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ABSTRACT

In this experiment, 376 undergraduates studied five instructional units through the audio-tutorial method during a five-week period. Instructional unit sequences included a Structure Based Unit Sequence (SBUS) and a Test Determined Unit Sequence (TDUS). The SBUS was based on an analysis of major concepts; units including concepts considered prerequisite to other units were put into the sequence on that basis. The TDUS began with the unit on which students scored highest on an achievement pretest and moved progressively to units represented by lower mean achievement scores. The two forms of control for within-unit experience sequences were Teacher Directed Experience (TDE) and Student Selected Experience (SSE). TDE subjects followed a teacher-prescribed sequence while SSE subjects used lists of objectives and related activities to select within-unit sequences. The findings included: treatment groups did not differ significantly in biology achievement or attitude toward the biology course; subjects in all treatment groups made highly significant gains in achievement; and SSE subjects used significantly more time than TDE subjects on two instructional units. A combination of factors which included SAT-mathematics score, grade point average, and the score from a biology achievement pretest were the best predictors of biology achievement. (Author/MH)

THE EFFECTS OF DIFFERENT SEQUENCES OF INSTRUCTIONAL UNITS AND EXPERIENCES WITHIN INSTRUCTIONAL UNITS ON THE ACHIEVEMENT AND ATTITUDES OF COLLEGE GENERAL BIOLOGY STUDENTS

By

Alfred V. Gunter, Ph.D.

The Ohio State University, 1973

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The effects of two different sequences of instructional units and two forms of control for within-unit experience sequences on the achievement and attitudes of students in a college introductory biology course were investigated.

In the experiment, 376 undergraduate students studied five instructional units through the audio-tutorial method during a five week period. Instructional units included Photosynthesis, Respiration, Mitosis and Meiosis, Genetics, and Control Mechanisms. In addition to independent study sessions (ISS), subjects attended a weekly discussion period in which problems encountered in the ISS were discussed.

Instructional unit sequences included a Structure Based Unit Sequence (SBUS) and a Test Determined Unit Sequence (TDUS). The SBUS was based on an analysis of major concepts included in the five instructional units. Units including concepts considered prerequisite to other units were put into the sequence on that basis. The unit considered to be dependent on the other four was given terminal status in the sequence. The TDUS was based on results obtained from the administration of an achievement pretest which included a scale for each instructional unit. The TDUS began with the unit on which subjects scored highest and moved progressively to instructional units represented by lower mean achievement scores.

The two forms of control for within-unit experience sequences were Teacher Directed Experience (TDE) and Student Selected Experience (SSE). TDE subjects followed a teacher-prescribed sequence while SSE subjects used lists of objectives and related activities to select within-unit sequences.

Upon completion of the experimental units, treatment groups did not differ significantly in biology achievement, or attitude toward the biology course. When subjects in the SBUS and TDUS groups were compared on the basis of average time used to complete instructional units, significant differences favored the TDUS group by two to one. Both groups used a greater amount of time to complete the units they encountered first in a sequence. SSE subjects used significantly more time than TDE subjects on two instructional units.

Other findings included: (1) a combination of factors which included SAT-Mathematics score, grade point average, and the score from a biology achievement pretest were the best predictors of biology achievement, (2) within-unit experience sequences selected by SSE subjects were not similar to those prescribed by an instructor for that same unit, (3) subjects with high grade point averages used more time to complete instructional units and scored higher on the achievement posttest than did low grade point average subjects, and (4) subjects in all treatment groups made highly significant gains in achievement.

Stanley L. Helgeson

THE EFFECTS OF DIFFERENT SEQUENCES OF INSTRUCTIONAL UNITS AND EXPERIENCES WITHIN INSTRUCTIONAL UNITS ON THE ACHIEVEMENT AND ATTITUDES OF COLLEGE GENERAL BIOLOGY STUDENTS

DISSERTATION

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

By

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* * * * *

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Major Field: Science Education.

Minor Fields: Biology and Higher Education.

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Chapter 1

INTRODUCTION TO THE PROBLEM

Introduction and Need for the Study

Many types of instructional materials and a variety of audio-tutorial equipment are available for use in college general biology courses. Items such as conceptopaks, minicourses, modules, and complete audio-tutorial packages provide those with a responsibility for teaching biology to general education students a real opportunity for innovative instruction.

A cursory inspection of what is now available might lead to the impression that the real problem in biology teaching is to select the right program or package. However, a closer examination quickly reveals that there is really not much agreement as to how general biology should be taught. Textbooks do not always include the same instructional units and those that do often have them arranged in different patterns. Moreover, the same is true within instructional units where the sequence of experiences varies considerably from program to program.

There is nothing inherently wrong with a multiplicity of approaches to biology teaching and the corresponding variety of available instructional materials. The real problem is our inability to effectively use that which is available.

It seems reasonable to say that there is fairly unanimous agreement among educators that instruction should be geared to the individual learner. However, observations of many biology classrooms and laboratories indicate that we really do not know too much about how to get the job done. Quite often all students are expected to follow one pattern in the instructional sequence and they are expected to progress at fairly uniform rates. The pattern or sequence of events might be that of a textbook, or one provided by the instructor which he "feels" is right.

This approach (authoritative) to course development is no longer acceptable to many individuals. Miel (1968) suggests that students may go through different sequences in arriving at similar points of understanding, and that there is real danger in insisting that large groups of students follow indefensible sequences of instruction. She goes on to say that our old ideas about the "best order" in teaching are being challenged.

Individualizing the rate of instruction is a problem that has a technological solution. However, sequencing instructional units and experiences within units is another matter. Bellack (1964:277) states that it is necessary to go beyond sequencing that is based on tradition or feelings.

Theoretical Basis for Study

An examination of college biology textbooks written for general education indicates that there is little or no agreement among textbook writers as to the overall sequence for instructional units. Although there is probably better agreement concerning the sequence of concepts within instructional units there is no uniform pattern of development.

If variety exists among biology textbooks, then it must also be true that biology courses for non-science students are even more diverse. College biology courses are designed by individuals or small groups of instructors who are usually professional biologists. They develop instructional units and complete courses on the basis of the way in which they understand their discipline. In many cases, it is probably fair to say, no real attempt is made to determine the effectiveness of instructional programs prepared in this manner. But even if evaluative techniques are employed, the basic approach may be entirely incorrect. Green (1967:70-71) has suggested that:

> The organization of instructional materials in accordance with common sense principles or even in terms of the logic of a subject matter may not necessarily be the best way to organize a course from the viewpoint of the learner.

It could very well be that we have reached a point in the history of undergraduate education where a logical approach in course development is no longer acceptable. It appears that, in the not too distant future, the colleges and universities will have to provide evidence to support the effectiveness of the programs and courses that are a part of their curricula. They will have to show that courses have been properly conceived and developed, and that the behaviors of students enrolled in them change in a predictable and measurable manner.

At this point those who have been active in the area of programmed instruction would say that there is really nothing unique about preparing effective instructional materials. For example, Green (1967:70) states that program development requires a description of desirable end states, some knowledge of the learner's initial level of understanding, and a reasonable progression of steps leading to mastery.

Much that has been written about learning theory would seem to support this approach. In the Sixty-third Yearbook of the National Society for the Study of Education, Bruner (1964:313) makes the following statement:

> Instruction consists of leading the learner through a sequence of statements and restatements of a problem or body of knowledge that increase the learner's ability to grasp, transform, and transfer what he is learning. In short, the sequence in which a learner encounters materials within a domain of knowledge affects the difficulty he will have in achieving mastery.

In another publication Bruner (1960:31) further emphasizes the importance of underlying principles and overall structure in the development of a basic understanding of a subject.

Some of the major ideas presented by Gagne (1970:26-27) are very similar to those of Bruner. Gagne also feels that knowledge acquisition is sequential and new capabilities are based on previously learned capabilities. He suggests that there are a number of different types of learning and that they are arranged in a hierarchy. Gagne also agrees that the preparation of instructional materials must involve content analysis and the designation of terminal behaviors.

A somewhat different approach to concept learning is described by Ausubel (1968). In his principle of subsumption he contends that learning is facilitated by the use of "advanced organizers." In other words, new learning tends to be subordinate to more inclusive or general ideas that are already a part of cognitive structure. Although

Mechner (1967:81-103) does not refer to "advanced organizers" or the subsumption principle, his discussion of instructional sequencing clearly parallels Ausubel's theory. Mechner refers to "backward fading" in chaining. This involves teaching the last member of a chain first, then the next to the last, etc.

A theory of instruction which takes into consideration both the nature of the subject matter and the events that occur in teaching has been advanced by Anderson (1966a:289). Anderson defines learning as stimulus - response conditioning resulting in the production of chains of responses. The function of the teacher is to present information and activities in a sequence that will promote desirable chain formation. Anderson suggests that the sequence of presentation has a considerable influence on the ease of response chain formation.

Thus it appears that, among educational theorists, there is fairly good agreement that some type of cognitive structure must be a part of the learning situation. Ausubel (1968:128) describes the situation by stating that "if cognitive structure is unstable, ambiguous, disorganized, it tends to inhibit meaningful learning." Anderson (1969:227) goes a bit beyond the views of Ausubel by suggesting that a structure does indeed exist and that in science the structure must have a chronological basis. According to Anderson a curriculum which is chronologically sequenced should facilitate the development of inquiry skills and the retention of knowledge.

Although there is agreement that cognitive structure is important to learning, there does not seem to be any real concensus concerning the nature of that structure. For example, Bruner (1964:313) says:

> There are usually a variety of sequences that are equivalent in their ease and difficulty for learners. There is no unique sequence for all learners, and the optimum in any particular case, will depend upon a variety of factors, including past learning, stage of development, nature of the material, and individual differences.

In a discussion of Gagne's hierarchy, Hilgard (1966:571) makes the following observations:

> . . . it is by no means clear that a sequence of instruction can be designed upon it [Gagne's hierarchy] or that that basic notion is sound that the lower steps of the hierarchy have to be mastered before the higher steps can be learned. There may well be a cyclical development in learning, in which the various stages repeatedly assert themselves.

The foregoing discussion indicates that there are many unanswered questions that relate to sequencing in learning. Is there an overall sequence that is more effective than others? If so, how can it be defined for specific areas of instruction? Or, is it possible that the arrangement of events in learning experiences is not really critical? Obviously, answers to these and other questions can only be arrived at by experiments aimed at specific subject areas and the various types of students that are included in typical educational institutions.

Statement of the Problem

Major Problem

For college students studying introductory biology in a course for non-science majors, does the organizational sequence of instructional units and the control (student vs. teacher) of the sequence of experiences within instructional units affect biology achievement and students' attitudes toward the biology course?

Subproblems

For college students studying introductory biology in a general education course taught through the audio-tutorial method:

1. Is biology achievement affected by the organizational sequence of instructional units?

2. Does control (student vs. teacher) of the sequence of experiences within instructional units affect biology achievement?

3. Is there an interaction between the organizational sequence of instructional units and control (teacher vs. student) of the sequence of experiences within instructional units that affects biology achievement?

4. Is there a single characteristic, or a combined set of characteristics, that will reliably predict biology achievement?

5. When students are permitted to select the sequence of experiences within instructional units, will their attitudes (toward the course) differ from the attitudes of students following a teacher directed sequence?

6. Does control (student vs. teacher) of the sequence of experiences within instructional units affect the amount of time required to complete instructional units?

7. Does the organizational sequence of instructional units affect the amount of time required to complete instructional units?

8. When students are permitted to select the sequence of experiences within an instructional unit, will the sequence they select be similar to the teacher directed sequence for the same unit?

Assumptions

1. It is possible to devise and utilize several different sequences of instructional units for a college introductory biology course.

2. It is possible to devise and utilize a teacher directed sequence of experiences within the instructional units included in a college introductory biology course.

3. The entry level biology achievement of students enrolled in a college introductory biology course can be measured.

4. Instruments that measure biology achievement and student attitudes toward a college introductory biology course can be developed.

5. When giv: ı the opportunity, students in a college introductory biology course will select a within-unit experience sequence.

Limitations

1. Subjects were limited to students enrolled in Basic Biology at Shippensburg State College during the 1972-73 academic year.

2. Discussion group meetings were taught by eight different instructors.

3. Instructional units included in the study were traditionally oriented (did not emphasize human biology, population problems, ecology, etc.).

Delimitations

1. Important cognitive and non-cognitive outcomes of the learning process other than biology achievement and subjects' attitudes

toward a biology course were not considered.

2. Only selected instructional units were included in the study.

Definitions of Terms

1. Instructional unit - a major segment of study included in many college introductory biology courses (cell structure and function, genetics, respiration, etc.).

2. Structure based unit sequence - an arrangement of instructional units which begins with a unit which includes major concepts that are considered prerequisite to other units and moves progressively through units of increasing conceptual sophistication to a terminal unit which is structurally dependent on those which precede it.

3. Test determined unit sequence - a sequence of instructional units which is based on results obtained from an achievement pretest. Mean achievement scores for instructional units (which are represented by test scales) are used to arrange units in a sequence which progresses from high to low achievement.

4. Teacher directed experience - an arrangement of experiences within an instructional unit based on an analysis of concepts included in each instructional unit.

5. Student selected experience - an arrangement of experiences within an instructional unit resulting from student selection of major objectives and related learning experiences.

6. Learning experiences - activities that constitute an instructional unit (observing demonstrations, reading, listening, viewing films, etc.).

7. Achievement - knowledge attained or skills developed in school subjects, usually designated by test scores or marks assigned by teachers.

8. Attitude - a readiness to act toward or against some situation, person, or thing in a particular manner.

Hypotheses

For college students studying introductory biology in a general education course taught through the audio-tutorial method:

1. The organizational sequence of instructional units does not affect biology achievement.

2. Control (student vs. teacher) of the sequence of experiences within instructional units does not affect biology achievement.

3. There is no interaction between the organizational sequence of instructional units and control (student vs. teacher) of the sequence of experiences within instructional units that affects biology achievement.

4. For college students studying introductory biology in a general education course taught through the audio-tutorial method, there is no single characteristic, or set of combined characteristics, that will reliably predict biology achievement.

5. Control (student vs. teacher) of the sequence of experiences within instructional units does not affect students' attitudes toward the biology course.

6. The organizational sequence of instructional units does not affect the amount of time required to complete instructional units.

7. Control (student vs. teacher) of the sequence of experiences within instructional units does not affect the amount of time required to complete instructional units.

8. Sequences of experiences within specific instructional units that are selected by students will not be similar to teacher directed sequences for those same units.

Description of Basic Biology Course

At Shippensburg State College Basic Biology is a general education course for non-science students. Each semester it is taken by 350 to 500 students from the broad fields of teacher education (elementary and secondary) and the arts and sciences curriculum. The course is one semester in length and, during the experimental period, it included the following instructional units:

1. Chemical Basis of Life.
2. Cell Structure.
3. Movement of Materials.
4. Photosynthesis.
5. Respiration.
6. Mitosis and Meiosis.
7. Genetics.
8. Control Mechanisms.
9. Animal Reproduction and Development.
10. Evolution.
11. Ecology.

With the exception of Ecology all instructional units were one week in length. Three of the eleven units (Chemical Basis of Life, Evolution, and Ecology) were taught through a conventional lecture-discussion approach. All remaining units were taught through the audio-tutorial approach.

During the weeks that instructional units were taught through the audio-tutorial approach subjects attended an independent study session (ISS) and a small group (30 students) discussion period. The ISS area was available during daytime and evening hours on Monday, Tuesday, Wednesday, and Thursday each week. Independent study sessions were approximately two hours in length. During the ISS subjects listened to audio tapes; read from textbooks, manuals, and mimeographed sheets; engaged in experimental activities; and observed demonstrations and short films. All of the subject matter considered in the course was included in the ISS. Discussion periods were 50 minutes in length and provided students with an opportunity to discuss those items included in the ISS. The seventeen discussion groups were taught by eight different instructors.

The instructional units titled Photosynthesis, Respiration, Mitosis and Meiosis, Genetics, and Control Mechanisms were included in the experiment.

Chapter 2

REVIEW OF RELATED STUDIES

Major Sources of Information Consulted

A systematic review of the following broad sources of information was conducted.

1. ERIC Educational Documents Index, CCM Information Corp., New York.

2. Current Index to Journals in Education, CCM Information Corp., New York.

3. Handbook of Research on Teaching (edited by N. L. Gage), Rand McNally and Co., Chicago, Illinois, 1963.

4. Dissertation Abstracts, University Microfilms, Ann Arbor, Michigan.

5. Encyclopedia of Educational Research, American Educational Research Association, The Macmillan Co., New York, 1960.

6. Education Index, The H. W. Wilson Co., New York.

7. Readers Guide to Periodical Literature, The H. W. Wilson Co., New York.

8. Review of Educational Research, American Educational Research Association (NEA), Washington, D. C.

9. Psychological Abstracts, American Psychological Association, Lancaster, Pa.

Categories of Research Studies Reviewed

Studies included in the review were assigned to one of the following areas:

1. Sequential Learning.
2. Learner Control of Instruction.
3. Effect of Instructional Method on Achievement.
4. Student Characteristics as Predictors of Achievement.
5. Effect of Instructional Method on Students' Attitudes Towards a Course.
6. Student Characteristics as Learning Variables.
7. Individualized Instruction.

Sequential Learning

From available studies of sequential learning, several represent tests of Ausubel's advanced organizer theory. For example, Ausubel and Fitzgerald (1962) investigated the relationship between background knowledge, antecedent learning, and sequential verbal learning. College students were asked to learn two sequentially related passages from the subject of endocrinology. Results of the study indicated that (1) background knowledge was helpful in learning the first passage, (2) knowledge of the first passage was important in learning the second passage, and (3) advanced organizers enhanced the learning of students with relatively poor verbal abilities.

The effect of advanced organizers on the acquisition and retention of knowledge has also been tested by Kuhn (1967). Subjects in Kuhn's study were elementary education majors enrolled in a college biology class. Results indicated that the acquisition and retention of meaningful material was enhanced by the use of organizers. Kuhn also found a significant relationship between acquisition and retention of knowledge and analytical ability.

Grotelueschen and Sjogren (1968) have tested the effect of structure and sequence in a learning experience on ability to perform related learning tasks. Experiments were conducted with adults and graduate students. Subjects were required to complete an introductory mathematics program prior to completion of a related task. Introductory materials varied in structure. Related tasks were sets of paired associates which varied in degree of sequence from complete, through partial, to no sequence. The investigators concluded that (1) introductory materials do facilitate learning of a number base concept, and (2) partially sequenced materials had a facilitating effect on transfer.

In a study reported by Pella and Triezenberg (1969), three different forms of an advanced organizer were tested. Students in grades seven and nine were taught ecological principles through use of a Mobile Video Distribution System. The concept of equilibrium was the basis for the advanced organizer. Modes of presentation included (1) verbal, (2) verbal supplemented with sketches, and (3) verbal supplemented with a mechanical model. Following a uniform introductory lesson, subjects in the three treatment groups were exposed to eight lessons on ecological subjects that involved the concept of equilibrium. All lessons contained the same basic concepts--the difference between lessons was in the way in which the advanced organizer was utilized.

Conclusions included:

1. working models for advanced organizers were more effective in promoting student achievement at the comprehension level.

2. advanced organizers produced higher mean test scores in grade 9 than in grade 7 at the knowledge level for all pupils, and at the comprehension level for pupils of high and average ability.

In a study involving fourth, fifth, and sixth grade science students, Pyatte (1968) investigated the effects of unit structure on achievement and transfer. Structured units were based on Gagne's hierarchy. Pyatte concluded that there was no evidence to support the idea that teaching based on the structure of science is important. He found that grade level and ability were more significant to achievement than structure or mode of presentation.

Gagne's Hierarchical Learning Theory also served as a theoretical basis for a study conducted by Tamppari (1969). Principles related to photosynthesis were arranged in a sequence and tested on fifth, seventh, and ninth grade students. Tamppari found that achievement was directly related to grade level and that male subjects in grade nine outperformed females. He concluded that while it is possible to construct a model for biology curriculum development by organizing a hierarchy of pertinent concepts and principles, the regular curriculum being utilized by subjects had not been based on psychological theory.

Anderson (1967-1968) used programmed materials to investigate the effects of varying the structure of science content on the acquisition of science knowledge. Subjects were junior high school students with above average ability. Anderson found that programs with decreasing levels of structure resulted in a decrease in knowledge acquisition. In an earlier study Anderson (1966b) had obtained similar results.

Much of the experimental work related to sequential learning has been done by investigators working with various types of autoinstructional programs. For example, Roe (1962) and several colleagues investigated the effect of scrambling the internal sequence of a program titled Elementary Probability on the number of errors made during instruction, total time required to complete the program, and achievement. Subjects were college students enrolled in a psychology class. A control group used the regular program which was "logically" sequenced. Statistical tests did not reveal significant differences between the experimental and control groups on any of the dependent variables.

Levin and Baker (1963) have also investigated the effect of scrambling the sequence of items in an instructional program. Subjects were second grade students who used teaching machines to study an elementary geometry unit for fifteen minutes each day during a 17 day period. Items in three blocks within the program were scrambled for subjects in the experimental group. Controls studied the standard, logically sequenced program. At the conclusion of the experiment, subjects in the experimental and control groups did not differ significantly in median number of errors, mean work time, or achievement.

A study of sequencing in the area of economics was conducted by Newton and Hickey (1945). The program utilized was on the subject of Gross National Product and included three major sub-concepts. Programs containing different arrangements of sub-concepts were given to 132 college students enrolled in an introductory psychology course. Following completion of the program, which required one class period, subjects were tested for achievement with a ten item multiple choice test. Treatment groups did not differ significantly in achievement or number of errors made during instruction. The investigators found that the amount of time required to complete the program was related to the sequence of the sub-concepts.

