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The Ohio State University

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LEVELS OF QUESTIONING AND FORMS OF FEEDBACK:
INSTRUCTIONAL FACTORS IN COURSEWARE DESIGN

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the
Degree Doctor of Philosophy in the
Graduate School of
The Ohio State University

By
John Austin Merrill, B.S., M.A.

*****

The Ohio State University
1985

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*** To my wife, Mary Christine Druffel ***

Your undaunted efforts to maintain hearth and home made this doctorate possible for both of us.
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Major Field: Instructional Design and Technology

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Studies in Program Design and Evaluation. Dr. James W. Altschuld

Studies in Educational Psychology. Dr. Philip M. Clark
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Chapter 1
INTRODUCTION

Problem Statement

Over the past several years important trends in the research and development of instructional technology have been identified (Kemp, 1981; Meierhenry, 1981), which attest to a sustained commitment of educators to seek answers to the many questions raised by the presence of advanced technology within educational settings. This study seeks in particular to add to the growing body of knowledge on the design and development of computer-based instructional systems by examining specific instructional factors related to courseware design. The need for this study arises for three reasons: (a) data are critically insufficient on appropriate uses of computers in education (Kearsley, Hunter, & Seidel, 1983; Schloss, Schloss, & Cartwright, 1984); (b) research conducted by Hall, Comer, Merrill, and Wenig (1983) strongly suggested that "probably the single most important factor in producing courseware of a high educational quality is the nature of the questions which are presented to the learner" (p. 10); and (c) the commission report, A Nation at Risk: The Imperative for Educational Reform, refers to rapid changes fostered by computer-based technology
as a major contributor to the need for reforms in our educational system, but fails to suggest how this same technology might be used as a basis for reform (Peter, 1983).

**Major outcomes of recent CBI research.** Kearsley et al. (1983) analyzed over 50 major computer-based instruction (CBI) projects for their practical and theoretical significance to the field of education. They grouped these projects into eight categories ranging from the development of hardware, software, and courseware prototypes; authoring languages/systems; to intelligent CAI. From their analysis they identified nine major outcomes, four of which are significant for the present study:

1. There is ample evidence that computers can make instruction more efficient or effective.
2. We know relatively little about how to individualize instruction.
3. CBI has spurred research throughout the entire field of instruction.
4. We have just scratched the surface of what can be accomplished with computers in education. (p. 90).

**Psychology and instructional design.** One would think that with ample evidence regarding the efficiency or effectiveness of computers as a medium of instruction, computer presence within educational settings would be more widespread. Yet Kearsley et al. (1983) have noted that we know relatively little about how to individualize instruction. Major factors interfering with the instructional use of computers are the discrepancies which exist among behavioral and
cognitive approaches to the design of instruction that is appropriate to computer-based systems.

A behavioral approach to instructional design might incorporate such characteristics as detailed statements of student performance outcomes, that is, behavioral objectives, task analyses, linear instructional sequences, corrective feedback, and performance posttests that assess student acquisition of the behavioral objectives. These components provide a beginning set of principles for instructional design, but given the unique and powerful attributes of computer technology it is possible to move towards the development of CBE/CBI systems that incorporate higher levels of human cognition. Computer technology should be viewed as a means for further research and development, not simply as an end for perfecting a behavioral approach to learning and instructional design (Tennyson, 1981).

A cognitive approach to instructional design might borrow some of the structural elements of the behavioral approach (e.g., objectives, feedback, and posttests) but the elements would be modified to reflect an information processing model rather than a stimulus-response paradigm. Instructional designers who follow behavioral approaches organize and represent knowledge in discrete units. Instructional designers with a cognitive orientation are more likely to structure the content of the knowledge to be learned according to concept hierarchies. Students can examine the necessary concept relationships when the concepts have been developed according to their attributes and organized in a hierarchical fashion for instruction. Students
probably have a better chance of grasping and retaining concept relationships through an integrated approach such as a concept hierarchy than if the same information were presented in discrete units.

Attributes of quality CBE courseware. The research conducted by Hall et al. (1983) sought to identify the attributes of quality computer-based education (CBE) courseware. Content structure, levels of learning, learner differences, and questioning techniques were examined. Hall et al. concluded that levels of learning are largely determined by content structure and the level of questioning. Learner differences did not emerge as significant because:

An adaptive instructional strategy which makes 'real-time' adjustments to the demonstrated performance of each learner has, in effect, dealt appropriately with the individual differences of learners without the need to categorize or label those differences.

(Hall et al., 1983, p. 5).

Some may take issue with the above statement as though it implies that individual differences are of little consequence to CBE. Such is not the case. Content structure, questioning, and levels of learning have been identified as attributes of computer-based courseware because these attributes can be incorporated as actual components of the courseware design. Individual differences, however, are not elements under the direct control of the courseware developer.
Individual differences. The confusion regarding individual differences is understandable given the history of instructional research. Theoretically, students with high or low verbal, mathematical, spatial reasoning, or mechanical comprehension abilities should react differentially to alternative instructional treatments in the context of specific content. However, Cronbach and Snow (1977) found that special abilities generally do not interact with treatment, whereas general ability is much more likely to do so. Snow (1977) noted that aptitude-treatment interaction (ATI) results to date have not made instructional theory impossible, but may make general instructional theory impossible, that is, instructional treatments applied in a specific setting and at a specific time with a specific student or group of students, may be effective but the same instructional treatments may not generalize to all settings, students, instructors, and times (Snow, 1977).

Most educators would agree that learning is a highly complex process that is affected by a number of interacting variables. Years of aptitude-interaction research could not identify individual variables with sufficient power to enable us to design instructional materials around them. We do know that learning is affected by a number of variables including prior knowledge, age, intelligence, social experience and competence, creativity, and motivation. Traditionally, adjustments for these variables have been made at the curriculum development stage to insure that learners and instructional expectations are within a suitable range. Once instruction is
started, little attention is paid to systematic adaptation to learner differences (Hall, 1983). The development of high-quality courseware that includes an adaptive instructional strategy will allow individual differences to receive consistent attention through the flexibility of instructional strategies within the courseware (Merrill, 1983).

**Impact of computer-based education.** The impact of computer-based education is likely to influence the conventional wisdom regarding classroom instruction and perhaps the structure of schools and educational systems. Changes associated with such an impact have been and will be heavily dependent on individual attitudes and perceptions regarding the role of CBE. Attitudes and perceptions can influence the successful implementation of CBE systems, but as an educational issue or a research goal implementation is quite apart from the more specific focus of how to design and develop computer-based instructional systems.

The purpose of this study was to gain insight regarding the principle elements of quality CBE courseware as media of instruction in their own right, such that high-quality, adaptive courseware can be designed. No efforts were made in this study to compare student learning from conventional instruction with learning from computer-based instruction, although that has been a central concern in other studies (Taylor, 1982).
Research Objective

The particular focus of this investigation was the independent variables of questioning and feedback. Past research has indicated that questioning during conventional instruction typically occurs at lower cognitive levels (Gall, 1970). Research in CBE provides an opportunity to closely examine the elements of questioning necessary both to write questions and to cause learning at higher cognitive levels. The materials designed for this study span a range of question levels from simple recall to the higher cognitive skills of analyzing, synthesizing, and evaluating.

Feedback is integral to the questioning process if the process is to be one in which a learner has the opportunity to expand his or her base of knowledge. Therefore, forms of feedback need to be understood if they are to be used appropriately and effectively in CBE courseware. Feedback as a term within the educational research literature is generally interpreted from a behavioral perspective where it has its origins in Thorndike's (1898) animal behavior experiments. Skinner (1954) later applied many of Thorndike's principles to human learning problems. CBE provides an opportunity to provide feedback in a manner that moves beyond the perspective of the stimulus-response paradigm. Efforts were made in this study to determine the appropriate uses of an instructional form of feedback from a cognitive perspective. Literature searches conducted by the author revealed few major studies which investigated the cognitive attributes or applications of instructional feedback (see Note 1).
The author hoped to find a significant correspondence among the elements of questioning and feedback by combining two levels of questioning and two forms of feedback within a CBE lesson and by statistically analyzing the performance measures of those students who received instruction via the CBE lesson. Each student experienced the same lesson content, but the four different combinations of questioning and feedback integrated within the content yielded four different versions of the same lesson. Each version was used separately as the experimental treatment with one of the four different groups.

Definition of Terms

**Computer-based education (CBE).** Computer-based education (CBE) was used as a more comprehensive term to encompass computer-based instruction (CBI), computer-managed instruction (CMI), and computer-based instructional simulations.

**Individualized instruction.** Individualized instruction may range from agreement between student and teacher on a general level of stated objectives to a more advanced level of student-determined instruction. In the latter, student judgment may be exercised in any or all of the following aspects of learning: (a) selection of objectives, (b) selection of the particular materials, resources, or exercises to be used, (c) selection of a schedule within which work on different academic subjects will be allocated, (d) self-pacing in
reaching each objective, (e) self-evaluation as to whether the objective has been met, and (f) freedom to abandon one objective in favor of another one (Gagne & Briggs, 1979,).

Adaptive education. Adaptive education is argued by Mitzel (1981) to be a higher level concept than individualized instruction. In the previous definition, emphasis is on student selection of objectives, materials, etc., but no mention is made of the structure of the material to be learned. In adaptive education emphasis would be on "the tailoring of subject-matter presentations to fit the special requirements of each learner" (Mitzel, 1981, p. 93). This conception remains largely a theoretical issue which awaits the development of more sophisticated computer-based delivery systems.

Delivery system. A delivery system is the combination of the appropriate personnel, media, materials, and learning activities that can be used to reach the instructional goal.

Cognitive processes. Cognitive processes are the internal mechanisms of the mind by which an individual perceives, acquires, stores, searches, retrieves, and utilizes information about his or her environment.
Instructional question. An instructional question is an inquisitory statement used to aid a learner in retaining old knowledge or in acquiring new knowledge. The most widely known criteria for judging the level of a question are drawn from Bloom's Taxonomy (Bloom, 1956; Seddon, 1978).

Bloom's Taxonomy of the cognitive domain includes knowledge recall, comprehension, application, analysis, synthesis, and evaluation. Each of these cognitive skills represents the internal processing of a learner in response to a question which can be written to cause a learner to respond in a particular range represented within Bloom's Taxonomy. For example, high-level questions are intended to cause learners to analyze, synthesize, and evaluate information. Low-level questions require less sophisticated cognitive skills, as in recalling basic facts.

The instructional intent of a question may not always match the learner's response, that is, a high-level question may not engender a high-level response. Courseware authors and instructors need to be sensitive to this and to make adjustments in the questioning when it is necessary (see Appendix C for a list of verbs useful in question writing).

Principles of human learning. Principles of human learning is a phrase that refers to the vast amount of research conducted by behavioral and cognitive psychologists in an attempt to develop theories and models which describe the behaviors or processes
associated with knowledge acquisition. The issue of how humans extract information from their environment and fashion it into meaningful units has given rise to two major categories of models for interpreting the phenomena associated with this issue—namely, the structural models and the information processing models. The structural models include the sensory register, short-term memory (STM), and long-term memory (LTM), and are primarily concerned with the temporal characteristics of what is encoded. The information models are concerned with the deeper, more elaborative processes that enable students to generate meaning from what they experience. The levels of processing which occur do not correspond to STM and LTM in the same structural components sense.

The fundamental assumption of the levels approach is that an incoming stimulus can be processed in many different ways (or levels), and that these various manners of processing can be viewed as forming a dimension called depth (or level) of processing. (Klatzky, 1980, p. 22).

**Learner's response.** A learner's response is defined here as an activity that is the outcome of cognitive processing. This definition is placed in the context of an information-processing model of learning as opposed to a behavioral model. In the latter, a response constitutes an observed behavior elicited by a stimulus with little if any intervening internal processing by the learner. This represents a conventional S-R paradigm in which multiple stimuli are generally difficult to handle. An information-processing model, however,
advocates a more powerful conception of humans as learners who are capable of using their internal perceptual and memory structures to process multiple incoming stimuli and to interpret these stimuli according to existing schemata.

Learner responses in this study were interpreted from a cognitive perspective that considers the influences of questioning and feedback on response construction, even though both models ultimately rely on some externally observable performance criteria to measure the effects of instruction.

Feedback. Feedback is defined as an external instructional event or strategy that provides information to the student following his response. Feedback from the external environment serves as a "reinforcing event" to a number of intervening processes that support each single act of learning (Gagne, 1977). Gagne states that "In theory, such an event provides learners with information concerning the correctness, and often with the degree of correctness, of their performances" (1977, p. 297). In many cases feedback is self-generated, that is, provided by the learner through self-observation of the effects of his performance.

Feedback that is external to the learner has taken many forms in the research literature (Kulhavy, 1977), but the following two types have been identified for the purposes of this study:
1. **Corrective Feedback (CF)** - informs learners of the correctness or incorrectness of their answers and provides the full text of the correct answer in response to a student's incorrect answer. The full text of the answer may consist of a single word, phrase, or short paragraph.

2. **Attribute Isolation Feedback (AIF)** - informs learners of the correctness or incorrectness of their answers and isolates the attributes of the concepts being studied to improve further responses. Attribute isolation helps to focus attention on the critical attributes or on the troublesome variable attributes (Merrill & Tennyson, 1977).

**Reinforcement.** Reinforcement is conventionally used by many educators according to Skinner's conception (1968) in which "reinforcement" is the name for a particular arrangement of stimulus and response conditions that bring about the learning of a new association. According to this conception, the response conditions would have to be favorable enough to an individual such that the new association becomes increasingly strengthened and thus retained as new information.

Skinner's conception of reinforcement was originally based on Thorndike's (1898) early trial-and-error learning studies with animals in which a reward was used to strengthen the learning of a new act. Schedules of fixed-ratio, variable-ratio, or interval reinforcement determined the strength of the reward and the acquisition of the
desired behavior. This trial-and-error prototype, however, is not representative of human learning (Gagne, 1977), and says nothing of the mental strategies employed by humans as they recall, apply, analyze, synthesize, or evaluate information. For instructional purposes, a more appropriate conception of reinforcement needs to be stated in cognitive terms.

The reinforcing function of feedback as used in the present study is not based on Skinner's conception. Critical distinctions between an S-R paradigm versus an information-processing model rest largely upon how the paradigm or model is inserted into the research design, even though the terminology may appear similar at times. An accurate S-R paradigm would require that the S-R condition be repeated over time according to some pre-determined schedule of reinforcement in order for the desired behavior to be shaped. The S-R paradigm may explain certain behavioral phenomena but it is not an adequate principle for instructional design intended for concept learning.

**Content structure.** Content structure is defined as a hierarchical arrangement of concepts that organizes a body of information or knowledge. Superordinate, coordinate, and subordinate denote the relative positions of concepts within the hierarchy (see Appendix A). An examination of the relationships assists in defining and clarifying the critical and variable attributes which ultimately will be presented to the learner.
The critical or variable nature of an attribute can shift depending on the concept's placement within the hierarchy. For example, variable attributes of a superordinate concept become critical attributes of the subordinate concepts, concepts which are in turn coordinate with one another. Coordinate concepts generally differ on their critical attributes because by definition "a critical attribute is a characteristic necessary for determining class membership" (Merrill & Tennyson, 1977, p. 24). Some sharing of critical attributes may occur across classes without losing class distinction. Variable attributes are useful for describing class members, but are not necessary for determining class membership (see Appendix A).

Limitations of the Study

Factors in the learning process. The knowledge that a learner acquires is not the result of a single incident. Many factors contribute to both the quality and the quantity of what is learned, such as the content of instruction, the delivery of instruction, the student's cognitive abilities, and the organizational setting in which the instruction occurs. All of these factors interact over time to produce the myriad effects which shape an individual's learning.

As stated earlier, the purpose of this research was to gain insight regarding the principal elements of quality CBE courseware as media of instruction. The content and delivery of instruction, and individual student's cognitive abilities were factors integral to the
conduct of this study. While the structure of the content used in this research provided a context for testing the independent variables, it was not an object of research itself.

**Learner differences.** Courseware which includes adaptive instructional strategies does not ignore the presence of learner differences (e.g., maturity, cultural background, peer relationships, emotional behavior, self-concept, or physical handicap) nor the vast amount of research on cognitive styles. Courseware which includes well-designed instructional strategies can create highly flexible CBE courseware that satisfies a broad spectrum of learners' needs. Analogous to this conclusion, Gagne and Briggs (1979) asserted that prior learning, motivation, and an attitude of confidence are internal states essential for learning. These internal states are presumed to be present as preconditions to the design of instruction.

**Cognitive styles.** Martin (1981) conducted an in-depth literature review examining the ten most prominent cognitive styles that have been identified to date and concluded "although substantial research has been conducted on cognitive styles, few definitive results with educational implications have been found" (p. 65). Her conclusion stressed educational implications because her intent was to examine relationships between cognitive styles and instructional variables. Cognitive style research has focused primarily on psychological issues and personality variables. The largest amount of
research has been conducted on the analytic-global dimension of cognitive functioning (i.e., on field-independence / field-dependence (FI/FD), respectively), and thus it offered the most potential for an exploratory study.

Past research has identified three major instructional variables which impact differentially on field independent and field dependent individuals. First is the amount and type of feedback an individual receives; second is the degree of structuring provided within a lesson; and third is the relevance of cues or amount of distracting material presented.

(Martin, 1981, p. 70)

The results of studies on the above variables have shown that FD individuals perform better when feedback is present and when material is structured. FI individuals perform about the same in the presence or absence of feedback and with structured or unstructured materials.

Martin's study was designed to investigate the effects of three levels of feedback (i.e., maximum, medium, and no feedback) on the error rate of FI/FD individuals on a set of scientifically-oriented instructional materials. The results showed that maximum feedback decreased the error rate of FDs to a point where the mean error rate was equivalent to that of the FIs, as hypothesized by Martin. Martin recommended that continued investigation of cognitive styles and feedback can provide for a more truly individualized CBE system.

All subjects in the present study completed a Hidden Figures Test (HFT) following the CBE lesson. Although little data on the reliability and validity of the HFT has been published, its
predecessor - the Group Embedded Figures Test (GEFT) - is well
documented. Past investigations of the reliability and validity of
the GEFT have shown acceptable reliability coefficients (Spearman
Brown = .82) and reasonable indications of validity (Witkin, Oltman,
Raskin, & Karp, 1971). GEFT data is often cited to support use of the
HFT (Ekstrom, 1984). The HFT was chosen for this study for reasons of
cost and ease of scoring.

Experimental design. The experimental design for this research
had four combinations of questioning and feedback all at fixed levels
(e.g., high-level questioning with corrective feedback - see Table 1
in Chapter 3). These levels were fixed for experimental purposes only
and do not necessarily represent an optimal form of instruction
(Arons, 1984; Roblyer, 1983).

Courseware design and development. The computer-based lesson
used as the experimental treatment provided about one hour of
instruction. The courseware was pilot tested with individual students
prior to data collection. The decision to provide one hour of
instruction was based on the need to create an experimental treatment
that would fit within the schedule of a public school setting.

Development time for CBE materials can range from 150-200 hours per
one hour of instruction depending on the experience of the developer
and/or on the authoring language used. The courseware design and
development activities for this study ranged from the initial lesson
structuring and programming to pilot testing and final editing. These activities required approximately 250 hours.

**Instructional media.** The computer and the instruction it conveys constitutes a specific form of instructional media. The primary focus of this study was on the development of instructional materials suited to the computer medium to enable learners to acquire and retain knowledge in ways not possible through conventional means of instruction. Thus an in-depth assessment of other dimensions of instructional media was not provided, such as their relationship to mental symbolic processes or how differences among symbol systems affect knowledge acquisition and cognition.

**Assumptions of the Study**

**Lesson content.** The content of the computer-based lesson for this research is based on the Xenograde System, which is a collection of very small systems similar in structure to an atom or the solar system (Arlin, 1973; Martin, 1981; Merrill, 1964; see Note 2). This author assumed that most subjects in the experimental sample had limited knowledge of these systems, and no single student had a major advantage due to prior knowledge. Subjects were assumed to be of average intelligence.

**Courseware attributes.** The research also assumed an intimate relationship among the attributes of content structure, questioning,
cognitive processing, student response, and feedback. Both the substance and structure of the content had a direct bearing on the questions that were asked. The questions in turn caused some level of processing and resulted in or produced student responses to which a computer program provided feedback. In the courseware developed for this study, the interrelationships of all the above attributes is represented by a linear mode in Figure 1.

| Content Presented | Questioning | Student's Cognitive Processing | Student's Response | Feedback |

Figure 1. The interrelationships of CBE courseware attributes.
Chapter 2
LITERATURE REVIEW

Rationale

Computer-based instructional systems offer a unique opportunity to study and apply instructional theory, concepts, strategies, and principles not possible in a conventional educational setting. Efforts to improve training in business and industry and the widespread emergence of computers in education are enhancing this opportunity (Boutwell, 1979; Patton, 1980; Snelbecker, 1983).

The development of instructional theory and its application to instructional design is a complex process, and no single instructional theory serves to guide educators through the development or conduct of sound instruction. Indeed, instructional theory has been in a confused state because of the widely divergent views existing among behavioral and cognitive psychologists, such that effective theoretical applications to instructional design have been lacking.

Credit must be given to some of the major models and theories that have been developed. Skinner has already been mentioned as the major theorist among behavioral psychologists, and his contributions will also be discussed later in this chapter. Although teaching
machines as envisioned first by Pressey (1926) and later by Skinner (1954, 1968) represented one practical application of an instructional theory, the development of computer-based instructional systems is becoming more closely aligned with recent advances in cognitive science. Some of the major theoretical work which has contributed either directly or indirectly to this effort has been produced by Ausburn and Ausburn (1978), Briggs (1982), Fleming (1980), Gagne (1977), Gagne and Briggs (1979), Glaser (1976), Merrill (1983), Mitzel (1981), Reigeluth and Stein, Tennyson (1981), Tennyson and Park (1980), and Wittrock (1978). Their collective influence represents a primary distinction between cognitivists and behaviorists.

Cognitivists, be they psychologists, instructional developers or both, view the learner as someone who is highly interactive with the environment and who utilizes both internal conditions (e.g., intellectual skills and cognitive strategies) and external conditions (e.g., objects, symbols, pictures, sounds, or verbal communications) in the learning process. Gagne and Briggs (1979), for example, have integrated principles of human learning within a systems approach to instruction. The resulting framework for designing instruction includes: needs analysis, specific course objectives, clear instructional sequences, and assessment procedures. The systems approach provides a context for the application of human learning principles to the process of instructional design.
Potential of CBE. The field of instructional design is stronger in matching objectives, instruction, and tests to each other than it is in matching the task and instruction to the learner (Briggs, 1982) because there is a tendency among instructional designers to overlook the role of cognitive processes in learners. Mitzel (1981) also addressed this problem when he explicated four roots on which a theory of computer-based adaptive education can be constructed: (a) measuring individual differences to acquire more data on how individual difference variables affect a person's acquisition and retention of new knowledge, (b) studying the psychology of a responsive environment to provide for better quality and a greater quantity of feedback, (c) developing criterion-referenced evaluations in order to have an achievable mastery criterion for each course, and (d) incorporating recent advances in cognitive psychology on the generative functions of the brain and on long-term and short-term memory structures. The focus of this study is in line primarily with Mitzel's second theoretical root of a responsive psychological environment, with an additional emphasis on questioning levels.

The full impact that Mitzel's and other theoretical conceptions will have on CBE remains to be seen. Research to date has shown that CBE offers the potential of consistent, high-quality instruction that is less vulnerable to the normal differences of teacher preparedness, school environment and peer pressure (Hall, 1982). Ideally, CBE can provide a high degree of individualized one-to-one interaction. For CBE to achieve full potential, much more needs to be known about the
elements of questioning, learner response, and feedback that can engage learners in high-level thinking. More knowledge can be gained about CBE by examining the quality and quantity of both questioning and feedback as integrated elements within a responsive instructional environment.

As the field of CBE has evolved, educators and courseware developers have been faced with many challenges, notably: (a) what is the quality of the content organization of the CBE material, (b) how is the material presented to the learner (this would include such factors as levels of questions and forms of feedback), and (c) how well does the CBE material complement the learner's own aptitudes and strategies? The evolution of the field and of the courseware it generates is heavily dependent on the prevailing conceptions of people as learners. For example, a stimulus-response paradigm will likely generate courseware with immediate and simple feedback plus controlled branching. A cognitive model will likely produce courseware with more elaborate feedback and a variety of options for the learner.

