surface waters to take up CO_2 is governed largest by the reaction of CO_2 with the carbonate ion to form bicorbonates.

$$CO_2 + CO_3^- + H_2O \rightarrow 2HCO_3^-$$

f. Some carbon is trapped in sediments for about 10^8 yrs.

$$2H\ CO_3^- + Ca^{2+} \rightleftarrows H_2O + CO_2 + CaCO_3$$

g. Carbon dioxide content of the atmosphere up to the lower stratosphere declines during early spring north of the 30°N latitude; by October the level increases again South of the 20°N latitude.



Alanine + water → Lactate + ammonia

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6. Intrusions

a. The CO_2 flux has been disturbed by the rapid injection of CO_2 from the burning of fossil fuels and the clearing of forests.

b. methane and carbon monoxide are being discharged into the atmosphere.

c. input of CO_2 has risen from 260 ppm in 1900 to 360 ppm in 1986

d. 34% of excess CO_2 generated is stored in the surface and thermocline gyres, and 13% is carried into the deep seas, 53% in atmosphere.

7. The Greenhouse Effect
   a. As CO_2 becomes accumulated in the atmosphere it absorbs solar radiation.
   b. Doubling of CO_2 concentration causes doubling of the amount of absorption of solar radiation in the trophosphere.
   c. Methane contributes to the greenhouse effect by absorbing infrared radiation.
   d. global warming trends: predicted rise of 1°C from year 1850 to 2000; predicted rise 2°-3°C by year 2100. Either increase in temp. would yield an ↑ in water-use efficiency CO_2 would no longer be limiting.

D. THE NITROGEN CYCLE

1. Processes
   a. 79% of the atmosphere is N_2, but it can only be available to most life through the processes of fixation, ammonification, nitrification, and denitrification.
   b. Fixation is the conversion of gaseous N_2 into ammonia or nitrate (fixation by lighting on cosmic radiation).
   c. Fixation is accomplished by symbiotic bacteria that live in the roots and nodules of leguminous plants, blue-green algae and free-living soil bacteria. Examples:
      (1) symbiotic bacteria: Rhizobium
      (2) free-living soil bacteria: Chlostridium
      (3) bg algae in lakes: Arabaena
   d. In ammonification

      $CH_2NH_2\ COOH + 1\frac{1}{2}\ O_2 \rightarrow 2\ CO_2 + H_2O + NH_3 + 176$ kcal
   e. In nitrification

      $NH_3 + 1\frac{1}{2}\ O_2 \rightarrow HNO_2 + H_2O + 165$ kcal $\quad HNO_3 \rightarrow H^+ + NO_2^-$;
      (Temp. 14-16°C, pH 6.5)
   f. Two groups of microorganisms involved in nitrification:
      (1) Nitrosomonas oxidizes 35 mols of nitrogen for each mol of CO_2 assimilated
      (2) Nitrobacter oxidizes 100 mols.
   g. In denitrification: denitrifiers; Pseudomonas,

      $C_6\ H_{12}\ O_6 + 4NO_3^- \rightarrow 6\ CO_2 + H_2O + 2N_2$; (Temp. 15°C; pH 6-7)

2. Cycling of Nitrogen
   a. Nitrogen becomes available to plants in the form of ammonia by the process of fixation.
   b. Plants incorporate the nitrogen into amino acids.

c. Consumers take up these amino acids and transform them into others.

d. Wastes and decaying matter are broken down into ammonia by decomposers.

e. Nitrates may be taken up directly by plants, stored in the soil or washed away.

f. Wasted away nitrates end up in aquatic ecosystems where they contribute to the cycling of nitrogen.

g. Aquatic ecosystems lack soil reserves of nitrogens; decomposition of organic materials is the main source of nitrogen.

h. Nitrogen is lost by denitrification, volatilization, leaching, erosion, wind blown aerosols.

i. Ammonia is rapidly absorbed by phytoplankton utilized by plants immobilized by bacteria and stored in decomposing humus

3. <u>Intrusions</u>

a. Cultivation of grasslands has resulted in a steady decline of nitrogen content of the soil.

b. Commercial fertilizers increase soil nitrogen, much of which may be lost as nitrates to the ground water. Heavy addition of commercial fertilizer especially in the form of anhydrous ammonia increases the amount of nitrogen in crop land.

c. Source of nitrate pollution is animal and human waste.

d. Automobiles and power plants are the source of nitrogen dioxide, $NO_2 \xrightarrow[lt.]{uv} NO + O \quad O_2 + O \rightarrow O_3 \quad NO + O_3 \rightarrow NO_2 + O_2$ in time the reaction favors production of O_3, and NO_2 disappears.

III. SEDIMENTARY CYCLES

A. MINERAL CYCLES

1. Mineral salts are derived from weathering.
2. Soluble salts are incorporated into the bodies of water.
3. Salts return to the earth's crust by sedimentation, incorporated into salt beds, silts, and limestones.

B. THE SULFUR-CYCLE

1. In the sedimentary phase, sulfur is tied up in coal, oil and peat, pyritic rocks and sulfur deposits.
2. It is released by weathering, erosion, decomposition and industrial production and is carried to terrestrial and aquatic ecosystems in salt solution.

3. Most sulfur is in the gaseous form of hydrogen sulfide from fossil fuels, volcanic eruptions and decomposition.
4. Hydrogen sulfide quickly oxidizes into sulfur dioxide SO_2, which precipitates in rain water as weak H_2SO_4.
5. Plants incorporate the dissolved sulfur into sulfur-containing amino acids.
6. Excretions and decomposition carry sulfur back to the soil and the bottom of aquatic ecosystems, where microorganisms release it as hydrogen sulfide for sulfate.
7. Other microorganisms convert inorganic sulfates to organic forms.
8. Sulfur bacteria reduce hydrogen sulfide to sulfur and elemental S.
9. Green and purple bacteria utilize hydrogen sulfide as the oxygen acceptor in photosynthesis.
10. Sulfur in the presence of iron under anaerobic conditions will precipitate as ferrous sulfide:

    $2FeS_2 + 7O_2 + 2H_2O \rightarrow 2FeSO_4 + H_2SO_4$

    and

    $12FeSO_4 + 3O_2 + 6H_2O \rightarrow 4\,Fe_2(Co_4)_3 + 4Fe(OH_3) \downarrow$
11. <u>Intrusions</u>
    a. Industrial burning of coal pours 147 mill tons of SO_2 into the atmosphere, which forms H_2SO_4.
    b. Atmosphere sulfuric acid can harm the <u>respiratory</u> tract and injure plants.

C. ACID RAIN
1. Some of the sulfur dioxide and nitrogen oxides discharged into the atmosphere become oxidized into sulfates and nitrates and precipitate in the form of weak sulfuric and nitric acids; lowers the pH from 5.4 to 4.0.
2. Acid precipitation lowers the normal pH of water, causing the release of aluminum, retards growth, gonadal development.
3. Acidification of lakes reduces bacterial decomposition and nutrient regeneration, and ↓ phytoplankton + invertebrates.
4. Deposition of sulfur, nitrates and ammonia cause increase in Al, Ca, Mg, K, and decreases emergence of mayflies and stoneflies.