Payne, Krathwohl, and Gordon (1967) explored the effect of different amounts of scrambling, within a series of programs, on achievement. The three programs used in the study dealt with the basic concepts of educational measurement. One treatment group was given three scrambled programs and another was given three standard, logically sequenced programs. Other treatment groups were given different combinations of scrambled and standard programs. Following the experiment, none of the treatment groups was significantly better in achievement.

A sequencing study which involved two very different subject areas was conducted by Wodtke, Brown, Sands, and Fredericks (1967). A mathematics program which had a very definite progressive sequence (hierarchical structure), and a program on the anatomy of the ear were included in the two part experiment. Experimental groups were given scrambled programs and controls used standard programs in both parts of the experiment. Although it was anticipated that scrambling would have a more detrimental effect on a program with an inherent hierarchical structure, this was not found to be true. Control and experimental groups did not differ significantly in achievement in either of the experiments. In the mathematics part of the experiment subjects using scrambled sequences used significantly more time and made more errors than controls. Similar differences were not found in the anatomy experiment.

The effectiveness of two different sequence patterns in teaching fifth grade science students multiple discrimination tasks has been tested by Short and Haughey (1966). In the multiple concept approach two concepts were introduced simultaneously at a very general level, followed by greater detail. In the single concept approach, one concept was introduced and taught in detail prior to the introduction of the second concept. During a five day period subjects were taught the characteristics of vertebrate animals through use of a slide-audiotape presentation. At the conclusion of the experiment subjects who had used the multiple concept approach made significantly higher scores on the posttest and retention test.

Summary

Studies by Ausubel and Fitzgerald; Kuhn; Grotelueschen and Sjogren; Pella and Triezenberg; and Anderson, lend support to the idea that sequence is important in the mastery of subject matter. Pyatte's study appears to contradict this idea.

In the area of programed instruction the work of Roe, Levin, and Baker; Newton and Hickey; and Payne, Krathwohl, and Gordon suggests that sequence (in short instructional programs) does not affect student achievement. Wodtke, Brown, Sands, and Fredericks found no significant difference in achievement when subjects using a scrambled form of a math program, that had a definite hierarchical structure, were compared with subjects using a standard form of that same program. In another part of the same experiment Wodtke's group investigated the effect of scrambling on a program which did not possess a hierarchical structure. When subjects using scrambled programs were compared with subjects using standard programs, non-significant differences in achievement and time were obtained. This study provides limited support for the idea that sequence might be important in some instructional programs but not in others.

Wodtke also found that subjects using scrambled forms of the math program used a significantly greater amount of time. Wodtke's findings on time utilization are in fairly good agreement with those of Newton and Hickey who found that the amount of time required to complete the program on Gross National Product was related to the arrangement of subconcepts in the program. However, studies by Roe, and Levin and Baker produced nonsignificant differences when the effect of scrambling on time utilized in the completion of programs was analyzed.

Learner Control of Instruction

Very few studies that involve learner control of the instructional sequence have been reported. A training program for engineers (recent graduates preparing to begin industrial assignments) has been described by Mager and McCann (1961). Subjects were given a detailed description of the course objectives and information concerning a variety of resources. They were then permitted to select the activities and sequences which they preferred. Results included (1) training time was reduced by approximately 50%, and (2) trainees were as good as or better than those prepared through the conventional program.

Olson (1957) compared the effectiveness of two methods of instruction in a college biology course. When students in a "student-centered" or permissive subgroup were contrasted with those in a "teacher-centered" or authoritarian subgroup, it was found that the controls (teacher-centered) outperformed the experimentals on subject matter tests. In a study in which biology students were gradually given greater responsibility for planning learning experiences, Brown (1966) found that the posttest achievement scores of subjects were above predicted scores of students with comparable scholastic ability from randomly selected schools.

Rainey (1965) has investigated the effects of directed and non-directed laboratory work on the achievement of high school chemistry students. Four classes were separated into directed and non-directed groups. The directed groups completed activities that were based on detailed instructions. Students in the non-directed groups were simply given a problem to solve. Both groups were present during recitation-discussion periods. Results of the study indicated that control and experimental groups did not differ significantly in terms of knowledge of principles and descriptive chemistry.

The effect of self-directed study on achievement has also been tested by Hovey, Gruber, and Terrill (1963). This study compared the lecture approach with self-directed small groups. Subjects were college students in an educational psychology course. Although the students in the self-directed groups were slightly superior to those in the lecture groups, there was no significant difference in the mastery of course material.

Judd, Bunderson, and Bessent (1970) studied the effects of learner control of instruction with three remedial mathematics programs. Subjects were college students who used computer assisted instruction to study Exponents, Logarithms, and Dimensional Analysis. Four levels of control which ranged from full learner to full program control were built into the experiment. While subjects in the full learner control group had the option of omitting segments of the program, subjects in the full program control group were required to complete all of the programs. Subjects in groups that were intermediate in control had less freedom than subjects in the full learner control group but more freedom than subjects in the full program control group. Statistical tests revealed (1) treatment groups did not differ significantly in the amount of time used to complete the program, and (2) there was a very small but significant difference in achievement, which favored the learner control group, for the unit on exponents. The investigators concluded that control of instruction did not contribute substantially to student achievement.

A Gagne-type sequence and a student controlled instructional sequence were compared in terms of their contributions to achievement by Oliver (1971). Subjects were college students who used computer assisted instruction to study "imaginary science." Oliver found that learner controlled sequences resulted in poor performance on a criterion measure. The Gagne sequence resulted in fewer errors but did not give subjects a significant advantage on the criterion measure. Oliver concluded that the instructional sequence for relatively short programs may be unimportant.

In a similar study that preceded Oliver's, Campbell and Chapman (1967) explored the effect of learner vs. program control of instruction on achievement. In the experiment 216 fourth and fifth graders studied geography through the use of programed materials for one school year. Although subjects in the learner control group made a significantly greater gain from pretest to posttest on an interest survey instrument, learner and program controls did not differ significantly in achievement.

A study that compared the effects of the lecture approach and independent study on student achievement was conducted by Stavick (1971). College students in a general education biology course were subjects in the experiment. They were pretested and posttested for achievement with the Nelson Biology Test. Treatment groups did not differ significantly in biology achievement at the conclusion of the study.

Summary

The investigation conducted by Mager and McCann provides support for the hypothesis that learning is enhanced when students are permitted to determine the approach they use in a learning experience. Studies by Olsen; Brown; Rainey; and Hovey, Gruber, and Terrill do not support this same hypothesis.

Studies involving various forms of self-instruction have also produced conflicting results. Oliver found that subjects in "learner control" groups performed poorly on a criterion measure. Campbell and Chapman determined that although learner control groups made large gains in achievement, they were not significantly better than controls. Judd, Bunderson, and Bessent reported a small but significant difference in achievement, which favored the learner control group, in one of three math programs used by subjects in an experiment involving computer assisted instruction. Treatment groups did not differ significantly in time used to complete the programs.

Effect of Instructional Method on Student Achievement in Introductory College Biology Courses

Many studies that compare conventional biology instruction (lecture-laboratory) with the audio-tutorial approach have been reported.

Sparks and Unbehaun (1971) compared the effect of audio-tutorial and conventional instruction on the achievement of college biology students. The audio-tutorial students had a large group meeting, an independent study session, and a discussion period each week. Conventional classes attended three lectures and a two hour laboratory each week. Although all students in the study showed significant gains in achievement, the control and experimental groups did not differ significantly.

The effect of audio-tutorial and conventional instruction on biology achievement has also been investigated by Grobe and Sturges (1973). Subjects were college students who were non-science majors. The experimental (A-T) and control groups were exposed to the same content for the same length of time. When the control and experimental group were compared on the basis of posttest achievement scores, they were not significantly different.

Similar studies comparing the audio-tutorial and conventional methods of biology teaching have been conducted by Mitchell (1971), Quick (1971), Himes (1971), and Russell (1968). The biology courses in these studies were of the introductory type. While Mitchell found no significant difference in achievement for audio-tutorial and conventional groups, Himes reported a significant difference in achievement which favored the A-T group (the significant difference was obtained in the second semester of a two semester study), and Quick reported that A-T subjects achieved at a higher level than conventional subjects on a test of biological facts. Himes also reported that male A-T subjects outperformed male subjects in the conventional instruction group. Russell, on the other hand, found that subjects in the conventionally instructed group scored significantly higher than subjects in the A-T group on the Nelson Biology Test.

A study which compared audio-tutorial and conventional instruction as methods of instruction for a course in plant physiology has been reported by Marinos and Lucas (1971). Forty-six college sophomores were separated into a control group, which had two lectures and one three-hour laboratory each week, and an experimental group which utilized an "open" A-T laboratory and attended a one-hour seminar each week. At the end of the nine week period A-T subjects did better on the achievement test. However, achievement differences were not significant.

The effect of two different types of audio tape presentations on student achievement has been investigated by Hoffman and Druger (1971). Students in a college general biology course were divided into direct and non-direct groups. Direct groups received lessons that were descriptive. Non-direct groups were taught through a lecture-question-answer method. Both groups completed the same units of instruction. Although students in the non-direct group performed significantly better on a test of problem solving ability, the groups did not differ significantly on tests that measured the retention of facts and concepts.

Simons (1972) has compared the relative effectiveness of audio tapes and written scripts in teaching biology to college students. Units on genetics and developmental biology were taught during a six week time period. Following instruction, subjects in the treatment group that used audio scripts performed at a significantly higher level on an achievement test for the unit on developmental biology. No significant difference in achievement was found for the genetics unit. Simons also determined that subjects with high scholastic aptitude did well regardless of treatment.

In a study by Strickland (1971) programed instruction and the lecture approach were compared. College students in two general biology classes served as subjects. Strickland found that subjects in the group that used programed instruction scored significantly higher on a biology achievement test.

Shanon (1968) has also compared two different approaches to teaching college biology classes. A conventional recitation-laboratory group was compared with an integrated, independent study group. Shanon found that the conventional approach was more effective in helping students to learn facts and principles.

Alternative methods for teaching general biology to large groups of college students have been studied by Bell (1970). Bell compared the lecture approach (three meetings per week) with a variety of other methods. These included optional attendance, assigned readings, seminars, and tutoring by peers. Audio tapes from lectures were made available to all subjects. On a content type final examination subjects in all of the experimental groups scored significantly higher than control subjects.

The effectiveness of closed circuit television (CCTV) as a method for college biology instruction has been tested by Madson (1969). During the quarter that the experiment was conducted all subjects (college freshmen) attended one three-hour laboratory each week. In addition Group A attended three CCTV sessions and a one hour discussion period, Group B had three live lectures (by the CCTV instructors) and a discussion period, and Group C had three CCTV sessions. Results obtained from achievement tests showed no statistically significant difference in achievement between treatment groups.

The effect of the verbal behavior of biology instructors of college introductory biology courses on student achievement has been investigated by Sayer, Campbell, and Barnes (1972). Interaction analysis was used to identify three instructors who were instructor-centered and three who were student-centered. An achievement posttest based on the first four levels of Bloom's Scale was used to compare subjects in the two treatment groups following instruction. The groups did not differ significantly in biology achievement.

Summary

Most of the studies that have compared audio-tutorial with conventional (lecture-laboratory) biology instruction (Sparks and Unbehaun; Grobe and Sturges; Mitchell; and Marinos and Lucas) have reported no significant difference in biology achievement. However, Himes found that A-T subjects scored significantly higher during one semester of a two semester study, and Quick reported that A-T subjects achieved at a higher level than subjects in conventional groups. Russell, on the other hand, found that conventional subjects significantly outscored A-T subjects. In another audio-tutorial study, Hoffman and Druger found that direct and non-direct tapes did not significantly influence achievement. Simons found that students who used audio scripts were significantly higher on an achievement test than students who used audio tapes.

Significant differences in achievement, which favored experimental groups, have been reported by Strickland who compared programed instruction with the lecture approach, and Bell who compared a variety of instructional formats with the lecture approach. Shanon found that conventionally taught subjects scored significantly higher on achievement measures than subjects who participated in independent study. Madson who compared closed circuit television and the lecture approach, and Sayer, Campbell, and Barnes who compared teacher centered and student centered instructors found that treatment groups were not significantly different in performance on achievement measures.

Student Characteristics as Predictors of Achievement in College Introductory Biology Courses

The relationship between student abilities and achievement in college introductory biology courses has been investigated by Meleca (1968), Sherrill and Druger (1971), and Grobe (1970). Meleca's study involved students enrolled in a course that was taught through an auto-instructional approach. He found that mathematics and biology aptitude scores were good predictors of biology achievement. Sherrill and Druger concluded that mathematics aptitude was the best predictor of biology achievement. However, Grobe reported that student aptitude was not a good predictor of biology achievement and that high school science background was not significant in the promotion of biclogy achievement for students using the audio-tutorial approach.

Scott (1966) attempted to identify predictors of success in college science and math by comparing student performance in high school science and math with performance in college science and math. Statistical tests on data collected from the records of 1,095 college graduates resulted in the following conclusions.

1. average high school mathematics grade is a good predictor of success in college science and mathematics.

2. in general, high school science grades are good predictors of college science grades.

Findings of Tamir (1968), in a study that examined the influence of high school science background on performance in a college introductory biology course, are in agreement with those of Scott. Tamir found that students who had not taken high school biology and/or chemistry were severely punished in college introductory biology.

In a recent review of research related to Ausubel's theory of learning, Novak, Ring, and Tamir (1971) list high school biology achievement as the best predictor of college biology achievement, and high school chemistry achievement as the best predictor of biology achievement for college freshmen.

Summary

Results of most of the studies that have explored student characteristics as predictors of biology achievement support the idea that math and biology aptitude are good predictors of biology achievement and that achievement in high school science is directly related to achievement in introductory college biology courses. However, results obtained by Grobe indicate that student aptitude and prior coursework in science are not always effective predictors of achievement in college introductory biology courses.

Effect of Instructional Method on Students' Attitudes Toward a College Introductory Biology Course

Several investigators who have compared conventional (lecture-laboratory) instruction with the audio-tutorial (A-T) approach have reported an improvement in student attitudes toward the A-T approach. Although differences in mean attitude score for treatment groups were not reported as significant, Himes (1971) found a "favorable response" to A-T, and Quick (1971) detected a "high level of satisfaction" for A-T subjects. Simons (1972), who compared the effectiveness of audio scripts and audio tapes, found that treatment groups differed significantly in attitude toward the biology course and that the difference favored the treatment that had been given first. Hoffman's study (1969), which compared the effect of direct and non-direct tapes on students' biology achievement, produced a significant shift in the attitudes of subjects (in both treatment groups) towards A-T instruction.

Investigations involving a variety of instructional approaches have produced conflicting results concerning students' attitudes toward a biology course. Wodtke, Brown, Sands, and Fredericks (1967) found no significant difference in attitude toward CAI when subjects who had used scrambled programs were compared with subjects who had used traditional programs. Bell (1970) also reported no significant difference in attitudes when subjects who had been taught through the lecture approach were compared with subjects who had been exposed to a variety of instructional approaches that did not include lecturing. In a study which included closed circuit television, Madson (1969) found that subjects whose only contact with an instructor was in the laboratory had positive attitudes toward laboratories. Madson also found that subjects who had been provided with "live lectures" had more positive attitudes toward lecturers than subjects who studied through the use of closed circuit television.

Summary

Researchers who have compared the audio-tutorial (A-T) approach with conventional instruction (Himes and Quick) report attitudes that are favorable to the A-T approach. Simon, who compared the effectiveness of audio scripts and audio tapes, found significant differences in the attitudes of subjects which favored the instructional method that they had used first. Hoffman determined that both direct and non-direct audio tapes had a positive effect on the attitudes of subjects toward A-T instruction.

The effect of instructional method on students' attitudes toward a course or instructional program has been investigated by Bell; Madson; and Wodtke, Brown, Sands, and Fredericks. Bell found no significant difference in attitude resulting from subjects' participation in a variety of instructional procedures. Similar results were obtained by Wodtke's group when subjects using CAI to study programs with different internal sequences were compared. Madson found that subjects whose only contact with their instructor was in a laboratory, had positive attitudes toward laboratories and subjects who had been taught by "live" lecturers had more positive attitudes toward lecturers than subjects who had studied through the medium of closed circuit television.

Student Characteristics As Learning Variables

Many investigators who have examined possible relationships between personality variables and achievement have utilized the medium of Computer Assisted Instruction (CAI). For example, Tobias (1972) studied the effects of distraction, response mode, and anxiety on the achievement of college students who studied heart disease with a CAI program. Distraction was in the form of nonsense syllables that were periodically flashed on terminal screens. Subjects in the distracted treatment group were expected to memorize the nonsense syllables while studying the regular program. Response modes included reading and constructed response (subjects had to respond overtly by typing a message). Tobias found that subjects who constructed responses had high anxiety levels and that distraction did not affect achievement. Tobias also found that construction of responses led to higher achievement.

In a study that preceded the work of Tobias, O'Niel (1970) also found that constructed responses produced high state anxiety. However, O'Niel did not find significant differences in achievement for constructed response and reading response subjects. O'Niel's study also involved college students who studied heart disease through CAI. Because constructed response subjects took almost twice as much time as reading response subjects to complete the CAI program, O'Niel repeated the study with a shorter version of the program. He found that shortening the program did not reduce state anxiety for constructed response subjects. O'Niel concluded that instructional time is not the critical variable for reducing state anxiety or improving achievement.

The effect of a shortened program on state anxiety and achievement has also been investigated by Leherissey, O'Niel, Heinrick, and Hansen (1971). Subjects were college students who studied heart disease through a CAI program. Shortening the program did not reduce state anxiety, but did improve the performance of subjects with medium level state anxiety. However, the shortened program had a debilitating effect on the performance of subjects in the high level anxiety group.

The relationship between anxiety and dogmatism has been studied by Rappaport (1971). Female college students in a psychology course were assigned to treatment groups on the basis of high or low dogmatism and trait anxiety. During the performance phase of the study, subjects used a CAI program to study mathematics. Rappaport found no relationship between state anxiety and dogmatism. High and low dogmatism subjects did not differ in state anxiety during the study.

Smith (1971) examined the relationship between personality characteristics and attitudes toward instruction-related variables. Subjects were college students who used a CAI program to study behavioral objectives. The Myers-Briggs Personality Type Indicator was used to classify subjects in terms of Extraversion-Introversion and Sensing-Intuition. In addition, subjects were assigned to four treatment groups which were characterized by different forms of instructional sequence control. Control patterns varied from complete program control to varying degrees of student control. Smith concluded that student attitude was related to personality characteristics, and that Sensing subjects had more positive attitudes toward CAI, the CAI program, and the content of the CAI program. The positive attitudes of the Sensing subjects were most pronounced when they were given greater freedom to determine the instructional sequence.

Jelden (1971) attempted to identify student personality variables that could be used in the prediction of student success in an individualized, multimedia type course. College students in an electronics class were permitted to select verbal and/or visual instructional media. Jelden found that the majority of students viewed learner control in a positive manner, and that high achievers did well with either verbal or visual media.

Summary

Studies by Tobias and O'Niel have produced evidence which indicates that the manner in which a student interacts with a learning experience is related to state anxiety. The study conducted by Tobias also suggests that state anxiety is related to response mode, and that subjects who construct responses have high state anxiety and are significantly better on achievement measures than are subjects using passive response modes. O'Niel and Leherissey have both reported that shortening an instructional program does not reduce state anxiety.

In other studies Rappaport found no relationship between dogmatism and state anxiety and Smith reported a relationship between student attitude and a personality characteristic described as "sensing" (which was measured with the Myers-Briggs Personality Type Indicator). Smith also reported that the positive attitudes of sensing students were more pronounced when they were given greater freedom in the determination of instructional sequences.

Individualized Instruction

A traditional and an individualized college physics course have been compared by Branson, Brewer, and Deterline (1971). Students at the United States Naval Academy participated in the experiment. Experimental subjects were provided with materials, equipment, and a variety of media for "self-paced" independent study. Experimental subjects progressed at their own rates, selected materials and experiences which they preferred, and requested performance measures. Traditional subjects attended lectures and completed laboratory exercises. On the basis of results obtained from achievement tests and attitude measures the investigators concluded that the individualized program was at least as good as the traditional course, and that the method of instruction was not the critical element in an instructional program.

A study conducted by Friend, Fletcher, and Atkinson (1972) included a provision for student control of the instructional sequence. College students who studied computer science in a CAI course were permitted complete freedom in sequencing fifty lessons. Subjects also controlled the amount of instruction (they could request additional information), and review procedures. The investigators reported that student success on responses (approximately 65%) was below the anticipated level (75%), and that subjects rarely used control options.

The feasibility of improving students' performance on higher level cognitive tasks has been investigated by Wheatley (1972). Subjects were volunteers from a larger student population enrolled in an audio-tutorial biology course for college students. All subjects studied regular instructional units. In addition, subjects in the experimental group completed activities designed to improve higher level cognitive skills. Wheatley found that experimental subjects who had completed at least one half of the special activities had significantly higher achievement scores on one of the three unit tests used in the study. He also found that experimental subjects outscored control subjects on several regular course examinations. Wheatley concluded that the performance of students on higher level cognitive questions can be improved by providing appropriate activities.

A basic premise of Individually Prescribed Instruction (IPI) is that a subject can be arranged in a logical sequence of units which can ultimately be mastered. The program, which is for elementary school students, originated at the Learning Research and Development Center at the University of Pittsburgh. On the basis of results from diagnostic tests teachers write a "prescription" for individual student learning experiences. Students use various combinations of methods and materials to complete prescribed activities.