Conceptions of individualized instruction. Mitzel (1981) discussed five different conceptions of learners prevalent among educators. According to these conceptions, learners should: (a) be allowed to proceed through teaching materials at a comfortable, self-determined pace, (b) be able to work at times convenient to themselves, (c) begin instruction in a given subject at a point appropriate to their past achievement, (d) receive proper diagnosis
and remediation for easily identifiable skills or knowledge, and (e) be able to choose from a wealth of instructional media (pp. 94 - 95).

Mitzel found none of these entirely adequate to his conception of adaptive education, by which he means "the tailoring of subject-matter presentations to fit the special requirements of each learner" (p. 93). The presence of inadequate conceptions of individualized learning appropriate to Mitzel's conception for adaptive education are largely the result of research focused on how students can be better learners within conventional instructional environments.

The first attempts to automate individualized instruction using the power of the computer, conducted under the leadership of Donald Bitzer at the University of Illinois, occurred only as recently as 1959 (Hall, 1982). The literature covering two decades of computer-based instruction projects since then still indicates that relatively little is known about how to individualize instruction (Kearsley et al., 1983). The expanding application of computer technology to the development of instructional systems is likely to generate other conceptions of individualized instruction apart from those based on conventional learning environments.

Concern for the characteristics of individualized instruction is essential to the development of quality CBE courseware which can encompass a broad range of instructional functions, such as: (a) display content to the learner, (b) provide practice with the content, (c) provide feedback to the learner, (d) consolidate learning, and enhance retention (Hall, 1982). Appropriate types of
feedback and levels of questioning are necessary not only to provide adequate opportunity for practice, but to ensure that the learner acquires, fully comprehends, retains, and can apply, analyze, synthesize, and evaluate the content that has been studied.

Summary

The instructional process has many facets (e.g., content structure, quality of student-content interaction, levels of questioning, forms of feedback), and over time educational researchers place varying degrees of emphasis on each. With the development of CBE, the process of instruction can be replicated and analyzed repeatedly, in contrast to the idiosyncratic nature of most classroom instruction. This is not to place a value judgment on either of the two approaches. Nor is it to imply that it would be desirable to replace all conventional classroom instruction. Rather, the comparison is made to emphasize that elements of a given instructional process can be selected and stabilized for closer study using computer-based instructional technology to determine the effectiveness of those elements in achieving stated objectives.

This literature review contains three sections: content structure; questioning; and feedback. Content structure is presented first to provide a context for the investigation of the independent variables (i.e., the levels of questioning and the types of feedback). Questioning and feedback are then reviewed for their importance in establishing appropriate levels of student interaction. Major points
from the literature will be analyzed in relation to the present study.

Content Structure

It seems reasonable to assume that the quality of interaction that occurs during instruction is in some manner dependent on the content structure and content sequence of the instruction. Thus, it is not surprising that planning for appropriate content structure and sequence in instructional materials has been of concern to educators throughout this century (Ausubel, 1964; Bruner, 1960; Dewey, 1902; Gagne, 1962; Mayer & Greeno, 1972; Popham & Baker, 1970; Rugg, 1926; Scandura, 1973; Tyler, 1950). Content that is to be used most effectively needs to employ a structure that reveals, explicitly or implicitly, the relationships among the concepts, that is, what is the superordinate concept, what are the subordinate and coordinate concepts, and what are the critical and variable attributes and examples of each. Content structure of this nature is most evident in disciplines related to the hard sciences but can also be employed in organizing concepts in the humanities (Wilson, 1963).

Concepts as mental constructs have been called the basic tools of thought, "the critical component of an individual's continuously changing, enlarging cognitive structure" (Klausmeier, 1979, p. 7). Merrill and Tennyson (1977) and Reigeluth and Merrill (1978) have generated significant research in developing useful concept hierarchies in the form of superordinate, coordinate, and subordinate relationships among related constructs in a subject matter
This form of hierarchy is taxonomic in nature, of which there are two kinds - a "kinds" taxonomy and a "parts" taxonomy (Reigeluth & Merrill, 1978). In a "kinds" taxonomy a subordinate concept is a type of the superordinate concept to which it is subordinate. For example, a bear is a type (or kind) of mammal. In a "parts" taxonomy a subordinate concept is part of the superordinate concept, such as a respiratory system is part of a mammal. Those concepts which are subordinate to the same superordinate concept are coordinate to one another.

Concept relationships, particularly the coordinate relationships, help to define and clarify the critical and variable attributes which must be presented to the learner. Analysis of concept relationships and attributes are based on the inherent nature of the subject material and serve the primary purpose of conveying an organized content structure throughout the instruction. Lists of critical and variable attributes which result from such an analysis provide the basis for constructing and/or organizing examples and non-examples for initial presentation and subsequent feedback.

Use of examples and nonexamples. In studying a body of material, a student must have sufficient opportunity to encounter the various concepts, examples, and non-examples to assure their acquisition. The process of acquiring new information requires exposure to examples and nonexamples which contain the critical and
variable attributes of the concepts to be learned. Instruction based on content structure which contains an inadequate number of appropriate examples and nonexamples is likely to result in the learner committing errors of undergeneralization, overgeneralization, or misconceptions. For example, a student response could represent an undergeneralization if the learner classified a concept example as a non-example of the concept. Suppose a student has encountered the concept of an adjective and has been presented with several sentences in which he is to indicate whether or not the underlined word is an adjective, for example, "He wants the dark purple shirt". If the student responds that "dark" is not an adjective, he has incorrectly identified an example of an adjective as a nonexample of an adjective (i.e., he has undergeneralized). In such a case, the instruction likely failed to include examples which have few missing critical attributes (i.e., difficult examples), or failed to provide adequate practice. The undergeneralization can be corrected by presenting difficult examples and feedback which identifies the missing attributes (see Appendix B).

Presenting content. One method for presenting content for instruction (after the initial concept analysis and content structuring is done) is outlined in a series of steps developed by Merrill and Tennyson (1977):
1. **Present Definition:** Names the concept, identifies the relationship to the superordinate concept, and defines its critical and variable attributes.

2. **Provide Expository Instance:** Presents information drawn from an instance pool of matched examples/nonexamples, but does not solicit an overt response from the student.

3. **Provide Inquisitory Instance:** Presents information from a random sample of unmatched examples/nonexamples and solicits an overt response from the student about this information.

4. **Provide Practice:** Draws from the same set as above in a divergent, random fashion with examples ranging from easy to difficult.

5. **Provide Feedback:** Isolates the critical and variable attributes and continues to provide examples in order to correct for undergeneralization, overgeneralization, or misconceptions; once criterion is reached the learner can go on to a higher level of the same concept, or on to a coordinate concept, if available.

The above method for presenting content represents one of three types of structure discussed by Tennyson (1981) (i.e., the structure of the content as represented by the instruction). The other two types are the structure according to the discipline and the structure as it resides in the learner’s memory. According to Tennyson, instructional content structure has the potential of providing a bridge between the discipline’s structure and the learner’s memory.
structure. By looking at a discipline's content structure in reference to instructional content structure, inferences can be made about an individual's information processing and memory storage (Tennyson, 1981), which in turn can effect further changes in the instructional content sequence.

**Conclusion: Content Structure**

The cognitive structures which students utilize or evolve in a learning process depend largely on the content structure they encounter in the material to be learned. The structuring and sequencing of concepts can affect the manner in which the concepts are acquired and retained for future use. Thus content structure and ultimately the presentation of the content to the learner are seen as central to the instructional process. Instructional content structure can be designed to act as a bridge between the content structure of the discipline from which it is derived, and the structure of the material as it resides in a learner's memory. Principles from the psychology of human learning can guide content structuring to facilitate appropriate matches between learner and task.

The process of content structuring does not require the aid of a computer. However, to enable the method for content presentation previously outlined to operate interactively as a form of instruction requires a computer-based format. Merrill, Tennyson, Reigeluth, and a host of other researchers have conducted experimental work on content structuring, but few studies have been conducted which incorporate
this method in the development of CBE courseware. The courseware developed for this study incorporated the basic elements of the method outlined above, and also provided a context for the investigation of the independent variables of questioning and feedback.

Questioning

The role of questioning in instruction has been a significant concern among educators for well over a half-century. Piaget and Dewey (Newton, 1978) proposed intellectual development through questioning, and over the years educators have advocated the use of effective questions to stimulate thinking among learners (Burton, 1929; Hunkins, 1968; and Taba, 1967). The interest of educators in the use of questions is reflected in (a) the many classification systems for categorizing questions which emerged during the 60's (Gall, 1970) and in (b) the inclusion of these systems in teaching methodology textbooks in the 70's (Ryan, 1973).

Despite the level of interest, Gall (1970) concluded that in the fifty years prior to his research there had been no essential change in the types of questions teachers emphasized in the classroom. About 60 per cent of teachers' questions require students to recall facts, 20 per cent require students to think, and the remaining 20 per cent are procedural. In short, little is known about student behavior caused by different types of questions (Buggey, 1972; Dunkin & Biddle, 1974; Hunkins, 1972; Rosenshine & Furst, 1971; Ryan, 1973; Savage, 1972; and Tyler, 1972).
Even though only 20 per cent of the questions asked in the classroom require the learner to think (Gall, 1970), few persons would disagree that helping learners develop creative and critical thinking abilities is a major purpose of education. Watson and Glaser (1964) defined critical thinking as the composite attitudes of inquiry; knowledge of inferences, abstractions, and generalizations; and skills in applying the above. Dressel and Mayhew (1954) identified a range of abilities related to critical thinking, including the ability to (a) define a problem (analysis), (b) draw valid conclusions (synthesis), and (c) judge the validity of inferences (evaluation). The extensive use of advance organizers and adjunct questions in textual material are two examples of attempts to design materials aimed at developing critical reading and thinking skills.

Cognitive processing. Andre (1977, p. 3) defined a question as "a direction to a learner to examine instructional material or his memory of it to produce some response." In this sense, a question is an instructional tool designed to cause a learner to cognitively process facts and concepts within a given content domain in order to gain further understanding of that content. Similarly, Merrill (1983, p. 306) characterized questions as inquisitorial presentations designed to cause a student "to respond by completing the statement or applying a given generality to a specific case."

O'Neill (1979) defined the cognitive processing required to respond to three orders of questions: (a) low-order questions require
little or no interpretation or insight into cause and effect or underlying relationships, (b) mid-order questions require at least some interpretation of underlying factors or causes, and (c) high-order questions require answers that show a high degree of cognitive organization and perception of underlying principles and relationships.

O'Neill's (1979) definitions indicate the importance of appropriately worded questions that will stimulate a learner's cognitive processing. Good questions are difficult to replicate consistently in conventional classroom instruction because much of the instruction is extemporaneous. Thus, CBE courseware that has been systematically developed to incorporate levels of questioning and feedback will influence the quality of instruction.

Ryan (1973) dichotomized questions into low levels (recall category) and high levels, which includes process, relationship, application, educated guess, synthesis, and opinion. Ryan found that high-level questions were more efficient than low-level questions for moving students toward both low and high level understandings because high-level questions require students to recall facts and data, then analyze and synthesize the data before responding to higher level questions.

Recall questions may also be referred to as verbatim questions in which only very specific information is requested, such as to fill in a specific word in a sentence. However, verbatim questions tend to enhance posttest performance only for information that is pertinent to
the question. Retention of incidental material or posttest performance of problem solving are generally not affected by verbatim questions and in some cases decreases in retention or performance have been measured (Cook & Mayer, 1983).

**Levels of learning.** To facilitate verbatim encoding is only one function of question answering. Cook and Mayer (1983) also discuss the functions of building internal and external connections with the aid of what they call structural and integration questions. Structural questions focus on "the logical or sequential relations among events or elements" (p. 113) which may encourage the learner to look for internal relations (or connections) and are analogous to questions requiring the learner to use the cognitive skills of application and analysis. Integration questions cause a learner to find relations between the (external) subject material and his existing knowledge base and are analogous to questions requiring the learner to use the cognitive skills of synthesis and evaluation. Several reports cited by Cook and Mayer (1983) indicated that structural and integration questions have enabled students to make the necessary internal and external connections to successfully encode a broad range of information.

The work of Ryan (1973), O'Neill (1979), and Cook and Mayer (1983) suggests that the level of questions defines the level-of-learning resulting from the instruction, and therefore should be conducted purposefully and systematically. "Level-of-learning"
means that the instructional intent of the question should have a direct bearing on the level at which information is processed and subsequently learned. The correspondence of level-of-question to level-of-learning cannot always be guaranteed because of the idiosyncratic nature of most learning strategies resident in the learner, but the correspondence can be enhanced with greater precision by writing questions that use specific verbs according to the desired level-of-learning (see Appendix C for a list of verbs for stating cognitive outcomes).

Each time a decision is made to provide instruction to a learner, an accompanying decision of level-of-learning should be made. Several taxonomies of instructional objectives have been developed, but Bloom's Taxonomy of Educational Objectives (1956) is the most widely known and accepted, and exhibits the characteristics of validated communicability, usefulness, and suggestiveness; emphasis on types of learning tasks generally encountered in instructional environments; quality documentation; and congruence with the structure of knowledge and the tasks learners are expected to perform within the structure of knowledge (Hall et al., 1983; Madaus, Woods, & Nuttall, 1973; Seddon, 1978).

Bloom's taxonomy defines the cognitive behaviors required of the learner at each level as follows:

Knowledge -- repetition of information in the form it was presented. Questions at this level are often labeled factual or recall questions.
Comprehension -- recognition or production of some paraphrase of material presented in instruction.

Application -- use of presented information in some new situation. Application could include recognizing new examples of a concept or using a principle in a problem solving situation.

Analysis -- decomposing a given situation into its component parts and analyzing their relationships. Analysis typically requires the use of some previously taught scheme to decompose the whole, for example, the student may be assigned to interpret the elements of a short story based on the writing techniques associated with a particular literary form.

Synthesis -- requires production of some product given appropriate elements (e.g., writing a short story).

Evaluation -- requires judgments about the value of information, concepts, or ideas relative to some goal or purpose.

Prior use of Bloom's taxonomy and other similar taxonomies (Gagne, 1962; Merrill, 1971) has been restricted primarily to conventional instructional environments. While the use of such taxonomies may provide positive results in some individual classrooms, the research literature does not establish definitive outcomes which indicate higher achievement due to higher-level questioning (Strykowski, 1983). Much of the earlier data was collected through classroom observation of instructional events which were not replicable (Andre, 1979). Andre concluded that "observational
research on teachers' in-class questions is not an appropriate vehicle for systematically examining the effects of higher-level questions on student learning" (p. 283).

If knowledge is produced in response to questions, and new knowledge results from the asking of new questions (Postman & Weingartner, 1969), the ability to form concepts and the ability to formulate and respond to questions are related. In order to formulate questions and build concepts, a learner must be able to identify and discriminate critical and variable attributes, discriminate examples from non-examples, generalize to new examples, discriminate between concepts and create new concepts. Research-based instructional principles for helping learners gain these skills have been developed (Klausmeier, Ghatala, & Frayer, 1974; Markle & Tiemann, 1969; Merrill & Tennyson, 1977). CBE now provides a means of verifying these principles and of designing courseware based on these principles.

Conclusion: Questioning

Questioning learners (and encouraging learners to question) appears to be a commonly accepted process for achieving the higher cognitive goals of education. Indeed, the importance of questioning in instruction has been a dominant concern among educators for well over a half century. Bloom's taxonomy was cited for its usefulness in defining the cognitive behaviors required of the learner at the various levels of learning. The levels of questioning that are intended to stimulate these cognitive behaviors need to be
interrelated with the content structure. Thus, the degree to which concepts have been defined and structured will affect the quality of the questions a courseware author can write. The development of quality CBE courseware necessitates that questions be constructed and presented with greater precision. Courseware which incorporates structural and integrative approaches to questioning analogous to levels within Bloom's Taxonomy will produce powerful instructional material that enables learners to attain the desired level-of-learning.

Feedback

Historically, man has always expressed a desire to exercise some control over his environment. Particularly since the Industrial Revolution there has been "a conscious effort by man to analyze elements in his environment and to control them automatically" (Smith & Moore, 1976, p. 354). As the ability to analyze and control the performance of complex devices and processes grew, a unified body of knowledge developed, which by 1950 was called "feedback control theory" (Smith & Moore, 1976). Hence, the term "feedback" is technical in origin. By the late 1950's "feedback" appeared in the experimental psychology literature and has since appeared in the educational research literature, although feedback terminology generally has not been used with much consistency (Joseph & Maguire, 1982).
Origins in experimental psychology. The feedback literature from experimental psychology studies conducted in the late 50's and early 60's was based on experiments conducted in laboratory environments and reflected a behavioral orientation. Much of this literature was generated by Skinner and focused on the effects of item-by-item feedback as a reinforcement mechanism for specific behaviors. Skinner's original operant conditioning paradigm was based on animal studies, but he later transferred this concept to the teaching machine for human learners (Skinner, 1954, 1968). Operant conditioning is nothing more than an explanation of the process of "reward and punishment" in which the reward or punishment is contingent upon some specific behavior. Thus for Skinner teaching could be reduced to the arrangement of contingencies of reinforcement which are manipulated with precision to shape and control behavior. His research was not concerned with non-observable cognitive events.

When Skinner transferred his paradigm to the teaching machine, he was not applying the same topography of behavior to humans as he did to pigeons or rats. Humans were recognized as far too complex. Yet Skinner believed that certain basic human processes in man responded to contingencies of reinforcement in much the same way as these processes did in animals (i.e., the more often a learner received immediate feedback or reinforcement for a particular response the more likely he was to acquire and retain that response). Skinner's rationale for immediate feedback for instructional purposes was based on the assumptions that immediate feedback "holds interest" (and thus
shapes thinking behavior), and immediate feedback encourages more careful reading of programmed instruction than in conventional reading texts where the consequences of attention or inattention are long deferred.

With these assumptions in mind, Skinner sought ways in which his operant conditioning model could be applied to rectify problems he encountered in conventional educational practices. He observed that students often failed to progress in their education beyond a general set of abilities because their learning processes or experiences lacked precise contingencies at the appropriate learning moments. The teaching machines he devised utilized contingencies of reinforcement to establish desired behaviors. Shaping behavior in this way was the process of bringing responses (the outcomes of thinking) under the control of appropriate stimuli. The established behavior served as evidence of a learner’s mental states or processes. His lack of concern with the development or structure of these mental processes became a point of departure between Skinner and contemporary cognitivists who were researching the mental constructs necessary for learners to engage in higher-level processes such as analyzing, synthesizing, evaluating and problem solving.

Origins in cognitive psychology. Kulhavy (1977), questioned the use of feedback for simple reinforcement and asserted that Skinner's operant conditioning model did not apply outside laboratory conditions. He defined feedback as a generic term to describe any of
numerous procedures that inform students about their progress through a test or body of instruction and felt that this definition would help circumvent the confusion often caused by diffuse terms such as Knowledge of Response (KR), Knowledge of the Correct Response (KCR), Correctional Review (CR), etc. (Kulhavy, 1977). The confusion to which he refers might decrease if feedback researchers treated the various terms as subordinate concepts to the superordinate concept of feedback. Attention might then focus on the critical attributes of each form of feedback to make clearer distinctions possible.

As more educational researchers became interested in feedback conditions the feedback literature began to reflect a greater diversity of perspectives and research designs (see Table C in Appendix D). Some researchers focused on feedback in relation to academic self-concept (Joseph & Maguire, 1982), while others were concerned with the inability of feedback to alter a student's natural problem solving strategies (Steinberg, 1980). Most of the feedback literature includes the effect of feedback versus no-feedback conditions on test or task performance, delayed versus immediate feedback, some combination of no-feedback and delayed feedback, and response confidence. When viewing the majority of studies to date a great deal of controversy has revolved around the efficacy of delayed versus immediate feedback. However, most of these studies focused on verbal learning tasks and not tasks involved with discrimination learning or concept formation and acquisition.
The concept instruction research of Merrill and Tennyson (1977) is the earliest example of a formal comprehensive effort to explicate the uses of an instructional form of feedback from a cognitive perspective. Their work is based on several major propositions, one of which is the most relevant for an understanding of feedback as used in this study:

Correct classification of newly encountered instances is more probable if during instruction using "example" presentations each instance is accompanied by attribute isolation and if during instruction using "practice" presentations a learner's response (either right or wrong) is followed by attribute isolation feedback.

(Merrill & Tennyson, 1977, p. 203)

This proposition is supported by earlier studies conducted by Merrill and Tennyson (1971), Young (1972), and Tennyson, Steve, and Boutwell (1975), in which the addition of attribute isolation to the concept learning task yielded significant results on posttest performance. Young's study in particular is relevant because treatment groups which were presented with instances in "practice" (inquisitory) rather than "example" (expository) mode performed significantly better on posttest performance.

Merrill (1983) has developed an even more extensive role for feedback in his Component Display Theory (CDT). In CDT Merrill defines a set of primary and secondary presentation forms (or strategies). The primary presentation forms (i.e., generalities and/or instances presented in an inquisitory and/or expository mode)
act as the major vehicles of instruction, and the secondary presentation forms serve as elaborations of the primary presentations. Merrill characterizes feedback as a secondary presentation strategy that facilitates student processing in support of the primary ones.

Feedback in its elaborative forms may vary from the presentation of the correct answer to a complete reworking of the problem with the student (Merrill, 1983). Although Merrill (1983) does not refer to attribute isolation feedback within CDT, he does emphasize the need for some degree of attention focusing feedback at appropriate points in the instruction to help indicate to a student how an alternative representation of an example corresponds to the original.

The use of "correct answer" feedback within CDT at first seems analogous to corrective feedback in a lesson that provides knowledge of results and perhaps a restatement of the concept to be learned. Corrective feedback (CF) has been consistently criticized as being incapable of producing "true concept learning" because it only serves as external reinforcement and does little to affect a learner's cognitive strategies (Inhelder, Sinclair, & Bovet, 1974). Cohen (1983) criticized CF for providing only minimal remediation and cited this factor as being "one of the greatest deficits that software programs exhibit" (p. 23). However, CDT does not prescribe feedback in isolation from the context of the rest of the instructional process. For example, "correct answer" feedback may also be accompanied by graphic or pictorial presentations of relationships or
may demonstrate the application of a principle to a particular example.

More than 50 experimental studies concerned with aspects of CDT have been conducted by Merrill (1983) and his associates. "There is considerable evidence to support the recommendations for secondary presentation forms" (Merrill, 1983, p. 331). Hence, the hypotheses for the present study have roots in earlier as well as current concept instruction research.

Corrective feedback in the present study might appear to be nothing more than a "straw man," but in comparison to earlier feedback studies in experimental psychology very little current data has been collected on appropriate forms and uses of feedback from courseware based on concept learning principles (see Note 1). Both CF and AIF were included in the research design for this study to test the effects of each separately and in combination with levels of questioning.

**Conclusion: Feedback**

Feedback was used in this study as an element within instruction that allowed the learner to build successively on the presented concepts. CBE generally requires immediate feedback as would a normal conversation or tutorial dialogue (Arons, 1984), although feedback delays or learner control of feedback can be built into courseware where it has been judged appropriate. Immediate feedback has been criticized for possible interference caused by constant presentation,
but this criticism has been raised only in a testing situation. Immediate feedback can be used to a student’s advantage, even in a testing situation, if instructions are given to pay attention to certain cues and if optimal time exists to study the relationships among the items. Variations can exist within the form of immediate feedback to match levels of questioning to produce high-quality interactive courseware.

A no-feedback condition was not relevant for this study. Research indicates that students in a no-feedback condition do not perform very well on posttests (Anderson, Kulhavy, & Andre, 1971; Gilman, 1969; Kulhavy & Yekovich, 1979; Sturges, 1978; Martin, 1981). The evidence was strong enough to warrant exclusion of such a condition from the present study.

**Summary**

The three sections of this literature review are interwoven by the common theme of instructional effectiveness within a computer-based learning environment. Instructional effectiveness was analyzed according to level of instructional question and the type of feedback provided. The investigated variables required that a comprehensive view be taken of the instructional process. Thus, content structure and sequencing were discussed first for their impact on the acquisition of concepts.

Merrill and Tennyson (1977) have developed a useful instructional design guide for teaching concepts. Tennyson (1981) incorporated
recent advances in cognitive psychology to expand the principle of content structure to include the structure of the content according to (a) the discipline or knowledge domain, (b) the instruction of that discipline or domain, and (c) the content structure as it resides in the learner's memory. Application of the instructional design principles should make a contribution towards the development of quality courseware for interactive computer-based environments.