D. THE PHOSPHORUS CYCLE
1. Elemental phosphorus is absent in the atmosphere but is present in the soil in the form of either calcium or iron phosphates.
2. Heavy discharges of phosphorus cause an explosive growth of algae.

3. The main reservoir of P is rock and natural phosphate deposits, from which P is released by weathering, leaching, erosion, and mining.
4. In terrestrial ecosystems organic phosphates are reduced by bacteria to inorganic phosphates.
5. Some phosphates are recycled to plants, some are incorporated into the soil and the bodies of microorganisms, and some ends up in aquatic ecosystems.
6. In aquatic ecosystems, the main reservoir of phosphorus is organic matter, including phytoplankton.
7. Zooplankton may excrete as much P daily as is stored in their biomass.
8. Seasonal overturns return the P deposits in the bottom sediments to photosynthetic zones, where it is taken up by phytoplankton during the period of active growth (bloom).
9. In tidal marshes, marsh grasses withdraw P from surface sediments.
10. Half of the extracted P is fixed in the plant tissues.
11. Detritus-feeders (e.g. the ribbed mussel) feed on the dead grass which removes P-rich particles from the water, depositing them in the mud, where deposit-feeders take them.
12. Phosphates from fertilizers are present in the soil as insoluble salts. Some removed in harvested crop → incorporated in waste
13. Phosphorus accumulation in aquatic ecosystems are mainly due to only 30% removal of P from sewage waters.
14. P is the primary substance involved in eutrophication of fresh water ecosystems. When in large supply-rapid growth of algae.

E. CYCLING OF HEAVY METALS, HYDROCARBONS AND PCBs

1. <u>Lead</u>
   a. 98% of lead in the atmosphere is due to automobile emissions.
   b. Plants take up lead from contaminated air or soil, or from particulate matter on leaf.
   c. The concentration of lead in humans is 30X that of pre-industrial society.
   d. Induces palsy, paralysis, death, loss of hearing
2. <u>DDT and other Chlorinated Hydrocarbons</u>
   a. It is mostly used as a pesticide applied by aerial spraying, which results in great quantities of pesticide staying in the atmosphere and entering the global biogeochemical cycle.
   b. DDT and related compounds tend to concentrate in the tissues of organisms. → Death + impaired genetic constitution.

c. The high solubility of DDT in lipids allows the magnification.

d. Because it breaks down slowly.

3. Polychlorinated Biphenyls (PCBs)

a. PCBs are used as dielectric fluids, in plastics, solvents, and printing inks.

b. Have high affinity for fatty tissue and degrade slowly.

c. Its main source is sewage outfalls and industrial discharges into rivers + atmosphere.

d. Fish take up PCBs and concentrate them in their tissues.

e. Predatory fish-eating birds contain high concentrations.

IV. **RADIONUCLIDES**

A. INTRODUCTION

1. Nuclear radiation consists of high-energy, short wavelength radiations.

2. Fission products of uranium include strontium, cesium, barium, and iodine, which can enter the food chains, causing cancer and genetic defects.

3. Release of these products into the atmosphere and nuclear waste can result in radioactive rain and dust.

B. TERRESTRIAL ECOSYSTEMS

1. Dispersion of radionuclides comes from gaseous, particulate, and aerosol deposition and from liquid and solid wastes.

2. Plants absorb radionuclides from the soil - through foliage.

3. Strontium-90 and Cesium-137 are among the most destructive radioactive materials in nuclear waste, affecting primarily the arctic tundra.

4. Lichens absorb almost all radioactive particles they are exposed to.

5. ^{90}Sr and ^{137}Cs absorbed by lichens, affecting caribous, reindeer and even Eskimos and Alaskan Indians.

C. AQUATIC ECOSYSTEMS

1. Nuclear pollution of water ecosystems is mainly due to nuclear waste disposal.

2. Radioactive materials become incorporated in bottom sediments, where they can be absorbed by bottom-dwelling animals and ultimately fish.

3. The concentration of radionuclides may decrease at higher tropic levels.

4. Aquatic organisms concentrate radionuclides as they do stable elements.

An Example Exposition of the Serialistic Presentation
Example Topic: Carbon Cycle

After introductory remarks the presentation begins with

"The carbon cycle is sometimes identified as the C-cycle.
First, the main sources of the carbon are the atmosphere and bodies of water.
Second, the Carbon cycle is closely tied to the energy flow in the ecosystem: for example

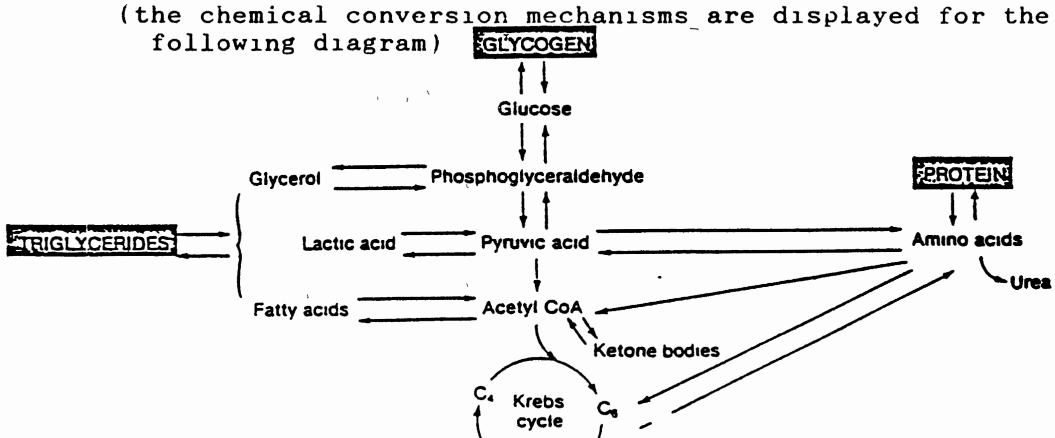
a. Plants convert carbon dioxide into glucose"
(the formula for photosynthesis is displayed)

b. From glucose, they synthesize fats and sugars and store them as plant tissue

(the following chemical conversion mechanisms are displayed)

empirical formula for two glucose molecules	------------> dehydration synthesis	empirical formula for maltose
empirical formula for glucose	-----------> catabolic pathway	empirical formula phosphoglyceraldehyde
empirical formula for triglyceride	<----------- anabolic pathway	empirical formula for glycerol

c. Herbivores digest these compounds and synthesize them into other carbon compounds.
(the chemical conversion mechanisms are displayed for the following diagram)



d. Carnivores redigest and resynthesize these compounds into other forms (reference is made to the diagram above) special note is given to Carbon in proteins

e. Some carbon is returned to the atmosphere in the form of carbon dioxide as a by-product of respiration, the remainder becomes incorporated in the biomass.

f. Carbon in dead plant and animal tissues is freed up by decomposers (the chemical mechanisms for catabolic reactions freeing carbon dioxide are displayed)

APPENDIX B

HOLISTIC PRESENTATION

HOLISTIC PRESENTATION

BIOGEOCHEMICAL CYCLES

I. **INTRODUCTION**

A. TWO TYPES OF BIOGEOCHEMICAL CYCLES

1. gaseous (e.g. O_2, O_3, C and N_2 cycles)
2. sedimentary (e.g. sulphur + phosphorus cycles)