Although papers that describe the effectiveness of IPI are readily available, research reports are not abundant, and results from available reports are difficult to interpret. For example, Spinks (1972) reported that IPI second graders scored significantly higher on mathematics and spelling tests than did students in conventional classes. However, when Spinks compared IPI and conventional students at higher grade levels (third and fifth), they were not significantly different in mathematics, spelling, reading, or study skills. In a similar study Johnson and Ostrum (1971) found that IPI students had greater achievement gains in mathematics than did students in three similar schools. Johnson and Ostrum also reported that students and teachers had positive attitudes toward IPI materials.

Summary

Branson, Brewer, and Deterline have reported findings which suggest that individualized instruction in college physics is at least as effective as traditional instruction. Subjects who used CAI to learn computer science in the study conducted by Friend, Fletcher, and Atkinson did not achieve at a prescribed level and were reluctant to use sequence control options. Wheatley found that students who were provided with appropriate activities developed higher level cognitive skills (for one of three experimental instructional units). Studies of Individually Prescribed Instruction conducted by Spinks and Johnson and Ostrum indicate that the effectiveness of IPI may be related to grade level.

Chapter Summary

There is no overwhelming evidence that tends to either support or reject the notion that instructional sequencing is important and/or necessary in learning experiences. Results of some studies suggest that the necessity for a specific instructional sequence depends on the nature of the learning experience.

Although there are exceptions to the rule, studies in which learner control of instruction has been compared with instructor or program control of instruction have produced nonsignificant differences in achievement. Many investigators who have compared the effectiveness of conventional and nonconventional instructional methods have also reported nonsignificant differences in achievement. However, it is possible to find support (or lack of it) for almost any existing instructional approach.

In the area of achievement prediction there seems to be reasonable agreement that mathematics and biology aptitude and high school science grades are reliable predictors of college biology achievement.

Results of studies in which audio-tutorial (A-T) and conventional instruction have been compared suggest that the attitudes of the A-T subjects were generally more positive than those of subjects in conventional groups. Results from other studies which involved a variety of instructional methods are not conclusive.

Studies of personality factors that have utilized CAI indicate that anxiety is related to the role of the student during instruction, and that response mode can influence student achievement. In addition, student attitudes (which appear to be related to personality characteristics) may be influenced by the amount of freedom provided by the instructional program.

Chapter 3

PROCEDURES

Subjects

Basic Biology is offered by the biology department of Shippensburg State College as a general education course for non-biology majors. Each semester it is elected by approximately 350 to 500 students from a variety of departments within the college. Out of the 493 students enrolled in Basic Biology during the first semester of the 1972-73 academic year 376 were included in the study.

Treatment Groups

Subjects were randomly assigned to groups A, B, C and D. Treatments were as follows:

Group	Instructional Unit Sequence	Within-Units Experience Sequence
A	Structure Based	Teacher Directed
B	Structure Based	Student Selected
C	Test Determined	Teacher Directed
D	Test Determined	Student Selected

The Structure Based Unit Sequence and Teacher Directed Experience within-unit sequences were determined through the analysis of concepts included in the units. A Sequence Test, administered prior to the study, which measured student biology achievement for each of the instructional units, was used to establish the Test Determined Unit Sequence.

Development of the Structure
Based Unit Sequence

Since the Structure Based Unit Sequence was to be a sequence of instructional units, each of the five units was examined for concepts that could be used in the establishment of the sequence. Flow charts like the one included in Appendix A were constructed for this purpose. The following arguments were then used as a basis for the development of the sequence:

1. Photosynthesis should precede Respiration. The incorporation of energy into the bonds of fuel molecules should be considered prior to energy release and ATP formation.

2. Meiosis and Mitosis should precede Genetics. An understanding of the basic principles of meiosis is essential to the understanding of important concepts of genetics (e.g. variety that results from the sexual process, crossing over, and recombination).

3. Genetics should precede Control Mechanisms. An understanding of the relationship between chromosomes, DNA, and genes should be developed prior to the study of protein synthesis. In other words, Mendelian genetics should precede molecular genetics.

4. Photosynthesis and Respiration should precede Meiosis and Mitosis, Genetics, and Control Mechanisms. Processes which produce energy in living organisms should be considered prior to processes that consume energy. Although it may be difficult to see the relationship between Meiosis and Mitosis and Genetics and energy consumption (in the

specific units included in the study), these units are related to Control Mechanisms, which does involve energy consumption, by the arguments included in statements 2 and 3.

The Structure Based Unit Sequence was as follows:

1. Photosynthesis.
2. Respiration.
3. Mitosis and Meiosis.
4. Genetics.
5. Control Mechanisms.

Development of the Test Determined Unit Sequence

Data for the establishment of the Test Determined Unit Sequence (TDUS) were obtained through the administration of the Sequence Test which was designed to measure subjects' entry level biology achievement. The instrument was administered to all subjects prior to instruction. Analysis of variance for a one way design was used to compare student scores on each of the five scales included in the instrument (each scale represents an instructional unit). Results of the analysis are shown in Table 1.

Since the F-ratio obtained (95.08) was considerably larger than the table value ($F = 2.37$ at the .05 level), there was a significant difference in the biology achievement of subjects for the five instructional units included in the experiment. The Scheffé procedure was used to identify significant differences in the mean scores from

Table 1

Scale Means and Analysis of Variance Table for Subjects' Biology Achievement Scores on the Five Scales of the Sequence Test

Scale Means

	[a]Scale 1 (n = 423)	Scale 2 (n = 423)	Scale 3 (n = 423)	Scale 4 (n = 423)	Scale 5 (n = 423)
Means	3.17	3.89	3.21	3.92	5.17

Analysis of Variance

Source of Variance	Sum of Square	Degrees of Freedom	Mean Square	F Ratio
Between Treatments	1107.49	4	276.87	95.08
Within Treatments	6144.09	2110	2.91	
Total	7251.58	2114		

$F_{.05}$ (4, 2110) = 2.37

[a]Scales represent the following subject areas:

1. Photosynthesis
2. Respiration
3. Meiosis and Mitosis
4. Control Mechanisms
5. Genetics

the five scales. The minimum difference (d) between means which could be considered significant was calculated as follows:

$$d = \sqrt{\frac{2(k-1)\ (\text{Tabled } F)\ (MS_w)}{n}}$$

$$d = \sqrt{\frac{2(4) \times 2.37 \times 2.91}{423}}$$

$$d = .36$$

where

d = minimum difference between means which is significant.

k = number of groups.

MS_w = within groups mean square.

n = number of subjects.

Mean achievement scores for all subjects on the five scales of the Sequence Test were:

1.	Genetics	5.17
2.	Control Mechanisms	3.92
3.	Respiration	3.89
4.	Mitosis and Meiosis	3.21
5.	Photosynthesis	3.17

The mean achievement score for the Genetics scale was significantly greater than the mean scores for the Control Mechanisms and Respiration scales, and the mean scores for the Control Mechanisms and Respiration scales were significantly greater than the mean scores for the Mitosis and Meiosis and Photosynthesis scales. These differences were used as the basis for the establishment of a hierarchy of instructional units. Since the differences between the mean scores for the Control Mechanisms and Respiration scales and the Mitosis and Meiosis and Photosynthesis scales were not significant, non-significant differences in mean scores were used to establish the positions of these instructional units in the sequence.

Design and Assignment of Subjects

The basic model utilized was the 2 x 2 factorial type. It is shown in Figure 1.

Approximately 125 subjects were randomly assigned to each of the four treatment groups. To ensure proper implementation of the design the 32 station audio-tutorial facility was sectioned into four areas each of which included eight student booths. Subjects in all treatment groups were provided with specific instructions on how to use available materials (see Appendix B).

Treatments

The experimental phase of the study covered a five week period which began on October 9, 1972. Each week subjects completed an independent study session (in the audio-tutorial facility) and attended a small group discussion meeting. Prior to the experiment, subjects completed several basic instructional units. In the completion of these introductory units, they developed skills necessary for effective performance in an audio-tutorial type system.

During the experiment subjects in groups A and B followed a structure based sequence of instructional units. As described earlier,

		Control of Within-Unit Experience Sequence	
		Teacher Directed	Student Selected
Instructional Unit Sequence	Structure Based	Group A X, Y, Z	Group B X, Y, Z
	Test Determined	Group C X, Y, Z	Group D X, Y, Z

X = Achievement Scores

Y = Attitude Scores

Z = Time

Figure 1

Experimental Design

this sequence was determined through an analysis of concepts included in the five instructional units. The Structure Based Unit Sequence (SBUS) was:

1. Photosynthesis
2. Respiration
3. Mitosis and Meiosis
4. Genetics
5. Control Mechanisms

Subjects in groups C and D followed a sequence of instructional units based on results obtained from the administration of the Sequence Test. Scores of all subjects were used to arrange the units in a sequence that progressed from high to low mean score. The Test Determined Unit Sequence (TDUS) was:

1. Genetics
2. Control Mechanisms
3. Respiration
4. Mitosis and Meiosis
5. Photosynthesis

During each of the five weeks of the study the SBUS and TDUS treatment groups studied different instructional units. However, during the experiment subjects in both groups completed the same basic set of five instructional units. For each instructional unit they completed the same activities (observed films and microscope slides, examined demonstrations, etc.) and were exposed to the same basic information. However, subjects in groups A and C were required to follow a within-unit sequence of experiences that was teacher directed. Subjects in groups B and D were permitted to select a within-unit sequence of experiences.

Teacher Directed Experience (TDE) and Student Selected Experience (SSE) within-unit sequences represent different ways to control the experience sequence within instructional units. Subjects in both of these groups were provided with audio tapes, mimeographed scripts (from audio tapes), and all other materials needed to complete each instructional unit. However, the tapes, materials, etc. for the TDE and SSE groups were different. While the basic content for both groups was the same, tapes for the TDE group included experiences arranged in a definite sequence and tapes for the SSE group were designed so that no specific sequence of experiences was apparent. Subjects in the SSE group selected experiences by examining objectives included in a card file. Each card corresponded to a mimeographed sheet which included a statement of the objective, lists of activities related to the objective, a numerical index to the section of the audio tape that corresponded to the objective, and the audio script.

During the experimental period, weekly discussion group meetings were used primarily to answer student questions about items included in the independent study sessions. No structured lectures were presented.

Instructional Materials

The five audio-tutorial instructional units included in the study were developed over a two year period. The units included Photosynthesis, Respiration, Mitosis and Meiosis, Genetics, and Control Mechanisms. Audio scripts and related laboratory activities developed by Sparks and Nord (1968) served as a starting point in the developmental phase. The investigator and a number of colleagues prepared unit objectives, audio tapes, visual materials, and laboratory exercises for the course. Each semester, prior to the study, the materials were revised on the basis of feedback from students and faculty.

Following the development of the five basic instructional units, within-unit sequences of experiences for subjects in the Teacher Directed Experience (TDE) treatment group were prepared. Corresponding materials for subjects in the Student Selected Experience (SSE) treatment group were developed by relating experiences and discussion to specific objectives. Audio scripts and tapes were then prepared for subjects in both groups. Sample audio scripts from the unit titled Mitosis and Meiosis are included in Appendix C.

All materials were tested in a pilot study during the summer of 1972. Results of the pilot study indicated that the materials, following revision, were technically usable.

Instrumentation

An entry level biology achievement test (Sequence Test), an Achievement Posttest, and an attitude scale (Student Reaction to Audio-Tutorial Basic Biology) were developed for the study.

Sequence Test

This instrument was designed to measure student achievement prior to instruction. Data obtained from its administration were used to establish the Test Determined Unit Sequence. The test was based on established unit objectives and included fifty multiple choice questions

(10 items per instructional unit). The test was developed by the investigator with assistance from a number of colleagues (see Appendix D), administered to several large groups of Basic Biology students, analyzed and revised. During the experiment, data from 203 student response sheets were analyzed. Results of the analysis are listed below.

Range	0-35
Mean difficulty of items	38.02
Kuder-Richardson 20 reliability	0.59
Test mean	19.01
Variance	26.07
Standard Deviation	5.11
Standard error of measurement	3.26

A copy of the Sequence Test and a list of difficulty indices, discrimination indices, and point-biserial correlations for each question are included in Appendix E.

Achievement Pretest and Posttest

A posttest was designed to measure achievement following instruction. It was given to all subjects following the completion of the five instructional units. The test was also administered as a pretest to one half of the subjects in each treatment group. It consisted of 70 multiple choice questions (14 items per instructional unit). Items were selected or written to measure student achievement of specific unit objectives. Sources of test items included Dressel and Nelson (1956) and a recent publication of the Commission on Undergraduate Education in the Biological Sciences (1967). Original questions were written by the investigator and a number of biology professors who were involved in teaching Basic Biology (see Appendix D). All test items were checked for discrimination and reliability by including them in regular course examinations. During a two year period all questions were analyzed and revised. The test (in its present form) was administered to several hundred Basic Biology students in the spring of 1972. It was also used in a pilot study during the summer of 1972. During the experiment, 113 student response sheets were randomly selected for item analysis. Results of the analysis were as follows:

Range	26-70
Mean difficulty of items	66.31
Kuder-Richardson 20 reliability	0.83
Test mean	46.42
Variance	76.10
Standard Deviation	8.72
Standard error of measurement	3.60

A copy of the Achievement Posttest and a list of difficulty indices, discrimination indices, and point-biserial correlations for each test question are included in Appendix F.

Attitude Scale

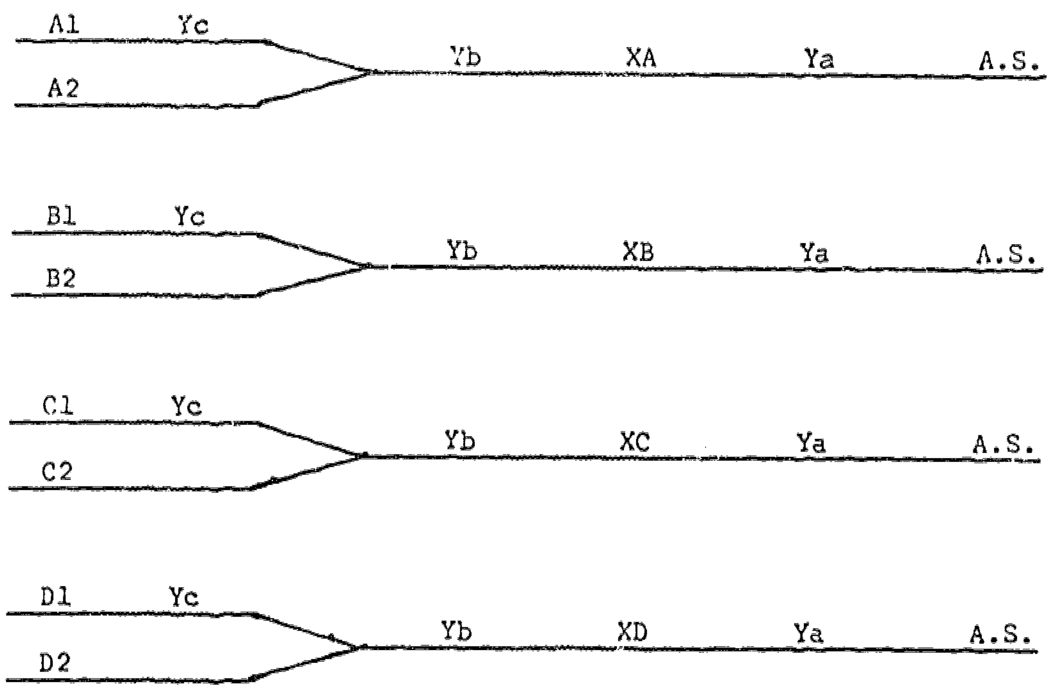
A Likert-type scale designed to measure students' attitudes toward Audio-Tutorial Basic Biology was developed prior to the study. Starting material for the development of the scale was a similar instrument prepared by Gelinas (see Appendix G). The scale, in its original form, contained 45 statements. Over a period of approximately two years, the instrument was administered to several large classes of Basic Biology students, analyzed, and revised. Analysis involved the determination of discrimination indices as described by Edwards (1957). The form that was eventually used in the study included 25 statements.

The reliability of the attitude scale was established by correlating student scores for the odd-even halves of the instrument (this approach was used because the available item analysis program required specific answers for test items). The value for r was .81. When r was corrected through application of the Spearman-Brown Prophecy Formula the reliability of the attitude scale was .89. A copy of the Student Reaction to Audio-Tutorial Basic Biology is included in Appendix H.

Administration of Instruments

The design of the experiment, with specific reference to instrumentation, is shown in Figure 2.

Approximately one half of the subjects in each treatment group were randomly selected for a pretest (the Achievement Posttest was used as the pretest). Following the pretest, the Sequence Test was administered to all subjects. The Achievement Posttest and the Student Reaction to Audio-Tutorial Basic Biology attitude scale were administered following the completion of the five instructional units included in the study.



A, B, C, and D - Treatment groups.

A1, B2, etc. - One-half of a treatment group.

Yc - Achievement Pretest (Posttest administered to one-half of the subjects in each treatment group).

Yb - Sequence Test.

XA, XB, XC, XD - Treatments (various combination of unit and within-unit sequences).

Ya - Achievement Posttest.

A.S. - Student Reaction to Audio-Tutorial Basic Biology attitude scale.

Figure 2

Sequence for the Administration of Instruments

Analysis of Data

The following data items were utilized:

1. Grade point averages.

2. College Entrance Examination Board (CEEB) scores.

3. Sequence Test scores.

4. Scores from the Achievement Posttest.

5. Pretest scores (Achievement Posttest used as a pretest).

6. Scores from Student Reaction to Audio-Tutorial Basic Biology attitude scale.

7. Time required for the completion of individual instructional units.

8. Within-unit experience sequences used by students in groups B and D.

9. Student characteristics (sex and college major).

College Entrance Examination Board scores and grade point averages were obtained from student records. Student characteristics (sex and major) were taken from available class lists. Time used in the completion of instructional units was obtained from individual student record cards. A sample student record card included in Appendix I. Information concerning within-unit experience sequences used by groups B and D was obtained through the use of a check list. A sample check list is included in Appendix J.

Analysis of variance for a one-way design was used to analyze scores obtained through administration of the Sequence Test. All data used to test for the equivalence of treatment groups were analyzed with a multivariate statistical program. Data obtained from criterion measures were analyzed through the use of regression analysis and multivariate analysis of variance. Regression analysis was also used to determine the predictive value of student characteristics on biology achievement. The significance of gains in achievement made by subjects in each treatment group was tested through application of the t-test for repeated measures. Within-unit sequences used by SSE subjects were compared with the sequence used by subjects in the TDE group through the use of a special program prepared by the staff of the computer center at Shippensburg State College. A check for pretest sensitization involved the utilization of a one-way analysis of variance.

Pilot Study

A pilot study was conducted during the summer of 1972. Results of that study are summarized below:

1. For subjects in the four treatment groups, average scores from the scales of the Sequence Test were not significantly different. Since similar scores obtained from a larger group of subjects (361) during the previous academic year were significantly different, it was decided that the Test Determined Unit Sequence for the pilot study would be based on scale mean scores.

2. Posttest achievement scores were significantly different at the 0.10 level for subjects in the four treatment groups. Since the number of subjects in each treatment group was small (6 or 7), the Kruskal-Wallis test was used. Inspection of group mean scores indicated that subjects in the treatment group that used a structure

based unit sequence and student selection of experiences within units, scored considerably lower (approximately 10 points) than subjects in the other treatment groups.

3. When subjects in the teacher directed and student selected experience treatment groups were compared on the basis of average time devoted to instructional units, it was determined that the teacher directed group required more time. However, the average time per unit for the group was not significantly greater than that for the student selected experience group.

4. Observations of subjects and feedback obtained through informal discussion sessions with subjects indicated that the materials developed for the study were generally acceptable. Information obtained from the pilot study was utilized in a revision of materials prior to the experiment.

Chapter 4

RESULTS

A description of subjects, tests of treatment group equivalence, and tests of specific hypotheses are summarized in this chapter.

Subjects

At the beginning of Semester I of the 1972-1973 academic year 493 students were enrolled in Basic Biology. Prior to and during the experimental period 33 students dropped the course for a variety of reasons. Upon completion of the experimental phase of the course, subjects who had been absent during any of the five instructional units included in the experiment were removed from the study. Thirty-seven subjects had two or more absences and thirty-two subjects missed one instructional unit. An additional fifteen subjects were randomly dropped from the experiment to equalize the number of subjects in each of the treatment groups. The results of statistical tests, described in the remainder of this chapter, are based on 376 subjects who completed all of the instructional units included in the experiment.

During the remainder of this chapter, treatment groups will be designated as follows:

Treatment Groups	Instructional Unit Sequence	Control of Within-Unit Experience Sequence
A	Structure Based (SBUS)	Teacher Directed (TDE)
B	Structure Based (SBUS)	Student Selected (SSE)
C	Test Determined (TDUS)	Teacher Directed (TDE)
D	Test Determined (TDUS)	Student Selected (SSE)

Description of Subjects

Distribution of Sexes in Treatment Groups

Of the 376 subjects included in the study, 167 were males and 209 were females. This ratio was very similar to the ratio for all undergraduate students at Shippensburg State College during the first semester of the 1972-1973 academic year (1844 males and 2080 females). Three of the four treatment groups contained more female subjects. The number of females per treatment group varied from a high of 57 or 60.63% in Group C to a low of 47 or 50.00% in Group B. Males varied in number from 47 or 50.00% in Group B to 39 or 41.48% in Group C. The numbers of males and females per treatment group are shown in Table 2.

Table 2

Distribution of Subjects by Sex

	Group A	Group B	Group C	Group D	Total
Males	44	47	39	37	167
Females	50	47	55	57	209
Total	94	94	94	94	376

Distribution of Subjects by College Class

A large majority of the subjects (319) were freshmen. Within treatment groups the percentage of freshmen ranged from a high of 89.36% in Group B to a low of 80.85% in Group A. Each of the treatment groups included some upperclassmen. Group B had the smallest number of upperclassmen (10) and Group A the largest (18). Numbers of subjects belonging to each of the four undergraduate classes are listed by treatment groups in Table 3.