Next, questioning literature was reviewed for its importance in establishing appropriate levels of learning. The research on questioning behavior both in students and teachers has approached the problem from a multitude of angles and has met with mixed success. Educators who conduct observational research have had difficulty establishing cognitive correspondence between teachers' questions and students' responses. Observational research is also difficult to replicate with precision.

The placement of questions in text (e.g., as advance organizers or as adjunct questions) has been shown to be helpful for some students but may not hold attention consistently over time. The use of appropriate questions is essential to a learner's concept development and great care should be taken with the development and presentation of questions. CBE now provides a means of verifying the principles put forth by Merrill and Tennyson (1977) and of designing courseware that includes more precision in questioning.
Feedback is integral to the questioning process if learners are going to have the opportunity to confirm, revise, or extend their levels of conceptual understanding. Research on the uses of feedback has been dominated by behavioral psychologists, but an expanded conception of feedback has been assisted through the development of information processing models. Although many forms of feedback have been investigated, attribute isolation feedback appears to offer the most promise for the interactive nature of CBE.

The development of quality computer-based courseware will require adherence to the most informed instructional design principles based on current knowledge of human learning. The combination of content structure with high-level questions and attribute isolation feedback based on these principles will likely result in powerful courseware. The present research was conducted to examine the effect of these instructional factors.
Chapter 3
RESEARCH METHODOLOGY

The literature review in Chapter 2 suggested the importance of cognitive processing in developing higher-level thinking skills. Students often lack the opportunity for deep cognitive processing in conventional classroom instruction because of normal differences of teacher preparedness, school environment, peer pressure, and student-teacher interaction. CBE offers the potential of consistent, high-quality instruction that can be designed to include such attributes as content structure, levels of questioning, and various forms of feedback to provide students with maximum opportunity for cognitive processing. Instructional principles need to be verified which support these and other attributes and which ensure the development of quality courseware. Insufficient evidence exists to support an optimum combination of instructional factors suitable for high-quality courseware development.

The methodology described in Chapter 3 was intended to yield data for subsequent analysis on one set of instructional factors (i.e., levels of questioning combined with forms of feedback). Included in this chapter are the research hypotheses, independent and dependent variables, an evaluation of question levels, the computer-based
lesson design, experimental controls, statistical procedures, descriptions of the pilot test and data collection settings, and internal and external validity of the study.

Research Hypotheses

The following general hypotheses were tested: (a) there will be a significant interaction between form of feedback and level of questioning from Posttest I to Posttest II, (b) there will be a significant main effect for level of questioning, and (c) there will be a significant main effect for form of feedback.

The primary hypothesis of the study was that students who received high-level questions and attribute isolation feedback in a computer-based lesson would perform significantly higher on Posttest I and Posttest II than students who received either high-level questions and corrective feedback, low-level questions and corrective feedback, or low-level questions and attribute isolation feedback in the same lesson.

The above hypotheses were derived from the literature review which indicated that high-level questioning is more likely to cause students to engage in deeper cognitive processing than low-level questioning. The case for attribute isolation feedback is not extensively supported by the literature and needs further substantiation.
Independent Variables

The independent variables (levels of questions and forms of feedback) were combined to create four combinations of questioning and feedback which were integrated with lesson content to form four versions of a computer-based lesson. Table 1 depicts the four combinations of questioning and feedback used in the research design.

<table>
<thead>
<tr>
<th>Experimental Treatments: Feedback Forms By Question Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feedback Forms</td>
</tr>
<tr>
<td>Corrective Feedback (CF)</td>
</tr>
<tr>
<td>Attribute Isolation Feedback (AIF)</td>
</tr>
</tbody>
</table>

Dependent Variables

The two dependent variables were scores on Posttest I and scores on Posttest II. Posttest II was similar to Posttest I in order to measure any retention effect caused by the combinations of questioning and feedback. Posttest I was administered one day after exposure to the experimental treatment. Posttest II was administered one week after exposure. Students were not informed that they were to take
Posttest II. Posttest I and Posttest II were treated as a repeated measurements factor within the research design (i.e., as a within-subjects factor). The two tests are often referred to subsequently as the posttests.

**Evaluation of Question Levels**

An evaluation of the question levels was conducted by submitting portions of the material to a neutral, independent panel for their review prior to the pilot test of the same materials. The neutral panel consisted of two high school science teachers from the data collection site, three graduate students majoring in instructional design, one graduate student in science education, and the director of a science program for gifted high school students. The purpose of the evaluation was to verify the accuracy of the questioning levels. The evaluation materials were paper and pencil instruments independent of a computer-based format (see Appendix E for sample evaluation materials).

To achieve the evaluation goals, the twenty questions intended for the high-level version were submitted to the panel. (Questions for the low-level version had already been determined by the researcher using the same evaluation tools). The high-level version contained some low-level questions because the initial subject matter required low-level questions to assist in the acquisition of the basic concepts. The panelists were asked to judge and code each question from 1-6 to correspond to the continuum of cognitive behaviors in
Bloom's Taxonomy, that is, from knowledge (recall) to evaluation respectively. Their judgments were also to reflect the prior science knowledge expected of the student at the beginning of the school year and the depth of cognitive processing being demanded by a particular question.

The seven panelists rated the twenty questions for a total of 140 separate ratings. Questions rated 1-3 were considered low-level and received 60% of the total ratings. Questions rated 4-6 were considered high-level and received 40% of the total ratings. The rationale for dividing the continuum into low and high ranges was to categorize the lesson version as either a low-level or a high-level version. The mid-range of the continuum (questions rated 3 or 4) received 56% of the ratings and may suggest overlap between the cognitive behaviors required of the learner at each level, and/or difficulty experienced by the evaluators in differentiating the two cognitive behaviors.

The evaluation results were used to rewrite some of the questions which had received a low-level rating so that the revised questions would be more likely to cause deeper cognitive processing. Some questions were rewritten for clarity. No further outside evaluations were conducted on these rewritten questions.
Reading Level

Reading skills among 11th and 12th-grade students can range from junior high to college level. The researcher designed the lesson material to be closer to the junior high level so that difficulty with reading did not become a confounding factor. Two samples drawn from the lesson yielded a Reading Grade Level (RGL) from 8.3 to 9.7 using the Flesch-Kincaid Readability Formula. The RGL was slightly higher than intended, but the teachers at the data collection site felt the material was appropriate to the level of work they expected of their students.

Computer-based Lesson Design

Lesson content. The computer-based lesson presented instructional material on the Xenograde System which is an imaginary system similar in structure to an atom or the solar system. Xenograde terminology and concepts were similar to the subject matter in a typical high school physics or chemistry course. The physical behaviors of components within the Xenograde System varied somewhat from normal physical laws which required students to generalize, extrapolate, problem-solve (i.e., to engage in deep cognitive processing). Although the Xenograde System has been used previously as a research vehicle (Arlin, 1973; Martin, 1981, Merrill, 1964; see Note 2), this researcher used concept mapping techniques to verify the internal consistency of the content structure.
Lesson content was fundamental, nontrivial, and identical for each version, but the levels of questioning and forms of feedback were varied. The levels of questioning corresponded to Bloom's taxonomy with low-level questions consisting of knowledge, comprehension, and application questions, and high-level questions consisting of analysis, synthesis, and evaluation questions. A high-level questioning condition contained a small percentage of low-level questions. From an instructional standpoint students presented with high-level questioning had the opportunity to function throughout the full range of question levels. Students presented with only low-level questioning were not afforded the same opportunity to develop the skills to function successfully with high-level questions. Therefore, the low-level questioning condition did not intentionally contain any high-level questions.

Lesson structure. The Apple SuperPILOT authoring system was used to develop four distinct modules to represent each of the four experimental conditions: (a) X1 - Lo/CF; (b) X2 - Hi/CF; (c) X3 - Lo/AIF; (d) X4 - Hi/AIF (the "X" stands for Xenograde). Each module began with two introductory screens that directed students to type their last name and initials and to await final instructions before beginning the lesson (see Appendix F for a sample lesson printout).

Screen format usually contained lesson concept(s), instructional questions (with reference to diagrams, tables, and/or answer options listed in the accompanying student booklet), a review option, and
corrective or attribute isolation feedback. Early in the lesson three to five sentences were required for concept presentation, while two or three sentences sufficed as the students became more familiar with the Xenograde System. Examples were presented as needed in the main body of the lesson.

Fourteen of the twenty questions in the lesson had one screen or less of concept information preceding them. Five questions had two screens preceding them, and one question had three screens. If concept information filled most of the screen, then the question and feedback appeared in sequence on the next screen.

Correspondence between question levels in the lesson presentation and the student booklet was extremely important. A few high and low questions had identical wording, but changes in numeric values within the question or in the graphs, diagrams, or tables in the booklet were intended to alter the degree of cognitive processing required.

Most answer options were presented in the student booklet to conserve screen space (see Appendix G). Students responded to questions by selecting the desired answer from a list of options (labeled a, b, c, and d) and by pressing the corresponding letter on the computer keyboard. The appropriate feedback was then displayed on the screen as shown in Table 2.
<table>
<thead>
<tr>
<th>Student Responses</th>
<th>Corrective Feedback</th>
<th>Attribute Isolation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Attempt</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct</td>
<td>&quot;Correct&quot;; student proceeds to next frame</td>
<td>&quot;Correct&quot;, plus summary of CAs.</td>
</tr>
<tr>
<td>Incorrect</td>
<td>&quot;Incorrect.&quot;</td>
<td>&quot;Incorrect.&quot;</td>
</tr>
<tr>
<td>(Review option)</td>
<td>(&quot;Would you like to see the information again?&quot; - presented for both CF and AIF conditions)</td>
<td></td>
</tr>
<tr>
<td><strong>Second Attempt</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct</td>
<td>&quot;Correct&quot;; student proceeds to next frame</td>
<td>&quot;Correct&quot;, plus summary of CAs.</td>
</tr>
<tr>
<td>Incorrect</td>
<td>&quot;Incorrect. The answer is: (full text of the correct answer).&quot;</td>
<td>&quot;Incorrect&quot;, plus summary of CAs and VAs</td>
</tr>
<tr>
<td><strong>No Second Attempt</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Program moves on automatically; no additional feedback provided)</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Where diagrams are presented in the student booklets as answer options, only the letter representing the diagram is used as feedback in corrective feedback conditions.
Table 2 shows the form of feedback provided for correct and incorrect responses following students' first and second attempts on question presentations (see Appendix H for a corresponding flow chart). The terms "critical attributes" and "variable attributes" are designated by the letters CAs and VAs respectively.

The review option following all first incorrect responses was intended to cause students to pay careful attention to avoid undesired screen repetition, to reduce guessing, and to provide an opportunity to review essential information. However, the review option did not allow a second chance without screen repetition and risked creating a sense of tedium in the learner by repeating the information in the same format.

Sample lesson screens illustrating each form of feedback are presented in Figures 2, 3, and 4. (The figures are formatted to represent the 40-column screens as viewed by the students). The label in each screen's upper left corner was inserted to help students keep track of their place in the lesson. For example, label D4.1 corresponds to Diagram 4 in the booklet.

For Figures 2 and 3, assume that the concept information has already been presented to the student. In Figure 2, the student read the paragraph, referred to Diagram 4, and attempted to answer the question. If the student answered incorrectly on two successive tries, corrective feedback was presented on the same screen with the question.
D4.1

Refer now to Diagram 4. The three rows of drawings represent the nucleus at various times. Which row of drawings shows breathing as it was just explained?

The answer is:

C  The drawings labeled C show the outward phase of the breathing cycle.

Figure 2. A question and feedback example from the Lo/CF treatment.

D8.2

In Diagram 8, a complete exhale phase and the beginning of an inhale phase are shown. How many total alphon seconds does it take for this system to complete its inhale phase?

Correct. Note that the xenograde system at Time-0 has 6 alphans. Thus, 6 seconds are required for the exhale phase (complete at Time-6) and 6 seconds are required for the inhale phase (complete at Time 12).

Figure 3. A question and feedback example from the Hi/AIF treatment.
Figure 3 illustrates a concept from the Hi/AIF treatment. If a student answered the question correctly a brief summary of critical attributes was presented.

Figure 4 illustrates the attribute summary, that is, a complete summary of critical and variable attributes. If a student answered incorrectly on two successive tries on the same question as in Figure 3, the attribute summary was presented on a different screen.

D8.3

ATTRIBUTE SUMMARY

An alphon second is a constant in Xenograde Systems.
The xenograde system in Diagram 8 has 6 alphones in the nucleus' center at Time-0.

For the 6 alphones to migrate outward (exhale) requires 6 alphon seconds.

Figure 4. A feedback example after two successive tries from the Hi/AIF treatment.

The lesson structure with its concept definitions, critical and variable attributes, examples, questions, feedback, and accompanying diagrams and graphs in the Student Lesson Booklet provided a source of cues to enhance transferability and later retention of the lesson.
material. "The more broadly based a learned capability, the better chance it will have to transfer to new and different situations" (Gagne, 1977, p. 296). Students had an opportunity with the xenograde material to transfer information as they encountered the successive development of the various concepts. Retention of the lesson material was measured with the use of posttests.

**Experimental Controls**

**Randomization.** The research was conducted in a public school setting in which students were randomly assigned within a given class to one of the four experimental treatments. Administration of the experimental treatments to the different classes occurred at various times throughout the school day and on two successive days (see Appendix I for the Data Collection Schedule). Potentially confounding factors such as time of day, mental fatigue, and hunger were distributed throughout all groups by random assignment of students to experimental treatments.

**Time-on-Task.** Time-on-Task (TOT), the length of time required for completion of the computer-based lesson, was recorded for each individual student during pilot testing and data collection. Knowledge of TOT from the pilot test was intended to provide general information on the average length of time students in the experimental conditions might need for completion. Knowledge of TOT from the data collection was important to determine the potential influence of TOT
as a covariate that could influence student performance on the posttests since subjects within any given experimental condition could complete the lesson at different rates.

**Posttests.** Posttest I and Posttest II were identical in content but not identical in structure. Each posttest contained ten items with high-level and low-level questions present in both forms of the tests in nearly equal percentages to span the full range of Bloom’s Taxonomy. The stimulus and response options of each test item were specific to the knowledge domain encountered by the students in the CBE lesson. Item sequence in the Posttest I corresponded to the concept sequence developed within the lesson. Posttest II items were arranged randomly to diminish any advantage students might have gained in memorizing the sequence of Posttest I items. For the same purpose, the response options of five identical test items from each posttest were rearranged to create a different sequence for those items.

The posttest questions were adapted from Martin’s (1981) Xenograde quizzes. No independent judgment was obtained on the content validity of these posttests, but every effort was made to eliminate extraneous or distracting information.
**Hidden Figures Test.** The Hidden Figures Test (HFT) is a timed test divided into two parts with 16 items each. Test administration guidelines specify 10 minutes per part. The HFT was administered to assess the field-dependence and field-independence of the students. Students in the experimental study were not assigned to treatments based on HFT data.

**Statistical Procedures**

The experiment used the three-factor, repeated measures design known as the two between-one within-subjects design. This design is defined by between-subjects variables $A$ (levels of questioning) and $B$ (feedback conditions), which cross, and the within-subjects factor $C$ (scores on Posttest I and Posttest II) treated as a repeated measurements factor (Kennedy, 1978, p. 454). Three main effects ($A$, $B$, $C$), three first order interaction effects ($AB$, $AC$, $BC$), one second order interaction effect ($ABC$ - the primary hypothesis of the study) were investigated. The structure of this design is represented by Table 3.
Table 3

Data Matrix for Two Between-One Within-Subjects Design

<table>
<thead>
<tr>
<th>A Question Level</th>
<th>B Feedback Form</th>
<th>C Posttests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Attribute</td>
<td>Posttests</td>
</tr>
<tr>
<td></td>
<td>Isolation</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td>II</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n=83</td>
<td>Attribute</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Isolation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=44</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Corrective</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=39</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Attribute</td>
<td></td>
</tr>
<tr>
<td>n=71</td>
<td>Isolation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Corrective</td>
<td></td>
</tr>
<tr>
<td></td>
<td>n=31</td>
<td></td>
</tr>
</tbody>
</table>

Equal n's were not a requirement of the research design. No plans were made to randomly eliminate observations to achieve equal n's because of the limited number of observations and the potential loss of statistical power.

Description of Pilot Test Setting

A pilot test was conducted between October 29 and November 9, 1984, at a high school within the Columbus (Ohio) City School System. Randomization, retention testing, and the statistical procedures described previously were not components of the pilot test.
**Pilot test objectives.** The objectives of the pilot test were:

(a) to identify programming, typographical, and grammatical errors in the computer-based lesson, Student Lesson Booklet, and posttest;

(b) to detect logic errors in the sequence of the presented concepts;

(c) to detect logic errors within concepts;

(d) to verify the clarity of the questions associated with each concept;

(e) to verify correspondence of the items in the Student Lesson Booklet with the computer-based lesson material;

(f) to verify congruence between the lesson material and the posttest items;

(g) to identify general problems students might have in taking the HFT; and

(h) to determine the average length of time needed to complete the lesson.

The objectives of the pilot test were met by recording student criticisms of the computer-based lesson, the student booklet, and the posttest; by administering the posttest and the HFT; and by recording TOT.
Sample. The subjects for the pilot test consisted of 12 senior physics students described by their teacher as "above average." The subjects volunteered to participate after a brief explanation was made to the class about the nature of the research project in which their role was highlighted as subjects and as critics in a doctoral study aimed at gathering and analyzing information about the quality of computer-based learning materials.

By the end of the pilot test, eleven of the scheduled twelve had participated. One student was a "no-show" and no replacement could be found.

Scheduling. The time available for the pilot test was organized into consecutive two-day blocks for a two-week period. Students were told that the first day would be for the computer-based lesson, and the second day would be for a followup quiz.

Students had less than forty minutes for the lesson by the time instructions were completed. The experimenter obtained permission from the students' physics instructor to overlap the next period if necessary. Dialogue with students during the lesson increased the length of time for completion, but the average (minus the dialogue time) was in the 40 to 45 minute range. Some students did need an additional ten to fifteen minutes to finish.
Equipment. The physical facility was a small office specifically equipped for the pilot test with three 64K Apple IIe microcomputers, three Apple III green phosphor monitors, and dual disk drives for each computer, all borrowed from the computer lab. The lesson material was on one disk (inserted into Drive 1), and a record-keeping file was on a second disk (inserted into Drive 2).

Student introduction. The three micros were arranged in a tight L-shape in one corner of the office. As students entered the room they were told by the experimenter to take a seat at any available computer while the remaining student(s) arrived. The lesson material had already been booted in each micro with a menu of lesson files displayed on each monitor. No introductory screens had yet been developed. Students were asked not to depress any key(s) until the necessary instructions had been given.

Experimenter's instructions. The experimenter provided instructions to the students on matters related to their lesson assignment, the time period for lesson completion, certain hardware and software limitations, proper use of the Student Lesson Booklet, and the nature of the response / feedback conditions (see Appendix J for a complete set of the experimenter's instructions).
Remember that you are both a student and a critic of this lesson. Please point out any program bugs, typos, or grammatical errors. If you question the logic of something, let's discuss that as well. If you do not have any questions at this time, you may type '1' from the menu and begin.

Time-on-Task. Quiet dialogue with individual students during the pilot test on lesson-related matters may have extended the time needed for completion. The pilot test provided general information on the average length of time needed by students in the experimental conditions.

Lesson conclusion. As students finished the computer-based lesson, the experimenter reminded them to use the remaining time for their own purposes. When the period ended (or as the last student finished), the experimenter collected the student booklets, reminded the students of the posttest the next day, and thanked them for their time.

Data collection. Posttest I (see Appendix K), the Hidden Figures Test (see Appendix L), and student criticisms of the computer-based lesson material and/or of the Student Lesson Booklet were used as data sources. SuperPILOT System.Log (a utility program for recordkeeping) was also used in an effort to collect data on student interaction with the lesson.

The Posttest I and the Hidden Figures Test (HFT) were administered during the same time period on the second day of each
time block. The posttest was used informally in the pilot test to identify troublesome items but no statistical analysis of posttest data was planned or attempted.

The HFT was not administered as a timed test since none of the students had enough time to complete it. Administering the HFT enabled the experimenter to identify difficulties students might have during the data collection. For example, pilot test students reported that they attempted to devise a particular strategy for detecting the simple pattern - such as concentrating on the number of vertical lines in a figure in relation to a particular angle. This information caused the experimenter to alter the HFT instructions to allow an extra five minutes for the first part for subjects at the data collection site.

**System.Log.** System.Log was used to record student responses to the questions during the entire lesson. The student response data was organized into six categories: (a) the number of questions correct on the first try, (b) the number of questions missed only on the first try, (c) the number of times review was chosen, (d) the number of times review was not chosen, (e) the number of questions missed on the second try, and (f) the number of questions correct on the second try (see Appendix M for an example of the six categories and a sample System.Log printout).
Findings from the Pilot Test

Progression through the computer-based lesson required the subjects to have minimal keyboard skills for responding to the questions. None of the subjects had difficulty using a computer during the pilot test, which indicated that novice computer users at the data collection site would have no difficulty.

For the most part, the Student Lesson Booklet corresponded to the computer-based lesson, and the lesson material was congruent with the posttest items. Questions were rewritten for clarity as needed. Student criticisms and comments on the computer-based lesson, the Student Lesson Booklet, and Posttest I provided invaluable information for correcting programming, typographical, grammatical, and logic errors in preparation for the data collection site.

A programming error rendered all System.Log pilot test data incomplete. Thus, no profiles of student behavior could be developed for the pilot test. The System.Log variables were re-dimensioned and re-ordered within each lesson file as needed (see Appendix H for a complete explanation of the System.Log variables).

Description of Data Collection Site

Data was collected between December 3 and December 11, 1984, at a suburban high school outside the city limits of Columbus, Ohio. The objectives were to test the hypotheses regarding levels of questions and forms of feedback described earlier under Research Hypotheses.
The participating subjects had been told by their teachers prior to the beginning of the data collection that an individual from The Ohio State University would be coming as part of a research project using computers to study science capabilities among high school science students. They understood that their school had been selected because students taking courses from the science department had done extremely well over the last four to five years in statewide competition, and a well-equipped computer lab was available. Students were not told that the researcher was a doctoral candidate investigating specific hypotheses regarding the design of computer-based education. The researcher did explain the hypotheses in simple terms at the conclusion of each group's participation in the data collection.

Sample. A total of one hundred sixty-eight students from seven classes was originally available. Seven of these students were absent for the experimental treatments. Seven more were absent for Posttest II and the HFT and were consequently dropped from the study. The final sample size consisted of 154 subjects (male=88, female=66).

Scheduling. Subjects from seven classes participated in the data collection during periods normally scheduled for their chemistry classes and labs (see Appendix I for the Data Collection Schedule). The class periods were about twice as long as those available in the
pilot test. All students had been volunteered by their instructors and were expected to participate as part of their course work.

**Equipment.** The computer lab was equipped with thirteen Apple II+ and seventeen IIe microcomputers each with 64K memory. Dual disk drive systems were not available for all the micros.

The micros were equipped with a variety of monitors: ten Amdek Color 1's, three Amdek Ambers, six Apple III green phosphors, and eleven Apple IIe green phosphors. The use of different monitors created variations in the visual appearance of the computer-based lesson material, but no conclusive evidence exists to suggest that the visual differences might have altered the experimental treatment ("Strain Is in the Eye of the Beholder," 1984).

The lesson material and a data collection file were all contained on one disk. The SuperPILOT `pr:ug` statement at the beginning of each lesson file enabled the researcher to debug freely throughout any given lesson. The `g` in `pr:ug` corresponded to a GOTO command which could be typed at "answer accept" points in the lesson to move forward and backward. However, student lesson disks at the data collection site only had a `pr:u` statement which changed all responses to upper case before attempting a match but did not permit use of the GOTO command. The change in statements was necessary to prevent students with programming knowledge from interrupting their lesson sequence.
**Student introduction.** The micros were arranged around the perimeter of the room at individual desk-top stations and in a double row down the middle of the room. As students entered the room they were told by the experimenter to take a seat at any available computer while the remaining students arrived. The following screen of information was displayed on each monitor for the students to read:

---

**Welcome to XENOGRADE SYSTEMS**

Before you begin, listen to any instructions or introductions from your teacher and the evaluator.

When you are instructed to do so, please type in your LAST NAME and INITIALS, and then press the Return key. Please wait for the instruction.