B. MAIN RESERVOIRS

1. of gaseous cycles: atmosphere & ocean
2. of sedimentary cycles: earth's crust

C. COMMON TO BOTH CYCLES

1. They involve biological & nonbiological agents.
2. They are tied to the water cycle.

II. **GASEOUS CYCLES**

A. OXYGEN CYCLE

1. Sources:

Major supply of free O_2 provided by 2 sources in the atmosphere

a. photodissociation of water vapor

b. photosynthesis

2. Characteristics:

Linkage of constituents of O_2 pool

a. major nonliving O_2 pool consists of molecular O_2, waste & CO_2

b. O_2 is biologically exchangeable (in such compounds as sulfates and nitrates, utilized by organisms that reduce them to ammonia and hydrogen sulfide):

(1) Atmosphere O_2 is used up in respiration and decay of organic matter

(2) O_2 reacts with reduced organic matter and minerals in the earth's crust

(3) Buried organic matter replaces oxygen consumed by weathering; therefore it's conserving atmos. oxygen and stabilizes the atmos. O_2 reservoir

3. Oxygen Cycle:

photosynthesis → atmosphere ⟶ (respiration & decay)
↓ → surface organic matter
atmosphere
↓ ↓
weathering <— reduced constituents <— burial
of the crust

4. Global Patterns:

The Ozone Layer

a. Location: Most O_3 resides in stratosphere
b. Characteristics: O_3 in upper thin layer where temperature increases with altitude
c. Function: Upper, thin layer of O_3 absorbs most of the UV-radiation: O_3-layer shields earth against harmful solar UV-radiation
d. Downward flow of stratospheric air supplies troposphere with O_3 necessary to initiate photochemical processes
e. O_3-layer is maintained by cyclic photolytic reaction of O_2:
   (1) $O_2 + hv \rightarrow O + O$ breakage of O_2 bond & combines with oxygen to form O_3
   (2) $O + O_2 + M \rightarrow O_3 + M$ (M being a catalyst)
f. The reverse reaction consumes O_3
   (1) $O_3 + hv \rightarrow O + O_2$
   (2) $O + O_3 \rightarrow 2O_2$
g. This production and consumption maintain balance between the rates of O_3 formation and destruction

5. Intrusions:

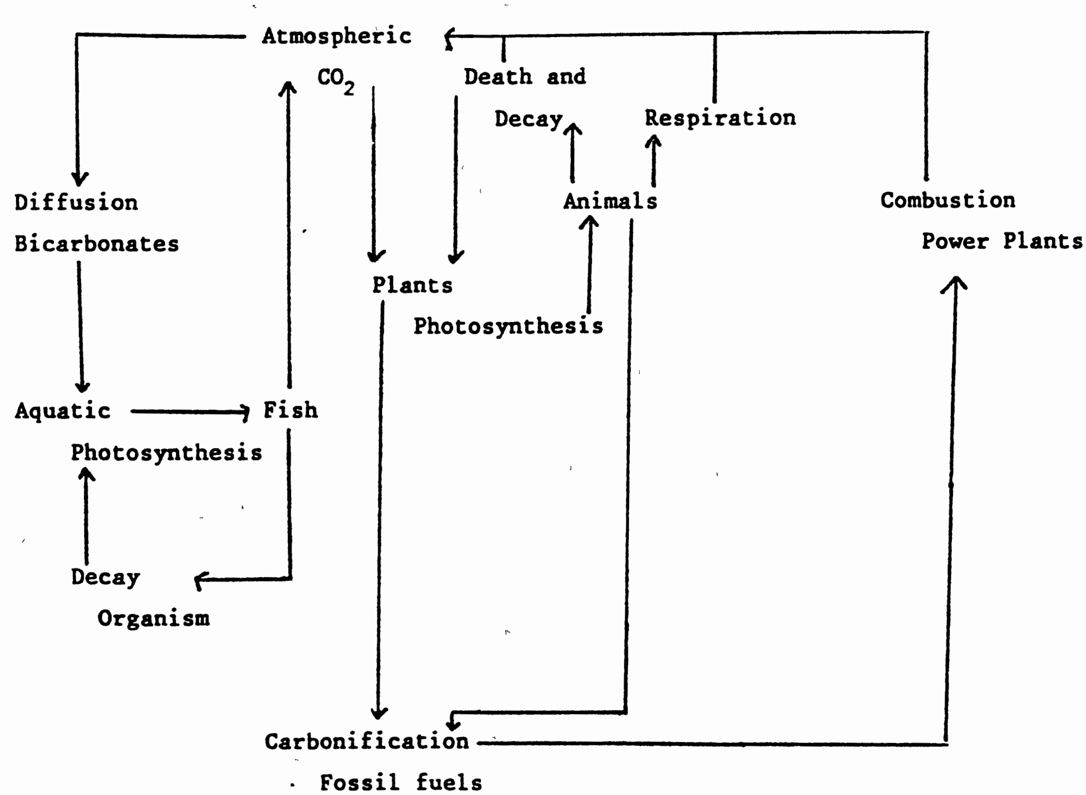
Chemicals injected into atmos. react to cause decrease in stratospheric ozone

a. The chlorine from chlorofluorocarbons in spray propellants can be involved in the catalytic destruction of O_3:
   $Cl + O_3 \rightarrow ClO + O_2$
   $O_3 + hv \rightarrow O + O_2$
   $ClO + O \rightarrow Cl + O_2$
   Net reaction: $2O_3 + hv \rightarrow 3O_2$
b. Similar reactions with methane (CH_4) and nitrous oxide (NO_2) from denitrification of synthetic nitrogen fertilizers
c. Anthropogenic and biological catalysts injected into the stratosphere cause a decrease in stratospheric ozone

d. Reductions in ozone layer can have adverse ecological effects on earth (e.g., altering DNA, increasing skin cancer via UV light; increase temperature in lower atmosphere; change air circulation patterns; contribute to greenhouse effect)

B. THE CARBON CYCLE

1. Source of all fixed carbon is CO_2 found in the:
   a. atmosphere
   b. bodies of water
2. Characteristics:
   a. Is closely tied to energy flow in ecosystem
   b. The rate of release depends upon environmental conditions (e.g., soil, moisture, temperature, and precipitation)
   c. Terrestrial (photosynthesis) and aquatic (photosynthesis) reactions interact with atmospheric CO_2 pool
3. Carbon Cycle:
   a.



b. Terrestrial ecosystem:
   (1) Plants convert CO_2 into glucose
   (2) From glucose, they synthesize fats and sugars and store them as plant tissue
   (3) Herbivores digest these compounds and synthesize them into other carbon compounds
   (4) Carnivores redigest and resynthesize these compounds into other forms
   (5) Some carbon is returned to the atmosphere in the form of CO_2 as a by-product of respiration, the remainder becomes incorporated in the biomass
   (6) Carbon in dead plant and animal tissues is freed up by decomposers

c. <u>Marine</u> and <u>Freshwater Ecosystems</u> in carbon cycle:
   (1) Phytoplankton utilize dissolved CO_2 and convert it into carbohydrates
   (2) The carbohydrates pass through the aquatic food chain
   (3) CO_2 from respiration is reutilized by the phytoplankton
   (4) Carbon bound as carbonates in the shells of mollusks and foraminiferans accumulate as sediments