Table 3

Distribution of Subjects by College Class

	Group A	Group B	Group C	Group D	Total
Freshmen	76	84	80	79	319
Sophomores	12	8	6	11	37
Juniors	6	1	6	1	14
Seniors	0	1	2	3	6
Total	94	94	94	94	376

Distribution of Subjects by College Curriculum

Subjects included in the study were from five broad curricula which included Secondary Education, Elementary Education, Arts and Sciences, Business Administration, and Library Science. Data describing the number of subjects from each of these curricula assigned to specific treatment groups are included in Table 4. Most of the subjects were in

Elementary Education (134) and Business Administration (119). The smallest groups of subjects were from the fields of Library Science (14) and Arts and Sciences (32).

Table 4

Distribution of Subjects by College Curriculum

	Group A	Group B	Group C	Group D	Total
Secondary Education	14	21	25	17	77
Elementary Education	35	27	31	41	134
Arts and Sciences	11	8	9	4	32
Business Administration	32	35	25	27	119
Library Science	2	3	4	5	14
Total	94	94	94	94	376

High School Science Backgrounds of Subjects

The high school biology, chemistry, and physics backgrounds of all subjects are shown in Table 5. Three hundred and seventy-one subjects (98.66%) had completed a high school biology course, 311 subjects (82.72%) had taken high school chemistry, and 171 subjects (45.47%) had taken high school physics.

Table 5

High School Science Courses Taken by Subjects

	Group A	Group B	Group C	Group D	Total
Biology	93	94	93	91	371
Chemistry	80	78	76	77	311
Physics	42	53	40	36	171

Tests of Group Equivalence

Although subjects were randomly assigned to four treatment groups, specific checks for group equivalence were made. Tests were based on student scores from the SAT tests of the College Entrance Examination Board, Achievement Pretest scores (Achievement Posttest administered as a pretest), Sequence Test scores, and grade point averages. All scores were analyzed with a multivariate analysis of variance program. Results of these tests are shown in Table 6.

Only one of the F-ratios obtained from multivariate tests was significant at the .05 level. TDE and SSE subjects had significantly different mean scores on the Achievement Pretest. Several univariate tests also produced significant F-ratios. The TDE and SSE treatment groups had significantly different mean scores on the Control Mechanisms scale of the Achievement Pretest and the SAT-Mathematics part of the CEEB, and the SBUS and TDUS treatment groups had significantly different mean scores on the Genetics scale of the Sequence Test (see Tables 7 and 8). Tables which include additional statistical

Table 6

Multivariate Analysis of Variance for SAT Scores, Sequence Test Scores, Grade Point Averages, and Achievement Pretest Scores, All Treatment Groups

Source of Variance	df	F	F (Critical)
[a]SAT Scores, Sequence Test Scores, and GPA's			
Unit Sequence	10, 363	0.79	1.87
Within-Unit Experience Sequences	10, 363	1.03	1.87
Unit Sequence x Within-Unit Experience Sequences	10, 363	1.25	1.87
[b]Achievement Pretest Scores			
Unit Sequence	5, 176	1.12	2.27
Within-Unit Experience Sequences	5, 176	2.65	2.27
Unit Sequence x Within-Unit Experience Sequences	5, 176	1.37	2.27

[a]Based on data from all subjects.

[b]Approximately one half of the subjects in each treatment group were pretested with the Achievement Posttest.

Table 7

Analysis of Variance for SAT and Achievement Pretest Scores, TDE and SSE Treatment Groups

Variable	MS	df	F	F (Critical)
	[a]CEEB Scores			
SAT-Mathematics	23083.03	1, 372	3.84	3.84
SAT-Verbal	6572.82	1, 372	1.16	3.84
SAT-Total	53882.57	1, 372	3.36	3.84
	[b]Achievement Pretest Scale Scores			
Photosynthesis	1.39	1, 180	0.34	3.90
Respiration	10.04	1, 180	3.53	3.90
Mitosis and Meiosis	0.09	1, 180	0.02	3.90
Genetics	8.70	1, 180	1.96	3.90
Control Mechanisms	18.92	1, 180	6.27	3.90

[a]Based on data from all subjects.

[b]Approximately one half of the subjects in each treatment group were pretested with the Achievement Posttest.

tests and means and standard deviations for data used in testing treatment group equivalence are included in Appendix K.

Table 8

Analysis of Variance for Sequence Test Scores, SBUS and TDUS Treatment Groups

Test Scale	MS	df	F	F (Critical)
Photosynthesis	0.17	1, 372	0.08	3.84
Respiration	0.10	1, 372	0.04	3.84
Mitosis and Meiosis	3.84	1, 372	1.32	3.84
Genetics	19.67	1, 372	5.48	3.84
Control Mechanisms	0.04	1, 372	0.01	3.84

Test for Pretest Sensitization

Prior to the experiment, approximately one half of the subjects in each treatment group were pretested with the Achievement Posttest. To check for pretest sensitization, the mean Achievement Posttest scores of pretested and non-pretested subjects in each treatment group were analyzed through the use of analysis of variance for a one-way design. Mean achievement scores are listed in Table 9 and results of the analysis of variance test are summarized in Table 10. The mean achievement scores of the pretested groups ranged from a high of 47.96 (Group C) to a low of 44.94 (Group A). Of the groups that were not pretested, Group B had the highest average achievement score (46.46) and Group C the lowest (45.83). In two of the groups (A and D) the pretested groups had lower mean scores on the Achievement Posttest. Since the computed F-ratio (0.46) was lower than the table value for F (2.01), there were no significant differences in mean achievement scores, and the pretest did not sensitize subjects to the Achievement Posttest.

Table 9

Mean Posttest Achievement Scores for Pretested and Non-Pretested Subjects

Treatment Groups	Pretest	No Pretest
A	44.94	46.21
B	46.49	46.46
C	47.96	45.83
D	45.14	46.24

Table 10

Analysis of Variance for Achievement Posttest Scores, Pretested and Non-Pretested Subjects

Source of Variance	SS	df	MS	^aF
Between Groups	284.64	7	40.66	0.46
Within Treatments	32442.95	368	88.16	
Total	32727.59	375		

$^aF_{.05}$ (7, 368) = 2.01

Achievement Hypoth...

Hypotheses 1, 2, and 3 were designed to test the effects of different sequences of instructional units and student vs. teacher control of within-unit experience sequences on the biology achievement of subjects. They were as follows:

Hypothesis No. 1

For college students studying introductory biology in a general education course taught through the audio-tutorial method, the organizational sequence of instructional units does not affect biology achievement.

Hypothesis No. 2

For college students studying introductory biology in a general education course taught through the audio-tutorial method, control (student vs. teacher) of the sequence of experiences within instructional units does not affect biology achievement.

Hypothesis No. 3

For college students studying introductory biology in a general education course taught through the audio-tutorial method, there is no interaction between the organizational sequence of instructional units and control (student vs. teacher) of the sequence of experiences within instructional units that affects biology achievement.

Hypothesis No. 4 was used to identify predictors of biology achievement. It was as follows:

Hypothesis No. 4

For college students studying introductory biology in a general education course taught through the audio-tutorial method, there is no single characteristic, or set of combined characteristics, that will reliably predict biology achievement.

Preliminary tests of achievement hypotheses were made through the use of multiple regression analysis. In an initial statistical test, total score from the Achievement Posttest was the dependent variable and all other variables of the experiment (scholastic aptitude scores, grade point average, pretest scores, time used in the completion of instructional units, instructor, treatment group, sex, and college major) were designated free variables. Results of this test are shown in Table 11. Most of the variables tested did not contribute significantly to the variance in Achievement Posttest scores. Of the variables that had significant F-ratios, only five (grade point average, Sequence Test score, SAT-Mathematics score, Instructor No. 8, and time) produced appreciable increases in R^2. A major proportion (42.3%) of the variance in achievement scores was accounted for by grade point average. Sequence Test and SAT-Mathematics scores accounted for 5.6% and 3.6% of the variance respectively. Instructor No. 8 and time each accounted for approximately 1.5% of achievement variance. Collectively the five variables accounted for 54.6% of the variance in Achievement Posttest scores.

The relationship of biology achievement to the five variables that accounted for more than one half of the variance in Achievement

Table 11

Multiple Regression Analysis for All Experimental Variables with Biology Achievement as the Dependent Variable

Step	Variable Entered	R	R^2	Increase in R^2	F to Enter or Remove	F (Critical)
1.	Grade Point Average	0.6507	0.4234	0.4234	274.61	3.84
2.	Sequence Test Score	0.6922	0.4791	0.0558	39.94	3.00
3.	SAT-Mathematics Score	0.7177	0.5150	0.0359	27.52	2.60
4.	Instructor No. 8	0.7284	0.5306	0.0155	12.28	2.37
5.	Average Time per Instructional Unit	0.7386	0.5456	0.0150	12.24	2.21
6.	Sex	0.7423	0.5510	0.0054	4.40	2.10
7.	Pretest Score	0.7443	0.5540	0.0031	2.55	2.01
8.	Instructor No. 5	0.7460	0.5566	0.0025	2.08	1.94
9.	Treatment Group No. 4	0.7472	0.5584	0.0018	1.49	1.88
10.	Instructor No. 3	0.7490	0.5610	0.0026	2.20	1.83
11.	Library Science Major	0.7497	0.5621	0.0011	0.91	
12.	Elementary Education Major	0.7501	0.5626	0.0005	0.43	1.75

Table 11 (continued)

Step	Variable Entered	R	R^2	Increase in R^2	F to Enter or Remove	F (Critical)
13.	Instructor No. 5	0.7503	0.5629	0.0003	0.23	
14.	Treatment Group No. 3	0.7504	0.5631	0.0002	0.17	
15.	Instructor No. 1	0.7506	0.5634	0.0003	0.27	1.67
16.	Instructor No. 2	0.7508	0.5637	0.0003	0.22	
17.	Business Administration Major	0.7509	0.5638	0.0001	0.08	
18.	Secondary Education Major	0.7509	0.5638	0.0000	0.03	

Posttest scores was further tested through the determination of correlation coefficients (see Table 12). With the exception of Instructor No. 8, all r values for the five variables were significant at the .05 level. Since r for Instructor No. 8 was not significant, and since grade point average accounted for a major proportion of the variance in Achievement Posttest scores, an additional multiple regression test was made. The effect of factors such as instructor, time, treatment, sex, and college major on the variance in Posttest Achievement scores was analyzed by forcing these variables into the prediction equation. All remaining variables were assigned "free" status. Results of this test are shown in Table 13.

None of the instructor variables produced a significant F-ratio and all instructors combined accounted for approximately 2.3% of the variance in Achievement Posttest scores. Time produced a highly significant F-ratio (26.[illegible]) and accounted for approximately 8.9% of achievement variance. [illegible] three of the four treatments entered the prediction equation (Group [illegible] was excluded) and none produced significant F-ratios. Of the six college majors, No. 5 (Business Education) entered first, and although it produced a significant F-ratio (3.75), it did not contribute greatly to achievement variance. Sex did not produce a significant F-ratio or increase R^2 appreciably. Variables which had been assigned "free" status (grade point average, Sequence Test score, and SAT-Mathematics score) entered the prediction equation after the forced variables and assumed the same relative positions that they held in the first multiple regression test.

Results obtained from "free" and "forced" multiple regression

Table 12

Correlation Matrix for Experimental Variables That Accounted for a Significant Proportion of the Variance in Biology Achievement Posttest Scores

Variables	1	2	3	4	5	6
1. Achievement	1.000	[a]0.651	[a]0.442	[a]0.406	0.090	[a]0.256
2. Grade Point Average		1.000	[a]0.337	[a]0.285	-0.030	[a]0.279
3. Placement Test Score			1.000	[a]0.266	-0.069	0.074
4. SAT-Mathematics Score				1.000	-0.023	-0.064
5. Instructor No. 8					1.000	-0.074
6. Average Time per Instructional Unit						1.000

[a]Significant at the .05 level.

Table 13

Multiple Regression Analysis for All Experimental Variables with Biology Achievement as the Dependent Variable and Instructor, Time, Treatment, Major and Sex as Forced Variables

Step	Variable Entered	R	R^2	Increase in R^2	F to Enter or Remove	F (Critical)
1.	Instructor No. 2	0.0924	0.0085	0.0085	3.22	3.84
2.	Instructor No. 8	0.1222	0.0149	0.0064	2.42	3.00
3.	Instructor No. 3	0.1399	0.0196	0.0046	1.76	2.60
4.	Instructor No. 6	0.1471	0.0217	0.0021	0.79	2.37
5.	Instructor No. 4	0.1512	0.0229	0.0012	0.46	2.21
6.	Instructor No. 7	0.1518	0.0230	0.0002	0.06	2.10
7.	Instructor No. 5	0.1520	0.0231	0.0001	0.03	2.01
8.	Average Time per Instructional Unit	0.2993	0.0896	0.0665	26.80	1.94
9.	Treatment Group No. 2	0.3055	0.0933	0.0037	1.50	1.88
10.	Treatment Group No. 1	0.3059	0.0936	0.0003	0.10	1.83
11.	Treatment Group No. 4	0.3060	0.0936	0.0000	0.02	
12.	Business Education Major	0.3207	0.1029	0.0093	3.75	1.75

Table 13 (continued)

Step	Variable Entered	R	R^2	Increase in R^2	F to Enter or Remove	F (Critical)
13.	Library Major	0.3258	0.1062	0.0033	1.33	
14.	Secondary Education Major	0.3270	0.1069	0.0008	0.31	
15.	Elementary Education Major	0.3281	0.1077	0.0007	0.29	1.67
16.	Business Administration Major	0.3282	0.1077	0.0001	0.02	
17.	Sex	0.3296	0.1086	0.0009	0.38	
18.	Grade Point Average	0.6866	0.471[illegible]	0.3628	245.01	
19.	Sequence Test Score	0.7255	0.5263	0.0549	41.25	
20.	SAT-Mathematics Score	0.7493	0.5615	0.0352	28.49	1.57
21.	Pretest Score	0.7509	0.5638	0.0024	1.92	

tests indicated that the variance in Achievement Posttest scores was primarily due to the influence of a relatively small number of variables. These included grade point average, Sequence Test score, SAT-Mathematics score, and time. Of these variables, grade point average and time accounted for the greatest proportion of achievement variance (approximately 36.3% to 42.3% and 1.5% to 8.9% respectively). The prediction equation for grade point average, Sequence Test score, and SAT-Mathematics score as combined predictors of biology achievement was:

$$\hat{Y} = 4.30804 + (0.02419 \times \text{SAT-Mathematics Score}) + (0.40334 \times \text{Placement Test Score}) + (8.77176 \times \text{Grade Point Average})$$

Additional tests of Hypotheses 1, 2, and 3 were made by utilizing the scores from the five scales of the Achievement Posttest. Because tests of group equivalence had revealed significant differences in SAT-Mathematics scores and one scale of the Sequence Test, these variables were used as covariates in a multivariate analysis which compared the mean biology achievement scores of subjects in the four treatment groups. Although TDE and SSE groups had significantly different mean scores on one scale of the Achievement Pretest (Achievement Posttest used as a pretest), pretest score was not used as a covariate. SAT-Mathematics and Sequence Test scores were used as covariates because they correlated significantly with Achievement Posttest scores (.41 and .44 respectively). The r value for the relationship between Pretest and Achievement Posttest scores was .10 which was not significant at the .05 level. Results of the multivariate analysis are shown in Table 14.

Table 14

Multivariate Analysis of Covariance for Scores from the Achievement Posttest with SAT-Mathematics and Sequence Test Scores as Covariates

Source	df	^{a}F
Unit Sequence	5, 366	1.64
Within-Unit Experience Sequences	5, 366	1.00
Unit Sequence x Within-Unit Experience Sequences	5, 366	0.33

$^{a}F_{.05}$ (5, 366) = 2.21

When analysis of covariance was used to compare the Achievement Posttest scores of subjects in the four treatment groups, no significant F-ratios were produced. Treatment groups did not differ significantly in mean biology achievement and there was no significant interaction between unit sequence and control of within-unit experience sequences which differentially affected biology achievement.

Since one half of the subjects in each treatment group were pretested (with the Achievement Posttest) prior to the experiment, tests for gains in mean biology achievement were made. The t-test for repeated measures was used to compare the pretest and posttest scores of subjects in each of the four treatment groups. These tests are summarized in Table 15. All t values were significant at the .05 level. The smallest gain (19.98 points) was made by Group A and the largest (22.85 points) was made by Group D.

Table 15

Mean Pretest and Posttest Biology Achievement Scores, Gains in Achievement, and t Values for Pretested Subjects

Treatment Group	n	Pretest Mean	Posttest Mean	Achievement Gain	t
A	47	24.96	44.94	19.98	[a]16.11
B	47	25.26	46.49	21.23	[a]21.29
C	49	23.96	45.14	21.18	[a]19.25
D	46	25.11	47.96	22.85	[a]17.16

[a]Significant at .05 level.

On the basis of results obtained from tests utilizing multiple regression analysis and analysis of variance, Hypotheses 1, 2, and 3 were not rejected. Neither the organizational sequence of instructional units nor control (teacher vs. student) of within-unit experience sequences differentially affected biology achievement. In addition, there was no significant interaction between the organizational sequence of instructional units and control (student vs. teacher) of the sequence of experiences within instructional units that differentially affected biology achievement.

On the basis of results obtained from multiple regression analysis, Hypothesis No. 4 was rejected. Characteristics which included grade point average, Sequence Test and SAT-Mathematics scores, and time used in the completion of instructional units were reliable predictors of biology achievement.

Attitude Hypothesis

Hypothesis No. 5 compared the attitudes of subjects in the Teacher Directed Experience and Student Selected Experience groups. It was as follows:

Hypothesis No. 5

For college students studying introductory biology in a general education course taught through the audio-tutorial method, control (student vs. teacher) of within-unit experience sequences does not affect students' attitudes toward the course.

Following the completion of the last instructional unit, the Stud Reaction to Audio-Tutorial Basic Biology attitude scale was administered to all subjects. It was assumed that results obtained from the administration of the attitude scale would be more candid if subjects were not asked to identify themselves beyond the treatment group level. Raw scores from the attitude scale ranged from 19 to 87 for TDE subjects, and from 11 to 90 for the SSE group. The mean attitude score for TDE subjects was 56.23 and the mean for SSE subjects was 54.71. Ana is of variance was used to compare the mean attitude scores of subjects in the four treatment groups. None of the F-ratios for main effects or interaction were significant at the .05 level. Results of this test are shown in Table 16.

Table 16

Analysis of Variance for Scores from Student Reaction to Audio-Tutorial Basic Biology Attitude Scale

Source of Variance	SS	df	^{a}F
Unit Sequence	370.00	1	1.98
Within-Unit Experience Sequences	231.44	1	1.24
Unit Sequence x Within-Unit Experience Sequences	109.56	1	0.59
Within Groups	69672.81	372	

$^{a}F_{.05}$ (1, 372) = 3.84

Subjects in the SSE and TDE treatment groups did not differ significantly in their attitudes toward Basic Biology. Hypothesis No. 5 was not rejected. Control (student vs. teacher) of the sequence of experiences within instructional units did not affect students' attitudes toward the biology course.

Time Hypotheses

Hypotheses 6 and 7 were designed to test for significant differences in the amount of time used by subjects in the four treatment groups in the completion of instructional units. They were as follows:

Hypothesis No. 6

For college students studying introductory biology in a general education course taught through the audio-tutorial method, the organizational sequence of instructional units does not affect the amount of time required to complete instructional units.

Hypothesis No. 7

For college students studying introductory biology in a general education course taught through the audio-tutorial method, control (student vs. teacher) of the sequence of experiences within instructional units does not affect the amount of time required to complete instructional units.

The source of data used in testing these hypotheses was the Student Audio-Tutorial Record Card (see Appendix I). Multivariate analysis of variance was used to compare the mean time used by subjects in each of the treatment groups in the completion of each of the five instructional units. The F-ratio obtained when subjects in SBUS and TDUS groups were compared was significant at the .05 level. Results of the multivariate test on time utilization are shown in Table 17.

Univariate tests used to compare subjects in the SBUS and TDUS groups on the basis of time utilization for individual instructional

Table 17

Multivariate Analysis of Variance for Mean Time Used to Complete Instructional Units

Source of Variance	df	^aF
Unit Sequence	5, 368	22.51
Within-Unit Experience Sequences	5, 368	1.76
Unit Sequence x Within-Unit Experience Sequences	5, 368	0.77

$^aF_{.05}\ (5, 368) = 2.21$

units are shown in Table 18. Three of the five F-ratios were significant at the .05 level. Of these significant differences, two favored the TDUS group (Genetics and Control Mechanisms units), and one (Photosynthesis unit) favored the SBUS group.

Although the multivariate test that was used to compare subjects in the TDE and SSE groups on the basis of time utilized in the completion of instructional units was nonsignificant, two of the five univariate tests for those treatment groups produced F-ratios that were significant at the .05 level. Results of univariate tests for individual instructional units for TDE and SSE treatment groups are shown in Table 19. Subjects in the SSE group used more time than subjects in the TDE group for all of the five instructional units. SSE subjects used a significantly greater amount of time than their counterparts in the TDE group for the Mitosis and Meiosis and Genetics units. Mean time used by subjects in all treatment groups is shown in Table 20.

Table 18

Analysis of Variance for Mean Time Used to Complete Instructional Units, SBUS and TDUS Treatment Groups

Instructional Unit	SS	df	^{a}F
Photosynthesis	46136.19	1, 372	22.96
Respiration	4350.81	1, 372	2.98
Meiosis and Mitosis	4550.19	1, 372	2.[illegible]
Genetics	77237.00	1, 372	[illegible]1.4[illegible]
Control Mechanisms	28980.50	1, 372	10.32

$^{a}F_{.05}$ (1, 372) = 3.84.