---

Figure 5. Introductory screen for all computer-based lesson versions of the Xenograde System.

When the teacher arrived he introduced the experimenter: "This is Mr. Merrill from Ohio State University. Remember I said last week that he would be here today as part of a testing program to check on how well you are doing with your science concepts. So please give him your attention."
Experimenter’s instructions. The experimenter provided instructions to the students on matters related to their lesson assignment, the time period for lesson completion, signing on to the computer, certain hardware and software limitations, proper use of the student lesson booklet, and the nature of the response / feedback conditions.

Before you begin the lesson you will be randomly assigned to a computer, which may be different from the one at which you are currently sitting.

The experimenter then randomly passed out 5x8 cards on which were written an X1, X2, X3, or X4 to indicate the assigned lesson version. Placards on the top of each computer were likewise alternately labeled X1, X2, X3, or X4. Students were then told to move to a computer that matched the letter/number combination on their cards. Once the students were resettled they were told to write their name, the letter identifying their class period, and their class standing (sophomore, junior, or senior) on the 5x8 card. The 5x8 card was also used to record each student’s completion time for time-on-task data. After the students had filled out their 5x8 cards, the experimenter continued with the instructions (see Appendix N for a complete set of the experimenter’s instructions).

Use of Student Lesson Booklet. A student booklet was placed at each microcomputer for each student to use with the lesson diskette. Each booklet contained diagrams and answer options needed to progress
through the lesson. There were two versions of the booklet to correspond to the experimental treatments. Booklets labeled X1 / X3 contained only low-level questions and corresponded to treatments 1 (Lo/CF) and 3 (Lo/AIF). Booklets labeled X2 / X4 contained a mixture of low-level and high-level questions with a majority in the high-level range and corresponded to treatments 2 (Hi/CF) and 4 (Hi/AIF). The experimenter ensured that the booklets and diskettes matched before students began working. An additional page entitled Work Sheet was attached to each lesson booklet with two graphs on it on which subjects could write to help them with questions 19 and 20.

Lesson conclusion. As students finished the computer-based lesson, the experimenter quietly announced the current time which students recorded on their 5x8 cards in a column marked "Time Completed". Students were reminded to use the remaining time quietly for their own purposes and to be courteous to those still working. When the last student finished in each group, each student was asked to turn in a completed 5x8 card and the Work Sheet with his/her name at the top, even if the Work Sheet had not been used. Students were told to leave the lesson booklets where they found them for the next group to use and to remember to bring a #2 pencil the following day for the quiz. The class instructor returned about this time to give directions for use of remaining time in the period.
Some students asked about scores on the lesson. The experimenter explained that the data in the record-keeping file did not yield simple raw scores, and that the data was intended for analysis of how each student interacted with the material, not necessarily of how well each student did. The students were also told that complete posttest scores could be made available to their instructors at a later date. Most students probably developed a sense of how well they comprehended and utilized the material by the nature of their interaction with the program.

No program "bugs" appeared during the data collection. Some students did not get credit for an answer and brought this to the attention of the experimenter at the time it occurred (i.e., the program responded "Incorrect" to what the student was certain had been a correct answer). Lack of credit was apparently due to carelessness in entering the answer which resulted in the subject's answer not appearing on the screen. Where this occurred, the student generally made the mistake only once.

**Testing Instruments**

Posttest I, Posttest II, and the Hidden Figures Test were the instruments used to collect data for statistical analysis (see Appendices K, L, and O, respectively). The intervals between posttests were the same for each group.
**Posttest I.** Posttest I was administered to each group one day after exposure to the experimental treatment. Work Sheets from the previous day were passed back for reference during the quiz. The experimenter pointed out to the students that a number of them were tracing the satellite paths in a random fashion rather than in a definite pattern. They were reminded that the horizontal baseline (on the Work Sheet graphs) is the point at which a satellite collides with the nucleus before it can return to its original orbit. Students recorded their names, the number 1, 2, 3, or 4 (for X1, X2, X3, or X4, respectively) in the vertical grade column to identify their assigned lesson group, and the posttest answers on general purpose opscan forms.

All students had sufficient time in which to take Posttest I (42 minutes, one class period). Students were asked not to discuss the posttest contents with students from other groups.

Those who were absent from Posttest I made it up as soon as possible under the supervision of their own instructor with the same instructions as received by other groups. Their scores were analyzed separately to determine if any measureable differences existed when compared to group scores on the same posttest.

**Posttest II and the Hidden Figures Test.** Posttest II and the Hidden Figures Test (HFT) were administered as unannounced tests one week after initial exposure to the computer-based lesson. The opscan forms used for Posttest I were passed back so that students could use side two. The HFT was administered first because it is a timed test,
which then left sufficient time (about 42 minutes) for Posttest II. At the conclusion of both tests, all papers and answer sheets were collected. The experimenter then read the answers for both and thanked the students for their time and effort.

The HFT was introduced as a pattern recognition test designed to measure degree of analytical thinking—not as an instrument for measuring cognitive styles. This approach enabled the experimenter to avoid a discussion of the cognitive styles of field-dependence and field-independence. The experimenter discussed instead the assumption that highly analytical people are more successful with computers. Students were cautioned about getting too anxious if they felt they were not good at pattern recognition because it only represents one type of problem-solving ability.

Based on the amount of difficulty experienced by students in the pilot test, the experimenter decided to use Part I of the HFT as a "warmup" by extending the time limit from ten to fifteen minutes. The purpose of the "warmup" was to reduce the "learning-to-learn" effects of the task and to enable more time for actual problem-solving. The students received no clues regarding successful pattern recognition strategies, but the experimenter did emphasize from the printed HFT instructions that the simple figures could be found in the complex patterns without any changes in size or rotation.

Students were cautioned against indiscriminate guessing prior to taking the HFT. Scores were adjusted for guessing by subtracting a fraction of the wrong answers from the number correct.
Posttest II was administered immediately after HFT booklets had been collected. The experimenter explained to the students that Posttest II was intended to measure how much they remembered from Posttest I without an opportunity for study as an indication of how effectively the computer-based lesson taught the science concepts. Posttest II had the same content items as Posttest I, but the items had been rearranged so the answers to the items on side one could be of no use as answers on side two. No Work Sheets were handed out for Posttest II.

Threats to Internal Validity

Six extraneous variables that frequently represent threats to the internal validity of a research design are discussed here: historical events, maturation, pretesting, measuring instruments, subject mortality, and selection-maturation interaction.

The instruments in this study were administered one week apart which diminished the potential of a historical event affecting the dependent variable. However, a scheduled field trip caused some subjects to take Posttest I a day or two late. Absenteeism caused four subjects to take Posttest II a day or two late also. These events probably did not invalidate the subjects' scores because the retention effect from a concept-based lesson should be stronger than retention from other learning tasks in which rapid extinction would be expected (e.g., an associative learning task).
Maturation of subjects was not a factor because passage of time for the computer-based lesson was only about one hour. Fatigue, hunger, lack of motivation, or other developmental factors were assumed to be randomly distributed among all experimental treatment groups although occurrence of these factors was not likely over such a short duration.

Pretesting exposure may affect a subject's performance on a subsequent test because the pretest sensitizes the subject to the lesson material. The research design for the present study did not include pretesting because it was assumed that subjects had no prior knowledge of the Xenograde System, and a retention effect observed from Posttest I to Posttest II was more valuable to the present study than a pretest - posttest comparison.

Posttest I and Posttest II were identical in content although not identical in structure. Therefore, difficulty level should not enter in as a causal factor of any observed differences in the two test scores.

Experimental mortality refers to loss of subjects over the course of an experiment. The short time span over which data was collected reduced experimental mortality. The research design also accounts for this by accepting unequal n's.

Selection-maturation interaction can be a problem where intact groups are used rather than randomly selected ones (i.e., intact group characteristics may influence experimental outcomes). Although intact groups were used in this study, use of the individualized,
computer-based treatments allowed random assignment of subjects within an intact group to one of four experimental treatments. Through random assignment the characteristic of higher rate of maturation within a particular intact group was probably dispersed among all groups.

**Threats to External Validity**

External validity was categorized into population validity and ecological validity. Population validity could have been enhanced if the subjects were drawn from a less restricted sample range. The subject sample consisted of 154 chemistry students in a predominantly white suburban high school in an area with a middle-high socio-economic status.

Ecological validity effects applicable to the present study were novelty effects, the experimenter effect, and the Hawthorne effect. The novelty of working with a microcomputer might be a factor in some settings, but the subjects attended a school where a microcomputer laboratory had been established and use of the laboratory was commonplace.

Experimenter effect is not likely to have introduced bias since the experimenter did not deliver content instruction or gather observational data. The experimenter introduced all students to the use of the computer, answered procedural questions, and monitored student use of the lesson. The experimenter also administered all posttests except in cases of absenteeism and schedule conflicts.
The Hawthorne effect is always a possibility in any experiment because a subject's knowledge that he or she is participating in an experiment may alter his or her response to the experiment. Changes in student behavior as a result of participation in the experiment may be attributed to positive or negative attitudes toward the aims of experimentation, desirability to do the right thing, and/or evaluation apprehension.

Attitude and desirability could not be controlled by the experimenter, and it is assumed that their potential influence was randomly distributed throughout the experimental treatment groups. The natural school setting probably decreased potential confounding by attitudes and desirability. A foreign setting (e.g., a clinical laboratory) with experimental activities dissimilar to those normally encountered in school would be more likely to mold subject behavior in ways uncommon to a real world setting.

Attempts to minimize evaluation apprehension were made by emphasizing to the subjects that the structure of the computer-based lesson was the object of the research activity - not their individual abilities. The terms "study," "evaluation," and "project" were used synonymously over the course of the data collection to describe to the students the nature of their involvement. The description, "You are subjects in an experiment," was never used. This approach was used to help diffuse the apprehension often attributed to the Hawthorne effect. Any apprehension effects in the lesson mode were assumed to have been randomly distributed.
Posttests I and II were used as testing instruments to obtain the scores needed for analysis of the hypotheses. The Hidden Figures Test (HFT), SuperPILOT System.Log (a record-keeping utility), and time-on-task were used as additional data sources. The posttest results and analysis are reported first since they provided the principal data source for determining the existence of the interactions and main effects needed to support the research hypotheses. Time-on-task and HFT data, an instrument reliability analysis, and System.Log data are reported after the hypotheses are evaluated.

Posttest Results

The sample (N=154) represented the number of students on whom complete posttest data was collected. The random assignment of the sample resulted in the assignment of 31 students to Lo/CF, 39 students to Hi/CF, 40 students to Lo/AIF, and 44 students to Hi/AIF. The distribution across class standings for each experimental group is shown with posttest means in Table 4.
Table 4
Composition of Experimental Groups by Class Standing by Treatment with Posttest Means

<table>
<thead>
<tr>
<th>Experimental Group</th>
<th>Class Standing</th>
<th>Posttests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soph.</td>
<td>Jr.</td>
</tr>
<tr>
<td>Hi/AIF</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>Hi/CF</td>
<td>3</td>
<td>32</td>
</tr>
<tr>
<td>Lo/AIF</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td>Lo/CF</td>
<td>3</td>
<td>26</td>
</tr>
<tr>
<td>Totals</td>
<td>14</td>
<td>128</td>
</tr>
</tbody>
</table>

Percentage of Sample
9%    83%   8%   100.0%

Note. The posttest means have not been adjusted for unequal n's and are slightly different from those means presented in Table 7.

The sophomores were advanced placement students, and the seniors were taking chemistry to complete their science credits for graduation. Both sophomores and seniors had been assigned earlier in the school year to the junior classes by the school's scheduling office. Prior to statistical analysis of the posttest data the individual Hi/AIF scores were examined to determine if the distribution of sophomores, juniors, and seniors across treatment groups contributed to the Hi/AIF group doing better than the other groups. Analysis of the individual class means within Hi/AIF suggested that the presence of the eight advanced placement sophomores increased the Posttest I mean for Hi/AIF. This effect diminished in Posttest II as shown in Table 5.
Table 5

Posttest Means for Hi/AIF Treatment Group by Class Standing

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Posttests</th>
<th>Combined Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hi/AIF</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>Soph.</td>
<td>Jr./Sr.</td>
<td>Jr./Sr.</td>
</tr>
<tr>
<td>8.12</td>
<td>7.22</td>
<td>6.25</td>
</tr>
<tr>
<td>7.22</td>
<td>6.25</td>
<td>6.61</td>
</tr>
<tr>
<td>6.61</td>
<td></td>
<td>7.19</td>
</tr>
<tr>
<td>7.19</td>
<td></td>
<td>6.92</td>
</tr>
</tbody>
</table>

The combined mean for the Hi/AIF sophomores was virtually identical to the combined mean for the Hi/AIF juniors/seniors. The presence of the sophomores in Hi/AIF does not seem to have given that group an undue advantage. The absence of advanced placement sophomores in Lo/AIF may or may not have contributed to that group's lower scores. Therefore, the data obtained from the sophomores was retained in the study for further analysis.

Late posttest scores. Some posttests were administered one or two days late because of absenteeism or the instructor's schedule. Of the ten students (6X) who took Posttest I late, six scored above the group mean (X=6.61, s=2.03), three were .29 of one standard deviation below the mean, and one was slightly more (1.28) than one standard
deviation below the mean. Scores from the late Posttest I group were retained for analysis because most of the scores were above the total group mean.

Four students (2.5%) took Posttest II late, but no single student took both posttests late. Of the four students, one scored above the group mean (X=5.97, s=2.29), one was .92 of one standard deviation below the mean, one was slightly more (1.23) than one standard deviation below the mean, and one was almost two (1.84) standard deviations below the mean. Scores from the late Posttest II group were retained for analysis because one was a perfect score, two were in the same standard deviation range as 17.4% of the total sample scores, and the fourth score, although low, was only .61 of a standard deviation below the score immediately preceding it.

Unweighted means analysis. The experimental groups contained unequal and slightly disproportionate n's at the conclusion of the data collection. The method of unweighted means was chosen as the most appropriate form of analysis (Kennedy, 1978, p. 291) since the unequal n's resulted from the random assignment process and subject mortality and not from the nature of the specific treatments. The analysis of variance summary is presented in Table 6, and the interaction and main effect means of the experimental groups are presented in Table 7.
Table 6
ANOVA Summary for Interaction and Main Effects Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Between Ss</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question Level(A)</td>
<td>1</td>
<td>92.92440</td>
<td>17.26162***</td>
</tr>
<tr>
<td>Feedback Form(B)</td>
<td>1</td>
<td>0.00959</td>
<td>0.00178</td>
</tr>
<tr>
<td>(AB)</td>
<td>1</td>
<td>15.20261</td>
<td>2.82403</td>
</tr>
<tr>
<td>S/AB</td>
<td>150</td>
<td>5.3833</td>
<td></td>
</tr>
<tr>
<td><strong>Within Ss</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttest (C)</td>
<td>1</td>
<td>11.64879</td>
<td>6.87796**</td>
</tr>
<tr>
<td>(AC)</td>
<td>1</td>
<td>10.91805</td>
<td>6.44650*</td>
</tr>
<tr>
<td>(BC)</td>
<td>1</td>
<td>3.02558</td>
<td>1.78643</td>
</tr>
<tr>
<td>(ABC)</td>
<td>1</td>
<td>2.65896</td>
<td>1.56997</td>
</tr>
<tr>
<td>SC/AB</td>
<td>150</td>
<td>1.69364</td>
<td></td>
</tr>
</tbody>
</table>

* p < .05  
** p < .01  
*** p < .001

Three main effects (A, B, C), three first order interaction effects (AB, AC, BC), and one second order interaction effect (ABC - the primary hypothesis of the study) were investigated. From Table 6 it can be observed that one interaction source and two main effects were statistically significant: the question-level by posttest interaction (p < .05), the question-level main effect (p < .001), and the posttest main effect (p < .01). The primary hypothesis of a question-level by feedback by posttest interaction was not sustained.
Table 7
Interaction and Main Effect Means from Posttests I and II by Question Level by Feedback Form

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>n</th>
<th>Posttest I</th>
<th></th>
<th>Posttest II</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>X</td>
<td>s.d.</td>
<td>X</td>
<td>s.d.</td>
</tr>
<tr>
<td>Hi/AIF</td>
<td>44</td>
<td>7.773</td>
<td>1.816</td>
<td>6.614</td>
<td>2.137</td>
</tr>
<tr>
<td>Hi/CF</td>
<td>39</td>
<td>6.942</td>
<td>1.835</td>
<td>6.564</td>
<td>2.049</td>
</tr>
<tr>
<td>High-Level</td>
<td>83</td>
<td>7.361</td>
<td>1.739</td>
<td>6.589</td>
<td>6.975</td>
</tr>
<tr>
<td>Lo/AIF</td>
<td>40</td>
<td>5.650</td>
<td>1.902</td>
<td>5.625</td>
<td>1.462</td>
</tr>
<tr>
<td>Lo/CF</td>
<td>31</td>
<td>6.097</td>
<td>1.739</td>
<td>6.097</td>
<td>2.006</td>
</tr>
<tr>
<td>Low-Level</td>
<td>71</td>
<td>5.874</td>
<td>5.861</td>
<td>5.867</td>
<td>5.867</td>
</tr>
<tr>
<td>Total</td>
<td>154</td>
<td>6.675</td>
<td>1.996</td>
<td>6.240</td>
<td>1.957</td>
</tr>
</tbody>
</table>

Note. The posttest means have been adjusted for unequal n's and are slightly different from those means presented in Table 4. Individual means were rounded. The total means for each posttest were taken directly from the computer output to avoid rounding error.

Interaction and main effects summary. The question-level by posttest interaction was significant with a difference of .77 between the high-level question means from Posttest I to Posttest II. The low-level question means were virtually identical and may represent a baseline for the experimental groups. A graphic representation of the question-level by posttest interaction would reveal that it was ordinal.
The question-level main effect indicated that students in the high-level question treatments performed better than students in the low-level question treatments at the .001 level of significance. The question-level main effect existed irrespective of feedback conditions.

The posttest main effect was significant at the .01 level with a decrease of .44 of one point from Posttest I to Posttest II. This result suggested strong retention over the one-week interval.

**Time-on-Task**

Task completion times varied from 25 to 58 minutes over the four groups. The TOT averages rounded to the nearest minute were: Lo/CF = 36; Hi/CF = 40; Lo/AIF = 39; Hi/AIF = 39. The differences among these TOT averages were not large enough to warrant using TOT as a covariate. For example, the Hi/AIF condition did not cause a student to spend much more time in the lesson on the average than the Lo/CF condition. Also, the spread of task completion times prohibited using TOT as a blocking variable because the n's per cell would have been too small.

The Lo/CF condition was expected to take less time than Hi/CF because low-level questions and corrective feedback would require less presentation time and less student processing time. Lo/AIF and Hi/AIF conceivably could have taken much longer than Lo/CF or Hi/CF because of the time required to read and process the attribute isolation summaries. However, when students in the Lo/AIF and Hi/AIF groups
were correct on the first try, as usually was the case, they did not
encounter the attribute isolation summaries and could proceed through
the lesson at an average pace similar to students in the Lo/CF and
Hi/CF groups. System.Log data supported this observation (see
condition 1 in Appendix M and Table D in Appendix Q).

Hidden Figures Test

The data collection schedule was arranged with the HFT in the
same class period as Posttest II. Administration of the HFT after the
experimental treatment risked violation of the ANCOVA assumption of
covariate-treatment independence (Kennedy, 1978, p. 408; Wildt &
Ahtola, 1978, p. 15). An ANCOVA was still computed as a check for any
differences that the HFT might have on the final analysis of variance
results. The ANCOVA yielded within-subjects results identical to the
unweighted means analysis. The ANCOVA between-subjects results were
slightly different in the numerical data, but the significant and
nonsignificant effects were the same. Thus, the HFT had negligible
impact as a covariate. The unweighted means analysis was retained as
the source of variance data.

A series of Pearson correlation coefficients was computed to
identify significant correlations between HFT and posttest scores
which might indicate a relationship between cognitive style and
posttest performance. (The Statistical Package for the Social
Sciences - SPSS-X - was used to compute the correlations). The
Pearson correlation coefficients between HFT and posttest scores are
shown in Tables 8, 9, and 10.

### Table 8

**Pearson Correlation Coefficients Between the Hidden Figures Test and Posttests I and II by Treatment Groups**

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>n</th>
<th>Posttests</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Hi/AIF</td>
<td>44</td>
<td>.3362*</td>
<td>.3053*</td>
</tr>
<tr>
<td>Hi/CF</td>
<td>39</td>
<td>.4545**</td>
<td>.4355**</td>
</tr>
<tr>
<td>Lo/AIF</td>
<td>40</td>
<td>.0695</td>
<td>.1782</td>
</tr>
<tr>
<td>Lo/CF</td>
<td>31</td>
<td>.3015</td>
<td>.1175</td>
</tr>
<tr>
<td>All Groups</td>
<td>154</td>
<td>.2821*</td>
<td>.2665</td>
</tr>
</tbody>
</table>

* * $p < .05$

** Table 9

**Pearson Correlation Coefficients Between the Hidden Figures Test and Posttests I and II by Question Level**

<table>
<thead>
<tr>
<th>Question Level</th>
<th>n</th>
<th>Posttests</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>High</td>
<td>83</td>
<td>.4285*</td>
<td>.3600*</td>
</tr>
<tr>
<td>Low</td>
<td>71</td>
<td>.1640</td>
<td>.1522</td>
</tr>
</tbody>
</table>

* * $p < .001$
Table 10

Pearson Correlation Coefficients Between the Hidden Figures Test and Posttests I and II by Feedback Form

<table>
<thead>
<tr>
<th>Feedback Form</th>
<th>Posttests</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>Attribute</td>
<td>84</td>
<td>.2375*</td>
<td>.2686*</td>
</tr>
<tr>
<td>Isolation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrective</td>
<td>70</td>
<td>.3383**</td>
<td>.2803*</td>
</tr>
</tbody>
</table>

* p < .05
** p < .01

The presence of significant correlations between HFT and posttests in the Hi/AIF and Hi/CF treatment groups was of sufficient interest to warrant the display of descriptive data in Table 11. The data shows posttest means for the field-dependent / field-independent subgroups within the experimental treatment conditions. The subgroups were derived from the full sample by applying lower third and upper third cutoff points (the 33.33 and 66.67 percentiles, respectively) to the distribution of HFT scores. Subjects in the lower third were classified field-dependent (FD), those in the upper third were classified field-independent (FI), while those in the middle third of the distribution were disregarded.
Table 11
Posttest Mean Scores for Field-Dependence and Field-Independence by Question Level by Feedback Form

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Posttests</th>
<th>Question Level Means Across Posttests(a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td></td>
<td>Cognitive Style</td>
<td>Cognitive Style</td>
</tr>
<tr>
<td></td>
<td>FD</td>
<td>FI</td>
</tr>
<tr>
<td>Hi/AIF 9 20</td>
<td>6.444</td>
<td>8.400</td>
</tr>
<tr>
<td>Hi/CF 19 9</td>
<td>6.316</td>
<td>8.556</td>
</tr>
<tr>
<td>(High) 6.380</td>
<td>8.478</td>
<td>5.834</td>
</tr>
<tr>
<td>Lo/AIF 14 13</td>
<td>5.357</td>
<td>5.615</td>
</tr>
<tr>
<td>Lo/CF 9 12</td>
<td>5.667</td>
<td>6.833</td>
</tr>
<tr>
<td>(Low) 5.512</td>
<td>6.224</td>
<td>5.405</td>
</tr>
<tr>
<td>Total 51 54</td>
<td>5.961</td>
<td>7.407</td>
</tr>
<tr>
<td>(N=105) s=1.990</td>
<td>s=1.938</td>
<td>s=1.948</td>
</tr>
</tbody>
</table>

Feedback Form
Means
AIF 5.783 7.303 5.348 6.879
Within CF 6.107 7.571 5.893 7.286
Posttests(a)

Note. Maximum score = 32.
(a) The question level means and the feedback form means were listed directly from the computer output to avoid rounding error.

The maximum raw score for the HFT was 32. The upper score value for the 33.33 percentile was 7.92 (X=2.95), and the lower score value for the 66.67 percentile was 15.00 (X=19.37). Fifty-one subjects were
classified as FD (33% of the full sample), and fifty-four subjects were classified as FI (35% of the full sample). Random assignment of subjects to experimental treatments resulted in the cell size differences.