4. <u>Local Patterns</u>:
   a. CO_2 concentration decreases during the day since plants withdraw CO_2 from atmosphere for photosynthesis
   b. CO_2 concentration increases during the night since plants stop photosynthesis in the absence of light

5. <u>Global Patterns</u>:
   a. The carbon budget is closely linked to the atmosphere, land, and oceans and the mass movements of air around the planet
   b. Carbon cycling in the sea is nearly a closed system: Oceans contain 93% of the carbon pool, mostly as bicarbonate and carbonate ions
   c. The preparation of carbon contained in organic matter on the soil to the living organic carbon is crucial for the carbon cycle on land
   d. Local and global CO_2 cycle exhibits annual variations (esp. in northern hemisphere)
   e. CO_2 content in the atmosphere fluctuates seasonally

6. Intrusions:
   a. The CO_2 flux has been disturbed by the rapid injection of CO_2 from the burning of fossil fuels and the clearing of forests
   b. Other gases, such as methane and carbon monoxide are being discharged into the atmosphere. (Source: microbes in swamps, decomposed animals, marshes, tundra, and industrial gases)
   c. Atmosphere CO_2 has increased 25% over the past century
   d. 40-50% of CO_2 injected into atmosphere remains; the rest must be stored in two possible sinks--the terrestrial biomass and the ocean
   e. Increasing dependence on fossil carbon mandates emphasis on sinks' ability to accommodate excess carbon
   f. Ocean is major sink--depends heavily upon eddy current circulation between deep and surface water
7. The Greenhouse Effect:
   a. As CO_2 becomes accumulated in the atmosphere, it acts as a shield, absorbing solar radiation (long wave) and trapping heat in the atmosphere; short wave radiation penetrates atmosphere
   b. Doubling of CO_2 concentration causes doubling of the average temperature in the troposphere
   c. Methane contributes to the greenhouse effect by absorbing infrared radiation and is much more effective than CO_2 in contributing to greenhouse effect because infrared absorptions are more likely with methane
   d. Rises in temperature would have pronounced ecological effects:
      (1) A short-term rise in plant productivity (CO_2 level would be no longer limiting)
      (2) Their water-use efficiency would increase because stomata would not need to be fully opened to gain sufficient CO_2, thereby reducing transpiration
      (3) Photorespiration would cease to be a problem
      (4) Provided water was not a problem, C_3 plants would compete with C_4 plants
   e. Other outcomes of global warming: melting permafrost would release methane and CO_2 locked into poorly decomposed detritus

C. THE NITROGEN CYCLE

1. Sources:

   79% of the atmosphere is N_2, but it can only be available to most life through the processes of fixation, ammonification, nitrification, and denitrification

2. Characteristics and processes:

   a. Fixation is the conversion of gaseous N_2 into ammonia (biological fixation) or nitrate (fixation by lighting on cosmic radiation)

   b. Biological fixation is accomplished by symbiotic bacteria that live in the roots and nodules of leguminous plants, blue-green algae and free-living soil bacteria, examples:

      (1) Symbiotic bacteria - Rhizobium

      (2) Free-living soil bacteria - Chlostridium

      (3) Process: $N_2 \rightarrow 2N$

   c. Ammonification, amino acids are broken down by decomposers to produce ammonia, which is absorbed by plant roots and incorporated into amino acids

      * $2N + 3H_2 \rightarrow 2\ NH_3$

      * $CH_2NH_2\ COOH + 1\frac{1}{2}\ O_2 \rightarrow 2\ CO_2 + H_2O + NH_3 + 176$ kcal

   d. Nitrification, ammonia is oxidized to nitrate or nitrite, yielding energy

      $NH_3 + 1\frac{1}{2}\ O_2 \rightarrow HNO_2 + H_2O + 165$ kcal

      $HNO_2 \rightarrow H^+ + NO_2^-$

      Two groups of microorganisms involved in nitrification: Nitrosomonas and Nitrobacter.

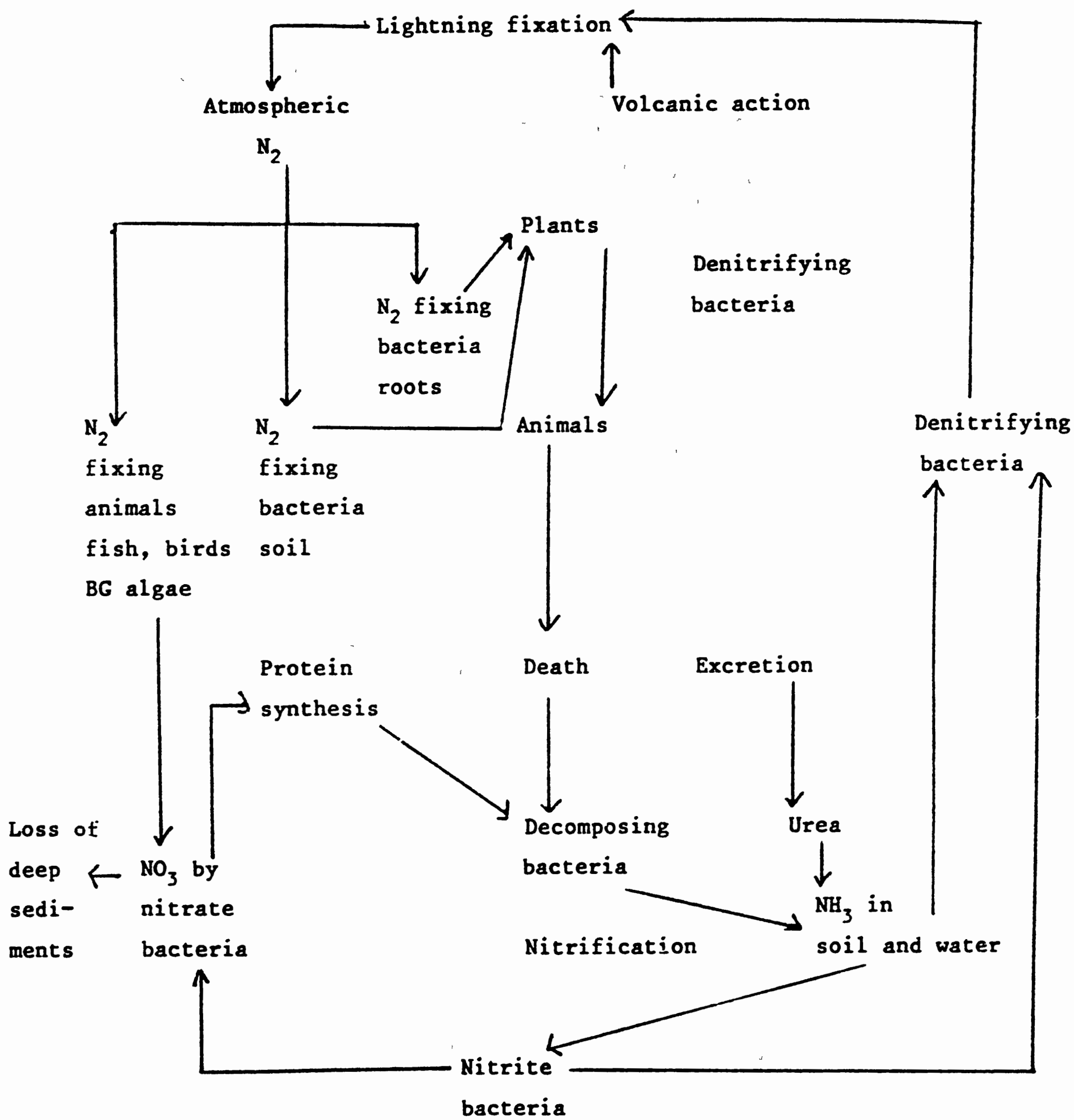
      (1) Nitrosomonas oxidizes ammonia to nitrite (NO_2-) and