Table 19

Analysis of Variance for Mean Time Used to Complete Instructional Units, TDE and SSE Treatment Groups

Instructional Unit	SS	df	^{a}F
Photosynthesis	6315.63	1, 372	3.14
Respiration	3271.12	1, 372	2.24
Meiosis and Mitosis	7813.31	1, 372	4.31
Genetics	16449.00	1, 372	4.57
Control Mechanisms	1367.69	1, 372	0.49

$^{a}F_{.05}$ (1, 372) = 3.84.

Table 20

Mean Time Used to Complete Instructional Units, All Treatment Groups

Instructional Unit	[a]SBUS	[b]TDUS	[c]TDE	[d]SSE
Photosynthesis	[e]137.01	114.86	121.84	130.03
Respiration	110.60	103.79	104.24	110.14
Meiosis and Mitosis	118.62	111.66	110.58	119.70
Genetics	131.99	160.65	139.70	152.94
Control Mechanisms	119.04	136.60	125.91	129.72

[a]Structure Based Unit Sequence.

[b]Test Determined Unit Sequence.

[c]Teacher Directed Experience.

[d]Student Selected Experience.

[e]Time in minutes.

Because average time used in the completion of instructional units was positively related to grade point average ($r = 0.279$) and achievement ($r = 0.256$), additional tests on high and low grade point average subjects were made. Correlation coefficients which show the way in which time relates to biology achievement and grade point average for high and low grade point average subjects in each of the four treatment groups are shown in Table 21.

When the relationship between time and achievement was tested, correlation coefficients were, with the exception of Group D, positive

Table 21

Correlation Coefficients for Time vs. Achievement and Grade Point Average for High and Low Grade Point Average Subjects

Treatment Group	High Grade Point Average	n	Low Grade Point Average	n
	Time vs. Achievement			
A	[a]0.45	42	0.15	42
B	0.22	39	0.15	43
C	0.19	42	0.09	46
D	0.19	55	-0.20	35
	Time vs. Grade Point Average			
A	[a]0.30	42	0.05	42
B	[a]0.40	39	[a]0.43	43
C	0.03	42	-0.03	46
D	0.14	55	0.11	35

[a]Significant at the .05 level.

and higher for high grade point average subjects. In Group D, the value for r was 0.19 for the high grade point average group and -.20 for the low grade point average subjects.

The relationship between grade point average and time varied considerably in the four treatment groups. In Groups A and D all r values were positive and favored the high grade point average subjects. In Group B both values of r were positive and favored the low grade point average subjects, and in Group C the value for r ranged from low positive, for high grade point average subjects, to low negative for low grade point average subjects. In all treatment groups the high grade point average subjects used a greater amount of time to complete instructional units. Time data are summarized in Table 22. The greatest time difference occurred in Group B and the smallest in Group C.

Table 22

Mean Time per Instructional Unit, High vs. Low Grade Point Average Subjects

Treatment Group	High Grade Point Average	Low Grade Point Average	High-Low
A	[a]126.26	106.71	19.55
B	140.02	112.74	27.28
C	119.36	118.78	00.58
D	139.98	116.54	23.44

[a]Time in minutes.

High grade point average subjects outscored low grade point average subjects on the Achievement Posttest. The greatest differences between high and low grade point average subjects (11 points) occurred in Groups A and B, and the smallest difference was found in Group D (8 points). These data are summarized in Table 23.

Table 23

Mean Scores from the Biology Achievement Posttest, High vs. Low Grade Point Average Subjects

Treatment Group	High Grade Point Average	Low Grade Point Average	High-Low
A	51	40	11
B	52	41	11
C	50	41	9
D	50	42	8

On the basis of results obtained from multivariate tests which compared subjects in all treatment groups on time used to complete instructional units, Hypotheses 6 and 7 were rejected. Both the organizational sequence of instructional units and control (student vs. teacher) of within-unit experience sequences significantly affected the amount of time used by subjects in the completion of instructional units.

Sequence Hypothesis

Hypothesis No. 8 was designed to compare the within-unit experience sequences used by subjects in the Student Selected Experience group with sequences utilized by Teacher Directed Experience subjects. It was as follows:

Hypothesis No. 8

For college students studying biology in a general education course taught through the audio-tutorial method, sequences of experiences within specific instructional units, that are selected by students, will not be similar to teacher directed sequences for those same units.

During the completion of each instructional unit, within-unit experience sequences used by subjects in the SSE treatment group were recorded on a check list like the one included in Appendix J. A special computer program was used to compare subjects' sequences with sequences prescribed for subjects in the TDE treatment group. Each student sequence was first examined for all possible two digit sequences included in the "key" sequence. One point was awarded for each two digit sequence included, regardless of its position in the total sequence. Sequences were next examined for three digit sequences and awarded two points for each. Four digit sequences were assigned three points, etc. Thus, for each student sequence, a total score was calculated. High student scores indicated a sequence that was similar or identical to the "key" or TDE sequence.

It was arbitrarily decided that a student sequence would be considered similar to the key if it had at least one-half of the items in the key sequence. This required a total score of approximately 10 to 12 points (the number of items per sequence in different units varied from 9 to 11). Sequences with scores around 10 were individually compared with the key sequence and a decision concerning similarity was made. The numbers of identical and similar sequences for SSE groups are shown in Table 24. Only one of the 10 groups produced similar sequences at a level beyond 5% of the total. The SBUS group had four identical and three similar sequences on the Genetics unit for a 7.45 percentage. The number of similar sequences varied from zero for the Respiration unit to seven for the Genetics unit. In all there were 15 similar sequences out of a total of 940 examined.

A further test was made to try to determine the basis for student sequencing. In this test the key sequence was the random sequence of objectives on check lists (see Appendix J) that subjects completed with each instructional unit (subjects were warned that the sequences on the check lists were random). Results of the test are shown in Table 25. In all but one of the treatment groups more than 5% of the subjects used the random sequences from the check lists. Percentages ranged from a low of 4.26% (SBUS group, Meiosis and Mitosis unit) to a high of 19.15% (TDUS group, Genetics unit). Out of the 940 sequences examined, 66 were identical and 50 similar to a key based on the random experience sequences from the check lists.

Hypothesis No. 8 was not rejected. Subjects who were permitted to select within-unit experience sequences did not select sequences similar to those prescribed for the TDE group.

Table 24

Number of Within-Unit Experience Sequences Selected by Student Selected Experience Subjects That Were Identical Or Similar to Teacher Directed Experience Within-Unit Sequences

Instructional Unit	n	Identical Sequences	Similar Sequences	Identical + Similar	% of Total
Photosynthesis					
SBUS	94	0	2	2	2.13
TDUS	94	0	0	0	0.00
Respiration					
SBUS	94	0	0	0	0.00
TDUS	94	0	0	0	0.00
Meiosis and Mitosis					
SBUS	94	0	0	0	0.00
TDUS	94	0	2	2	2.13
Genetics					
SBUS	94	4	3	7	7.45
TDUS	94	0	0	0	0.00
Control Mechanisms					
SBUS	94	0	1	1	1.07
TDUS	94	0	3	3	3.20
Total	940	4	11	15	1.60

Table 25

Number of Within-Unit Experience Sequences Selected by Subjects in the Student Selected Experience Group That Were Identical Or Similar to the Random Sequences from Check Lists

Instructional Unit	n	Identical Sequences	Similar Sequences	Identical + Similar	% of Total
Photosynthesis					
SBUS	94	9	5	14	14.90
TDUS	94	8	7	15	15.96
Respiration					
SBUS	94	4	3	7	7.45
TDUS	94	9	3	12	12.77
Meiosis and Mitosis					
SBUS	94	2	2	4	4.26
TDUS	94	5	6	11	11.71
Genetics					
SBUS	94	4	7	11	11.71
TDUS	94	11	7	18	19.15
Control Mechanisms					
SBUS	94	9	5	14	14.90
TDUS	94	5	5	10	10.64
Total	940	66	50	116	12.34

Chapter Summary

Results from statistical tests were as follows:

1. Achievement Hypotheses - treatment groups did not differ significantly in biology achievement on any of the five scales of the Achievement Posttest. There was no significant interaction between instructional unit sequence and within-unit experience sequences which differentially affected biology achievement.

2. Attitude Hypothesis - subjects who followed a teacher directed sequence of within-unit experiences and subjects who selected within-unit experience sequences did not differ significantly in their attitudes toward audio-tutorial biology.

3. Time Hypotheses - significant differences in time used to complete instructional units were found. Of these differences two favored the TDUS group and one favored the SBUS group. SSE subjects used significantly more time than did TDE subjects in the completion of two instructional units.

4. Sequence Hypothesis - subjects who selected within-unit experience sequences (SSE treatment group) did not select sequences similar to those prescribed for TDE subjects.

Chapter 5

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Achievement Hypotheses

Hypotheses 1, 2, and 3 tested the effects of different sequences of instructional units and within-unit experience sequences on biology achievement as measured by the Achievement Posttest. Hypothesis No. 4 was designed to identify predictors of biology achievement. They were as follows:

Hypothesis No. 1

For college students studying introductory biology in a general education course taught through the audio-tutorial method, the organizational sequence of instructional units does not affect biology achievement.

Hypothesis No. 2

For college students studying introductory biology in a general education course taught through the audio-tutorial method, control (student vs. teacher) of the sequence of experiences within instructional units does not affect biology achievement.

Hypothesis No. 3

For college students studying introductory biology in a general education course taught through the audio-tutorial method, there is no interaction between the organizational sequence of instructional units and control (student vs. teacher) of the sequence of experiences within instructional units that affects biology achievement.

Hypothesis No. 4

For college students studying introductory biology in a general education course taught through the audio-tutorial method, there is no single characteristic, or set of characteristics, that will reliably predict biology achievement.

Data used in testing these hypotheses were obtained from the five scales of the Achievement Posttest and student records. Statistical tests included multiple regression analysis and multivariate analysis of variance. On the basis of results obtained, Hypotheses 1, 2, and 3 were not rejected. Since a number of predictors of biology achievement were identified, Hypothesis No. 4 was rejected.

Discussion of Achievement Hypotheses

Most of the variance in scores from the Achievement Posttest was accounted for by factors that included grade point average, Sequence Test score, SAT-Mathematics score, and time used to complete instructional units. Treatments did not contribute significantly to the variance in Achievement Posttest scores. However, pretested subjects in all treatment groups made highly significant gains in mean biology achievement, and subjects with high grade point averages in all treatment groups used the instructional method, to which they were assigned, more effectively than subjects with low grade point averages.

Thus, it appears that structure based and test determined unit sequences were equally effective in the promotion of student achievement. In other words, the five instructional units (Control Mechanisms, Genetics, Meiosis and Mitosis, Photosynthesis, and Respiration) can apparently be put into a sequence that is based on scores from an achievement pretest, or the units can be sequenced according to the structure of biology (units that include concepts that are necessarily prerequisite to other units are sequenced on that basis), without sacrificing effectiveness as measured by a biology achievement test.

It might very well be true that in courses similar to Basic Biology, unit sequences are not very important. Briggs (1967:8) has suggested that " . . . a 'logical' outline or 'structure' may be entirely useful for the professional to communicate with another <u>about matters which they both understand</u>, but useless in guiding a student." Briggs further claims that courses can be classified on the basis of internal structure. Categories include: (1) flat, (2) vertical, (3) hierarchical, and (4) mixed (some combination of 1, 2, and 3). Flat courses are described as courses in which sequence is unimportant. It could be that Basic Biology belongs in the "flat" category.

Teacher and student control of within-unit experience sequences seem to be equally effective in the promotion of biology achievement. High grade point average subjects in both the Teacher Directed Experience group and the Student Selected Experience group used the control method, to which they were assigned, more effectively than low grade point average subjects. Results obtained are in agreement with those obtained by Stavick (1971); Campbell and Chapman (1967); Olsen (1957); Brown (1966); Rainey (1965); and Hovey, Gruber, and Terrill

(1963). All of these studies compared instruction that was teacher controlled with various types of student controlled instruction. Results obtained by Mager and McCann (1961); Judd, Bunderson, and Bessent (1970); and Oliver (1971) are not in agreement with those obtained in the experiment. Although Mager and McCann did not report statistical evidence, they described learner control subjects as being as good as, or better than, students studying in regular classes. Judd's group found that learner control subjects were significantly better on the achievement test for one instructional unit. Oliver, on the other hand, found that learner control subjects did poorly on a criterion measure.

Results obtained in the present study and several of those cited above suggest that programs which provide for learner control of instructional sequences are as effective in the promotion of student achievement as programs in which instructional sequences are controlled by the instructor. This idea is described in a slightly different way by Campbell and Chapman (1967:130).

> If students directing their own learning can achieve at the same academic level as students following the best program we can devise for them, perhaps we should not invest so much time in arranging the exact format of instruction, but rather in other areas of need such as clarifying objectives, improving the basic content elements of instruction and the means of evaluating progress, and motivating learners.

Mager and McCann (1961:17) have suggested that instruction which is rigidly patterned may actually inhibit learning.

> . . . the ever present instructor who tightly controls the curriculum and its sequencing may even constitute a significant hindrance in the path of the learners' progress.

In another pa of their report Mager and McCann suggest that a teacher controlled sequence of instruction does not take into consideration what the learner already knows and thus prevents the omission of segments of instruction that have been previously mastered.

While the present study did not attempt to relate various personality characteristics to achievement, results of the investigation conducted by Smith (1971) suggest that such factors should be taken into consideration in the assignment of students to instructional programs with varying degrees of structure and student control. Since subjects in the present study were randomly assigned to treatment groups, important personality factors should have been uniformly distributed in each of the groups. Such an arrangement would tend to cancel out any influence that personality characteristics may have had on the achievement of subjects in each of the four treatment groups.

Although the instructional methods used in the present investigation did not include programmed instruction, results obtained on the Achievement Posttest were within the range of acceptable success levels for many types of programmed materials. The mean achievement score for all subjects was 46.12 (out of a possible 70 points on the Achievement Posttest), and 50.70 for high grade point average subjects. On a percentage basis these scores represent success levels of 65.88% for all subjects and 72.42% for high grade point average subjects. This provides further support for the effectiveness of all of the treatments as methods of instruction.

In the present study the prediction of achievement for college students in introductory biology courses was most effective when grade point average, Sequence Test score, SAT-Mathematics score, and time (used to complete instructional units) were used as predictors. The best single predictor of biology achievement was grade point average. These findings are in accord with those of Meleca (1968) who reported that biology and mathematics aptitude were good predictors of biology achievement, and Sherrill and Druger (1971) who found a positive relationship between mathematics aptitude and biology achievement.

Summary for Achievement Hypotheses

Data of the experiment supported Hypotheses 1, 2, and 3. The organizational sequence of instructional units, and control (student vs. teacher) of within-unit experience sequences did not have a differential effect on biology achievement. There was no interaction between the organizational sequence of instructional units and control (student vs. teacher) of within-unit experience sequences which differentially affected biology achievement.

Data of the experiment did not support Hypothesis No. 4. Grade point average, Sequence Test score, SAT-Mathematics score, and time (used to complete instructional units) were reliable predictors of biology achievement.

Attitude Hypothesis

Following the completion of the five instructional units of the experiment, the Student Reaction to Audio-Tutorial Basic Biology attitude scale was administered to all subjects. Hypothesis No. 5 was designed to compare the mean attitude scores of subjects in the Teacher Directed Experience and Student Selected Experience groups. It was as follows:

Hypothesis No. 5

For college students studying introductory biology in a general education course taught through the audio-tutorial method, control (student vs. teacher) of the sequence of experiences within instructional units does not affect students' attitudes toward the course.

When analysis of variance was used to compare the mean attitude scores of subjects in the TDE and SSE groups, a significant difference was not found. Hypothesis No. 5 was not rejected.

Discussion of Attitude Hypothesis

Student and teacher control of within-unit experience sequences appear to be equally effective in terms of their influence on students' attitudes toward introductory biology taught through the audio-tutorial approach. Results obtained for Hypothesis No. 5 were in agreement with those obtained by Wodtke (1967). Wodtke found no significant difference in subjects' attitudes toward computer assisted instruction when the attitudes of subjects who had studied mathematics and science through the use of scrambled programs were compared with those of control subjects who used standard, logically sequenced programs.

Results obtained for Hypothesis No. 5 were not in agreement with those obtained by Smith (1971). Smith found a significant relationship between a personality characteristic described as "sensing" and subjects' attitudes toward CAI, a specific CAI program, and the content of the CAI program. Smith also found that the positive attitudes of "sensing" subjects were more pronounced when they were given more control of the instructional sequence.

In another study Jelden (1971) found that college students who studied electronics in a multimedia program viewed learner control of instruction in a positive manner.

Summary for Attitude Hypothesis

Data of the experiment supported Hypothesis No. 5. Control (student vs. teacher) of within-unit experience sequences did not have a differential effect on students' attitudes toward introductory biology.

Time Hypotheses

Hypotheses 6 and 7 tested the effect of different sequences of instructional units and within-unit experience sequences on the amount of time used to complete instructional units. They were as follows:

Hypothesis No. 6

For college students studying introductory biology in a general education course taught through the audio-tutorial method, the organizational sequence of instructional units does not affect the amount of time required to complete instructional units.

Hypothesis No. 7

For college students studying introductory biology in a general education course taught through the audio-tutorial method, control (student vs. teacher) of the sequence of experiences within instructional units does not affect the amount of time required to complete instructional units.

Data used in testing these hypotheses were obtained from student Audio-Tutorial Record Cards. For both of the time hypotheses significant differences in mean time used to complete instructional units were found for three of the five instructional units. Hypotheses 6 and 7 were rejected.

Discussion of Time Hypotheses

Subjects in the Test Determined Unit Sequence group used significantly more time than did subjects in the Structure Based Unit Sequence group for the Genetics and Control Mechanisms units. SBUS subjects used significantly more time to complete the Photosynthesis unit. Both groups (TDUS and SBUS) took significantly more time to complete the unit, or units, which were encountered first (SBUS subjects started with Photosynthesis and TDUS subjects started with Genetics). The differences could have been a result of subjects' lack of familiarity with experimental procedures. However, SBUS and TDUS subjects completed several audio-tutorial units prior to the study, and both groups included a Teacher Directed Experience group which used procedures that were very similar to those used in preliminary units. Thus the time differences for TDUS and SBUS subjects on initial instructional units could have resulted from the sequencing activity of SSE subjects. As the SSE subjects became more proficient in establishing within-unit sequences, they apparently used less time for instructional units and time differences between TDUS and SBUS groups became nonsignificant.

Subjects in the group that selected within-unit sequences of experiences took significantly more time to complete two of the five instructional units (Mitosis and Meiosis, and Genetics). It seems likely that the additional time used by subjects in the Student Selected Experience (SSE) group was expended in establishing a sequence, since it was necessary for SSE subjects to examine objectives and materials prior to the actual completion of activities. If this is the correct explanation for the differences, then permitting subjects to select within-unit sequences would offer no real advantage (since the SSE group was not significantly better than the TDE group in achievement or in attitude toward the course). However, if it can be shown that there is some other important effect that results from the utilization of additional time (such as better retention or understanding which might occur if the time is being used for cognitive structuring), then student selection of experience sequences would be justified.

In every treatment group the high grade point average subjects used more time in the completion of instructional units than low grade point average subjects. It seems that high grade point average subjects were more conscientious or more highly motivated than were the low grade point average subjects. This finding is in agreement with conclusions reached by Dubin and Traveggia (1968) in a review of research studies that compared the effectiveness of different methods of instruction. They concluded that no particular method of college instruction was more effective in terms of examination performance, and that time spent in study did contribute to improved grades.

Findings of the present study were inconsistent with those obtained by Judd, Bunderson, and Bessent (1970), who reported no significant difference in time for treatment groups in which subjects were given different amounts of control of a mathematics program. On the other hand, Newton and Hickey (1945) found that the amount of time subjects used in the completion of an economics program was related to the sequence of subconcepts in the program. Mager and McCann (1961) reported a very significant reduction in time for subjects participating in a learner control program for engineers.

Summary for the Time Hypotheses

Data of the experiment did not suppor. Hypotheses 6 and 7. The organizational sequence of instructional units, and the control (student vs. teacher) of within-unit experience sequences did influence the amount of time used by subjects in the completion of instructional units.

Sequence Hypothesis

Hypothesis No. 8 was designed to compare the similarities of within-unit experience sequences selected by subjects in the Student Selected Experience group with the sequence used by Teacher Directed Experience subjects. It was as follows:

Hypothesis No. 8

For college students studying introductory biology in a general education course taught through the audio-tutorial method, sequences of experiences within specific instructional units, that are selected by students, will not be similar to teacher directed sequences for those same units.

Data used in testing this hypothesis were obtained from check lists completed by subjects during each audio-tutorial session. Out of

940 sequences selected by subjects, only 15 were identical or similar to teacher directed sequences. The largest number of similar sequences produced by subjects for a specific unit was seven. Hypothesis No. 8 was not rejected.

Discussion of Sequence Hypothesis

When subjects in the Student Selected Experience group were permitted to select within-unit experience sequences, they did not select sequences which were similar to those used by subjects in the Teacher Directed Experience group. However, the sequences which were selected did not have a particularly detrimental effect on the achievement or attitudes of SSE subjects (mean achievement and attitude scores of SSE and TDE groups were not significantly different).

Perhaps the lack of similarity between student selected and instructor prescribed sequences was due to the fact that students and instructors sequence experiences in totally different ways. Instructor sequencing is based on a reasonably complete picture of the subject area. Student sequencing is probably related to a variety of unknown factors.