Some general observations were made on the descriptive data in Table 11:

1. FI posttest scores were consistently higher than FD posttest scores across three of the four posttest comparisons. The exception was the FI scoring pattern in the Lo/AIF treatment which appeared very similar to the overall scoring pattern established by the FDs. FI posttest scores in the Lo/AIF treatment did go up slightly from Posttest I to Posttest II, but still remained slightly below the FD posttest scores in the Hi/CF treatment.

2. FD and FI subjects in the high-level question treatment had higher scores than their counterparts in the low-level question treatment.

3. FD and FI subjects in the corrective feedback condition had slightly higher group means than their counterparts in the attribute isolation feedback condition.

4. The magnitude of difference between the FD group mean and the FI group mean was 1.4 for each ten-item posttest. The similarity in posttest means contrasted with the difference in means on the HFT observed after applying the percentile cutoff points to the distribution of HFT scores (i.e., $\bar{X}=2.95$ for the FDs and $\bar{X}=19.37$ for the FIs). Although the FIs had a much higher mean on the HFT, the
strength of their cognitive style did not give them an advantage on either posttest.

**Instrument Reliability and Validity**

Point biserial correlation coefficients, the Kuder-Richardson formula 20 (K-R 20), mean item difficulty and mean item discrimination indexes, standard deviations, and the standard error of measurement were computed to determine the reliability of individual items and the overall validity of Posttest I, Posttest II, and the Hidden Figures Test. The coefficients and indexes were computed on a sample of 161, although the unweighted means analysis used a sample of 154. Each of these indicators is displayed in Table 12.

Table 12

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Posttest I</th>
<th>Posttest II</th>
<th>HFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point biserial</td>
<td>.552</td>
<td>.507</td>
<td>.475</td>
</tr>
</tbody>
</table>

**Indexes**

<table>
<thead>
<tr>
<th>Indexes</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>K-R 20</td>
<td>.581</td>
<td>.672</td>
<td>.892</td>
</tr>
<tr>
<td>Item difficulty</td>
<td>.341</td>
<td>.403</td>
<td>.588</td>
</tr>
<tr>
<td>Item discrimination</td>
<td>.506</td>
<td>.584</td>
<td>.519</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>2.030</td>
<td>2.290</td>
<td>6.940</td>
</tr>
<tr>
<td>Standard error</td>
<td>1.430</td>
<td>1.450</td>
<td>2.540</td>
</tr>
</tbody>
</table>

1. The loss of seven students falls within the acceptable limits (≤5%) for maintaining statistical power.
The averages of the point biserial coefficients, computed separately, indicated strong relationships among the items within each posttest and among the items within the HFT. The moderately strong K-R indexes indicated homogeneous functioning among the items and thus reflected the content validity of the tests. The item difficulty indexes indicated that Posttest II was slightly more difficult than Posttest I. The rearrangement of test items for Posttest II may have contributed to this, but the lower mean score for Posttest II probably resulted more from memory loss than from increased item difficulty. The mean item discrimination indexes indicated that each posttest and the HFT contained very good items, while the standard error indexes further indicated the accuracy of the tests.

System.Log

System.Log was used to record student responses to the questions during the entire lesson (see Appendix H for an example of the response categories and a sample System.Log printout). Imprecise disk drive calibration and buffer overflow resulted in loss of some data.

Buffer overflow may have been the more serious problem. Block space on each disk had been carefully estimated for recording the System.Log data. Records for two students (e.g., from Groups A and B) could have been stored in each System.Log file before the file required saving and renaming (see procedures for data collection in Appendix P). However, System.Log can only be managed from
SuperPILOT's Editor. The physical task of pulling twenty to twenty-five disks from separate disk drives, saving the records, renaming the System.Log file space, and rebooting each disk consumed more time than was available prior to the arrival of the next groups (e.g., Groups C and D). Many disks did not get the System.Log space renamed which resulted in buffer overflow. Technical problems were also encountered with the SuperPILOT Editor being read by the computer.

System.Log was not part of the original methodology for this study, and loss of System.Log data in no way hindered the analysis of the independent variables. The data that was obtained provided a partial composite profile to be developed for each experimental group (see Appendix Q).

Summary

Posttest results, HPT scores, System.Log records, and time-on-task were all used as data sources. The posttest results provided the principal data source for determining the existence of interactions and main effects. Although the primary hypothesis was not sustained, statistical significance was obtained for the question-level by posttest interaction, the question-level main effect, and the posttest main effect.
Chapter 5
INTERPRETATION AND DISCUSSION OF RESULTS

The psychology of a responsive environment provided the underlying theoretical root (Mitzel, 1981) for the interpretation and discussion of results in this chapter. Further cognitive models of learning provided a set of instructional design principles (Merrill & Tennyson, 1977; Reigeluth & Stein, 1983). Courseware design and development, the conduct of the pilot test, and the data collection were guided by these principles.

The investigation of question-levels and feedback-forms as instructional factors in courseware design was implemented and the results analyzed according to the proposed research design. The primary hypothesis, the question-level by posttest interaction, and the question-level and posttest main effects are discussed along with methodological problems and Hidden Figures Test data. The absence of a statistically significant feedback-form main effect is also discussed since the feedback conditions were central to this study.
Primary Hypothesis

It was postulated that students who received high-level questions and attribute isolation feedback (Hi/AIF) in a computer-based lesson would perform significantly higher on Posttest I and Posttest II than students receiving either high-level questions and corrective feedback (Hi/CF), low-level questions and corrective feedback (Lo/CF), or low-level questions and attribute isolation feedback (Lo/AIF) in the same lesson.

The effects to be observed in the Lo/CF and Hi/AIF treatments were the main focus of the investigation because the greatest difference in means was expected here. The lack of attribute isolation feedback in Hi/CF may not have rendered the high-level questions ineffective, but to probe students with high-level questions and then to provide only corrective feedback is contrary to providing appropriate conditions for learning (Gagne & Briggs, 1979). The Lo/AIF treatment may have provided additional instruction in the form of attribute isolation feedback, but this may have been rendered ineffective by the presence of low-level questions, and would not form the basis of a strong instructional principle.

The primary hypothesis of a question-level by feedback by posttest interaction was probably not sustained for one or more of the following reasons: (a) the feedback forms were not encountered with enough frequency to impact student performance, (b) exposure to the experimental treatment was insufficient to demonstrate treatment effects, (c) treatment effects existed but the posttests were not
sensitive enough to detect them, or (d) the subject sample was selected from a restricted range. The feedback-form effect will be discussed following The Posttest Main Effect, and the other three factors will be discussed under Methodological Problems.

The Question-Level by Posttest Interaction

The question-level by posttest interaction differs from the overall question-level main effect in that the interaction of one variable can be observed over time as a function of a second variable. In this case, question-level as a function of the posttest variable (i.e., the repeated measurements factor) was virtually unchanged from Posttest I to Posttest II, which indicated a strong retention effect created by both the high-level and low-level questioning treatments (see Table 7).

Students in the low-level question groups performed below the total group means for each posttest, but the similarity in posttest scores for Lo/CF and Lo/AIF suggested that the effect of the low-level questions was strong enough to maintain a retention effect over the one-week interval. Students in the high-level questioning groups showed a decrease of less than one point across posttest scores which further indicated the strength of retention caused by the question-level variable.
The Question-Level Main Effect

The question-level main effect indicated that students in the high-level question treatments performed better than students in the low-level question treatments at the .001 level of significance. This effect is encouraging because the high-level treatment contained some low-level questions for the purpose of concept presentation at the beginning of the lesson. (A transition to high-level questions was made after the third question). The level of cognition required for low-level concept learning is above that for associative learning, but students presented with only low-level questions are still not afforded the same opportunity to develop the skills to function successfully with high-level questions. The fact that the high-level treatment also had low-level questions diminished the number of high-level questions in the rest of the treatment and hence the opportunity for higher cognitive processing. A highly significant (p < .001) question-level main effect was still achieved. The question-level main effect result partially supported the research on questioning conducted by Hall, et al. (1983) and assumed added importance vis-a-vis the absence of the feedback-form main effect.

The difference in combined means between the high and low groups in Table 7 is important given the use of ten-item posttests and the average treatment exposure time of 38.5 minutes. A greater difference in means might have occurred if the high-level question treatment contained high-level questions exclusively or if expanded content material and an increased number of high-level questions were
presented over a longer period of time.

Writing questions at various levels from the same content material constrained courseware development at times. For example, low-level questions were difficult to write for the graph interpretations in Lo/CF and Lo/AIF given the graph's complexity relative to material presented earlier in the lesson. These low-level questions had to cause the student to apply his or her knowledge of xenograde systems without causing analysis of the graph. Increased diversity in the available lesson concepts might have provided more flexibility in writing the high-level questions without running the risk of writing trivial, low-level questions based on the same concepts.

The Posttest Main Effect

Analysis of the posttest main effect was based on a comparison of the combined high-question and low-question level means from each posttest. (A decrease of .435 of one point from Posttest I to Posttest II can be observed in Table 7). The posttest main effect was significant at the .01 level and it is probable that the question-level main effect and question-level by posttest interaction contributed to the achievement of the posttest main effect. Reasons for the presence of this effect may be twofold: (a) the structure of the computer-based lesson design facilitated concept acquisition, and/or (b) the posttests were identical in content although not identical in structure.
The structure of the lesson with its concept definitions, critical and variable attributes, examples, questions, and accompanying feedback provided a framework in which students could process the lesson concepts. These structural elements also provided a source of cues which enhanced concept acquisition and retention.

The fact that Posttest II was identical in content to Posttest I may have facilitated the recall of information. The sequence of test items and the order of response options within other items were rearranged to diminish the occurrence of simple recall and to yield a more accurate indicator of retention.

The Feedback-Form Main Effect

The absence of the feedback-form main effect indicates that the potential benefits of either feedback form were not fully available to the students. A feedback-form main effect might have achieved statistical significance if students in the AIF groups had encountered the attribute isolation feedback more frequently. The attribute isolation feedback was structured to provide concept analysis that would enhance a student’s grasp of a given concept and to increase performance on posttest material. Subjects received the attribute isolation feedback after two incorrect responses. The System.Log data, although incomplete, suggested that students in the Lo/AIF and Hi/AIF groups may have received AIF less than one third of the time they were interacting with the lesson. Increased complexity in content and/or in question level may have caused more frequent AIF
feedback.

The critical attribute (CA) summaries received after the first correct response in Lo/AIF and Hi/AIF were designed to highlight the concept attributes but not to the level of detail present in the attribute isolation feedback. The CA summaries may have provided confirmation but little, if any, new information to subjects highly confident about their choice of a correct answer. If this were the case, then the CA summary as part of the AIF condition may have had no more impact than a CF condition. A comparison of AIF means (X=6.416) and CF means (X=6.427) across posttests (i.e., the feedback-form main effect) revealed no difference in the relative impact of the two feedback conditions.

Methodological Problems

Forms of feedback was one of the independent variables but a feedback-form main effect was not achieved. Significance for this main effect and other interaction sources may have occurred with increased exposure to the experimental treatments, more sensitive posttests, or a less restricted sample range.

Exposure time. The times for lesson completion varied from 25 to 58 minutes over the four groups resulting in an average of 38.5 minutes to complete the lesson. The lesson material was designed as an hour of instruction to ensure adequate time for concept development and acquisition by the subjects. The fact that the questioning
variable produced significant results despite an average single
treatment exposure of just over one half hour enhances the importance
of appropriate question-levels as an instructional design factor.

Treatment conditions could be modified to lengthen exposure time
if the benchmark of one hour is to be maintained in future research on
these hypotheses. A more highly developed content, increased
complexity of questions, and/or increased exposure to attribute
isolation feedback might have created divergent conditions capable of
producing more significant effects.

Posttests. The posttests each contained ten items which may have
been insufficient to detect a treatment effect. The posttests may
also have contributed to measurement error because they may not have
contained enough items to capture variability among the observations
(Glass & Hopkins, 1978). Future research on these hypotheses should
use a lengthened set of posttests and contain a greater variety of
content material.

Sample range. The two classification criteria used in selecting
the sample for the study specified that the students be currently
enrolled in high school and have a science background, preferably in
chemistry or physics. No special selection criteria were used to
group students, so randomization of ability throughout all treatments
was assumed. The chosen data collection site was a predominantly
white suburban high school in an area with a middle to high
socio-economic status. The homogeneity of the student population may have produced a restricted sample range for the experimental treatments in this study. Potential consequences of a restricted sample are reduced variability of observations (Glass & Hopkins, 1978) and an underestimation of an instrument’s ability to measure (Popham, 1981). Both consequences are interrelated and may have contributed to a potential inability of the posttests to detect treatment effects.

**Hidden Figures Test**

The mean item difficulty index for the HFT (.588) clearly showed that a majority of subjects were not adept at pattern recognition as measured by the HFT. The standard deviation of 6.94 also suggested a broad distribution of scores. The additional five minutes provided in Part I as a warmup for Part II may have lowered this index, but given the strength of the item difficulty index the warmup effect was probably negligible.

Subjects were not blocked on cognitive style as they were in Martin’s (1981) study. HFT data was collected for descriptive purposes only to determine if the performance of subjects classified for this study as field-dependent (FD) or field-independent (FI) were influenced by the combinations of question levels and feedback forms. The following discussion is based on the general observations made in Chapter 4 on the data in Table 11, and focuses mainly on the separate effects of the independent variables.
**Question level.** Data from Table 11 revealed that FIs consistently had higher scores than FDs across three of the four posttests when the four experimental treatment means were compared. This result seems to indicate that FIs were more successful than FDs with the xenograde learning material. If question-level effect alone was considered, FI and FD subjects in the high-level question treatment had higher scores across posttests than their counterparts in the low-level question treatment. The magnitudes of difference were .98 of a point between FDs and 1.94 points between FIs in the high-level and low-level question treatments, respectively. Although FIs scored higher than FDs in the high-level question treatment, their success may be attributable to the question-level main effect as much as to their analytical skills. FDs in the Hi/CF condition scored slightly higher than FIs in the Lo/AIF condition which may also reflect the influence of the question-level effect.

**Feedback form.** Both FIs and FDs scored slightly higher in the CF condition than in the AIF condition. This observation corresponds partially with Martin's (1981) study in which the FIs performed better under medium and no feedback conditions than in the maximum feedback condition (analogous to AIF). The maximum feedback condition in Martin's design apparently hindered the FIs' own problem-solving strategies. By contrast, the maximum feedback condition decreased error scores among FDs such that their performance was equivalent to the FIs' performance. The AIF condition in this study did not
equalize differences between the FDs and the FIs. Perhaps results similar to Martin's would have been obtained in this study if AIF had been encountered more frequently.

FDs in the medium and no feedback conditions in Martin's study made significantly more errors than their field-independent counterparts. Similarly, the FDs in the corrective feedback condition in this study had lower posttest means than the FIs.

Firm conclusions cannot be drawn from the above discussion because cognitive style was not used as a blocking variable in this study nor were FD and FI posttest scores statistically analyzed. Subjects in this study had been randomly assigned as individuals to the experimental treatments. Table 11 illustrates the resulting differences in cell size for FDs and FIs.

Conclusions

The attainment of a significant question-level main effect and a significant question-level by posttest interaction provided verification of the efficacy of levels-of-questions as an instructional factor in courseware design. The question-level main effect was particularly important given the relatively brief treatment exposure time and the short posttests. High-level questions were more likely to cause deep cognitive processing and to enhance retention than low-level questions, and should be included appropriately in the design of computer-based instructional systems.
Recommendations for Future Research

The present study focused on the instructional factors of questioning and feedback with the intention of demonstrating the efficacy of those factors for the design of high-quality courseware. The role of cognitive processing is essential to these two factors, but cognitive style was not included as a variable within the research hypotheses. Future research on these and related hypotheses could incorporate cognitive style as a variable to determine the need to consider cognitive style in the design and development of computer-based instruction.

Other future research endeavors for testing this study's hypotheses could be based on the same research design or on an extended model of the same design. Several possibilities exist with the present design. For example, the present study could be replicated with a younger age group (i.e., a middle school population) that would find the xenograde concepts more challenging. An increased perception of content complexity among younger students might increase the error rate and thus cause students to receive detailed feedback more frequently. The increased reliance on feedback might then result in a significant feedback-form main effect. Whether a younger subject sample was selected or a similar high school age group was used again, a less restricted sample range would be sought to increase the variability of observations. Programming changes could also be made to provide the complete attribute isolation summaries for correct responses. In any of these instances the goals would be to replicate
the strength of the question-level main effect, to support the primary hypothesis, and to significantly increase the reliance on feedback.

The same research design could also be used with other subject matter - perhaps content that is more complex and thus amenable to the writing of more high-level questions. An increase in the number of high-level questions would necessitate lengthening the lesson or dividing it into two or more lessons. The latter option might be more desirable for data collection over a longer period of time covering a greater diversity of concepts. Significant research results on questioning and feedback based on cumulative data would strengthen the case for the inclusion of those factors in courseware design.

A logical extension of the two between-one-within subjects design is the three between-one-within subjects design. In the extended model the additional factor could be two levels of complexity of the same content or a comparison of highly structured content versus less structured content from unrelated disciplines. In either case, the present research design would be replicated within each level of the new factor.

Extending the present design to include two levels of the same content would create some challenges for writing questions, but the research results might provide valuable insight on matching content structure with appropriate question levels and feedback forms. The second option for an extended model could yield important results for determining which types of content are the most suitable for delivery via a computer-based format.
The present study examined the effects of question levels and feedback forms on the cognitive processing of individual learners, and brought further attention to the critical need for quality courseware. Additional research on instructional factors in courseware design is necessary to substantially contribute to our knowledge base in this area.
REFERENCE NOTES

1. Literature searches were conducted by the author with the assistance of Mr. Ross Poli of the Mechanized Information Center (MIC) at the main library of the Ohio State University. Two separate searches of the feedback literature were initially conducted. The first crossed the following terms: CAI / Feedback. These terms yielded literature that primarily investigated conditions of no-feedback, immediate feedback, and delayed feedback. The research designs focused mainly on problems inherent in testing verbal learning material and reflected influences from behavioral psychology.

In order to find feedback literature with more of a cognitive orientation that was concerned with conceptual learning material, the second search was conducted crossing the following terms: Feedback / Cognitive Psychology; Feedback / Cognitive Science; Feedback / Artificial Intelligence; Feedback / Cognitive; Feedback / Intelligence; Feedback / Logical Thinking; and Feedback / Processing Information.

Current Awareness searches were also maintained on a monthly basis throughout the study. The vast majority of references from these searches were in the areas of group dynamics, guidance and counseling, and organizational behavior. Very few useful references
were obtained pertinent to the variables under investigation.

2. The Xenograde System was originally developed by Merrill (1964) for use in his doctoral research. The xenograde materials were also used in studies by Arlin (1973) and Martin (1981). For the present study the content of the xenograde lessons was adapted from Martin's (1981) study, but the questions and feedback were altered to correspond to the research variables. The original xenograde material consists of 10 lessons and quizzes and may be obtained from Burrows Microfilm Systems, 214-13 Jamaica Ave., Queens Village, N.Y. 11428. Request Document 00861.
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Merrill, M. D. *Transfer effects within a hierarchical learning task as a function of review and correction on successive parts* (Tech. Rep. No. 5, NONR 3985(04)). Urbana-Champaign: University of Illinois, Training Research Laboratory, 1964.


Pressey, S. L. *A simple apparatus which gives tests and scores—and teaches*. *School and Society*, 1926, 23 (586), 373-376.


Strain is in the eye of the beholder. *Personal Computing*, 1984, 8 (6), 196-197.


Example: Concept Hierarchy and Concept Documentation
EXAMPLE: CONCEPT HIERARCHY and CONCEPT DOCUMENTATION

**OPTICAL INSTRUMENTS**

**DEFINITION**
Devices designed to assist or improve vision

NAME telescope
NAME microscope

**DEFINITION**
1 Relation to General Class
   A telescope is an optical instrument which

2 Defining Features
   Enlarges the image of distant objects
   Is monocular

3 Irrelevant Features
   Size
   Reflecting or refracting
   Type or color of materials

**EXPLANATION**

1 For Teaching
   lunar eclipse
   ships at sea
   planets

2 For Testing
   wild birds
   football game

**EXAMPLES**

Early telescopes were important for studying the stars

---

**DEFINITION**
1 Relation to General Class
   A microscope is an optical instrument which

2 Defining Features
   Enlarges the image of objects too small to be seen by ordinary vision

3 Irrelevant Features
   Size
   Monocular or binocular
   Type or color of materials

**EXPLANATION**

1 For Teaching
   bread mold
   house dust
   butterfly wing

2 For Testing
   fish scale
   pond water

**EXAMPLES**

Microscopes were important for discovering the causes of illness and disease

---

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APPENDIX B

Learner Response Error, Identification, Classification, Causation, and Feedback Table
TABLE A

Learner Response Error, Identification, Classification, Causation, and Feedback Table

<table>
<thead>
<tr>
<th>If the Learner classified</th>
<th>then the response represents</th>
<th>and is probably caused by instruction which</th>
<th>and can be corrected by providing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correctly the instance as an example of non-example</td>
<td>Correct</td>
<td></td>
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</tr>
<tr>
<td>A non-example as an example</td>
<td>Over-generalisation</td>
<td>Failed to include non-examples OR Failed to match examples to non-examples</td>
<td>Additional matched example/non-example pairs AND Feedback which identifies the missing critical attributes</td>
</tr>
<tr>
<td>An example as a non-example</td>
<td>Under-generalisation</td>
<td>Failed to include difficult examples, i.e., which have few missing critical attributes</td>
<td>Present difficult examples AND Feedback which identifies the missing critical attributes</td>
</tr>
</tbody>
</table>

Copyright 1983 Instructional Design Associates, Inc.
TABLE A (cont.)