      (2) Nitrobacter oxidizes nitrite to nitrate (NO_3-)

   e. Denitrification, nitrates are reduced to gaseous nitrogen by denitrifiers such as fungi and Pseudomonas, who use NO_3- instead of O_2 in aerobic respiration (when O_2 is limited), releasing N_2 as a by-product

   f. Requirements: Nitrification and dentrification both require a sufficient supply of organic matter, a limited supply of molecular oxygen, a pH range of 6-7, an optimum temp. of 15°C

3. <u>Cycling of Nitrogen</u>:



a. Nitrogen becomes available to plants in the form of ammonia by the process of fixation
b. Plants incorporate the nitrogen into amino acids
c. Consumers take up these amino acids and transform them into other amino acids
d. Wastes and decaying matter is broken down into ammonia by decomposers

e. Ammonia may be lost to the atmosphere, may go through nitrification or may be directly absorbed by plants
f. Nitrates may be taken up directly by plants, stored in the soil or washed away
g. Wasted away materials end up in aquatic ecosystems where they contribute to the cycling of nitrogen
h. Aquatic ecosystems lack soil reserves of nitrogens; decomposition of organic materials is the main source of nitrogen
i. In terrestrial ecosystems nitrogen, depending upon variable conditions, is taken up by plants which convert it into amino acids
j. Nitrates may be utilized by plants, immobilized by microbes, stored in decomposing humus, or leached away

4. Local Pattern:
   Nitrogen lost from ecosystem by dentrification, volatilization, leaching, erosion, wind-blown aerosols, and transportation out of the system is balanced by biological fixation and other sources
5. Intrusions:
   a. Humans disrupt the nitrogen cycle by reducing or overloading the system
   b. Reduction of nitrogen:
      (1) Cultivation of grasslands has resulted in a steady decline of nitrogen content of the soil
      (2) Nitrogen is also removed from the soil by harvesting or grazing (especially harvesting timbers)
      (3) Commercial fertilizers, especially in the form of anhydrous ammonia, increases soil nitrogen, a lot of which may be lost as nitrates to the ground water
   c. Additions to system--overloading and possible pollution:
      (1) Heavy addition of commercial fertilizers, e.g., anhydrous ammonia
      (2) Other source of nitrate pollution is animal waste
      (3) Another source of nitrate pollution is human waste, particularly sewage
      (4) Automobiles and power plants are the source of nitrogen dioxide, which in the atmosphere reacts with O_2 to form ozone and other secondary air pollutants known as pan

III. SEDIMENTARY CYCLES

A. INTRODUCTION

1. Mineral cycles consist of two phases:
    a. the salt-solution phase and
    b. the rock phase
2. Mineral salts come from the earth's crust by weathering
3. Soluble salts then enter the water cycle, being incorporated into the bodies of water
4. Other salts return to the earth's crust by sedimentation, re-entering the cycle through weathering

B. THE SULFUR CYCLE

1. Sources:
    a. Organic deposit--coal, oil, peat
    b. Inorganic deposit--pyritic rock
    c. Gaseous--SO_2, SO_4, H_2S
2. Characteristics:
    a. The Sulfur cycle is both gaseous and sedimentary
    b. In the sedimentary phase, sulfur is tied up in organic and inorganic deposits
    c. Sulfur exists in gaseous form as SO_2, SO_4, or H_2S dissolved in atmosphere through burning of fossil fuels and decomposition
3. Cycling of Sulfur:
    a. Gaseous phase:
        (1) Sulfur sediment is released by weathering, erosion, decomposition and industrial production and is carried to terrestrial and aquatic ecosystems in salt solution
        (2) Most sulfur is in the gaseous form of hydrogen sulfide from fossil fuels, volcanic eruptions and decomposition
        (3) Hydrogen sulfide quickly oxidizes into sulfur dioxide (SO_2), which is water-soluble and precipitates in rain water as weak H_2SO_4
    b. Sedimentary phase:
        (1) Plants incorporate the dissolved sulfur into sulfur-containing amino acids
        (2) Consumers obtain sulfur from the producers
        (3) Excretions and decomposition carry sulfur back to the soil and the bottom of water ecosystems, where microorganisms release it as hydrogen sulfide for sulfate

(4) Other microorganisms convert inorganic sulfates to organic forms

(5) Sulfur bacteria reduce hydrogen sulfide to sulfur and oxidize it to sulfuric acid

(6) Green and purple bacteria utilize hydrogen sulfide as the oxygen acceptor in photosynthesis

4. <u>Global sulfur cycle</u>:

a. The gaseous nature of the S-cycle permits its circulation on a global scale (H_2S, SO_2, SO_4)

b. Rain concentrates SO_2

c. Both industrially-emitted sulfur and fertilizer sulfur are eventually carried to the sea; these two sources account for 50-million-ton annual increase of sulfur in the ocean

5. <u>Intrusions</u>:

a. Industrial burning of coal pours great amounts of SO_2 into the atmosphere, which combines with moisture to form H_2SO_4

b. Atmosphere sulfuric acid can harm the respiratory tract and seriously injure plants

C. THE PHOSPHORUS CYCLE

1. <u>Sources</u>:

a. It is present in the soil in the form of either calcium or iron phosphates

b. The main reservoirs of P are rock and natural phosphate deposits

2. <u>Characteristics</u>:

a. Elemental phosphorus is absent in the atmosphere and therefore differs from sulfur cycle

b. Phosphorus is in short supply under normal conditions

c. Phosphorus cycle follows hydrological cycle only partway from land to sea

3. <u>Cycling of phosphorus</u>:

a. Overview:

(1) P is released from natural deposits by weathering, leaching, erosion, and mining

(2) Heavy discharges of phosphorus cause an explosive growth of algae in aquatic ecosystems

(3) P is passed on through terrestrial and aquatic ecosystems by plants, grazers, predators, and parasites

(4) P is returned to the ecosystem by excretion, death and decay

b. Terrestrial ecosystems:

(1) In terrestrial ecosystems organic phosphates are reduced by bacteria to inorganic phosphates

(2) Some phosphates are recycled to plants, some become immobilized in the soil and the bodies of microorganisms, and some ends up in aquatic ecosystems

c. Aquatic ecosystems:

(1) In aquatic ecosystems, the main reservoir of phosphorus is particulate organic matter, including phytoplankton

(2) P in phytoplankton or detritus-feeding organisms

(3) Zooplankton may excrete as much P as is stored in their biomass

(4) Excreted P is taken up by phytoplankton

(5) In tidal marshes, marsh grasses withdraw P from surface sediments.