It is also possible that, in any group of students, some will not want to sequence experiences. Friend, Fletcher, and Atkinson (1972) have reported that students who studied computer science through use of a CAI program which permitted them to control the instructional sequence, the actual amount of instruction, and review procedures were reluctant to use control options. The fact that many subjects in the present study used a random experience sequence, after being warned that check list sequences were random, is an indication that some students have little desire to structure their learning experiences.

Mager (1961) reported that subjects studying electronics in a learner control program used sequences that were similar to those of other subjects, but considerably different from those used by instructors in conventional courses. He observed that subjects, with freedom to select a sequence of experiences, progressed from a simple whole to a more complex whole, or from the general to the specific. Mager concluded that content sequences that are really meaningful to learners are different from those that the instructors use.

Summary for Sequence Hypothesis

Data of the experiment supported Hypothesis No. 8. Sequences of within-unit experiences selected by students were not similar to sequences prescribed by an instructor for those same instructional units.

Conclusions

1. Since different unit sequences did not have a differential effect on biology achievement or subjects' attitudes toward the course, the approach to sequencing instructional units (Photosynthesis, Respiration, Mitosis and Meiosis, Genetics, and Control Mechanisms) in college introductory biology courses should be based on instructor and/or student preference.

2. If instructor time is limited, students in college introductory biology courses should be permitted to devise within-unit experience sequences.

3. If a major goal of an instructional program is efficiency (maximum student learning in a minimum of instructional time), the within-unit sequences for college introductory biology courses should be teacher directed.

4. Factors which include grade point average, score from an entry level biology achievement test, and SAT-Mathematics score should be used in the advisement of college students seeking enrollment in introductory biology courses.

5. Since all of the various combinations of instructional unit sequences and control forms (for within-unit experience sequences) were effective in the enhancement of students' biology achievement, they should all be considered acceptable as methods of biology instruction for students similar to those included in the experiment.

6. Because students with high grade point averages achieved at a much higher level than did low grade point average students (in all treatment groups), the instructional methods represented by the four treatments should be considered especially effective and desirable for use with high grade point average students.

Recommendations for Further Study

1. A study in which individual students are permitted to select instructional unit sequences should be conducted. The study would be technically complex, but could be conducted if treatment groups were kept small. If objectives were carefully structured, the achievement and attitudes of subjects could be compared with those of subjects following an instructor prescribed sequence of units.

2. The present study should be repeated with an entirely different group of subjects. Many studies that have tested the effects of various instructional methods on students' attitudes and achievement have utilized students in general education courses as subjects. Results obtained in these studies should be compared with those obtained from similar studies involving upper-level courses for students majoring in specific areas. The present study could be repeated using students in General Zoology or General Botany as subjects.

3. Additional studies in which students are permitted to select sequences of experiences are needed. An attempt should be made to determine the basis for student selected sequences. This information would be useful in the development of more effective instructional programs. Since a great many studies that have compared learner control with teacher or program control on the basis of students' achievement have reported nonsignificant differences, a search for other more sensitive dependent variables should be made.

4. Valuable information for the individualization of biology instruction might be obtained from a study of learner control in which emphasis is placed on the identification of student characteristics that can be used to prescribe different amounts of learner control and/or teacher direction for individual learners.

5. Since high grade point average subjects used more time than low grade point average subjects and scored higher on the biology achievement test, a study in which time is controlled should be conducted. This would make it possible to determine the effect of

increased instructional time on the achievement of low grade point average subjects.

6. The effect of different instructional unit sequences, and various forms of control for within-unit experience sequences, on students' retention of important biological principles should be explored.

7. The relationship between specific personality factors and the effective utilization of different combinations of instructional unit sequences and forms of control for within-unit experience sequences should be investigated. If it can be shown that certain personality types use specific instructional sequences and control forms more effectively than others, matching of students to appropriate instructional programs would be greatly facilitated.

Summary of the Investigation

The effects of two different sequences of instructional units and two forms of control for within-unit experience sequences on the achievement and attitudes of students in a college introductory biology course were investigated.

In the experiment, 376 undergraduate students studied five instructional units through the audio-tutorial method during a five week period. Instructional units included Photosynthesis, Respiration, Mitosis and Meiosis, Genetics, and Control Mechanisms. In addition to independent study sessions (ISS), subjects attended a weekly discussion period in which problems encountered in the ISS were discussed.

Instructional unit sequences included a Structure Based Unit

Sequence (SBUS) and a Test Determined Unit Sequence (TDUS). The SBUS was based on an analysis of major concepts included in the five instructional units. Units including concepts considered prerequisite to other units were put into the sequence on that basis. The unit considered to be dependent on the other four was given terminal status in the sequence. The TDUS was based on results obtained from the administration of an achievement pretest which included a scale for each instructional unit. The TDUS began with the unit on which subjects scored highest and moved progressively to instructional units represented by lower mean achievement scores.

The two forms of control for within-unit experience sequences were Teacher Directed Experience (TDE) and Student Selected Experience (SSE). TDE subjects followed a teacher-prescribed sequence while SSE subjects used lists of objectives and related activities to select within-unit sequences.

Upon completion of the experimental units, treatment groups did not differ significantly in biology achievement, or attitude toward the biology course. When subjects in the SBUS and TDUS groups were compared on the basis of average time used to complete instructional units, significant differences favored the TDUS group by two to one. Both groups used a greater amount of time to complete the units they encountered first in a sequence. SSE subjects used significantly more time than TDE subjects on two instructional units.

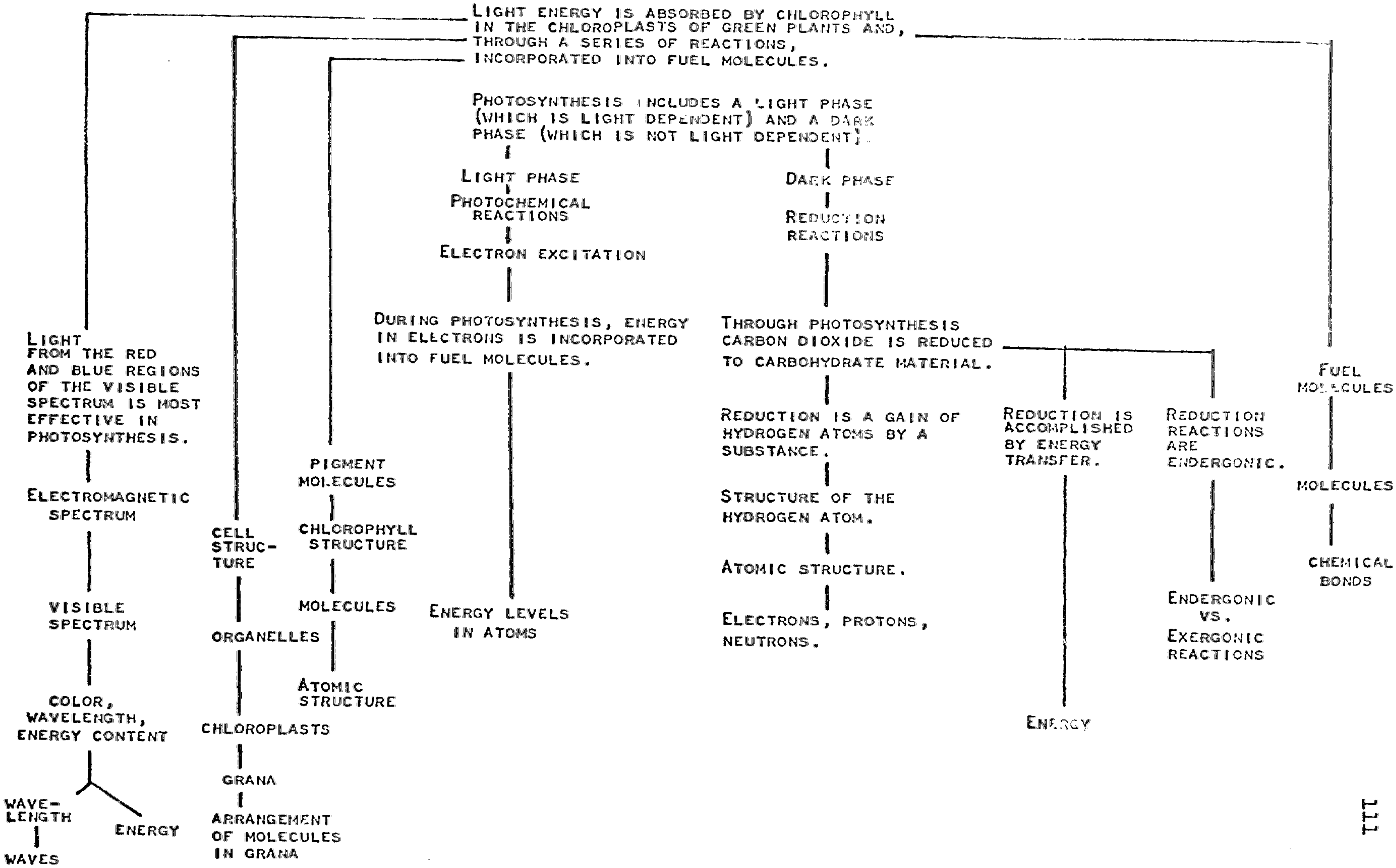
Other findings included: (1) a combination of factors which included SAT-Mathematics score, grade point average, and the score from a biology achievement pretest were the best predictors of biology achievement, (2) within-unit experience sequences selected by SSE subjects were not similar to those prescribed by an instructor for that same unit, (3) subjects with high grade point averages used more time to complete instructional units and scored higher on the achievement posttest than did low grade point average subjects, and (4) subjects in all treatment groups made highly significant gains in achievement.

APPENDICES

Appendix A

Flow Chart Used in the Analysis of Concepts Included in an Instructional Unit

CONCEPT ANALYSIS
PHOTOSYNTHESIS



Appendix B

Instructions for Subjects in Teacher Directed and Student Selected Treatment Groups

Student Selected Experience Group

1. Find the sheet titled Check List. Scan the objectives that it includes and set up a sequence that you will follow in completing the unit. Please avoid the sequence on the sheet; it is a random sequence. Arrange the objective cards in the sequence you have established. Flip them as you move through the unit.
2. There is a plastic notebook in your booth labeled Audio Script. It includes a sheet (or sheets) of information related to the objectives. (Objectives are listed at the top of each sheet.) The information provided is the same as that on the tape (the Tape Index Number indicates the place, on the tape, where the information is located). In completing the unit you may use the audio script, the tape, or a combination of the tape and audio script. PLEASE do not remove the audio script from the booth. A musical signal indicates the end of the information related to an objective. Activities that are between musical signals will be indicated by a bell.
3. As you complete each objective use the sheet headed Check List to indicate the sequence you have used (put a "1" behind the objective completed first, etc.). Give this to the instructor when you have completed the unit.
4. When you have completed the activities for the first objective,

select another (use the card file) and proceed as before. Continue in this manner until you have completed all of the objectives.

Teacher Directed Experience Group

1. In your booth you will find a set of mimeographed materials. These papers contain the information that is on the tape.
2. In completing the unit you may use the tape, the mimeographed sheets, or a combination of the tape and mimeographed sheets. Please do not remove the sheets from your booth.

Appendix C

Excerpts from Audio Scripts for Teacher Directed and Student Selected Experience Sequence Groups

Excerpt from a Teacher Directed Experience Audio Script

Meiosis and Mitosis

In the middle of the last century, biologists first observed cells. They knew that the growth of organisms involved an increase in cell number, but the explanation of how one cell produced another remained obscure. It has now been well established that cell division involves two separate sequences. One, the duplication of the nucleus into two identical nuclei, and two, the division of the cytoplasm. The nucleus contains the chromosomes which are made up of genes and a gene contains the genetic information for a single heritable trait. Every cell has a complete set of genetic material; therefore, when cells divide each cell must receive a copy of every gene.

The genetic code is stored in the double stranded DNA molecule. So if the genetic code is to be duplicated then the DNA must be duplicated. At this point we need to look at the way in which this duplication takes place. Accurate duplication is possible since a given base will pair with only one other base. Now look at section A on page 1 in your study guide.

The DNA strand in diagram 1 represents a portion of a molecule before cell division. The strands are bound together by bonds between the bases of the two strands. The two strands start to separate. We might say that DNA unzips, because the bonds holding the nitrogen bases of the two separate strands in close proximity break. In diagram 2 this unzipping is not quite complete because as you can see there are still two pairs of bases bound together. The synthesis of the new strands has already started for the far right of each of the old strands. The base sequence on the new strands is predetermined since a given base will pair with only a specific one of the other three. When the synthesis is complete two identical molecules are formed. These are shown in diagram 3. If you do not fully understand this process, review Figure 17.2 on page 240 of your text. Where do the parts for the synthesis of the individual nucleotides come from? Ribose can be obtained from glucose. Nitrogen bases can be formed from intermediates in metabolic pathways. For example, purines come from PGAL. Phosphate is taken in as a nutrient from an external source We take it in as part of the food supply; plants absorb it from the soil.

We know that the DNA is an important component of chromosomes, so let us say something about the duplication of chromosomes. Look at diagram 4 on page 2 in your study guide. The top diagram labeled "a" shows one chromosome. The DNA is indicated by the helical structure within the chromosome. The remainder of the diagram represents protein. Note in the diagram labeled "b" that the helical DNA is duplicating. The newly synthesized portion of the DNA is shown in red. Finally in the lower portion of the diagram labeled "c" chromosome duplication is complete. At this point the chromosome is said to be composed of two chromatids, each with a duplicate copy of DNA. The chromatids are joined together at a location called the centromere. After cell division, the chromatids with their duplicate copies of DNA end up in separate cells. Now see if you can relate the events in diagram 1 through 3 in your study guide with events in diagram 4. Diagrams 1, 2, and 3 show how one molecule of DNA duplicates. Diagram 4 shows what happens on a larger scale when one chromosome which contains replicating DNA duplicates and becomes two chromatids.

Excerpt from a Student Selected Experience Audio Script

OBJECTIVE

Give examples of plant and animal cells that divide mitotically.

Tape Index Number

Audio Script

In unicellular organisms, cells resulting from cell division are genetically identical organisms. But in multicellular or many celled organisms cells resulting from cell division usually stay together. They may enlarge and begin to differentiate into specialized cells that will play some vital role in the organism. For example, in an animal, cells might become flattened and eventually form epithelial tissue which lines the inside of our cheeks. In the case of plants they might become part of a tissue found in the roots, the stems, or the leaves. Areas where cell division takes place in plants are confined to the meristems at the terminal areas of the root and the stem. In animals, areas of cell division are rather widespread. Rates of division vary; the highest are generally found in embryonic regions, the lowest in aged tissues. Some cells cannot reproduce at all, for example, nerve cells cannot be replaced. Muscle and liver cells seldom divide. However, most cells do retain the potential to reproduce.

OBJECTIVE

Distinguish between haploid (n) and diploid (2n).

Give examples of plant and animal cells that divide meiotically.

Tape Index Number

Activities

Study Guide - Diagram 7

Audio Script

The genetic material is stored in structures called chromosomes. In order to understand the significance of the sexual process it will be necessary to emphasize the relationship of chromosome numbers to the organism. Each species of plant or animal has a specific number of chromosomes in each cell. For example, man has 46 chromosomes per cell. Watch Diagram 7 while we discuss the human life cycle.

Both the egg and the sperm contain one set consisting of 23 chromosomes. But each cell of adult man contains two sets or 46 chromosomes. Where do the 46 originate? When gametes (sex cells) fuse at fertilization, two sets of chromosomes come together in a single cell. Thus, man gets 23 chromosomes from his mother and 23 from his father. These 46 chromosomes are made up of 23 pairs. One member of each pair comes from the egg and the other comes from the sperm, or one member of each pair comes from the mother and one from the father. The chromosomes which make up a single pair contain genetic information (genes) controlling the same traits.

Since the cells of adult man have two sets of chromosomes, they are said to be diploid. Cells such as gametes (which are produced by both plants and animals) have only one set of chromosomes and are haploid. The change in chromosome number (from diploid to haploid) results from meiosis.

Appendix D

Professors Who Assisted in the Preparation of Objectives and Test Items

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3. Leon W. Kreger, Professor of Biology, Shippensburg State College, Shippensburg, Pa.
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Appendix E

Sequence Test

1. Organisms that produce energy rich fuel molecules (sugar, etc.) are classified as
   (1) heterotrophs (3) saprotrophs
   (2) holotrophs (4) autotrophs

2. The component of visible light that has short wavelength and high energy is
   (1) blue (3) green
   (2) red (4) yellow

3. In certain cells of green plants carbohydrate molecules are produced initially in structures called
   (1) mitochondria (3) chloroplasts
   (2) ribosomes (4) lysosomes

4. A factor that does not affect the rate of photosynthesis is
   (1) oxygen concentration (3) CO_2 concentration
   (2) light intensity (4) temperature

5. Photosynthesis consists of two phases or reaction sequences which are referred to as the light reaction and dark reaction. The dark reaction occurs
   (1) only in the presence of light
   (2) only in darkness
   (3) in either light or darkness
   (4) only during extended periods of darkness

6. The carbohydrate produced during photosynthesis is from the
   (1) light reaction which involves chemical oxidation
   (2) light reaction which involves chemical reduction
   (3) dark reaction which involves chemical oxidation
   (4) dark reaction which involves chemical reduction

7. Substances required for the dark reaction of photosynthesis that are produced in the light reaction include
   (1) CO_2 + H_2O (3) H_2O + O_2
   (2) ATP + $NADPH_2$ (4) RDP + PGAL

8. An equation that includes the reacting materials and products for photosynthesis is
(1) $C_{16}H_{12}O_6 \longrightarrow CO_2 + C_2H_5OH$
(2) $CO_2 + C_6H_{12}O_6 \longrightarrow O_2 + H_2O$
(3) $CO_2 + H_2O \longrightarrow C_6H_{12}O_6 + O_2$
(4) $C_6H_{12}O_6 + O_2 \longrightarrow CO_2 + H_2O$

9. Chlorophyll is essential in photosynthesis because it
(1) reflects red and green light (3) reflects green and blue light
(2) absorbs red and blue light (4) absorbs green and blue light

10. A technique that is used to separate the components of complex mixtures of chemical substances (e.g. plant pigments) is
(1) centrifugation (3) autoradiography
(2) microscopy (4) chromatography

11. More directly usable energy is produced during which of the following cellular processes?
(1) anaerobic respiration (3) aerobic respiration
(2) protein synthesis (4) alcoholic fermentation

12. Energy is released from fuel molecules in which of the following organelles?
(1) mitochondria (3) chloroplasts
(2) ribosomes (4) lysosomes

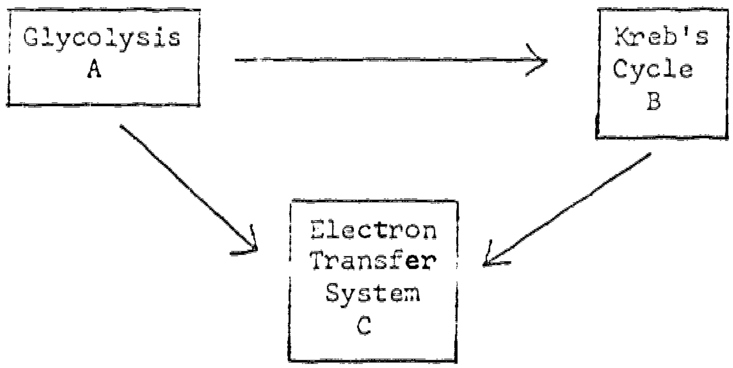
13. Cellular respiration
(1) does not occur in green plants
(2) occurs in both plants and animals
(3) occurs in plants during darkness but not in light
(4) occurs in all animals but only in plants that lack chlorophyll

14. An equation that includes the reacting materials and products for aerobic respiration is
(1) $CO_2 + H_2O \longrightarrow C_6H_{12}O_6 + O_2$
(2) $CO_2 + O_2 \longrightarrow C_6H_{12}O_6 + H_2O$
(3) $C_6H_{12}O_6 + O_2 \longrightarrow CO_2 + H_2O$
(4) $C_6H_{12}O_6 \longrightarrow CO_2 + C_2H_5OH$

15. When cellular respiration is considered in a very general way which of the following is true?
(1) it involves chemical oxidation and is energy releasing
(2) it involves chemical oxidation and is energy consuming
(3) it involves chemical reduction and is energy releasing
(4) it involves chemical reduction and is energy consuming

16. Kreb's Cycle and electron transfer reactions are typical of
(1) aerobic respiration
(2) the light reaction of photosynthesis
(3) anaerobic respiration
(4) the dark reaction of photosynthesis

17.



The above diagram represents aerobic respiration. Most of the ATP produced during aerobic respiration comes from
(1) A (3) A and B
(2) B (4) C

18. The energy carrier molecule (which traps energy released in cell respiration and makes it available for processes which consume energy) in living cells is
(1) glucose (3) ATP
(2) DNA (4) PGAL

19. Which of the following is true?
(1) glycolysis (which converts glucose to pyruvic acid) occurs in aerobic respiration
(2) glycolysis does not occur in the fermentation process
(3) glycolysis occurs in anaerobic but not in aerobic respiration
(4) glycolysis does not occur in plant cells

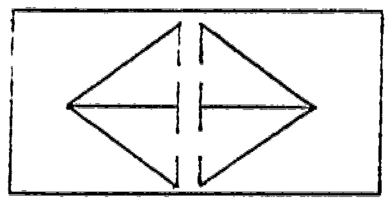
20. Living organisms can extract more energy from which of the following types of molecules?
(1) carbohydrates (3) proteins
(2) fats (4) nucleic acids

21. That a sample of tissue has come from the testis of a cat and <u>not</u> from its kidney can be determined by the presence of cells
(1) in various stages of mitosis
(2) with the diploid chromosome number
(3) which lack nuclei
(4) with the haploid number of chromosomes

22. In animals, gametes (sperms and eggs) are produced through
(1) meiosis which reduces the number of chromosomes
(2) mitosis which reduces the number of chromosomes
(3) meiosis which does not change the number of chromosomes
(4) mitosis which does not change the number of chromosomes

23. A cell having 20 chromosomes would, during mitosis, give rise to two cells each of which would have a chromosome number of
(1) 10 (3) 40
(2) 20 (4) 80

24.