Learner Response Error, Identification, Classification, Causation, and Feedback Table (continued)

<table>
<thead>
<tr>
<th>If the Learner classified</th>
<th>then the response represents</th>
<th>and is probably caused by instruction which</th>
<th>and can be corrected by providing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-examples (Which share a particular variable attribute) as examples OR Examples (which do not share this particular attribute) as non-examples.</td>
<td>Misconception</td>
<td>Uses examples in which the variable attributes are the same.</td>
<td>Additional matched examples and non-examples with differing variable attributes AND Feedback emphasizing the non-critical nature of this variable attribute.</td>
</tr>
</tbody>
</table>
APPENDIX C

Verbs for Stating Cognitive Outcomes for Levels of Learning
### TABLE B

Verbs for Stating Cognitive Outcomes for Levels of Learning

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Comprehension</th>
<th>Application</th>
<th>Analysis</th>
<th>Synthesis</th>
<th>Evaluation</th>
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<tbody>
<tr>
<td>Acquire</td>
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<td>Apply</td>
<td>Analyze</td>
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<td>Appraise</td>
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<td>Change</td>
<td>Choose</td>
<td>Categorize</td>
<td>Classify</td>
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<td>conclude</td>
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<td>Classify</td>
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<td>Compare</td>
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<td>Consider</td>
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<td>Contrast</td>
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<td>Define</td>
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<td>Demonstrate</td>
<td>Reduce</td>
<td>Derive</td>
<td>Decide</td>
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| Recall    |               | recognize   |          |           |           |
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| Transform |               | Transfer    |          |           |           |
|           |               |             |          |           |           |
|           |               |             |          |           |           |
|           |               |             |          |           |           |
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| Recall    |               | recognize   |          |           |           |
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| Transform |               | Transfer    |          |           |           |
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|           |               |             |          |           |           |
|           |               |             |          |           |           |
|           |               |             |          |           |           |
|           |               |             |          |           |           |

| Recall    |               | recognize   |          |           |           |
|           |               |             |          |           |           |
|           |               |             |          |           |           |
|           |               |             |          |           |           |
|           |               |             |          |           |           |
|           |               |             |          |           |           |
APPENDIX D

Summary of Research Designs from Studies on Feedback Conditions
<table>
<thead>
<tr>
<th>Authors</th>
<th>Type of Study</th>
<th>Hypotheses/Questions</th>
<th>Feedback Conditions</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson, Kulhavy, &amp; Andre (1971)</td>
<td>Investigation of immediate KCR* in a CBI lesson on myocardial infarction.</td>
<td>Students who get KCR learn more than students who do not, i.e., KCR is facilitative only when students do not peak at answers before responding.</td>
<td>Experiment I - 8 feedback conditions ranging from 0% KCR to voluntary selection of KCR or no KCR.</td>
<td>Students who received KCR after every frame performed better on the criterion test than students who received no KCR.</td>
</tr>
<tr>
<td>Bardwell (1981)</td>
<td>Assessment of feedback on a school-related German vocabulary learning task.</td>
<td>What is the effect of immediate &amp; delayed feedback on the acquisition &amp; retention of a learning task? Is an informational or reinforcement theory supported?</td>
<td>Two groups (N=204) were equally divided into immediate &amp; delayed feedback on a paired-associate learning task.</td>
<td>Feedback is informational rather than reinforcing; delayed feedback facilitated retention.</td>
</tr>
<tr>
<td>Fisher, Williams &amp; Roth (1981)</td>
<td>Assessment of a computer-assisted self-evaluation (CASE) system of multiple-choice testing with immediate computer feedback.</td>
<td>How does frequency of testing and type of feedback affect student learning?</td>
<td>One group (N=34) received 24 quizzes with immediate feedback, and the other group (N=30) received two midterms with delayed feedback.</td>
<td>Multiple-choice testing can be effective in promoting meaningful learning due to systematic reinforcement of immediate feedback.</td>
</tr>
</tbody>
</table>

1. The various hypotheses, questions & results may not be reported here in their entirety, but the key elements of each are summarized as accurately as possible.
<table>
<thead>
<tr>
<th>Authors</th>
<th>Type of Study</th>
<th>Hypotheses/Questions</th>
<th>Feedback Conditions</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gilman (1969)</td>
<td>Investigation of several feedback modes in a general science lesson.</td>
<td>Providing subjects with a combination of feedback modes may take advantage of reinforcing &amp; informational effects.</td>
<td>(N=75) Five modes of immediate feedback A) no feedback B) feedback of &quot;correct&quot; or &quot;wrong&quot; C) feedback of the correct response choice D) feedback appropriate to the student's response E) a combination of B, C &amp; D.</td>
<td>Posttest results indicated better immediate retention for those students receiving a combination of feedback modes. The means of groups C, D &amp; E were significantly better (p&lt;0.01 than those groups A &amp; B) which received no KCR. Providing extensive information in the feedback enhances retention.</td>
</tr>
<tr>
<td>Joseph &amp; Maguire (1982)</td>
<td>An examination of the interaction between feedback schedule and academic self-concept with arithmetic skills.</td>
<td>Do students of different aptitude levels have different degrees of difficulty in overcoming response competition?</td>
<td>(N=236) Classes were randomly assigned to one of three treatments: 1) Immediate post-test knowledge of results (IKR). 2) 2-day delayed knowledge of results (DKR). 3) A control group that did not receive feedback until the end of the study.</td>
<td>Findings were consistent with the interference-perseveration hypothesis. High self-concepts could do well in IKR condition (i.e., in a condition of response competition). Low self-concepts improve more in a delayed condition.</td>
</tr>
<tr>
<td>Authors</td>
<td>Type of Study</td>
<td>Hypotheses/Questions</td>
<td>Feedback Conditions</td>
<td>Results</td>
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</tr>
<tr>
<td>Kulhavy &amp; Yekovich, (1976)</td>
<td>Investigation of the efficacy of feedback in relation to a student's confidence level at time of response.</td>
<td>High confidence in a correct response should yield the lowest feedback study times. High confidence in a wrong response will have the reverse effect.</td>
<td>Students were equally and randomly assigned to a no-feedback or an immediate feedback (after each response) group. All students were post-tested immediately and after a one-week delay.</td>
<td>The hypotheses were supported. A model relating feedback, confidence, &amp; post-response behavior is strongly supported.</td>
</tr>
<tr>
<td>Sassenrath, (1975)</td>
<td>Reanalysis of three previous studies based on paired associate tasks.</td>
<td>Is delayed feedback more effective than immediate feedback?</td>
<td>(Various IF or DF conditions as reported in the three studies).</td>
<td>Anderson's interference-perseveration theory is found to be preferable to Sassenrath's verbal rehearsal theory.</td>
</tr>
<tr>
<td>Steinberg, (1980)</td>
<td>Investigation of problem-solving tasks using CAL.</td>
<td>Can students generate &amp; then generalize their solution strategies?</td>
<td>(N=93) Students were randomly assigned to one of three conditions: 1) Experience only 2) Visual record of work done in first 3) Interactive instructional feedback</td>
<td>Experience alone was as effective as the feedback conditions. The author hypothesized that the feedback conditions failed because they did not enable students to eliminate their natural, although incorrect, strategies.</td>
</tr>
<tr>
<td>Authors</td>
<td>Type of Study</td>
<td>Hypotheses/Questions</td>
<td>Feedback Conditions</td>
<td>Results</td>
</tr>
<tr>
<td>---------</td>
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</tr>
<tr>
<td>Sturges (1978)</td>
<td>Effects of delayed informative feedback in computer-assisted testing in an educational setting are studied.</td>
<td>Does delay of informative feedback affect retention in computer-assisted testing?</td>
<td>(N=112) Within each of four blocks of a randomized block design, students were randomly assigned to one of four feedback groups: a) no feedback b) 2-sec. delay c) 20-min. delay d) 24-hour delay</td>
<td>Long-term retention of academic material following some delay of informative feedback is superior to that with immediate informative feedback. A limitation exists, however, due to lack of evidence on the relative effectiveness of immediate &amp; delayed informative feedback on repeated tests throughout a course.</td>
</tr>
</tbody>
</table>
APPENDIX E

Materials for the Evaluation of Question Levels by Independent Panelists
August, 1984

To the Evaluator:

Thank you for your participation in this evaluation activity. The materials you will be evaluating are part of a computer-based lesson. Enclosed with this cover letter you will find (a) two pages of terminology for use throughout the evaluation entitled "Levels-of-Learning", (b) a Rating Code and directions page entitled "XENOCRASE SYSTEMS / Evaluation of Question Levels", (c) twenty content items and the twenty questions to be evaluated (pp. 4 - 10), (d) an Answer Key, and (e) a draft of the Student Lesson Booklet. The booklet is intended to be used with the computer-based lesson.

As you proceed through the evaluation activity, there are several points to bear in mind:

a) The material as presented here does not represent an optimal form of instruction. It is designed for evaluative purposes only.

b) The material as presented here does not reflect the interactive nature of the lesson as it will appear to the student.

c) The material in its final form will be field tested among high school juniors in beginning chemistry.

The twenty questions you will be evaluating have been designed to potentially cause a student to engage in cognitive processing across the range of Bloom's Taxonomy (referred to in "Levels-of-Learning Definitions"). In addition to rating each individual question, feel free to make suggested revisions of the content items or questions - use the margins or the space reserved on page 10.

Sincerely,

John A. Merrill

P.S. Please complete the evaluation activity by the end of August and return to your cooperating professor or directly to me at: 1507 North Star Rd. / Columbus, Ohio 43212. If you have any problems or questions feel free to call me at 486-9059. Thank you.
Levels-of-Learning

Each time a decision is made to provide instruction to a learner, an accompanying decision of level-of-learning should be made. Several taxonomies of instructional objectives have been developed, but Bloom’s Taxonomy of Educational Objectives (1956) is the most widely known and it exhibits the following characteristics: (a) validated communicability, usefulness, and suggestiveness; (b) emphasis on types of learning tasks generally encountered in instructional environments; (c) quality documentation; and (d) congruence with the structure of knowledge and the tasks learners are expected to perform within the structure of knowledge (Hall et al., 1982, p. 4).

Bloom’s taxonomy defines the cognitive behaviors required of the learner at each level as follows:

Knowledge -- repetition of information in the form it was presented. Questions at this level are often labeled factual or recall questions.

Comprehension -- recognition or production of some paraphrase of material presented in instruction.

Application -- use of presented information in some new situation. Application could include recognizing new examples of a concept or using a principle in a problem-solving situation.

Analysis -- decomposing of a given situation into its component parts and analyzing their relationships. Analysis typically requires the use of some previously taught scheme to decompose the whole, e.g., the student may be assigned to interpret the elements of a short story based on the writing techniques associated with a particular literary form.
**Synthesis** -- working with parts, elements, etc., and combining them in such a way as to produce a pattern or structure not clearly there before.

**Evaluation** -- requires judgments about the value of information, concepts, or ideas relative to some goal or purpose.

Use the above definitions when applying the Rating Code on the following page to the content items on pages 4-10.
XENOGRAD SYSTEMS
Evaluation of Question Levels

RATING CODE
Knowledge = 1  Comprehension = 2  Application = 3
Analysis = 4  Synthesis = 5  Evaluation = 6

Directions: Read each numbered content item. Following each content item is a corresponding question or statement (labeled as QUESTION for simplicity). In most cases the question or statement will require the student to refer to a diagram or chart in the lesson booklet. As an evaluator you will also need to refer to the lesson booklet which accompanies this evaluation form. Use the Rating Code above to evaluate all questions and statements according to the following criteria:

a) the depth of cognitive processing being demanded of the student;

b) the prior knowledge in science that you would expect your students to have at the beginning of the school year.

When using the Rating Code refer to the definitions of the terms as often as needed to maintain distinction between the terms. Although some overlap can occur depending on the nature of the question, please use only one code number per question. After you have evaluated a question / statement, place your code number in the underlined space immediately following the question number, e.g., Question #21 __ .

An Answer Key to the questions has been provided at the end of the evaluation form.
XENOGRADE SYSTEMS (1)

CONTENT #1
Xenograde (pronounced Zen'-o-grade) systems are very small imaginary systems similar in structure to an atom or to the solar system. As in the atom, the center body of the Xenograde System is called the NUCLEUS.

In each Xenograde System there are three bodies revolving around the nucleus. Each of these bodies is called a SATELLITE. There are always three satellites in every xenograde system.

QUESTION #1 (Place your code number here).
Refer to Diagram 1 in your booklet and then select the answer you believe to be correct from the choices listed.

CONTENT #2
The nucleus of a xenograde system contains tiny particles called ALPHONS. These alphons may be in the very center of the nucleus, i.e., in the INNER REGION, or they may be against the shell of the nucleus, i.e., at the OUTER SHELL.

In Diagram 2, some of the characteristics described above are illustrated.

QUESTION #2 Identify the correct description from those listed next to the diagram, then press the corresponding letter.

CONTENT #3
You have learned that Xenograde Systems consist of two main parts - a) the center, called the nucleus, which contains small particles called alphons, and b) three satellite bodies which revolve around the nucleus.

The paths followed by the satellites are called ORBITS, similar to what is found in the solar system. Each orbit is at a unique distance from the center of the nucleus. However, these orbits are not always circular in shape.

QUESTION #3 Now let's see if you know which of the things labeled in Diagram 3 is an orbit. When you have decided, press the letter corresponding to your choice.

1. Content items here do not perfectly match the student booklet content in Appendix G.
Some other interesting facts are known about alphon inside the nucleus. It has been found that they move or migrate between the inner region and the outer shell. After all of them have migrated outward they move one-by-one back into the inner region. This one-by-one migration from one region to another and back is called breathing.

Refer now to Diagram 4. The three rows of drawings represent the nucleus at various times.

**QUESTION #4**

Compare each row of drawings and decide which sequence of alphon migration correctly represents one half of the breathing cycle.

In Diagram 5A every drawing has been given a number indicating the time when a migration takes place. We can keep track of how many alphon are in the inner region and at the outer shell by assigning "times" to the various alphon movements.

Diagram 5B shows three ways of depicting Time-10.

**QUESTION #5**

Press the corresponding letter which shows what time-10 should look like.

While the alphon are breathing inside the nucleus, the satellites are moving around the nucleus in circular paths called orbits. However, when the Xenograde System is placed in a magnetic field the satellites no longer travel in circular orbits but travel in irregular orbits.

When first placed in a magnetic field the satellites begin to move toward the nucleus until they collide with the nucleus. Then they move out until they reach their original orbit and then move back again to the nucleus. This movement by the satellites continues as long as the Xenograde System is in the magnetic field.

Refer now to Diagram 6. One of the three drawings shows a Xenograde System after it has been placed in a magnetic field. Note that there is only one satellite shown for simplicity.

**QUESTION #6**

Compare each of the drawings and determine which one represents a xenograde system after it has been placed in a magnetic
CONTENT #7  Note that the satellite never goes beyond its original orbit and it always collides with the nucleus before moving outward again.

It might be easier to remember this behavior if you think of a satellite as a yo-yo. A yo-yo cannot go beyond the length of its string and, like a yo-yo, a satellite moves "up and down", or more precisely out and back from the nucleus on an elliptical path.

QUESTION #7 — Refer to Diagram 7 and identify the distance indicated as Z.

CONTENT #8  Under magnetic field conditions, satellites normally collide with the nucleus at regular intervals. When a satellite collides with the nucleus as the alphones are migrating outward it may pick up one alphon at a time from the nucleus. Picking up an alphon causes a satellite to increase velocity.

In Diagram 8 a satellite has collided with its nucleus.

QUESTION #8 — If a satellite picks up an alphon when it collides with the nucleus, when will the next collision take place?

CONTENT #9  During the inward migration of alphones, satellites may drop off or leave alphones in the nucleus. When this happens the velocity of the satellite decreases and it travels more slowly.

QUESTION #9 — Refer to Diagram 9 and answer the following question: If a satellite drops off an alphon in the nucleus on one collision, at what rate will the satellite return to its original orbit?

CONTENT #10  Alphon pickup by the satellites only occurs during the outward migration of alphones. Alphon dropoff only occurs during the inward migration of alphones.

Since satellites only collide with the nucleus when a xenograde system is in a magnetic field, alphones can only be exchanged when the system is in a magnetic field.

In Diagram 10 a series of drawings indicate various states of
When the system is in a magnetic field, alphon pickup could occur only during which time span?

The remainder of this lesson places emphasis on a very important concept which was introduced earlier in the lesson—"breathing".

Remember that there are a number of small particles called alphons in the nucleus of a xenograde system. The alphons migrate one-by-one between the inner region of the nucleus and its outer shell. After all of the alphons have migrated one way they reverse direction.

This regular process of one-by-one migration resembles the inhaling and exhaling of air. For this reason it is called breathing.

Diagram 11 illustrates this breathing process. Each new time corresponds to the migration of an alphon (note that time-3 and time-4 have not been shown).

The schematic representation of time-9 would look like which of the three choices presented?

Breathing consists of two phases. One is outward migration of alphons and the other is inward migration of alphons. Similar to the breathing of air, the outward migration of alphons is the exhale phase and the inward migration of alphons is the inhale phase.

Each phase must be complete before the next one can begin. The two phases taken together form a single "breathing cycle".

In Diagram 12 the exhale phase ends and the inhale phase begins between what two times?

Each time an alphon migrates a unit of time has passed as indicated by a number, e.g., time-4 is one unit of time later than time-3. The time between the migration of one alphon and the migration of the next alphon is constant for any given xenograde system.

The length of time between the migration of the first alphon and of the second alphon is exactly the same length of time as that
between the migrations of the second alphon and of the third, the third and the fourth, etc. This period of time between two successive alphon migrations is an "alphon second".

QUESTION #13 ________ In Diagram 13 how many alphon seconds does it take for this system to complete its inhale phase?

CONTENT #14 An alphon second is the time between the migration of one alphon and the migration of the next alphon. This is NOT the same as the time required for one alphon to migrate from the inner region to the outer shell or in the reverse direction.

The migration of a single alphon is so fast that we can consider its movement instantaneous. We can consider it as zero time in making any calculations.

(There is no diagram for this next question. Refer to D14 for the answer options).

QUESTION #14 ________ How long does an alphon take in migrating from the inner region to the outer shell or from the outer shell back to the inner region?

CONTENT #15 Time for Xenograde Systems is always given in alphon seconds. When we first put a system in a magnetic field before any alphones have migrated outward, we call the time, time-0 or t0 for short. Each succeeding time corresponds to the migration of another alphon. Therefore t5 indicates two things:

a) 5 alphon seconds have passed since we placed the system in a magnetic field.

b) 5 alphones have migrated outward.

(There is no diagram for this next question. Refer to D15 for the answer options).

QUESTION #15 ________ Suppose that a xenograde system has just been placed in a magnetic field prior to any outward alphon migration. Based on the way of counting in Xenograde Systems described previously, we would always know that at t10 there would be _____ alphones in the inner region and _____ alphones at the outer shell.

CONTENT #16 The total number of alphones in the nucleus of a system is called the alphon number. The alphon number differentiates
Xenograde Systems from one another. For example, when we speak of a system we may write Xenograde-8, which means that system has 8 alphons in the nucleus under normal conditions.

QUESTION #16 — What would be the alphon number of the system illustrated in Diagram 16?

CONTENT #17 — The use of diagrams to illustrate breathing in Xenograde Systems is a rather inefficient way of illustrating data. Another way is to present the readings of our measuring instruments in a table. D17 - D20 in your booklet show tables of readings for different xenograde systems. D17 in your booklet shows a table of readings for a Xenograde-3 System.

QUESTION #17 — At t5 there are two alphons in the inner region and one alphon at the outer shell. At what other time are there two alphons in the inner region and one at the outer shell?

CONTENT #18 — In making records of xenograde systems t0 is the first reading. It is the reading in which no alphons have yet migrated. At t0 all of the alphons will be found in the inner region. (D18 is blank in your booklet. Read and answer the following question before proceeding to D19).

QUESTION #18 — At t9 in a Xenograde-7 System with normal breathing the outer shell would have _____ alphons? (The choices presented on the computer screen to the student will be: a) 7 alphons; b) 5 alphons; c) 2 alphons

CONTENT #19 — (There is no new material for Content #19. The student will have to refer to earlier material).

QUESTION #19 — If the table in D19 was recorded for a xenograde system, how many alphons would be in the inner region at t7?
CONTENT #20
(There is no new material for Content #20. The student will have to refer to earlier material).

QUESTION #20 From the part of the xenograde record shown in D20, it can be determined that the inhaled phase starts between t___ and t___ ?

Suggested Revisions
(Use an extra sheet if needed)
ANSWER KEY for DRAFT BOOKLET

1. A 11. C
2. C 12. A
3. C 13. D
5. A 15. C
6. A 16. B
7. A 17. A
8. C 18. B

EXAMPLE KEY for RATING CODE (2)

1. 3 11. 2
2. 4 12. 4
3. 2 13. 4
4. 3 14. 1
5. 5 15. 3
6. 4 16. 2
7. 3 17. 4
8. 5 18. 3
9. 6 19. 5
10. 2 20. 4

2. Not part of the original materials submitted to the panelists.
A  a is the nucleus and
   b is a satellite
B  a is a satellite and
   b is the nucleus
C  a and b are both
    satellites
D  a is an atom

Diagram 1
(D1)
A a is the nucleus, c is an alphon

B a is the inner region of the nucleus; b is the nucleus; c is an alphon

C a is the outer shell; b is the inner region; c is an alphon

Diagram 2
(D2)
A The solid line (b) encircling the nucleus is an orbit.

B The solid lines enclosing the satellites (c₁, c₂, c₃) are orbits.

C The dotted lines (a₁, a₂, a₃) encircling the nucleus are orbits.

Diagram 3
(D3)
Diagram 5A

Diagram 5B

Diagram 5 (DS)
NOTE: There is only one satellite shown for simplicity.

DIAGRAM 6
(D6)
Diagram 7 (D7)

- **A**: the same as distance X and distance Y
- **B**: greater than distance X but less than distance Y
- **C**: less than distance X but greater than distance Y
- **D**: the same as distance X but greater than distance Y
A. The next collision will take place normally at the regular interval.

B. The next collision will take place later than normal.

C. The next collision will take place earlier than normal.

Diagram 8
(08)
A. The satellite will return to its original orbit at an equivalent rate.

B. The satellite will return to its original orbit at a slower rate.

C. The satellite will return to its original orbit at a faster rate.

Diagram 9 (D9)
A Time-1 to Time-5
B Time-5 to Time-10
C Time-6 to Time-10
D none of the above

Time-0 to Time-5

DIAGRAM 1D
(D 1D)
The schematic representation of time-9 would like which of the following?

A B C

DIAGRAM II
(DII)
Diagram 12

A  time-5 and time-6
B  time-10 and time-11
C  time-4 and time-5
A 5 alphon seconds
B 12 alphon seconds
C Not enough information to answer.
D 6 alphon seconds

DIAGRAM 13
(D 13)
(D14)

A about one alphon second
B less than one alphon second
C one half of an alphon second

(D15)

A 8 alphons in inner region,
   18 alphons at outer shell.
B 18 alphons in inner region,
   8 alphons at outer shell
C Not enough information
to answer.

(D14 + D15)
A Xenograde-5
B Xenograde-9
C Xenograde-4

DIAGRAM 16
(DIL)
<table>
<thead>
<tr>
<th>t</th>
<th>Inner</th>
<th>Outer</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

1. t stands for time (always given in alphon seconds).
2. Inner means the number of alphons in the inner region.
3. Outer means the number of alphons in the outer shell.
(D18) - No diagram or table

(D19)

<table>
<thead>
<tr>
<th>t</th>
<th>Inner</th>
<th>Outer</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>5</td>
<td>6</td>
<td>7 alpHns</td>
<td>5 alpHns</td>
<td>2 alpHns</td>
<td>5 alpHns</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(D20)

<table>
<thead>
<tr>
<th>t</th>
<th>Inner</th>
<th>Outer</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>6</td>
<td>3</td>
<td>t₅ and t₆</td>
<td>t₉ and t₁₀</td>
<td>t₈ and t₉</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(D19 + D20)
APPENDIX F

Sample Lesson Printout from Hi/AIF Treatment
Welcome to XENOGRADE SYSTEMS.

Before you begin, listen to any verbal instructions or introductions from your teacher and the evaluator.

When you are instructed to do so, please type in your LAST NAME and INITIALS, and then press the Return key. Please wait for the instruction.

Thank you. Your name is now being saved to the record-keeping file.

When the Return cursor (the white square) appears in the lower right corner, go ahead and press Return.
Right now we are waiting for everyone to get their names typed in correctly. The Smiths have got it made, but the Rimsky-Korsakows out there may take a little longer!

When told to begin, you may press Return and begin the lesson. Please wait for that instruction so everyone can start at the same time.

Xenograde (pronounced Zen'-o-grade) Systems are very small imaginary systems similar in structure to an atom or to the solar system. As in the atom, the center body of the Xenograde System is called the NUCLEUS.

In each Xenograde System there are three bodies revolving around the nucleus. Each of these bodies is called a SATELLITE. There are always three satellites in every Xenograde System.

Refer to Diagram 1 in your booklet and then select the answer you believe to be correct from the choices listed.

Press the corresponding letter on the computer's keyboard.
k1A
k1, sas
m1A

Correct. "A" is the nucleus because it is the center body of the xenograde system. "B" indicates a satellite—one of the three bodies revolving around the nucleus.

The bodies inside the nucleus have not been discussed yet.

The nucleus of a Xenograde System contains tiny particles called Alphons. These alphons may be in the very center of the nucleus, i.e., in the INNER REGION, or they may be
against the shell of the nucleus, i.e., at the OUTER SHELL.

In Diagram 2, some of the characteristics described above are illustrated.

Identify the correct description from those listed next to the diagram, then press the corresponding letter.

a: $a$
k: C
k: 2, a$
m: C

Correct. The outer shell contains the inner region. Within the inner region may be found alphons, which are tiny particles smaller than satellites.

The outer shell contains the inner region, which is at the very center of the nucleus.

The alphons are the tiny particles found within the nucleus. They are smaller than satellites.

Alphons may be in the inner region or at the outer shell.
*** Subroutine Library ***

*sub1
th:Incorrect. Would you like to see the information again? (Y/N)
a:
mi:Y
cy:ie=e+1
cy:im=m+1
e:

*pause
t:
g:m410,10;t(Return)
as:
e:

*record
k(incorrect trials): N
k(e=1): Review chosen: Yes
k(e=0&b=1): Review chosen: No
ks:
c(b=0): p=p+1
c(b=1): f=f+1
c(b=2): g=g+1
e:

*sub1
t:Incorrect.
t:
u:sub1.1
e:

*sub1.1
t:
t: The answer is:
t:
t: "a" is the nucleus;
t:
t: "b" is a satellite.
e:

*sub2
t:Incorrect.
u:sub2.1
e:
The answer is:

- "a" is the outer shell;
- "b" is the inner region;
- "c" is an alphon;
- "d" is an alphon.