(6) Some of the extracted P is fixed in the plant tissues

(7) Detritus-feeders feed on the dead grass, e.g. the ribbed mussel, which removes P-rich particles from the water, depositing them in the mud, where deposit-feeders take them, releasing phosphate back to the ecosystem

d. Phosphorus enrichment of aquatic ecosystems

(1) Phosphates from fertilizers become immobilized in the soil as insoluble salts

(2) Phosphorus accumulation in aquatic ecosystems are mainly due to only partial removal of P from sewage waters in sewage treatment plants

(3) P is the primary substance involved in eutrophication of fresh water ecosystems (K is usually present in excess, nitrogen is supplemented by fixation and phosphorus tends to be precipitated in sediments and cannot be supplemented naturally)

e. Local and global patterns:

Seasonal overturns return the P deposits in the bottom to photosynthetic zones, where it is taken up by phytoplankton during the period of active growth (bloom)

IV. ACID RAIN

A. SOURCES

Some of the sulfur dioxide and nitrogen oxides discharged into the atmosphere become oxidized into sulfates and nitrates and precipitate in the form of weak sulfuric and nitric acids

B. CHARACTERISTICS

Acid precipitation lowers the normal pH of water ecosystems, causing the release of aluminum (reducing nutrient availability and increasing solubility), which harms fish (i.e. retards growth, gonadal development, increase fish mortality rates)

C. LOCAL AND GLOBAL PATTERNS

1. Acidification of lakes reduces bacterial decomposition and nutrient regeneration, which affects the aquatic food webs by reducing phytoplankton and invertebrates upon which fish depend for food
2. Following acidification, stream concentrations of Al, Ca, Mg, and K increase
3. In terrestrial ecosystems, acidic precipitation may have adverse effects on plant life. Deposition of sulfur, nitrates and ammonia influences plant nutrition and soil chemistry.

V. CYCLING OF HEAVY METALS, HYDROCARBONS AND PCBs

A. LEAD

1. <u>Sources</u>:

   98% of lead in the atmosphere is due to automobile emissions

2. <u>Cycling of lead</u>:
   a. Plants take up lead from contaminated air or soil, or from particulate matter on leaf
   b. Lead is passed on through the food chain
3. <u>Effects</u>:
   a. The concentration of lead in humans has significantly increased since pre-industrial times
   b. Increasing mortality of birds
   c. Lead intake can cause palsy, partial paralysis, loss of hearing, and death

B. DDT AND OTHER CHLORINATED HYDROCARBONS

1. <u>Sources</u>:

   It is mostly used as a pesticide applied by aerial spraying, which results in great quantities of pesticide staying in the atmosphere

2. Characteristics:
   DDT has special characteristics that enable it to enter the global biogeochemical cycle. The high solubility of DDT in lipids allows the magnification of its concentration through the food chain
3. Effects:
   a. Some DDT ends up in water ecosystems, where it causes mortality of fish and aquatic invertebrates
   b. DDT and related compounds tend to concentrate in the tissues of organisms. (interferes with Ca^{++} metabolism, reduces uptake in sarcoplasmic reticulum)
   c. Because it breaks down slowly, DDT accumulates to high and toxic levels as it passes up the food chain

C. POLYCHLORINATED BIPHENYLS (PCBs)
1. Sources:
   PCBs are used as dielectric fluids, in plastics, solvents, and printing inks
2. Characteristics:
   a. PCBs have a high affinity for fatty tissue, degrades slowly, accumulates in food chain
   b. Flow in food chain:
      (1) Its main source is sewage outfalls and industrial discharges into rivers
      (2) Fish take up PCBs and concentrate them in their tissues
      (3) Predatory fish-eating birds are specially vulnerable
3. Effects:
   a. Thinning of eggshells
   b. Causes deformities in newborns
   c. Reduction in growth rates of certain marine diatoms

VI. **RADIONUCLIDES**

A. INTRODUCTION AND SOURCES
1. Nuclear radiation consists of high-energy, short wavelength radiations
2. Sources of gamma radiation are atomic blasts from weapons testing, nuclear reactors, and radioactive wastes
3. Release of these products into the atmosphere and nuclear waste can result in radioactive rain and dust

B. TERRESTRIAL ECOSYSTEMS

1. Dispersion of radionuclides comes from gaseous, particulate, and aerosol deposition and from liquid and solid wastes
2. Plants absorb radionuclides from the soil
3. Radionuclides pass through the ecosystem along the food chain
4. Strontium-90 and cesium-137 are among the most destructive radioactive materials in nuclear waste, affecting primarily the arctic tundra
5. Lichens absorb almost all radioactive particles they are exposed to
6. ^{90}Sr and ^{137}Cs travel up the chain, affecting caribous, reindeers and even Eskimos and Alaskan Indians

C. AQUATIC ECOSYSTEMS

1. Nuclear pollution of water ecosystems is mainly due to nuclear waste disposal of nuclear power plants
2. Radioactive materials become incorporated in bottom sediments, where they can be absorbed by bottom-dwelling animals and ultimately fish
3. Concentrations of radionuclides vary with the system and the species
4. The concentration of radionuclides does not necessarily increase consistently through the food chain
5. Aquatic organisms concentrate radionuclides as they do stable elements

D. EFFECTS

1. Radioisotopes become magnified in animal tissues
2. Fission products of uranium include strontium, cesium, barium, and iodine, which can enter the food chains, becoming incorporated into living organisms and causing cancer and genetic defects

An Example Exposition of the Holistic Presentation
Example Topic: Carbon Cycle

After introductory remarks the presentation begins with "The carbon cycle, or c-cycle, has two main sources--

a. the atmosphere ...and
b. bodies of water.

The <u>characteristics</u> of the carbon cycle are

a. closely tied to the energy flow of the ecosystem ...and
b. depend upon the environmental conditions.
   For example soil, moisture, temperature, and precipitation play a major role in the rate of release of carbon dioxide into the atmosphere or body of water.
c. Terrestrial and aquatic habitat maintain photosynthetic reactions which interact with the atmospheric pool of carbon dioxide.

When studying the following diagram (given at the bottom of p. 3 of the notes from the holistic presentation), consider the various aspects of the carbon cycle......

(diagram is displayed and each component is reviewed with emphasis on the interactions of the constituents)

The review would be followed with a short question and answer session. Questions such as .....

What happens if abnormally high levels of carbon dioxide are released into the atmosphere?

If this situation were compounded by abnormally high or low amounts of rainfall, what would happen to the aquatic organisms sensitive to small changes in pH?

What other industrial plant effluent might compound or jeopardize the delicate balance in the ecosystem?

What effect would this have on the concentration of metals in the soil (e.g., aluminum)?

APPENDIX C

BIOGEOCHEMISTRY PRETEST

BIO 312 - Ecology Lecture
Special Pre-Test
Dr. John Korstad

Name____________________

Date____________________

Questions 1-18: MULTIPLE CHOICE - Choose the one best answer. (2 points each)

1. The nutrient element most likely to limit a lake ecosystem's productivity is:
   a. carbon.
   b. hydrogen.
   c. phosphorus.
   d. oxygen.
   e. nitrogen.