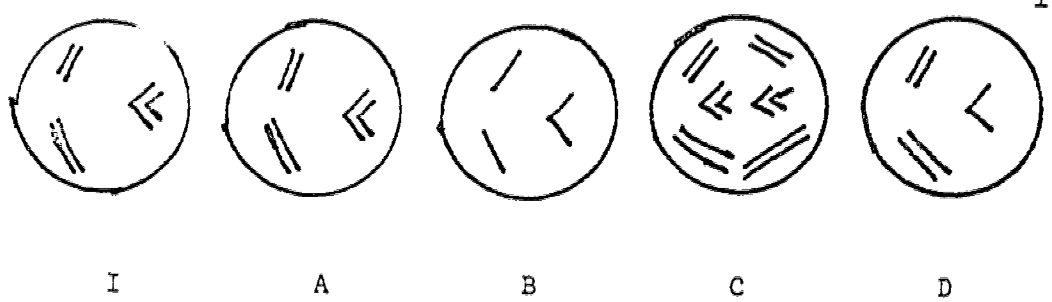


The above drawing represents a stage of mitosis in a plant cell. The stage is
(1) interphase (3) metaphase
(2) prophase (4) anaphase

25. As compared with the amount of DNA contained in the body cell of the frog, how much DNA is found in the sperm cell of the frog?
(1) 1/4 as much (3) an equal amount
(2) 1/2 as much (4) twice as much

26. Human body cells have 23 pairs of chromosomes in their nuclei. A term that is used to describe cells that have the maximum number of chromosomes for a particular species is
(1) diploid (3) polyploid
(2) haploid (4) monoploid

27. Sexual reproduction is typical of
(1) plants only
(2) animals only
(3) both plants and animals
(4) all animals but only flowering plants



In the above series of pictures "I" represents the nucleus of a cell taken from the leaf of a common green plant. Questions 28 and 29 relate to the four lettered diagrams.

28. A functional sperm nucleus from a pollen grain produced by this plant could resemble
(1) A (3) C
(2) B (4) D

29. The nucleus of a zygote formed from normal gametes in this plant would most likely resemble
(1) A (3) C
(2) B (4) D

30. Crossing over (a process through which adjacent chromosomes exchange segments) occurs during
(1) prophase of mitosis (3) telophase of mitosis
(2) anaphase of meiosis (4) metaphase of meiosis

31. The total genetic code (or hereditary information) is stored in human cells in which of the following
(1) RNA (3) DNA
(2) NAD (4) a gene

32. Protein molecules are synthesized in
(1) mitochondria (3) ribosomes
(2) chloroplasts (4) the cell nucleus

33. Hereditary information is transferred from the cell nucleus to special areas in the cytoplasm by
(1) DNA (3) transfer RNA
(2) messenger RNA (4) genes

34. Protein synthesis as an overall process is
(1) endergonic or energy consuming
(2) endergonic or energy releasing
(3) exergonic or energy consuming
(4) exergonic or energy releasing

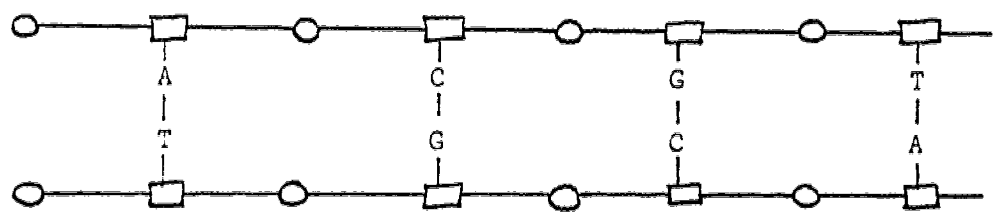
35. Protein molecules are essential in living cells because they are
(1) subunits in amino acid molecules
(2) primary fuel molecules
(3) enzymes
(4) denatured by excess heat

36. Energy for the synthesis of protein molecules comes from
(1) DNA (3) enzymes
(2) ATP (4) peptide bonds

37. Systems in living organisms tend to self-adjust. This results in physiological stability or maintenance of the "steady state." A very general term that is used to describe this phenomenon is
(1) unbalanced feedback (3) osmoregulation
(2) homeostasis (4) tropic response

38. The human kidney maintains the concentration of substances in the blood by reabsorbing them from the tubules. An item that is reabsorbed in large quantities is
(1) H_2O (3) urea
(2) protein (4) red cells

39. Breathing rate in man is controlled by a center in the brain which is sensitive to the concentration (in the blood) of which of the following?
(1) hemoglobin (3) red cells
(2) O_2 (4) CO_2



KEY ○ = a phosphate group

□ = a sugar molecule

Letters A, T, C, and G = nitrogen bases

40. The above structure represents a small segment of
(1) a protein molecule (3) t-RNA
(2) m-RNA (4) DNA

41. New combinations of genes result from
(1) mitosis in the body cells of animals
(2) mitosis in the gametes (sex cells) of animals
(3) meiosis in the body cells of animals
(4) meiosis in the gametes (sex cells) of animals

42. An organism that has identical alleles (different forms of a gene) for a particular trait is described as
(1) homozygous
(2) monozygous
(3) heterozygous
(4) isozygous

43. An organism has both alleles of a gene for a particular trait. How many different types of sex cells (with respect to only this trait) can this organism produce?
(1) 0
(2) 1
(3) 2
(4) 4

44. An allele that completely masks or conceals the presence of its other form is
(1) incompletely dominant
(2) recessive
(3) dominant
(4) codominant

The punnett square shown below represents possible patterns of inheritance in dihybrid crosses where black (B) is dominant to white (b) and straight hair (S) is dominant to curly hair (s).

	BS	Bs	bS	bs
BS	Q	U	Y	H
Bs	R	V	Z	J
bS	S	W	F	K
bs	T	X	G	L

Questions 45 and 46 are based on the above information.

45. The genotype for organisms of type "J" is
(1) Bbss
(2) black with curly hair
(3) BBss
(4) white with straight hair

46. The phenotype for organisms of type "K" is
(1) black, straight hair
(2) bsbS
(3) white, straight hair
(4) bbSs

Figure 1.

	R	r
R	RR	Rr
r	Rr	rr

47. Figure 1 represents a cross between two heterozygous parents. "R" is dominant over "r". The phenotype ratio in this cross is
(1) 1 : 2 : 1
(2) 3 : 1
(3) 4 : 0
(4) 1 : 1

48. The genotype ratio for the cross represented in Figure 1 is
(1) 1 : 2 : 1
(2) 3 : 1
(3) 4 : 0
(4) 1 : 1

49. A male with a Tt genotype (for a particular trait) is crossed with a female of the same genotype. What is the probability that a tt offspring will be produced?
(1) 1/2
(2) 1/4
(3) 1/8
(4) 1/3

50. An organism has a Tt genotype for a particular trait. The parents of this organism could have which of the following genotypes?
(1) TT and TT
(2) tt and tt
(3) TT and tt
(4) T and t

Appendix E, Table 26

Point-Biserial Correlations, Discrimination Indices, and Difficulty Indices for Questions from the Sequence Test

Question No.	[a]PBC	[b]DI	[c]I of D
1.	.28	21.67	.28
2.	.12	35.96	.02
3.	.15	59.61	.14
4.	.20	36.45	.28
5.	.11	23.65	.14
6.	.03	9.85	.00
7.	.06	25.12	.12
8.	.33	47.29	.46
9.	.14	22.66	.24
10.	.15	49.26	.24
11.	.09	27.09	.04
12.	.36	41.87	.44
13.	.32	72.91	.40
14.	.35	37.44	.48
15.	.18	32.51	.26
16.	.29	49.[illegible]	.38
17.	.06	20.69	.00
18.	.33	49.75	.42
19.	.28	37.93	.40
20.	-.06	11.82	-.06

Table 26 (continued)

Question No.	aPBC	bDI	cI of D
21.	.24	35.96	.32
22.	.25	16.75	.16
23.	.21	44.83	.20
24.	.08	47.78	.10
25.	.30	26.11	.28
26.	.32	27.59	.36
27.	.07	24.14	.04
28.	.26	30.54	.26
29.	.25	24.63	.20
30.	.16	29.56	.20
31.	.28	46.31	.34
32.	.23	59.11	.30
33.	.19	53.20	.30
34.	.24	26.20	.22
35.	.20	29.06	.24
36.	.13	23.65	.16
37.	.30	51.23	.40
38.	.21	36.95	.28
39.	.24	18.23	.26
40.	.24	35.96	.30
41.	.20	41.38	.18
42.	.39	46.80	.54

Table 26 (continued)

Question No.	[a]PBC	[b]DI	[c]I of D
43.	.08	37.44	.16
44.	.30	68.47	.32
45.	.24	48.77	.28
46.	.29	50.25	.36
47.	.27	46.31	.34
48.	.28	35.96	.30
49.	.34	51.72	.40
50.	.32	72.91	.32

[a]PBC - Point-Biserial Correlation

[b]DI - Difficulty Index

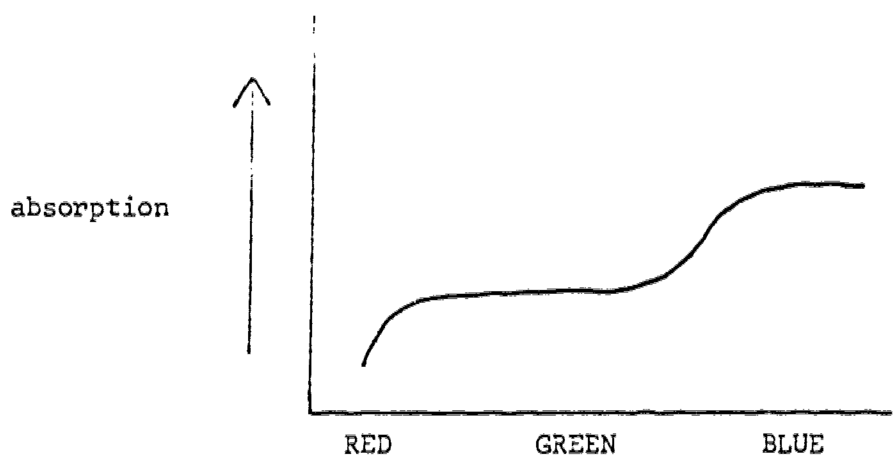
[c]I of D - Index of Discrimination

Appendix F

Achievement Posttest

1. For the visible portion of the electromagnetic spectrum, which of the following is true?
   (1) red light has higher energy than blue light.
   (2) red light has shorter wavelength than blue light.
   (3) green light has less energy than red light.
   (4) blue light has short wavelength and high energy.

2. An experiment was set up involving autotrophic plants, all of the same species, under the influence of light of different colors. In any given period of time, in which light would the plants probably release the <u>least</u> amount of oxygen?
   (1) red. (3) green.
   (2) orange. (4) violet.



3. The above graph represents the absorption pattern for a mixture of pigments from an exotic plant. A true statement that might be made about the plant is that it
   (1) is green. (3) absorbs light.
   (2) is photosynthetic. (4) reflects mostly blue.

4. The light reaction of photosynthesis occurs
   (1) in both light and dark. (3) only in light.
   (2) only in dark. (4) in either light or dark.

5. In green plants the reactions of photosynthesis occur in
   (1) chloroplasts. (3) mitochondria.
   (2) ribosomes. (4) vacuoles.

6. Chromatography can be used to separate the pigment molecules in a mixture because
   (1) chlorophyll is soluble in alcohol.
   (2) smaller molecules move up the paper column very rapidly.
   (3) pigment molecules that are more soluble in the solvent move farther up the paper column.
   (4) the paper column interferes with the movement of non-chlorophyll type molecules.

7. From the list below identify the <u>products</u> of the <u>light reaction</u> of photosynthesis.
   (1) NADP, ADP and H_2O.
   (2) PGAL and H_2O.
   (3) CO_2 and H_2O.
   (4) $NADPH_2$, ATP and O_2.

8. Oxygen given off by a particular plant during photosynthesis is found to be radioactive. Other substances involved in the process are tested. Which of the following will be radioactive?
   (1) H_2O.
   (2) CO_2.
   (3) glucose.
   (4) PGAL.

9. We often speak of "limiting factors" in biology, that is, conditions or substances which limit processes by absence or by inappropriate amounts. Which of the following would <u>not</u> limit photosynthesis, regardless of presence, absence, or quantity?
   (1) oxygen.
   (2) CO_2.
   (3) light.
   (4) water.

10. Which of the following substances, supplied to a green plant kept in the dark, would make it possible for the plant to remain alive?
   (1) NAD alone.
   (2) PGAL.
   (3) NAD and CO_2.
   (4) H_2O and CO_2.

11. Which environmental change is most likely to <u>increase</u> the rate of photosynthesis in a bean plant?
   (1) a drop in temperature to 15° C.
   (2) an increase in the intensity of green light.
   (3) a rise in the oxygen concentration in the air.
   (4) a rise in the carbon dioxide concentration in the air.

12. In the dark reaction of photosynthesis PGA is reduced to PGAL. This reduction requires
   (1) ADP and NADP.
   (2) NAD and ATP.
   (3) ATP and $NADPH_2$.
   (4) light and chlorophyll.

13. A green plant is kept in the dark for several days. It is then placed in light but deprived of CO_2. After several hours its leaves give a negative starch test. This is because
    (1) the light reaction of photosynthesis is accelerated.
    (2) O_2 from CO_2 is released in photosynthesis.
    (3) darkness destroys chlorophyll.
    (4) carbon dioxide is necessary for the dark reaction of photosynthesis.

14. Which of the following represents the overall process of photosynthesis?
    (1) carbon dioxide + water ⟶ glucose + oxygen + carbon dioxide.
    (2) glucose + water ⟶ carbon dioxide + water.
    (3) carbon dioxide + water ⟶ glucose + oxygen.
    (4) glucose + oxygen ⟶ carbon dioxide + water.

15. The overall description of aerobic respiration which includes reactants and products is
    (1) glucose ⟶ alcohol + carbon dioxide.
    (2) carbon dioxide + water ⟶ sugar + water.
    (3) sugar + oxygen ⟶ carbon dioxide + water.
    (4) carbon dioxide + water ⟶ carbohydrate + oxygen + water.

16. Which life function is represented by the diagram below?

$$\text{glucose} \xrightarrow{\text{enzymes}} \text{ethyl alcohol} + CO_2 + \text{ATP}$$

    (1) anaerobic respiration.
    (2) photosynthesis.
    (3) aerobic respiration.
    (4) Kreb's citric acid cycle.

17. Heterotrophic animal cells carrying on aerobic respiration were placed in an artificial atmosphere in which all the oxygen present was oxygen-18 (a radioactive form of oxygen). During respiration the cells took in and used oxygen-18 just as they would use ordinary oxygen-16. The oxygen-18 would most likely leave the cell as part of a molecule of
    (1) glucose.
    (2) CO_2.
    (3) H_2O.
    (4) pyruvic acid.

18. Most of a cell's ATP is produced
    (1) during glycolysis.
    (2) during the $C_3 \longrightarrow C_2$ stage.
    (3) during the Kreb's cycle.
    (4) during the cytochrome system stage.

19. The yield of energy from anaerobic respiration
    (1) is greater than from aerobic respiration.
    (2) is smaller than from aerobic respiration.
    (3) is the same as in aerobic respiration.
    (4) varies depending on whether a plant or animal is considered.

20. The synthesis of ATP in respiration is essentially an oxidation process involving the "removal of" energy from
    (1) CO_2. (3) oxygen.
    (2) water. (4) electrons.

21. The product(s) of the energy-yielding breakdown of glucose in yeast cells in the absence of ample oxygen is (are)
    (1) lactic acid.
    (2) alcohol and carbon dioxide.
    (3) pyruvic acid and water.
    (4) acetic acid and carbon dioxide.

22. Cellular respiration can occur in living protoplasm at temperatures that are much lower than those at which combustion in non-living things occurs because
    (1) more oxygen is used by the protoplasm.
    (2) less carbon is present in protoplasm than in non-living things.
    (3) enzymes are present in protoplasm.
    (4) protoplasm releases less carbon dioxide during the process of combustion than do non-living things.

23. In the metabolic breakdown of glucose to yield carbon dioxide and water, most of the different reactions which represent oxidations are those in which
    (1) molecular oxygen is added to a carbon-containing molecule.
    (2) a water molecule is added to a carbon-containing molecule.
    (3) hydrogen atoms are removed from a carbon-containing molecule.
    (4) carbon-containing molecules are split into halves.

24. The common immediate source of energy in cellular activity is
    (1) PGAL. (3) NAD.
    (2) ATP. (4) glucose.

25. In explaining aerobic respiration, a student made the following generalizations.

The carbon dioxide produced is the direct result of Kreb Cycle chemistry.

Oxygen in the cells functions as a donator of high energy electrons.

All biochemical energy in the form of ATP is packaged in the electron transport system.

The process is common only in animal tissue.

Which is the best summary of his knowledge?
(1) Excellent! Correct on all points.
(2) Poor! He should review the topic.
(3) Good, but a little weak in which organisms have aerobic respiration.
(4) Fair, but confused on the Kreb's Cycle.

26. Which of the following is not an energy consuming process?
(1) osmosis in root hairs.
(2) active transport in human kidney cells.
(3) movement (total organism).
(4) synthesis of large molecules.

27. Which of the following includes molecules that are respired in living cells?
(1) ATP, glucose and CoA.
(2) $NADPH_2$, glucose and ATP.
(3) PGAL, glycogen, and glucose.
(4) CO_2, fats and pyruvic acid.

28. Which of the following is true?
(1) glycolysis occurs in mitochondria.
(2) Kreb's Cycle reactions occur in the cytoplasm.
(3) glycolysis and Kreb's Cycle reactions occur in mitochondria.
(4) glycolysis occurs in the cytoplasm.

29. Which of the following is true?
(1) mitosis occurs in plants, but not in animals.
(2) meiosis occurs in animals, but not in plants.
(3) meiosis occurs only in plants and mitosis occurs only in animals.
(4) meiosis and mitosis occur in both plants and animals.

30. To the species involved, the chief advantage of sexual reproduction is that it
(1) keeps the DNA material constant from generation to generation.
(2) protects the embryo.
(3) leads to new DNA combinations.
(4) involves two organisms.

31. An advantage of asexual reproduction in the propagation of a superior strain of an ornamental plant is that
(1) this method offers the possibility of improving the strain.
(2) asexual reproduction guarantees larger numbers of offspring than would sexual reproduction.
(3) asexual methods offer an increased chance of uniform quality.
(4) asexual methods tend to eliminate weaknesses from the plants involved.

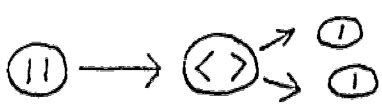
32. Which would be the result if, during the process of mitosis, chromosomes did not replicate themselves?
(1) sperm cells would have double the number of chromosomes present in the parent cell.
(2) each daughter cell would have the same number of chromosomes as the parent cell.
(3) each daughter cell would have double the number of chromosomes present in the parent cell.
(4) each daughter cell would have half as many chromosomes as the parent cell.

33. A major difference between meiosis and mitosis is that
(1) in mitosis chromosomes pair up prior to duplication.
(2) in meiosis chromosomes pair up prior to duplication.
(3) tetrads are involved in mitosis.
(4) metaphase occurs in meiosis.

34. Chromosomes do not occur as homologous pairs in
(1) fertilized eggs.
(2) gametes.
(3) zygotes.
(4) body cells.

35. If each line represents a chromatid, then mitosis in a cell which has one pair of chromosomes in its nucleus is represented by

(1) 

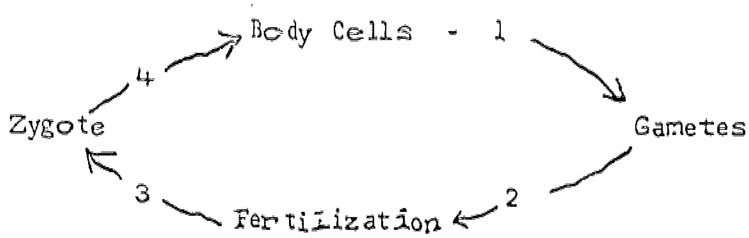
(2) 

(3) 

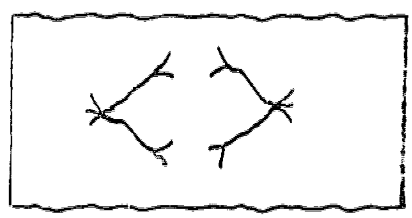
(4) 

36. If the symbol > is used to indicate that an item is an integral part of a larger more complex structure (ex. glucose > starch molecule) then the arrangement for the genetic material is
(1) DNA > chromosomes > genes.
(2) genes < DNA < chromosomes.
(3) DNA > genes > chromosomes.
(4) genes > DNA > chromosomes.

37. In a normal body cell of a certain shark there are 24 chromosomes. How many chromosomes are likely to be found in each gamete produced by this animal?
(1) 6.
(2) 12.
(3) 24.
(4) 48.