Print of lesson 2XENO4.1B

This is 2Xeno4.1B. It contains D3.

d3<5> c:e=0; b=0

*D3a
 c:b=0; e=0

*D3
gies
t:D3
t:
th: The total number of alpons in
the nucleus of a system is called the
talphon number. The alphon number
differentiates xenograde systems from
one another. For example, we may
write
th:Xenograde-8 for a system that
has 8 alphons in the nucleus under
normal conditions.

gies
t:D3.1
t:
th: What would be the alphon number
of the system illustrated in Diagram
12?
The total number of alphons in the nucleus of a xenograde system is called the alphon number.

The total number of alphons in the nucleus of a xenograde system can be derived by adding the number of alphons in the inner region to the number located at the outer shell.

The total number of alphons within an individual xenograde system is constant.

The number of alphons between or among xenograde systems is not necessarily constant.

**ATTRIBUTE SUMMARY**

The total number of alphons in the nucleus of a xenograde system can be derived by adding the number of alphons in the inner region to the number located at the outer shell.

The total number of alphons within an individual xenograde system is constant.

The number of alphons between or among xenograde systems is not necessarily constant.

**Subroutine Library**

Incorrect. Would you like to see the information again? (Y/N)
Print of lesson 3XENO4.1C

r: This part of H1/ALF contains D4 - D5 and is on file as 3Xeno4.1C.
dia$(5)
c 1e=0; b=0
pr: u

*D4a
c : b=0; e=0
* D4
gies
 t : D4
Some other interesting facts are known about alphonns inside the nucleus. It has been found that they move or migrate one by one between the inner region and the outer shell. After all of them have migrated outward one by one they move back one by one into the inner region. This one-by-one migration from one region to another and back is called "breathing".

Refer now to Diagram 4. The three rows of drawings represent the nucleus at various times. Compare each row of drawings and decide which sequence of alphon migration correctly represents one half of the breathing cycle.

Correct. Migration by alphonns is solitary (one-by-one) and unidirectional (first one way, then the other).
Migration by alphones occurs one at a time.

Migration occurs first one way (e.g., outward) and then the other way (e.g., inward).

The drawings labeled "C" show the proper sequence in alphon migration, but only the first half of the cycle is represented.

In Diagram 5A every drawing has been given a number indicating the time when a migration takes place. We can keep track of how many alphones are in the inner region and at the outer shell by assigning "times" to the various alphon movements.

Diagram 5B shows three ways of depicting Time-10. Press the corresponding letter which shows what Time-10 should look like.

Correct. Two of the alphones at Time-5 have moved inward to the positions depicted at Time-7. Note that the outward migration must always be complete before inward migration can begin.
Alphons move back to the inner region one-by-one after outward migration is complete. Thus, Time-7 shows two alphons which have moved inward from their positions at Time-5.

An outward migration must be complete before an inward migration can begin. The reverse is also true.

Diagrams 5A and 5B show 5 alphons in the nucleus. The number of alphons can vary from five in other xenograde systems.

Time-0 and Time-10 can look similar depending on which phase of the cycle is occurring.

*** Subroutine Library ***
*sub1
th:Incorrect. Would you like to see the information again? (Y/N)
a:
m:Y
cy:e=e+1
cy:m=m+1
e:
*pause
t: g;m410,10; t(Return)  
as:  
e:  

*record
k: Number of incorrect tries: #b  
k(e=1): Review chosen: Yes  
k(e=0&b=1): Review chosen: No  
ks:  
c(b=0): p=p+1  
c(b=1): f=f+1  
c(b=2): g=g+1  
e:  

*sub4
t: Incorrect.  
t:  
u: sub4.1  
e:  

*sub4.1
t:  
t: The answer is:  
t:  
t: C The drawings labeled C show the  
t: outward phase of the breathing  
t: cycle.  

*sub5
t: Incorrect.  
t:  
u: sub5.1  
e:  

*sub5.1
t:  
t: The answer is:  
t:  
t: A Time-10  
e:  

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Note that the satellite never goes beyond its original orbit and it always collides with the nucleus before moving outward again. It might be easier to remember this behavior if you think of a satellite as a yo-yo. A yo-yo cannot go beyond the length of its string and, like a yo-yo, a satellite moves "up and down" or, more precisely, out and back from the nucleus on an elliptical path.

Refer to Diagram 15 and identify the distance indicated as Z.

Correct. The distance a satellite can travel from its nucleus after a collision is always the same.
ATTRIBUTE SUMMARY

The distance a satellite can travel from its nucleus after a collision is always the same.

The elliptical path of a satellite occurs only under magnetic field conditions.

Under magnetic field conditions, satellites without alphon collides with the nucleus at regular intervals. When a satellite collides with the nucleus as the alphon are migrating outward, it may pickup one alphon at a time from the nucleus. The alphon must be in contact with the outer shell for the exchange to occur.

Picking up an alphon causes a satellite to increase velocity.
In Diagram 8 a satellite has collided with its nucleus. If a satellite picks up an alphon when it collides with the nucleus, when will the next collision take place?

Correct. Alphon pickup increases satellite velocity causing the satellite to return to its original orbit sooner.

Alphon exchange can occur only under the following conditions -

a) during outward migration;

b) under the influence of a magnetic field; and

c) as the result of a collision between a satellite and a nucleus.

Only one alphon is exchanged at a time.
Alphon pickup may occur during outward migration, but not unless an alphon is at the outer shell at the point of collision.

Alphon pickup increases satellite velocity.

During the inward migration of alphons, satellites may drop off or leave alphons in the nucleus. When this happens the velocity of the satellite decreases and it travels more slowly.

Refer to Diagram 17 and answer the following question: If a satellite drops off an alphon in the nucleus on one collision, at what velocity will the satellite return to its original orbit?

Correct. Satellite velocity decreases after alphon drop-off.
ATTRIBUTE SUMMARY

Alphon pickup increases satellite velocity.

Alphon drop-off decreases satellite velocity.

With decreased velocity the satellite will return to its original orbit later than normal (i.e., at a slower rate).

Alphon drop-off may occur during inward migration, but not necessarily.

Alphon pickup by the satellites occurs only during the outward migration of alphons. Alphon dropoff occurs only during the inward migration of alphons.

Since satellites collide with the nucleus only when a Xenograde system is in the magnetic field, alphons can be exchanged only when the system is in a magnetic field.
In Diagram 18 a series of drawings indicate various states of a xenograde nucleus. When the system is in a magnetic field, alphon pickup could occur during which time span(s)?

Correct. Alphon pickup occurs only during outward migration. Time-1 to Time-5 shows outward migration only. Time-1 to Time-10 contains both outward and inward migration.

ATTRIBUTE SUMMARY

Alphon pickup occurs only during outward migration. Time-1 to Time-5 shows a complete phase of outward migration.

Time-1 to Time-10 contains a complete cycle of both inward and outward migration.

At Time-0 no outward migration has yet begun.
**D19a**

 estilo DEVELOPMENT CONTINUES WITH D19

:IN A SEPARATE FILE, 9Xeno4.1K.

u:record

1:10Xeno4.1K,D19a

e:

*** Subroutine Library ***

*sub1

th:Incorrect. Would you like to see the information again? (Y/N)

ai:

m:Y
cye=e+1
cym=m+1
e:

*pause
t:
g:m410,10;t(Return)

as:
e:

*record

k:Number of incorrect tries: Wb

k(e=1):Review chosen: Yes

k(e=0&b=1):Review chosen: No

ks:
c(b=0):p=p+1
c(b=1):f=f+1
c(b=2):g=g+1
e:

*sub15

t:Incorrect.

t:

u:sub15.1

e:

*sub15.1

t:
t: The answer is:

t:

t:A 2 is the same distance as distance X

t:

t: and distance Y.
The answer is:

C  The next collision will occur earlier than the normal regular interval.

The answer is:

B  The satellite will return to its original orbit at a lesser velocity than the velocity it was traveling prior to alphon drop-off.

The answer is:

D  Both A and C are correct.
The use of diagrams to illustrate satellite movement is an imprecise method for tracking this movement. Another way is to present the readings of our measuring instruments in graph form. The graph in your booklet (p.17) shows measurements of satellite movement in a magnetic field.

(Use this graph to answer the questions for D19 and D20. Take time to interpret the graph carefully! It does make sense).

On the graph the horizontal dimension represents time in alphon seconds. The vertical dimension represents the distance in microns of the satellites (S1, S2, S3) from the nucleus.
The nucleus will always remain stationary with respect to the satellites' positions.

An electronic instrument is used to record positions of the satellites. This instrument is triggered by saphon migration and therefore records the position of each satellite every saphon second. The satellites' positions are indicated by "flashes" on a sensitive piece of graph paper.

A sample record is shown on the graph with a different flash symbol (a triangle, square, or circle) to designate each of the satellites.

SI's path between collisions and its original orbit has been traced for you (moving from left to right). Notice that SI's path has a definite pattern. The same holds true for S2 and S3.

You may want to use the attached worksheet at this time to trace the paths of S2 and S3. Do not make the mistake of simply connecting S2's and S3's flash symbols as though you were "connecting the dots."
Approximately how far are each of the three satellites (S1, S2, and S3) from the nucleus at t4.5?

Correct. At t4.5, S1 has continued its inward direction to about 1 micron. S2 has continued its outward movement to about 7 microns. S3 has also continued inward to about 2 microns.

Satellites in a magnetic field no longer travel in circular orbits but travel in irregular orbits.

When first placed in a magnetic field the satellites begin to move toward the nucleus until they collide with the nucleus.

After colliding they move out until they reach their original orbits. They then move back again to the
nucleus. This movement by the
satellites continues as long as the xenograde system is in the magnetic
field.

ATTRIBUTE SUMMARY (cont.)

On the graph each satellite's original circular orbit is indicated by the horizontal line proceeding to the right of the flash symbol. The irregular orbit of S1 was traced for you. The other orbits can be traced in a similar manner.

The collisions of satellites with the nucleus are recorded on the graph in a form called "blips". A continuous horizontal penline recorded at the top of the graph paper indicates when blips occur.

The baseline (x-axis) indicates when a satellite is 0 microns from the nucleus - the point at which a collision will occur.

Every time a collision occurs the penline jogs or blips. This
srecord is continuous, unlike the satellite positions which are recorded in intervals of alphon seconds. The position of the blip therefore indicates the exact time when the blip occurred.

Note that the first blip on the graph occurred about .5 of an alphon second after t1 (at t1.5). This is just one of several blips that could be recorded.

Based on S1's path and your own tracings of S2 and S3, how many collisions occurred between the nucleus and all THREE satellites in the time span from t2 and t10?

A) 1 collision
B) 7 collisions
C) 10 collisions
D) 2 collisions

Correct. S1 and S3 each collided twice with the nucleus between t2 and t10 while S2 collided with the nucleus three times in the same interval.
Satellites in a magnetic field no longer travel in circular orbits but travel in irregular orbits.

When first placed in a magnetic field the satellites begin to move toward the nucleus until they collide with the nucleus.

After colliding they move out until they reach their original orbits. They then move back again to the nucleus. This movement by the satellites continues as long as the xenograde system is in the magnetic field.

On the graph each satellite's original circular orbit is indicated by the horizontal line proceeding to the right of the flash symbol. The irregular orbit of S1 was traced for you. The other orbits can be traced in a similar manner.
The "end" file collects all of the cumulative data from throughout the lesson.

Record for student: 

No. correct on 1st try (cd.1): 

No. missed only on first try (cd.2&4): 

Total times review chosen (=2nd attempts; cd.2&3): 

Total times review not chosen (no 2nd attempts; cd.4): 

No. missed on 2nd try (cd.3): 

No. correct on 2nd try (cd.2):

You are now finished. Do not turn anything off. DO NOT press Return.

Please raise your hand to indicate that you are finished.

Thank you very much for participating in this evaluation.

*** Subroutine Library ***

*sub19
Incorrect.

*sub19.1

The answer is:

C S1 - 1 micron, S2 - 7 microns,
S3 - 2 microns
*sub20

t: Incorrect.
u: sub20.1

e:

*sub20.1
t:

t: The answer is: B 7 collisions

e:

*sub1

t: Incorrect. Would you like to see the information again? (Y/N)
a:
m: Y
cy: e = e + 1
cy: m = m + 1
e:

*pause
t:
gim410,10; t (Return)
as:
e:

*record

k: Number of incorrect tries: M
k(e=1): Review chosen: Yes
k(e=0&b=1): Review chosen: No
ks:
c(b=0): p = p + 1
c(b=1): f = f + 1
c(b=2): g = g + 1
APPENDIX G

Student Lesson Booklet
XENOGRADE SYSTEMS

Student Lesson Booklet
Which choice below correctly identifies the labeled parts?

A  a is the nucleus and
   b is a satellite

B  a is a satellite and
   b is the nucleus

C  a and b are both satellites

D  a is an atom
A  a is the nucleus; b is an alphon; c is the inner region (shaded area)

B  a is the inner region (shaded area); c is the nucleus; c is an alphon

C  a is the outer shell; b is the inner region (shaded area); c is an alphon
A Xenograde-5
B Xenograde-9
C Xenograde-4
DIAGRAM 4
(D4)

A

B

C
Diagram 5A
(DSA)

Diagram 5B
(DSB)

Inner Region

Outer Shell

Time-0  Time-1  Time-5  Time-7

A  B  C

Time-10  Time-15  Time-18
The representation of Time-9 would look like which of the following?

A  B  C
A  Time-3 and Time-6
B  Time-10 and Time-11
C  Time-0 and Time-5
A 5 alphaon seconds

B 12 alphaon seconds

C 6 alphaon seconds
D9 & D10

D9

A about one alphon second
B less than one alphon second
C one half of an alphon second

D10

A 0 alphones in the inner region,
   10 alphones at the outer shell.
B 10 alphones in the inner region,
   0 alphones at the outer shell.
C Not enough information to answer.
### D11 & D12

Use the following information for the tables below:

1. "t" stands for time (given in alphon seconds).
2. Inner means the number of alphons in the inner region.
3. Outer means the number of alphons at the outer shell.

<table>
<thead>
<tr>
<th>t</th>
<th>Inner</th>
<th>Outer</th>
<th>Answer Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
<td>0</td>
<td>A t1 (Time-1)</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
<td>B t2 (Time-2)</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2</td>
<td>C t3 (Time-3)</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>1</td>
<td></td>
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<table>
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<th>t</th>
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<th>Answer Options</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>7</td>
<td>0</td>
<td>A 7 alphons</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>1</td>
<td>B 5 alphons</td>
</tr>
</tbody>
</table>

(Please do not write in this space. Use scratch paper to complete the table if necessary.)
A. The solid line (b) encircling the nucleus is an orbit.

B. The solid lines enclosing the satellites (c₁, c₂, c₃) are orbits.

C. The dotted lines (a₁, a₂, a₃) encircling the nucleus are orbits.
NOTE: There is only one satellite shown for simplicity.
Diagram 15

A  Z is the same as distance X and distance Y.

B  Z is greater than distance X but less than distance Y.

C  Z is less than distance X but greater than distance Y.

D  Z is the same as distance X but greater than distance Y.
A. The next collision will occur at the normal regular interval.

B. The next collision will occur later than the normal regular interval.

C. The next collision will occur earlier than the normal regular interval.
A The satellite will return to its original orbit without a change in velocity.

B The satellite will return to its original orbit at a lesser velocity than the velocity it was traveling prior to alphon drop-off.

C The satellite will return to its original orbit at a greater velocity than the velocity it was traveling prior to alphon drop-off.
A  Time-1 to Time-5
B  Time-3 to Time-10
C  Time-1 to Time-10
D  Both A and C are correct.
## Answer Key for Student Lesson Booklet - Final Version

1. A  
2. C  
3. B  
4. C  
5. A  
6. C  
7. A  
8. C  
9. B  
10. C  

11. A  
12. B  
13. C  
14. A  
15. A  
16. C  
17. B  
18. D  
19. C  
20. B  

\{N.B. See Appendix F for the questions for 1 - 5 and 16 - 18\}. 
APPENDIX H

Program Branching Flow Chart for Response / Feedback Conditions
PROGRAM BRANCHING FLOW CHART

QUESTION PRESENTATION

CF Condition?

Yes

Correct answer?

No

1st attempt?

Yes

Yes

No

Incorrect.

Would you like to see the information again?

Correct.

"Correct."

+ Summary of CAs

Proceed to next frame

Incorrect.

+ Sum. of CAs/VAs

Yes

(Y/N)?

No

Yes

No

("Correct."

+ Summary of CAs)

("Incorrect.

+ Sum. of CAs/VAs")

("Correct."

+ Summary of CAs)

("Incorrect.

+ Sum. of CAs/VAs")
APPENDIX I

Data Collection Schedule
DATA COLLECTION SCHEDULE for DUBLIN HIGH SCHOOL  
(Dec. 3, 4, & 5; Dec. 10 & 11)

Participating Teachers: Don Russell, Dan Carlson

**Class Groupings**

<table>
<thead>
<tr>
<th>Carlson</th>
<th>A, C, E, G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russell</td>
<td>B, D, F</td>
</tr>
</tbody>
</table>

**Abbreviations:**
- CBE: computer-based lesson
- PT1: "immediate" posttest
- PT2: retention posttest
- HFT: Hidden Figures Test
- pd.: class period

<table>
<thead>
<tr>
<th>Monday (Dec. 3)</th>
<th>Tuesday (Dec. 4)</th>
<th>Wednesday (Dec. 5)</th>
</tr>
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<tbody>
<tr>
<td>A, pd. 1&amp;2, CBE</td>
<td>A, pd. 1, PT1 (Merrill)</td>
<td></td>
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<tr>
<td>E, pd. 2&amp;3, CBE</td>
<td>E, pd. 3, PT1 (Merrill)</td>
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</tr>
<tr>
<td>B, pd. 3&amp;4, CBE</td>
<td>B, pd. 3, PT1 (Russell)</td>
<td></td>
</tr>
<tr>
<td>F, pd. 4,5,6, CBE</td>
<td>F, pd. 5 &amp; 6, PT1 (Merrill)</td>
<td></td>
</tr>
<tr>
<td>C, pd. 6,7,8, CBE</td>
<td>C, pd. 6, PT1 (Carlson)</td>
<td></td>
</tr>
<tr>
<td>G, pd. 8&amp;9, CBE</td>
<td>G, pd. 9, PT1 (Merrill)</td>
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</tr>
<tr>
<td>D, pd. 9&amp;10, CBE</td>
<td>D, pd. 9, PT1 (Russell)</td>
<td></td>
</tr>
</tbody>
</table>

(The name adjacent to PT1 indicates the monitor for that period.)
FIELD TEST SCHEDULE (cont.)

*******************************************************************************

Monday                                        Tuesday
(Dec. 10)                                    (Dec. 11)

**************
A, pd. 1&2                                      E, pd. 2&3
HFT / PT2                                      HFT / PT2

**************
B, pd. 3&4                                      F, pd. 4,5,6
HFT / PT2                                      HFT / PT2

**************
C, pd. 6,7,8                                     G, pd. 8&9
HFT / PT2                                      HFT / PT2

**************
D, pd. 9&10
HFT / PT2

{ Merrill will administer / monitor all HFTs and PT2s during the second week.}
APPENDIX J

Experimenter's Instructions to Pilot Test Students
Experimenter's Instructions

The following subheadings organize for the reader the set of instructions paraphrased for the students:

Lesson Assignment
This computer-based lesson is entitled 'Xenograde Systems', which is nothing more than a fancy name for an imaginary system of science concepts. You will probably find the science concepts very similar to concepts you have already encountered in previous science courses. What you see displayed on your monitor screen is a menu of lesson files which link together to form one continuous lesson. Once you begin you will not see this menu again. There are different versions to this lesson, but you all have the same version to go through here today. (No details were given regarding level of question or type of feedback). Although you are sitting rather close together, please concentrate on doing your own work.

Time Period
You will have the remainder of this period and some of the next period in which to complete the lesson. The computer-based lesson was written as approximately one hour of instruction. Try to do your best with the available time.

Hardware and Software Limitations
We are operating under some hardware and software limitations, so please be patient if the program seems slow at times. The disk in Drive 1 contains all the lesson material, and the disk in Drive 2 contains a disk with a record-keeping file for recording your interactions with the lesson. Occasionally during the lesson the program will take a few moments to record your responses, and then will come back to the same point in the program.
Use of Student Lesson Booklet

Basically, you will progress through the lesson by reading one or more screens of information followed by a question and its related options. Accompanying the computer-based lesson is a student booklet entitled "XENOGRADE SYSTEMS". Make sure you have one and that the last page of your booklet is a Work Sheet, which you may mark on to help you with the last two problems. Make no other marks in the booklet. Feel free to use your own paper to take notes.

The booklet contains diagrams and charts related to the content presented by the computer. The lesson will direct you to the booklet at various times. When you are ready to answer a question, firmly press the letter that matches the multiple-choice option you want, then press Return so that the computer knows to accept that answer. Remember to use the left arrow key to correct an answer before pressing Return.

Response / Feedback Conditions

What happens after you enter your answer? Let’s review the five possible response/feedback conditions:

1. Student enters correct answer on first try, receives corresponding feedback, and the program moves on.
2. Student enters incorrect answer on first try, receives corresponding feedback, plus the message, "Would you like to see the information again?", followed by a (Y/N) prompt. The cursor hangs next to the prompt waiting for a "Y" or "N" response. Pressing "Y", "Return" takes the student back through the screens of information leading up to the same question. The student then has a second attempt to answer.

3. If the second answer is correct, the program responds accordingly and moves on to the next concept in sequence.
4. If the second answer is incorrect, the program likewise responds accordingly and moves on.
5. Same as condition 2, except student presses "N", "Return" in response to the (Y/N) prompt. By pressing "N" the student forfeits the opportunity for a second chance; the program moves on to the next concept without providing additional feedback.

Students were encouraged to take their time to avoid mistakes, but to also use the review option as needed.
Question 1. The following diagram illustrates a Xenograde System. Various elements of the system are identified by small letters.

Choose one of the lists below to correctly identify the elements labeled in the diagram.

A  B  C  D
a. alphon a. nucleus a. nucleus a. nucleus
b. alphon b. alphon b. satellite b. satellite
c. satellite c. satellite c. alphon c. alphon
d. nucleus d. inner region d. inner region d. inner region
e. inner region e. outer shell e. outer shell e. inner region
f. outer shell f. orbit f. orbit f. outer shell
g. satellite g. satellite g. alphon g. alphon
h. alphon h. alphon h. satellite h. satellite
Question 2. If a nucleus contains six particles and the number of particles in each region of the nucleus is counted each time a particle migrates, how many particles would be in the inner region and how many particles would be at the outer shell on the 6th such count? (Assume that all of the particles were in the center of the nucleus to begin with and that the first count was made when the first particle migrated).

A  2 at the outer shell; 4 in the inner region
B  4 at the outer shell; 2 in the inner region
C  5 at the outer shell; 1 in the inner region
D  0 at the outer shell; 0 in the inner region
Question 3. The diagram below illustrates the nucleus at various times during breathing.

Some of the following three statements may be true and some may be false. Choose the answer which correctly identifies which are true and which are false.

1. The inhale phase includes times 1 to 4 and exhale phase includes 5 to 6.
2. Time-5 would look like this:
3. At the end of each breathing cycle, the nucleus would look like:

A 1 and 2 true; 3 false  C 3 true; 1 and 2 false
B 1 true; 2 and 3 false  D All statements are false.
Question 4.

The following diagrams illustrate the nucleus at various times during breathing. The diagrams below either correctly or incorrectly indicate the number of alphon seconds which have passed since the system was placed in a magnetic field. Assume that all alphones were in the center of the nucleus.

Diagram a
Diagram b
Diagram c

2 alphon seconds
7 alphon seconds
8 alphon seconds

Determine which diagrams are correctly labeled. Choose the answer which correctly identifies which of the diagrams are correct and which are not.

A  a and c correct; b incorrect
B  b and c correct; a incorrect
C  b correct; a and c incorrect
D  All diagrams are correct.
Question 5. The diagrams below illustrate nuclei of several Xenograde Systems.

Choose the answer below which correctly describes which of these systems has Xenograde-7 as its alphon number.

A. 3 does; 1 and 2 do not
B. 2 does; 1 and 3 do not
C. 1 does; 2 and 3 do not
D. All have Xenograde-7 as their alphon number.
Question 6. Below are several Xenograde records. Which of these records demonstrates normal breathing?

<table>
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<tr>
<td>8</td>
<td>8</td>
<td>B</td>
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A.

<table>
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B.