2. In the biosphere, which of the following is not constantly recycled?
   a. carbon
   b. nitrogen
   c. water
   d. energy
   e. sulphur

3. The main reservoir for gaseous biogeochemical cycles is(are) the:
   a. atmosphere.
   b. earth's crust.
   c. plant life.
   d. ocean.
   e. Both a and d are correct.

4. Atmospheric nitrogen can become directly available for organic synthesis in lakes through:
   a. photosynthesis in green plants.
   b. blue-green algae.
   c. the process of weathering in soils.
   d. the nitrogenous waste products of animals.
   e. both a and d

5. Some bacteria live symbiotically on the roots of leguminous plants in nodules. The basic activity of these bacteria is part of the:
   a. organic cycle.
   b. carbon cycle.
   c. water cycle.
   d. nitrogen cycle.
   e. putrefaction cycle.

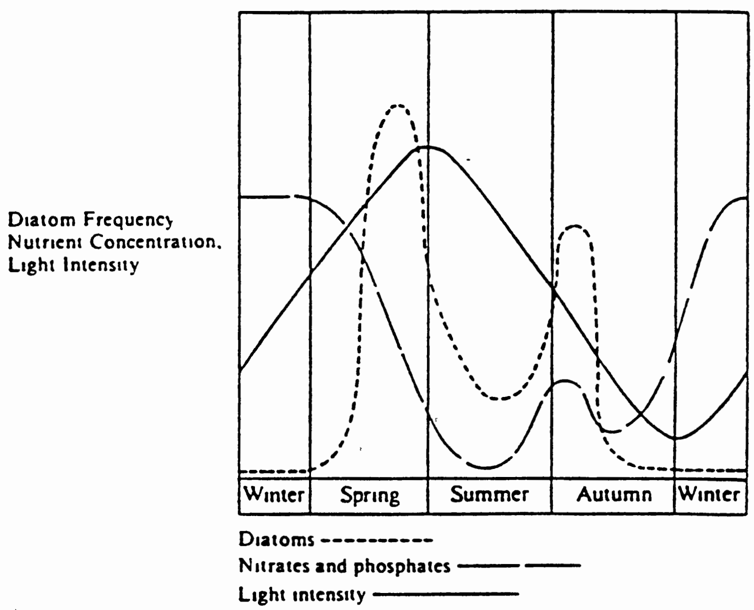
6. Of the five nutrient elements that are the most important constituents of living material, the only one without a gaseous reservoir is:
   a. carbon.
   b. hydrogen.
   c. phosphorus.
   d. oxygen.
   e. nitrogen.

7. Oxygen, free in the air or dissolved in water, is a by-product of:
   a. nitrogen fixation.
   b. the water cycle.
   c. respiration.
   d. lightning discharges.
   e. photosynthesis.

8. Who demonstrated conclusively the ability of nitrifying bacteria to obtain the energy required for carbon-compound synthesis from the oxidation of ammonia?
   a. Louis Pasteur
   b. Eduard Buchner
   c. C. S. Winogradsky
   d. Robert Koch
   e. George Beadle

Numbers 9-12 are based on the graph below:

SEASONAL FLUCTUATION IN DIATOM ABUNDANCE
IN THE NORTH ATLANTIC



9. Which of the following is an empirical generalization of the facts presented in the graph?
   a. The principal diatom pulses in the northern waters are vernal and autumnal.
   b. Light intensity increases during the summer, causing ocean currents that remove nutrients.
   c. The spring decrease in nitrates and phosphates results from increased decomposition of benthic organic remains.
   d. The greatest zooplankton pulse is in midsummer.
   e. The concentrations of nitrate and phosphate nutrients in ocean waters are relatively uniform at different depths.

10. To which of the following is the increase of nutrients in winter most logically attributable?
    a. increased replication of DNA molecules
    b. increased cell division of diatoms by binary fission
    c. the replacement of the least-adapted species by superior forms
    d. arrested diatom growth due in part to decreased sunlight
    e. sudden increases in populations of autotrophs

11. The annual spring increase in the population numbers of diatom is a striking example of:
    a. successful adaptation of new mutants.
    b. the lag phase of a population curve.
    c. genetic variation within populations.
    d. the normal effects of the Hardy-Weinberg Law.
    e. geometric reproductive rates.

12. Two factors probably responsible for the summer decline of diatom numbers are:
    a. the migration of diatoms to deep waters and the filtraton of the red rays of sunlight by the upper waters.
    b. the depletion by diatoms of the available nutrients and grazing by herbivores.
    c. reduced biotic potential and decreased intraspecies competition.
    d. the epigenic effects of pleiotropic genes and increased positive selection.
    e. an increased frequency of lethal genes and a decreased frequency of recessive genes.

13. The sedimentary biogeochemical cycle is represented by the:
    a. phosphorous cycle.
    b. oxygen cycle.
    c. hydrogen cycle.
    d. carbon cycle.
    e. nitrogen cycle.

14. The main reservoir for sedimentary biogeochemical cycles is (are) the:
    a. soil.
    b. earth's crust.
    c. atmosphere.
    d. ocean.
    e. Both a and b are correct.

15. Nitrogen is lost in the nitrogen cycle by:
    a. plants.
    b. animals.
    c. sedimentation.
    d. dead organic matter.
    e. all of the above

16. When are atmospheric CO_2 levels the highest?
    a. during the winter
    b. during the day
    c. during the fall
    d. during the night
    e. at dawn

17. Most of the ozone resides in what part of the atmosphere?
    a. hydrosphere
    b. biosphere
    c. stratosphere
    d. hemisphere
    e. thermosphere

18. Of all the human intrusions, which one has been the most detrimental to nutrient cycling?
    a. the spraying of DDT
    b. the burning of coal
    c. sulfure dioxide pollution
    d. acid deposition
    e. atmospheric pollution

Questions 19-25: True or False - Mark "A" for True and "B" for False. (2 points each)

____19. Mineralization is the process of converting the regolith into soil.

____20. The study of biogeochemical cycling in ecosystems is best understood as a dynamic process rather than as a static process.

____21. Trace elements are useful but not necessary for normal growth in most plants.

____22. The gaseous cycle only involves biological agents.

____23. The soil bacteria, clostridium, functions in carbon fixation.

____24. Increased CO_2 into the atmosphere has the potential of raising the average temperature of earth by several degrees.

____25. A considerable portion of sulfur is cycled in the gaseous state, which permits its circulation on a global scale.

APPENDIX D

BIOGEOCHEMISTRY POSTTEST

BIOGEOCHEMISTRY POSTTEST

1. The two types of biogeochemical cycles include:
   a. aqueous and terrestrial.
   b. gaseous and aqueous.
   c. gaseous and sedimentary.
   d. biological and chemical.
   e. abiotic and biotic.

2. All of the following are true about the ozone layer <u>except</u>:
   a. The temperature increases because the upper relatively thin layer of ozone absorbs most of the UV light.
   b. A downward intrusion of stratospheric air supplies the troposhere with the O_3 necessary to initiate photochemical processes in the lower atmosphere.
   c. The ozone layer shields the earth against biologically harmful solar UV radiation.
   d. Ozone in the outer atmosphere is maintained by a cyclic photolytic reaction.
   e. All of the above are true.