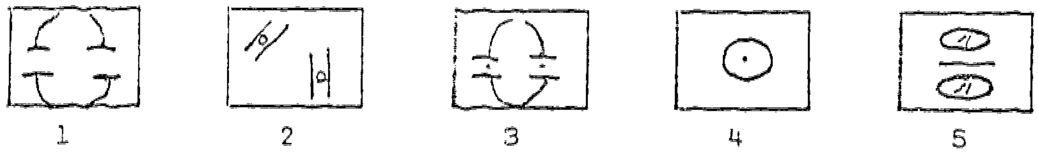
38. In the above diagram (which represents an animal life cycle) mitosis occurs at
(1) 1.
(2) 2.
(3) 3.
(4) 4.



39. The above diagram represents
(1) prophase in an animal cell.
(2) metaphase in a plant cell.
(3) anaphase in an animal cell.
(4) interphase in a plant or animal cell.

40. Chromatids, resulting from the duplicating of a chromosome during mitosis, are held together by
(1) astral rays.
(2) spindle fibers.
(3) centrioles.
(4) centromeres.

41. Crossing over during meiosis results in
(1) new gene combinations.
(2) tetrad formation.
(3) mutations.
(4) abnormal chromosome numbers.



42. The above drawings represent mitosis in a cell which has a diploid chromosome number of 2. Start with interphase and put the drawings in sequence. Select the correct sequence from the following
(1) 2, 3, 1, 5, 4. (3) 4, 2, 3, 1, 5.
(2) 4, 3, 2, 1, 5. (4) 4, 1, 2, 3, 5.

43. An animal is heterozygous for one trait (Aa) and homozygous for another (rr). The genes for these two traits are on different chromosomes. How many different types of gametes (with respect to these traits) can this organism produce?
(1) 1. (3) 3.
(2) 2. (4) 4.

44. Which statement concerning an allelic pair of genes controlling a single characteristic in man is true?
(1) both genes come from the father.
(2) both genes come from the mother.
(3) one gene comes from the father and one gene comes from the mother.
(4) the genes come randomly in pairs from either the father or the mother.

45. In man, the sperm cell determines the sex of the offspring because it contains
(1) two "X" chromosomes.
(2) two "Y" chromosomes.
(3) both an "X" and a "Y" chromosome.
(4) either an "X" or a "Y" chromosome.

46. A farmer is told that his black bull is a thoroughbred (homozygous black). Knowing that black color is dominant over red color in cattle, he decides to determine the purity of the strain by mating the bull with several red cows. If the bull is homozygous
(1) 100% of the offspring will be black.
(2) 100% of the offspring will be heterozygous red.
(3) 75% of the offspring will be black and 25% will be red.
(4) 50% of the offspring will be black and 50% will be red.

47. A student in the laboratory tossed 2 pennies from a container 100 times and recorded these results: both heads - 25; one head and one tail - 47; both tails - 28. Which cross would result in approximately the same ratio?
(1) Aa x AA. (3) AA x aa.
(2) Aa x Aa. (4) Aa x aa.

48. In peas, red flowers (R) are dominant over white flowers (r). Two plants that are heterozygous for flower color are crossed. What is the probability that the first plants produced will be pink?
(1) 1/2. (3) 1.
(2) 1/4. (4) 0.

49. A woman whose father was colorblind but who is not colorblind herself marries a man with normal vision. The chances for colorblindness in their children is
(1) 0%. (3) 50%.
(2) 25%. (4) 100%.

50. Which is the most likely result of crossing-over in plant breeding?
(1) elimination of some recessive genes.
(2) weakening of the dominant gene.
(3) increased number of gene mutations among offspring.
(4) increased variability among offspring.

51. In Jimson weeds purple flowers (P) are dominant over white flowers (p), and spiny pod (S) is dominant over smooth pod (s). A purple-smooth is crossed with a white-spiny producing:
106 purple-smooth
110 purple-spiny
102 white-smooth
114 white-spiny
The most likely cross giving these results would be
(1) Ppss x ppSs. (3) PpSs x ppSS.
(2) PpSs x PpSs. (4) PPss x ppSs.

52. Hemophilia is a sex-linked trait. Men are commonly affected by the disease, but women are rarely affected. This is due to the fact that the gene for hemophilia is
(1) dominant and carried only on the Y chromosome.
(2) dominant and carried only on the X chromosome.
(3) recessive and carried only on the Y chromosome.
(4) recessive and carried only on the X chromosome.

53. Black Andulusian chickens are BB, and white ones are WW. Heterozygous individuals are said to be "blue." This is an example of
(1) a sex-linked trait. (3) a mutation.
(2) incomplete dominance. (4) crossing over.

The information provided in question no. 54 will also be used in question 55.

54. The gene f when homozygous produces a smooth appearance. Its allele F produces a fuzzy appearance in either the homozygous or the heterozygous condition. One pair of parents has produced 30 fuzzy offspring and 32 smooth offspring. Which of the following pairs of genotypes fit these parents?
(1) Ff x ff. (3) FF x ff.
(2) Ff x Ff. (4) FF x Ff.

55. When an FF male is crossed with an Ff female, what percentage of the offspring should appear smooth?
(1) 0%. (3) 50%.
(2) 25%. (4) 75%.

56. In man, mutations that are transmitted from parent to offspring are
(1) the result of crossing over.
(2) found only in somatic (non-reproductive) cells.
(3) confined to potential reproductive cells.
(4) always found on the sex (X and Y) chromosomes.

57. Genes determine the structure of cells by controlling the synthesis of
(1) pigments. (3) vitamins.
(2) proteins. (4) hormones.

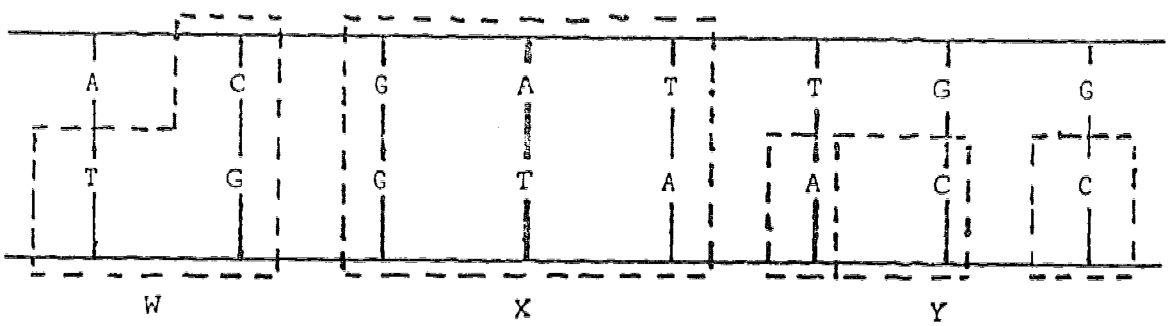
58. Translating a cell's coded information into a new enzyme molecule usually occurs in
(1) a chloroplast. (3) the nucleus.
(2) a mitochondrion. (4) ribosomes.

59. The kind of nucleic acid which contains the greatest amount of coded information is
(1) DNA. (3) t-RNA.
(2) m-RNA. (4) NADP.

60. Which statement concerning RNA is <u>not</u> true?
(1) the sugar present is ribose.
(2) it may contain uracil.
(3) it is single-stranded.
(4) it is found only in the nucleus.

61. Present knowledge indicates that messenger RNA is <u>synthesized</u>
(1) when the nucleus divides.
(2) using DNA as a template.
(3) using transfer RNA as a template.
(4) in ribosomes.

62. Messenger RNA
   (1) is manufactured in cell cytoplasm.
   (2) acts as a template for transfer RNA synthesis.
   (3) is produced as a complimentary copy of one strand of a DNA molecule in which case uracil is substituted for thymine.
   (4) attaches directly to amino acids during protein synthesis.



63. The above diagram represents a segment of a DNA molecule. The part of the molecule that codes for one amino acid is represented by the area labeled
   (1) w.
   (2) x.
   (3) y.
   (4) z.

64. In an overall sense protein synthesis is similar to
   (1) respiration which is energy releasing.
   (2) respiration which is endergonic.
   (3) photosynthesis which is energy consuming.
   (4) photosynthesis which is exergonic.

65. Which of the diagrams represents a functioning balanced control system?

66. In the human body the rate of breathing is chiefly dependent on chemical factors in blood, of which the most important is
   (1) oxygen concentration.
   (2) hemoglobin concentration.
   (3) nitrogen concentration.
   (4) carbon dioxide concentration.

67. The antibiotics streptomycin, viomycin, and others are thought to associate irreversibly with ribosomes in bacteria and thus disrupt their normal functioning. In other words these antibiotics destroy bacteria in which way?
(1) prevent them from reproducing normally.
(2) increases their respiration to an abnormal rate.
(3) prevents the synthesis of proteins.
(4) blocks cell wall synthesis.

68. Neurospora, a type of mold, can grow if it is supplied with a relatively simple diet. This is because it can synthesize complicated molecules (particularly amino acids) from basic nutrients such as glucose, inorganic salts, etc. However, it is well established that certain strains of Neurospora can only grow when their basic diet is supplemented with specific amino acids. This is because
(1) amino acids are enzymes.
(2) amino acids are converted to ATP.
(3) specific enzymes are lacking.
(4) a feedback mechanism results in death.

69. What happens to most of the water that passes into the filtrate in the kidneys?
(1) is is excreted in the urine.
(2) it is utilized in carbohydrate synthesis.
(3) it is reabsorbed into the blood.
(4) it is converted into digestive fluids which serve as vehicles of transport for enzymes.

70. One of the most important functions of the human kidneys is to
(1) assist in the elimination of indigestible wastes from the digestive tract.
(2) store glycogen for emergency use.
(3) excrete nitrogenous substances produced during protein metabolism.
(4) eliminate carbon dioxide from the body.

Appendix F, Table 27

Point-Biserial Correlations, Discrimination Indices, and Difficulty Indices for Questions from the Achievement Posttest

Question No.	[a]PBC	[b]DI	[c]I of D
1.	.26	75.57	.39
2.	.34	60.18	.43
3.	.25	59.29	.39
4.	.26	95.58	.14
5.	.01	93.81	.00
6.	.32	76.11	.36
7.	.26	88.50	.18
8.	.32	65.49	.32
9.	.41	70.80	.50
10.	.23	26.55	.18
11.	.30	76.99	.36
12.	.34	75.22	.32
13.	.15	72.57	.14
14.	.35	80.53	.36
15.	.40	75.22	.36
16.	.37	84.07	.29
17.	.24	48.67	.25
18.	.41	64.60	.54
19.	.31	75.22	.29
20.	.07	61.95	.04

Table 27 (continued)

Question No.	aPBC	bDI	cI of D
21.	.52	67.26	.71
22.	.31	57.52	.46
23.	.19	76.11	.25
24.	.18	82.30	.18
25.	.30	55.75	.36
26.	.18	88.50	.07
27.	.34	27.43	.36
28.	.36	65.49	.46
29.	.31	69.91	.32
30.	.37	87.61	.36
31.	.14	72.57	.11
32.	.34	78.76	.36
33.	.38	59.26	.50
34.	.22	51.33	.18
35.	.20	43.36	.29
36.	.14	23.01	.11
37.	.30	82.30	.29
38.	.20	29.20	.14
39.	.28	69.03	.36
40.	.36	74.34	.43
41.	.25	84.07	.29
42.	.40	89.38	.32

Table 27 (continued)

Question No.	aPBC	bDI	cI of D
43.	.10	69.03	.08
44.	.31	78.76	.32
45.	.22	41.59	.29
46.	.29	78.76	.32
47.	.23	82.30	.21
48.	.34	44.25	.39
49.	.11	48.67	.11
50.	.36	78.76	.32
51.	.32	52.21	.39
52.	.12	50.44	.11
53.	.45	75.22	.50
54.	.24	86.73	.14
55.	.34	76.99	.36
56.	.33	38.94	.32
57.	.23	83.19	.21
58.	.25	78.76	.29
59.	.41	75.22	.50
60.	.24	91.15	.21
61.	.38	55.75	.57
62.	.36	75.22	.46
63.	.45	59.26	.68
64.	.33	42.48	.32

Table 27 (continued)

Question No.	^{a}PBC	^{b}DI	^{c}I of D
65.	.14	50.44	.21
66.	.34	51.33	.50
67.	.35	56.64	.50
68.	.30	48.67	.36
69.	.29	69.91	.32
70.	.23	42.48	.29

^{a}PBC - Point-Biserial Correlation

^{b}DI - Difficulty Index

^{c}I of D - Index of Discrimination

Appendix G

Correspondence with Dr. D. A. Gelinas

SHIPPENSBURG STATE COLLEGE
SHIPPENSBURG, PENNSYLVANIA 17257
(717) 532-9121

October 24, 1972

Dr. Douglas A. Gelinas
University of Maine
Orono, Maine

Dear Dr. Gelinas:

Several years ago Mr. Leon Idoine of the Burgess Publishing Company gave me a copy of your instrument titled Student Reaction to Audio-Tutorial Introductory Botany Course. At that time the biology faculty at Shippensburg was getting ready to implement an A-T course in biology for non-science majors. We are now in our third year of A-T instruction and working to improve our program.

I am personally engaged in research that is directly related to the A-T method of instruction. In my research I am testing the effect of various sequences of instruction on achievement, attitudes, etc. I think that, with minor modifications, your instrument would prove very useful in this study. If you do not object, I will revise the instrument and utilize it in my research.

Sincerely,

Alfred Gunter
Associate Professor of Biology

jw

UNIVERSITY OF MAINE *at Orono*

Department of Botany and Plant Pathology

Deering Hall
Orono, Maine 04473
207/581-7561 581-7930

October 30, 1972

Dr. Alfred Gunter
Assoc. Professor of Biology
Shippensburg State College
Shippensburg, PA. 17257

Dear Dr. Gunter:

Thank you for your letter of October 24 requesting permission to use the evaluation form I developed for our audio-tutorial botany course at Maine. I would be pleased for you to use the evaluation in any way that may be helpful to you. I would appreciate receiving a copy of any revised form you may develop and would be interested in your results.

Sincerely,

Douglas Gelinas

Douglas Gelinas
Asst. Professor of Botany

DG:jf

Appendix H

Student Reaction to Audio-Tutorial
Basic Biology Attitude Scale

Information and Directions

In order to assess student reaction to the audio-tutorial approach, a list of statements has been prepared. You are asked to respond to the statements by indicating whether you: strongly agree (SA), agree (A), are neutral (N), disagree (D), or strongly disagree (SD). Circle your choices on the response sheet.

1. The A-T study session is preferable because the student can select a time adapted to his efficiency peak and his schedule.
2. It is easy to "bluff your way through" the discussion session without having completed the A-T study session.
3. The student in the audio-tutorial system feels more keenly the responsibility for learning than a student in the traditional system (lecture-laboratory).
4. The tapes in the A-T study session do not adequately explain the week's material.
5. The audio-tutorial method seems to bring about an informal, easy-going atmosphere.
6. I would probably listen to supplemental advanced tapes if they were available.
7. The audio-tutorial approach does not take into account individual differences in learning ability.
8. The A-T study session affords the student more individual attention than would a regular lab.
9. An audio-tutorial course is more impersonal than a conventional course.
10. I would like some of my other courses to be taught by audio-tutorial.
11. The audio-tutorial system places too much responsibility on the student.
12. The lab assistants are usually well informed about the material being studied.

13. The audio-tutorial system does not provide enough opportunity to ask questions about unclear material.

14. I would like to have more supplemental background tapes available for certain areas (chemistry, math, etc.).

15. It's harder to pay attention to the tape than to a lecturer.

16. I would take more biology courses if more were taught by audio-tutorial.

17. I'm just a number in an audio-tutorial course. Nobody knows who I am.

18. The audio-tutorial method makes it too hard to see the professors in charge of the course.

19. I prefer the A-T method over the lecture-laboratory approach.

20. It would be impossible to pass the course without completing the A-T study session each week.

21. I believe I would have learned more biology in a conventional lecture-laboratory course.

22. The tapes are boring, and it is hard to concentrate on them.

23. Students can study at their own pace in the A-T study session and repeat difficult parts as often as necessary.

24. Repeating part of the tape seldom helps clear up a difficult topic.

25. Wearing headphones and having an individual study area minimizes distractions by other students.

Appendix I

Student Audio-Tutorial Record Card

Name ______________________

week #	day	time in	time out	booth	check

Appendix J

Check List for Student Selected Experience Treatment Group

Name______________ Discussion Group Leader_____________ Class Hour____

Group Assignment A B C D (circle one)

Basic Biology
Meiosis and Mitosis

When you have completed this unit, you should be able to:

Discuss the significance of mitosis and meiosis in plant and animal life cycles.	
Manipulate objects (that represent chromosomes) through the sequence of events that occurs in mitosis and meiosis.	
Define sexual reproduction. Give examples of organisms that reproduce sexually.	
Recognize the stages of animal mitosis (when given significant characteristics of a stage). Relate (1) centrioles, (2) centrosomes, (3) chromatids, (4) spindle fibers.	
Compare meiosis and mitosis (in terms of changes in chromosome number and end products). Describe the significant events that occur during meiosis. Explain crossing over.	
Recognize the stages of plant mitosis (when given significant characteristics of a stage).	
Explain the way in which chromosomes, genes, and DNA are related.	
Define asexual reproduction. Give examples of organisms that reproduce asexually.	
Give examples of plant and animal cells that divide mitotically.	
Distinguish between haploid (n) and diploid (2n). Give examples of plant and animal cells that divide meiotically.	
	Sequence

GIVE THIS TO THE INSTRUCTOR
BEFORE YOU LEAVE.

Appendix K, Table 28

Means and Standard Deviations for SAT, Achievement Pretest, and Sequence Test Scores

Treatment Groups		A	B	C	D
		[a]C.E.E.B. Scores			
SAT Math	M	513.98	534.0[illegible]	519.90	531.14
	SD	76.79	68.[illegible]	85.85	77.92
SAT Verbal	M	465.11	480.22	473.35	474.96
	SD	70.73	79.28	75.04	76.04
		[b]Achievement Pretest Scale Scores			
Photosynthesis	M	6.43	6.38	6.06	6.50
	SD	1.76	2.02	1.90	2.31
Respiration	M	4.96	4.70	4.88	4.20
	SD	1.64	1.85	1.54	1.75
Meiosis and Mitosis	M	4.21	4.47	4.55	4.39
	SD	1.86	2.10	1.73	2.04
Genetics	M	4.96	5.00	4.12	4.89
	SD	2.29	2.34	1.92	2.04
Control Mechanisms	M	4.40	4.87	4.35	5.13
	SD	1.53	1.86	1.65	1.83

Table 28 (continued)

Treatment Groups		A	B	C	D
[c]Sequence Test Scale Scores					
Photosynthesis	M	3.19	3.26	3.30	3.06
	SD	1.52	1.41	1.39	1.58
Respiration	M	3.95	4.03	4.02	4.02
	SD	1.64	1.62	1.66	1.57
Meiosis and Mitosis	M	2.86	3.28	3.16	3.38
	SD	1.48	1.83	1.52	1.95
Genetics	M	5.15	4.79	5.35	5.50
	SD	1.82	1.93	1.89	1.93
Control Mechanisms	M	3.82	4.20	4.08	3.98
	SD	1.61	1.74	1.77	1.84

[a] - 94 subjects per treatment group

[b] - approximately one half of the subjects in each treatment group

[c] - 94 subjects per treatment group

Appendix K, Table 29

Analysis of Variance for SAT and Achievement Pretest Scores, SBUS and TDUS Treatment Groups

Variable	MS	df	F	F (Critical)
		[a]CEEB Scores		
SAT-Mathematics	208.59	1, 372	0.04	3.84
SAT-Verbal	208.63	1, 372	0.04	3.84
SAT-Total	767.10	1, 372	0.05	3.84
		[b]Achievement Pretest Scale Scores		
Photosynthesis	0.20	1, 180	0.05	3.90
Respiration	2.88	1, 180	1.01	3.90
Mitosis and Meiosis	1.06	1, 180	0.28	3.90
Genetics	17.04	1, 180	3.84	3.90
Control Mechanisms	0.66	1, 180	0.22	3.90

[a]Based on data from all subjects.

[b]Approximately one half of the subjects in each treatment group were pretested with the Achievement Posttest.

Appendix K, Table 30

Analysis of Variance for SAT and Achievement Pretest Scores, Interaction Test

Variable	MS	df	F	F (Critical)
		[a]CEEB Scores		
SAT-Mathematics	1850.12	1, 372	0.31	3.84
SAT-Verbal	4290.59	1, 372	0.76	3.84
SAT-Total	11517.92	1, 372	0.72	3.84
		[b]Achievement Pretest Scale Scores		
Photosynthesis	2.17	1, 180	0.54	3.90
Respiration	4.57	1, 180	3.53	3.90
Mitosis and Meiosis	1.06	1, 180	0.28	3.90
Genetics	12.52	1, 180	2.82	3.90
Control Mechanisms	0.66	1, 180	0.22	3.90

[a]Based on data from all subjects.

[b]Approximately one half of the subjects in each treatment group were pretested with the Achievement Posttest.

Appendix K, Table 31

Analysis of Variance for Sequence Test Scores, TDE and SSE Treatment Groups

Test Scale	MS	df	F	F (Critical)
Photosynthesis	0.68	1, 372	0.31	3.84
Respiration	0.17	1, 372	0.06	3.84
Mitosis and Meiosis	9.58	1, 372	3.29	3.84
Genetics	1.06	1, 372	0.30	3.84
Control Mechanisms	1.80	1, 372	0.59	3.84

Appendix K, Table 32

Analysis of Variance for Sequence Test Scores, Interaction Test

Test Scale	MS	df	F	F (Critical)
Photosynthesis	2.08	1, 372	0.96	3.84
Respiration	0.17	1, 372	0.06	3.84
Mitosis and Meiosis	0.86	1, 372	0.30	3.84
Genetics	6.13	1, 372	1.71	3.84
Control Mechanisms	5.63	1, 372	1.85	3.84

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REFERENCES

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