<table>
<thead>
<tr>
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<tbody>
<tr>
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</tr>
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<td>B</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

C.
Question 7. The diagrams below illustrate the motion of satellites when a Xenograde System is placed in a magnetic field. Which of these diagrams best illustrates the motion of a satellite in a magnetic field?
Question a. The diagram below illustrates the path of one satellite in a Xenograde System which was placed in a magnetic field at time-$t$. Each of the three statements below is either true or false. Read each one and decide whether it is true or false.

1. The nucleus has more alphans in it at time-3 than at time-1.
2. The amount of time between collision a and collision b is longer than between collision b and collision c.
3. The alphans in the nucleus are migrating inward at time-3.

Which of the following is correct?

A 1 and 2 true; 3 false
B 2 and 3 true; 1 false
C 2 true; 1 and 3 false
D All statements false
Question 9.
The diagram below is the same as for the preceding question. It illustrates the path of one satellite in a Xenograde System which was placed in a magnetic field at time-0. Read each one of the statements and decide whether it is true or false.

1. The satellite picks up an alphon from the nucleus at time-7.
2. The satellite is moving slower at time-8 than at time-6.
3. The satellite may leave an alphon at collision d.

Which of the following is correct?

A 1 and 3 true; 2 false  
B 2 and 3 true; 1 false  
C 2 true; 1 and 3 false  
D All statements are false
Question 10. The diagram below is the same as for the preceding two questions. Read each of the three statements below and decide whether it is true or false.

1. The satellite will have picked up all the alphons at time-5.

2. The satellite will be carrying three alphons between collisions c and d.

3. By the time all the alphons have migrated outward again to complete 1.5 breathing cycles, more than five collisions will have occurred.

A 1 and 2 true; 3 false
B 3 true; 1 and 2 false
C 2 true; 1 and 3 false
D All statements are false.
ANSWER KEY for POSTTEST I

2. B  7. A
3. D  8. C
5. D  10. B
Appendix L

Hidden Figures Test
This is a test of your ability to tell which one of five simple figures can be found in a more complex pattern. At the top of each page in this test are five simple figures lettered A, B, C, D, and E. Beneath each row of figures is a page of patterns. Each pattern has a row of letters beneath it. Indicate your answer by putting an X through the letter of the figure which you find in the pattern.

NOTE: There is only one of these figures in each pattern, and this figure will always be right side up and exactly the same size as one of the five lettered figures.

Now try these 2 examples.

The figures below show how the figures are included in the problems. Figure A is in the first problem and figure D in the second.

Your score on this test will be the number marked correctly minus a fraction of the number marked incorrectly. Therefore, it will not be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

You will have 10 minutes for each of the two parts of this test. Each part has 2 pages. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.
Part 1 (10 minutes)

A B C D E

A B C D E

A B C D E

A B C D E

A B C D E

A B C D E

A B C D E
Part 2 (10 minutes)

A  B  C  D  E

17. A B C D E
19. A B C D E
21. A B C D E
23. A B C D E

G O O N T O T H E N E X T P A G E
Part 2 (continued)

DO NOT GO BACK TO PART 1, AND
DO NOT GO ON TO ANY OTHER TEST UNTIL ASKED TO DO SO.

STOP.
ANSWER KEY for HIDDEN FIGURES TEST

1. A 17. E
2. B 18. C
3. E 19. D
5. B 21. A
6. D 22. B
7. E 23. C
8. A 24. B
10. D 26. E
11. C 27. D
12. A 28. A
13. E 29. D
15. C 31. E
16. C 32. A
Appendix M

SuperPILOT Variables Used to Store Data in System.Log
SuperPILOT Variables and System.Log Data

The following list of dimensioned variables were created using SuperPILOT to write statements and routines capable of collecting student data:

d:e(1)
d:b(2)
d:a$$(5)
d:p(20)
d:f(20)
d:m(20)
d:g(20)
d:n$(25)
c:e=0; b=0; p=0; f=0; m=0; g=0

The variables were written at the beginning of the first lesson file of each version of the experimental treatment. The values for variables e, b, and a$ were non-cumulative and had to be included at the beginning of each subsequent lesson file. The values for variables p, f, m, and g were cumulative and transferred from file to file automatically. The variable n$ was used only once for the student's name. The numbers in parentheses specify the allotted character space. (The selection and sequence of letters to identify the variables are arbitrary).

Non-Cumulative Variables (b, e, and a$)

Variable 'e' was dimensioned to record whether a student chose the review option for a given question. Variable 'b' was dimensioned to record students' incorrect tries for individual questions. These variables were reset to zero at the beginning of each question segment with the count statement c:e=0; b=0. Although variables 'e' and 'b' were non-cumulative from question to question, their values were stored in the other cumulative variables.

Variable 'a$' established the number of characters acceptable in the answer buffer. A single keystroke was sufficient for inputting answers. Five spaces were arbitrarily allotted, although a$(1) would have worked as well.

Cumulative Variables (p, f, m, and g)

The value of variable 'e' was stored in the non-cumulative variable 'm' within the subroutine labeled '*subI'. The '*u:subI' statement executed the '*subI' subroutine after every incorrect first try:
The values of variable 'b' were stored in the non-cumulative variables 'p', 'f', and 'g' in the subroutine labeled "record". At the beginning of each question (except for question 1), the 'u:record' statement would execute the "record" subroutine to record the value of 'b' from the previous question into the appropriate non-cumulative variable before 'b' was reset to zero. "Record" contains 'k' statements which tells the subroutine to 'keep' those values for Sys.Log:

In "record" the count statements (e.g., c(b=0):p=p+1) feed information into the cumulative variables regarding the status of 'b'. For example, if a student is incorrect twice on the same question this occurrence is stored in 'g'. Every similar occurrence has the value '1' added to the previous value of 'g'.

After the last question in the lesson, a 'j:end' statement would take the program to a subroutine labeled "end". The abbreviation 'cd.' in the subroutine stands for the response/feedback conditions encountered by the student during the lesson.

r:The "end" file collects all of the cumulative data from throughout the lesson.

k:
  k:Record for student
  k:
    k:No. correct on first try(cd.1): #p
    k:No. missed only on 1st try(cd.2&4): #f
    k:Total times review chosen (=2nd
The response / feedback conditions in Table 2 were used to construct and interpret the Sys.Log data:
1. Condition 1 (cd.1) corresponds to: correct response on the first try (or attempt).
2. Condition 2 (cd.2) corresponds to: incorrect response on the first try, review chosen, correct response on the second try.
3. Condition 3 (cd.3) corresponds to: incorrect response on the first try, review chosen, incorrect response on the second try.
4. Condition 4 (cd.4) corresponds to: incorrect response on the first try, review not chosen.

Sys.Log Data - Example 1
The data below provides an example of the 'end file' values recorded in Sys.Log:

K:Record for student: Smith, J. B.
K:No. correct on first try (cd.1): 12
K:No. missed only on first try (cd.2&4): 6
K:Total times review chosen (≥2nd attempts; cd.2&3): 8
K:Total times review not chosen (no 2nd attempts; cd.4): 0
K:No. missed on 2nd try (cd.3): 2
K:No. correct on 2nd try (cd.2): 6

Condition 1 (cd.1) in the record above equals 12. With twenty questions in the lesson eight responses belong in conditions 2-4. 'Cd.2' has six of the responses which leaves two for 'cd.3' and zero for 'cd.4'. The combinations of conditions 2, 4, and 2, 3 help to identify patterns in the student responses and also serve as verification for the accuracy of the cumulative variables. For example, the combination of conditions 2 and 4 equals the number missed only on the first try and reveals by default how many were missed on the second try, i.e., 8 - 6 = 2 = cd.3. The combination of conditions 2 and 3 equals the total number of times review was chosen and reveals by default how many times it was not chosen, i.e., 8 - 8 = 0 = cd.4.

Sys.Log Data - Example 2
The data below provides a complete example of Sys.Log data for an individual student. The data was recorded from a student assigned to a Hi/AIF experimental treatment (although the student name is fictional).
Print of lesson SYSTEM,LOG
*LXeno4.1A
K:Student Name: Henry. P. K.
K:A
K:1, A
K:Number of incorrect tries: 0
K:
K:C
K:2, B
K:C
K:2, A
K:Number of incorrect tries: 2
K:Review chosen: Yes
K:
L:2Xeno4.1B
K:B
K:3, B
K:Number of incorrect tries: 0
K:
L:3Xeno4.1C
K:C
K:4, C
K:Number of incorrect tries: 0
K:
K:A
K:5, B
K:A
K:5, A
K:Number of incorrect tries: 1
K:Review chosen: Yes
K:
L:4Xeno4.1D
K:C
K:6, A
K:C
K:6, B
K:Number of incorrect tries: 2
K:Review chosen: Yes
K:
K:A
K:7, A
K:Number of incorrect tries: 0
K:
K:C
K:8, B
K:C
K:8, A
K:Number of incorrect tries: 2
K:Review chosen: Yes
K:
Number of incorrect tries: 2
Review chosen: Yes

Number of incorrect tries: 0

Number of incorrect tries: 2
Review chosen: Yes

Number of incorrect tries: 0

Number of incorrect tries: 1
Review chosen: Yes

Number of incorrect tries: 0

Number of incorrect tries: 0

Number of incorrect tries: 0
K:18, D
K: Number of incorrect tries: 0
K:
L:10Xeno4,1K
K: C
K:19, B
K: C
K:19, A
K: Number of incorrect tries: 2
K: Review chosen: Yes
K:
K: B
K:20, B
K: Number of incorrect tries: 0
K:
K:
K: Record for student: Henry, P. K.
K: No. correct on first try (cd.1): 12
K: No. missed only on first try (cd.2&4): 2
K: Total times review chosen (=2nd attempts; cd.2&3): 7
K: Total times review not chosen (no 2nd attempts; cd.4): 1
K: No. missed on 2nd try (cd.3): 6
K: No. correct on 2nd try (cd.2): 1
E:
Appendix N

Experimenter's Instructions to Students at Data Collection Site
Experimenter's Instructions

The following subheadings organize for the reader the set of instructions paraphrased for the students:

Lesson Assignment
The computers are labeled X1, etc., because there are four different versions to the computer-based lesson. Each version is slightly different in the way the content, questions, or feedback is presented. There is no real advantage to looking at anyone else's answers since you are each sitting next to someone with a different version than your own.

No details were given regarding level of question or type of feedback. The students in X3 and X4 were not given any explanations about the frames labeled "Attribute Summary", but this did not seem to pose a problem for anyone.

Time Period
You will have the entire two-period block of time (84 minutes) in which to complete the lesson. The computer-based lesson was written as approximately one hour of instruction, and students in earlier versions of the lesson were able to finish comfortably within that time frame.

Signing On
Right now you are looking at the first frame of the lesson. The last frame will tell you to raise your hand to let me know that you are finished so that we can record your completion time.

You can, of course, raise your hand at any time during the lesson if you have a question regarding the program's functioning, e.g., a program error which might prevent the lesson from advancing in proper sequence. However, I cannot discuss any questions regarding lesson content. If you disagree with any of the presented information you will still have to answer the presented questions the best you
can within the context of the lesson.

Some of you have never used a computer before and may be a little nervous about all of this. You will need no programming skills and very minimal typing skills to proceed through the lesson successfully. Most of the time you will only need to respond to questions by selecting a multiple-choice response using the A, B, C, or D key to input your answer. Turn your attention again to the frame displayed on your monitor. Most of you have read it already, but take a moment to do so now if you have not. (Experimenter pauses). Xenograde Systems is nothing more than a fancy name for an imaginary system. You will probably find the science concepts in this system very similar to concepts you have already encountered in previous science courses or in your current chemistry course.

Now go ahead and type in your name - lower case letters are acceptable - and use the left-arrow key located in the lower right corner of the keyboard to correct any typing errors. After you have typed your name, go ahead and press Return.

After each student typed in his/her name, the following paragraph appeared in the bottom portion of the first screen:

Thank you. Your name is now being saved to the record-keeping file. When the Return cursor (the white square) appears in the lower right corner, go ahead and press Return.

When the student pressed the Return key, the above screen erased and the following complete screen appeared:
Right now we are waiting for everyone to get their names typed in correctly. The Smiths have got it made, but the Rimsky-Korsakovs out there may take a little longer!

When told to begin, you may press Return and begin the lesson. Please wait for that instruction so everyone can start at the same time.

The above frame was effective in preventing students from beginning early. Only in a couple of instances did a student start early, in which case the student was told to stop on the first content frame and to listen to the remaining instructions.

**Hardware and Software Limitations**
We are operating under some hardware and software limitations, so please be patient if the program seems slow at times. Each single disk contains all the lesson material plus a record-keeping file that records your interaction with the lesson. Occasionally during the lesson the program will take a few moments to record your responses, and will then come back to the same point in the program.

**Use of Student Lesson Booklet**
Basically, you will progress through the lesson by reading one or more screens of information followed by a question and its related options. (See Lesson Material for a detailed description). Accompanying the computer-based lesson is a student booklet entitled 'XENOGRADE SYSTEMS'. Make sure you have one and that the booklet is labeled in the upper right hand corner with an "XI / X3" if you are at an XI or X3 computer, or with an "X2 / X4" if you are at a X2 or X4 computer. Also make sure that the last page of your booklet is a Work Sheet, which you may mark on to help you with the last two problems. Make no other marks in the booklet. Feel free to use your own paper to take notes.

The booklet contains diagrams and charts related to the content presented by the computer. The lesson will direct you to the booklet at various times. When you are ready to answer a question, firmly press the letter that matches the multiple-choice option you want, then press Return so that the computer knows to accept that answer. Remember to use the left arrow key to correct an answer before pressing Return.
**Answer / Response Conditions**

What happens after you enter your answer? Let’s review the four answer/response conditions:

1. Student enters correct answer on first try, receives corresponding feedback, and the program moves on.

2. Student enters incorrect answer on first try, and receives the message, “Would you like to see the information again?,” followed by a (Y/N) prompt. (The cursor hangs on this line waiting for a “Y” or “N” response). Pressing “Y, Return” takes the student back through the screens of information leading up to the same question.

3. The student has a second attempt to answer. If the second answer is correct, the program responds accordingly and moves on to the next concept in sequence. If the second answer is incorrect, the program likewise responds accordingly and moves on.

4. Student enters incorrect answer on first try, and presses “N, Return” in response to the (Y/N) prompt. By pressing “N” the student forfeits the opportunity for a second chance, and the program moves on to the next concept.

Students were encouraged to take their time to avoid mistakes, but to also use the review option as needed.

**Final Comments**

Any technical problems with the program will not be held against you. Try not to read all the information as it is being displayed to the screen. Any initial increase in reading speed may be offset by eventual eye fatigue. There is a quiz on this material tomorrow. You may press Return and begin.

At this point the experimenter concluded his instructions and recorded the same starting time for all the students.

The statement, "Any technical problems with the program will not be held against you," was intended to give students the impression that there was a score associated directly with performance on the computer-based lesson. The experimenter took this approach on the
advice of the cooperating teachers who stressed that the students would apply themselves more if they felt a score was associated with their effort. The teachers, however, were playfully elusive when asked by individual students if participation would affect their chemistry grade.
Appendix O

Posttest II
Question 1. The diagrams below illustrate the motion of satellites when a Xenograde System is placed in a magnetic field. Which of these diagrams best illustrates the motion of a satellite in a magnetic field?

- **Original orbit**

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Description</th>
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<tbody>
<tr>
<td>A</td>
<td>Path of Satellite</td>
</tr>
<tr>
<td>B</td>
<td>Path of Satellite</td>
</tr>
<tr>
<td>C</td>
<td>Path of Satellite</td>
</tr>
<tr>
<td>D</td>
<td>Path of Satellite</td>
</tr>
</tbody>
</table>
Read each of the three statements below and decide whether

Question 2. It is true or false.

1. The satellite will have picked up all the alphon[s] at time-3.
2. The satellite will be carrying three alphon[s] between collisions c and d.
3. By the time all the alphon[s] have migrated outward again to complete 1.5 breathing cycles, more than five collision[s] will have occurred.

A 2 true; 1 and 3 false
B 1 and 2 true; 3 false
C 3 true; 1 and 2 false
D All statements are false.
Question 3. The following diagram illustrates a Xenograde System. Various elements of the system are identified by small letters.

Choose one of the lists below to correctly identify the elements labeled in the diagram.

A
a. alphon
b. alphon
c. satellite
d. nucleus
e. inner region
f. outer shell
g. satellite
h. alphon

B
a. nucleus
b. satellite
c. alphon
d. inner region
e. outer shell
f. orbit
g. alphon
h. satellite

C
a. nucleus
b. alphon
c. satellite
d. alphon
e. inner region
f. orbit
g. satellite
h. alphon

D
a. nucleus
b. satellite
c. alphon
d. inner region
e. inner region
f. orbit
g. alphon
h. satellite
Question 4. Below are several Xenograde records. Which of these records demonstrates normal breathing?

<table>
<thead>
<tr>
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<th>Outer</th>
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<tbody>
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<th>Inner</th>
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<td>8</td>
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<tr>
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</table>
Question 5. The diagram below illustrates the nucleus at various times during breathing.

Some of the following three statements may be true and some may be false. Choose the answer which correctly identifies which are true and which are false.

1. The inhale phase includes times 1 to 4 and exhale phase includes 5 to 8.

2. Time-5 would look like this: [Diagram of a nucleus with two dots]

3. At the end of each breathing cycle, the nucleus would look like: [Diagram of a nucleus with four dots]

A 1 and 2 true; 3 false  
B 1 true; 2 and 3 false  
C 3 true; 1 and 2 false  
D All statements are false.
Question 6.
The following diagrams illustrate the nucleus at various times during breathing. The diagrams below either correctly or incorrectly indicate the number of alphons seconds which have passed since the system was placed in a magnetic field. Assume that all alphons were in the center of the nucleus.

Determine which diagrams are correctly labeled. Choose the answer which correctly identifies which of the diagrams are correct and which are not.

A  a and c correct; b incorrect
B  b correct; a and c incorrect
C  b and c correct; a incorrect
D  All diagrams are correct.
Question 7. The diagrams below illustrate nuclei of several xenograde systems.

Choose the answer below which correctly describes which of these systems has Xenograde-7 as its alphon number.

A 3 does; 1 and 2 do not
B 2 does; 1 and 3 do not
C 1 does; 2 and 3 do not
D All have Xenograde-7 as their alphon number.
Question a. The diagram below illustrates the path of one satellite in a Xenograde System which was placed in a magnetic field at time-8. Each of the three statements below is either true or false. Read each one and decide whether it is true or false.

1. The satellite picks up an alphon from the nucleus at time-7.
2. The satellite is moving slower at time-8 than at time-6.
3. The satellite may leave an alphon at collision d.

Which of the following is correct?

A 1 and 3 true; 2 false  
B 2 and 3 true; 1 false  
C 2 true; 1 and 3 false  
D All statements are false
Question 9.
The diagram below is the same as for the preceding question. It illustrates the path of one satellite in a Xenograde System which was placed in a magnetic field at time-0. Read each one of the statements and decide whether it is true or false.

1. The nucleus has more alphans in it at time-3 than at time-1.
2. The amount of time between collision a and collision b is longer than between collision b and collision c.
3. The alphans in the nucleus are migrating inward at time-3.

Which of the following is correct?

A 1 and 2 true; 3 false  
B 2 and 3 true; 1 false  
C 2 true; 1 and 3 false  
D All statements false
Question 10. If a nucleus contains six particles and the number of particles in each region of the nucleus is counted each time a particle migrates, how many particles would be in the inner region and how many particles would be at the outer shell on the 8th such count? (Assume that all of the particles were in the center of the nucleus to begin with and that the first count was made when the first particle migrated).

A  5 at the outer shell; 1 in the inner region
B  8 at the outer shell; 0 in the inner region
C  2 at the outer shell; 4 in the inner region
D  4 at the outer shell; 2 in the inner region
<p>| | | | | |</p>
<table>
<thead>
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<td>D</td>
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<td>A</td>
<td></td>
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<td>5.</td>
<td>D</td>
<td></td>
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</tbody>
</table>
Appendix P

Procedures for Data Collection Using SuperPILOT System Log
System.Log Procedures

XENOGRADE SYSTEMS: Directions for Use

Equipment Needed:
Apple II+ or Apple IIe microcomputer
64K Memory
2 disk drives
(1 disk drive may be used but requires extra disk handling during data retrieval)
monitor
printer (for obtaining hard copy of data)

Running the Lesson
1. Put the Xenograde Systems disk in Drive 1.
2. Put the System.Log disk in Drive 2.
3. Turn on the computer and put down the drive doors as soon as each drive light comes on.
4. A menu will appear on the screen. In response to the question, "Run which lesson?", type 1 for menus with eight lesson files, and type 1X for menus with ten lesson files.
5. The program should be ready to run and the introduction should be displayed on the screen.
6. As instructed by the program, the student will type in his/her name and proceed with the lesson.
7. As instructed by the program, the student will raise his/her hand to indicate completion.

More data storage space is available when System.Log is on its own disk drive as opposed to when System.Log must share space on a lesson disk in a single drive system.

Maintenance of Records
After each student is finished, the System.Log record must be renamed because of limitations in the size of records that can be accessed by the SuperPILOT Editor.

For Dual Drives
1. Take the Xenograde Systems disk out of Drive 1.
2. Put the SuperPILOT Author disk in Drive 1.
4. Reset the computer. Remember to put the drive door down.

Proceed to Step 5 below.
For Single Drives

A dual disk drive system will be necessary for accessing student records.

1. Take the Xenograde Systems / System.Log disk out of the single drive and move to a computer with two disk drives.
2. Put the SuperPILOT Author disk in Drive 1.
4. Turn the computer on. Remember to put the doors down.

Proceed to Step 5 below.

5. When the main menu appears, choose "L" for Lesson Text Editor.
6. Type "E" for Edit, then choose System.Log.
7. Type "Q" for Quit. In response to, "Do you want to save this lesson as System.Log?", type NO. Give the file any appropriate name other than System.Log.
8. When the Editor menu appears again, type "E" for Edit and choose System.Log again.
9. Press "D" for Delete, type the number 1,000 (this will not appear on the screen), and press RETURN.
10. Press "Q" for Quit. In response to, "Do you want to save this lesson as System.Log?", type YES. (This procedure saves space again for another unique student record file).
11. Press "Q" to return to the main menu.

Repeat the maintenance steps for every student record to be saved. If another student is going to run Xenograde Systems, see Running the Lesson.
Appendix Q

System Log Data from Data Collection Site
System Log Profile

Difficulties in System Log data collection during the field test were reported in Chapter 3. A partial composite profile of the collected data is presented in this section.

The following percentages indicate the amount of complete System Log data collected from each group: Lo/CF - 42%; Hi/CF - 41%; Lo/AIF - 45%; and Hi/AIF - 44.7%. The average of the four groups equals 43%. Much of the 57% not reported exists on the individual disks but not in a sufficient manner for inclusion in the profile. Loss of more than half the available information prohibits a statistical analysis of the remaining data. However, group averages are displayed in Table D for the response/feedback conditions recorded by System Log (see Appendix M for details and examples of each condition). Some general observations are made based on these averages.
Table D

Comparison of Group Averages for Student Response. Conditions Recorded by System.Log

<table>
<thead>
<tr>
<th>Conditions</th>
<th>X1 (Lo/CF)</th>
<th>X2 (Hi/CF)</th>
<th>X3 (Lo/AIF)</th>
<th>X4 (Hi/AIF)</th>
<th>( \bar{X} )</th>
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<tr>
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<td>2.0</td>
<td>2.0</td>
<td>1.2</td>
<td>1.8</td>
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</tbody>
</table>

**Note:** The number in each row represents the group average of student responses during the lesson for the particular response condition recorded by System.Log.

The following observations can be made about the data in Table D:

1. The number patterns for each row of conditions reflect a general consistency, for example, the number missed on the second try (condition 3) or the total times review was not chosen (condition 4).
2. Students were correct on the first try 70% of the time.
3. Students chose review 3.5 times more than not choosing review.
4. Students were twice as likely to be correct versus incorrect on their second try.
5. Lo/CF and Hi/CF averages are identical.
6. Lo/AIF scored lowest on the first try, but also chose review more often and scored highest on the second attempts.

7. Hi/AIF scored highest on the first try, chose review less often, and missed fewer on the second attempt. Hi/AIF had the lowest number correct on second attempt (although almost identical to the other treatment scores) which could be attributed to most of the Hi/AIF scoring correctly on the first try.

Firm conclusions cannot be drawn from any of the identified patterns above. The generally consistent nature of the existing System.Log data does suggest that a reasonable percentage of the missing data might support these patterns.