3. Regarding the thinning of the stratosphere, all of the following are true <u>except</u>:
   a. Under natural conditions in the atmosphere a balance exists between the rate of ozone formation and destruction.
   b. A number of anthropogenic and biological catalysts injected into the stratosphere are reactive and cause a decrease in stratospheric ozone.
   c. Chlorofluorocarbons, methane, and nitrous oxide are involved in the catalytic destruction of ozone.
   d. Reductions in the ozone layer can have adverse ecological effects on the earth (e.g., altering DNA and increasing skin cancer).
   e. All of the above are true.

4. The rate of release of carbon contained in decomposing plant and animal matter is dependent upon all of the following environmental conditions <u>except</u>:
   a. soil moisture.
   b. temperature.
   c. sunlight.
   d. precipitation
   e. All of the above are true.

5. The global cycle of carbon dioxide in the northern hemisphere:
   a. is constant throughout the year.
   b. increases evenly every year.
   c. is highest in winter and lowest in summer.
   d. is highest in summer and lowest in winter.
   e. None of the above answers is correct.

6. Which of the following correctly depicts how nutrients and energy operate in ecosystems?
   a. Both nutrients and energy cycle
   b. Only nutrients cycle
   c. Only energy cycles
   d. Neither cycles
   e. There's no easy answer to this question unless more information is given.

7. Sources of human nitrogen pollution include all of the following except:
   a. heavy additions of commercial fertilizers.
   b. animal wastes such as feedyards.
   c. human wastes such as sewage
   d. volcanic eruptions.
   e. All of the above are true.

8. The sudden, heavy input of "acid rain" in aquatic ecosystems can result in all of the following except:
   a. reduced release of aluminum ions.
   b. slower growth of fish.
   c. decreased fish egg production.
   d. greater fish mortality
   e. All of the above are correct.

9. All of the following are contributors to acid rain except:
   a. H_2CO_3
   b. H_2SO_4
   c. H_3PO_4
   d. $HNO4_3$
   e. More than one of the above are not contributors to acid rain.

10. Changes in which one of the following cycles would likely have the most profound effect on competition between C_3 and C_4 plants?
    a. Oxygen Cycle
    b. Nitrogen Cycle
    c. Carbon Cycle
    d. Sulphur Cycle
    e. Phosphorus Cycle

11. Which of the following cycles does not involve decomposers?
    a. Phosphorus
    b. Carbon
    c. Nitrogen
    d. Sulphur
    e. All of the above involve decomposers.

12. Biological nitrogen fixation would most likely be a significant source of available nitrogen in which of the following ecosystems?
    a. lakes
    b. ocean
    c. mountains
    d. agricultural fields
    e. More than one of the above.

13. Biogeochemical cycles involve all of the following except:
    a. abiotic components
    b. biotic components
    c. energy
    d. water
    e. All of the above are involved.

14. Fluctuations in the ozone layer can be linked to which of the following cycles?
    a. Oxygen
    b. Carbon
    c. Nitrogen
    d. Sulphur
    e. More than one of the above.

15. Approximately what percent of the atmosphere is composed of nitrogen?
    a. 10-20%
    b. 20-40%
    c. 40-60%
    d. 60-80%
    e. 80-100%

16. Nitrogen is lost as a gas from ecosystems to the atmosphere via which of the following processes?
    a. Nitrogen fixation
    b. Denitrification
    c. Nitrification
    d. Ammonification
    e. More than one of the above

17. Of the nutrients needed for aquatic plant growth, which is usually precipitated in the sediments and cannot be supplied naturally by the plants?
    a. Carbon
    b. Nitrogen
    c. Sulphur
    d. Phosphorus
    e. Potassium

18. Volcanic activity plays a major role in all of the following cycles <u>except</u>?
    a. Oxygen
    b. Carbon
    c. Nitrogen
    d. Sulfur
    e. Volcanic activity plays a major role in more than one of the above.

19. Human intrusion into the nitrogen cycle involves all of the following inputs except:
    a. nitrogen dioxide (NO_2)
    b. nitrogen gas (N_2)
    c. nitrate (NO_3)
    d. ammonia (NH_3)
    e. All of the above are correct.

20. How did my lecture style (not topic) on biogeochemistry compare with my other lectures? (Be honest; this question will not be graded.)
    a. much worse; dull
    b. less interesting
    c. about the same
    d. more interesting
    e. much better; motivating

21. How much (%) information for answering the questions on biogeochemistry did you get from reading Chapter 12 (Biogeochemistry) in the textbook? (This question will not be graded.)
    a. <20%
    b. 20-40%
    c. 40-60%
    d. 60-80%
    e. 80-100%

Questions 22-23. MATCHING - Match the one best chemical process on the right that describes the term on the left. (Note: Formulas are not "balanced"). (2 points each)

22. Nitrogen fixation	a.	$C_6 H_{12}O_6 + 4NO_3 \rightarrow 6CO_2 + H_2O + 2N_2$
	b.	$CH_2 NH_2 COOH + 1\frac{1}{2}O_2 \rightarrow 2 CO_2 + H_2O + NH_3$
23. Nitrification	c.	$NO_3 \rightarrow NO + O$
	d.	$N_2 \longrightarrow 2 N; 2 N + 3H_2 \rightarrow 2 NH_3$
	e.	$NH_3 + 1\frac{1}{2} O_2 \rightarrow HNO_2 + H_2O + HNO_2 \rightarrow H^+ + NO_2$

Question 24-26. TRUE (A) OR FALSE (B): (2 points each)

24. Carbon cycling in the sea is nearly a closed system.

25. All (100%) of the total carbon injected into the atmosphere remains there, so "sinks" are unimportant.

26. DDT, but not PCBs, has an affinity for fatty tissue in animals.

VITA

Mark D. Weber

Candidate for the Degree of

Doctor of Philosophy

Thesis: A COMPARATIVE ANALYSIS OF HOLISTIC AND SERIALISTIC PEDAGOGICAL METHODOLOGY FOR BIOGEOCHEMISTRY

Major Field: Environmental Science

Biographical:

Personal Data: Born in Lima, Ohio, February 1, 1953, the son of Cletus J. and Marylou W. Weber. Married to Kara J. Wade on July 19, 1980.

Education: Graduated from H. B. Plant High School, Tampa, Florida, in June, 1971; received Bachelor of Arts degree in Zoology from the University of South Florida, Tampa, Florida, in March, 1975; received Master of Arts degree in Education from Oral Roberts University, Tulsa, Oklahoma, in May, 1985; received Doctor of Education degree from Oklahoma State University, Stillwater, Oklahoma, in July, 1988; completed requirements for the Doctor of Philosophy degree from Oklahoma State University, Stillwater, Oklahoma, in May, 1992.

Professional Experience: Assistant Professor, Oral Roberts University, Department of Biology, 1990-Present; Assistant Professor, Oral Roberts University, School of Medicine, 1988; Part-time Instructor, Tulsa, Junior College, 1987; Chairman of Math/Science Department of Victory Christian School, Tulsa, Oklahoma, August, 1983 to June, 1988; Math and Science Instructor at Victory Christian School, Tulsa, Oklahoma, August, 1981 to June, 1983; Sales Associate for Zimmer-Hoffman, Oklahoma City, Oklahoma, April, 1980 to December, 1980; Southwestern Sales Manager and Sales Representative for Florida Orthopedics, May, 1978 to March, 1980.