To the Graduate Council:

I am submitting herewith a dissertation written by Raúl Enrique Rivero entitled "The Immediate Achievement and Retention of Botany Content in a Natural Science Course Taught by Audio-Tutorial and Conventional Laboratory Methods." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Education, with a major in Curriculum and Instruction.

A. Paul Wishart

A. Paul Wishart, Major Professor

We have read this dissertation
and recommend its acceptance:

Russell L. French

John R. Ray

James D. Caponetti

Accepted for the Council:

Carl W. Minkel

The Graduate School

THE IMMEDIATE ACHIEVEMENT AND RETENTION OF BOTANY CONTENT IN A NATURAL SCIENCE COURSE TAUGHT BY AUDIO-TUTORIAL AND CONVENTIONAL LABORATORY METHODS

A Dissertation

Presented for the

Doctor of Education

Degree

The University of Tennessee, Knoxville

Raúl Enrique Rivero

June 1984

DEDICATION

This study is dedicated to all of the persons who have encouraged, motivated, and inspired the investigator in his teaching and research in the field of Botany. Special dedication is addressed to my parents, Guillermo and Conchita, and to my grandmother, Mamâ Ana, who always supported my professional activities.

ACKNOWLEDGMENTS

The author expresses words of recognition and appreciation to all those persons who, in one way or another, contributed to complete this project, whose names remain nameless but will not be forgotten. Special thanks are addressed to his Doctoral Committee, Drs. James Caponetti, Russell French and John Ray, for their valuable suggestions in the preparation of the manuscript. Distinctive acknowledgments are given to Dr. A. Paul Wishart, Chairperson, and his wife Mrs. Mary Alyce Wishart. The professional assistance of Drs. Reyna Valbuena, Manuel Vaquerizo and doctoral students Flavia Escalona and Jerry Barker are fully appreciated.

The writer wishes to thank Associate Professors Luz S. de Contreras, José Contreras and Assistant Professor Olga S. de Romero for their participation and encouragement in conducting this investigation.

The author also wishes to express sincere thanks to his wife, Maria Luisa, and daughter, Marianna, for their support and cheerfulness throughout this project.

ABSTRACT

The purpose of this investigation was to compare the use of two instructional methods, Audio-Tutorial and Conventional-Expositive, in teaching natural science at the college level. Freshmen college students were selected for both the experimental (A-T) and the control groups. The two groups involving twenty-one students were randomly selected from a population of 102 students and tested over a period of six weeks.

Measurements of two main dependent variables, immediate achievement and retention, were obtained by using two equivalent test forms given to the students during the first week of study (pretest) and during the sixth week (posttest). Three weeks after the students were posttested, a follow-up test (retest) was administered. An ancillary dependent variable, i.e. "memory" and "analysis" questions, was also tested in this investigation with the same equivalent test forms. An "attitude" questionnaire was developed in order to identify the responses of students and instructors toward the laboratory testing methods.

Analysis of Variance was used to identify and compare any significant differences at the .01 level of the A-T and Conventional groups for the achievement and retention scores. The analysis of data indicated that the A-T instructional group scored significantly higher than the Conventional-Expositive group in the immediate achievement. The A-T instructional group scored significantly higher than the Conventional-Expositive group in their level of retention

and remembered about 10% of the mastery knowledge tested by the retest. The A-T group did not achieve as high a level on "memory" items as those using the Conventional method. However, the A-T group retained about 50% more knowledge (memorization) than did the Conventional group. The A-T method resulted in higher achievement on "analysis" items when compared with the Conventional method. The A-T group retained 80% of the posttest mastery knowledge, whereas the Conventional group retained their same mean scores.

Data obtained from the "attitude" questionnaire indicated superiority of the A-T method in the areas of students' motivation, and involvement and use of reinforcement strategies. Students also benefitted from preciseness of the instruction, procedures, and accommodation to perform individually.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

LIST OF PLATES

PLATE PAGE

CHAPTER I

INTRODUCTION

I. BACKGROUND TO PRESENT STUDY

The population and knowledge explosion at higher education levels in Venezuela over the last 15 years have demanded an examination of instructional methods. Great diversity of backgrounds and capabilities are found, particularly in the students enrolled in freshmen courses in colleges. In order to accommodate both the increase in enrollment and the great range of capabilities, teaching techniques are needed to provide flexible learning situations to meet each student's needs.

Science programs and science courses have not escaped from these varied challenges. For many years the Venezuelan Association for Science Advancement (A.S.O.V.A.C.) and National Center to Improve Science Teaching (C.E.N.A.M.E.C.) have been dealing with different projects to study science programs and the teaching techniques used most frequently by science educators. Satisfactory results have been obtained by doing continuous follow-up activities conducted in many locations of the country. However, these studies have focused only on secondary school programs and basic teaching methods for this educational level.

The college level has not been included in these nationwide science education programs, and for this reason, very few investigations and experiences have been reported by individual researchers for the last 10 years. Only a few educational investigations are known in the science field and these have been conducted only for science symposiums and congresses. Teaching botany or plant science content has received little attention from investigators. Again, of the small number of these investigations which have been completed, only a part of the discussion topics were studied by the Venezuelan Botanical Congresses. No groups, however, have emphasized the comparison of different teaching methodologies in laboratory work.

The first attempt to examine instructional techniques in teaching botany was done in Venezuela in the 1970's when the Instituto Universitario Pedagógico Experimental de Barquisimeto (I.U.P.E.B.) biology staff attempted to review all botany content included in primary and secondary school programs. The main concerns were in the specific objectives, teaching content, methods and activities currently in use for the appropriate educational levels. Staff members in 1978 from the I.U.P.E.B. conducted a descriptive study in which biology instructors analyzed teaching procedures used in botany courses from 1957 to 1977.

For many years educational problems such as those referred to in Venezuela have been largely overcome through the use of numerous comparative studies in which communication media and audio-visual aids became important factors. The permanent use of these media was included when instructional designs and teaching techniques needed to be evaluated.

Since 1960 the Audio-Tutorial (hereafter designated as A-T) system was introduced by Professor Samuel Postlethwait from Purdue University. This teaching-learning procedure was developed after many years of great dissatisfaction with the traditional lecture method for the teaching of botany. Through the use of instructional models, it also was found that there was a possibility of providing for students who had different and very diverse backgrounds and capabilities.

After taking into consideration all different experiences obtained when the A-T method was used around the world and especially in the United States, the I.U.P.E.B. biology staff decided to examine the possibility of examining the A-T method as an alternative instructional model in teaching biology courses. A formal proposal study was developed by the investigator in 1979 and submitted (to his Committee members) as the dissertation topic for consideration and approval.

II. PURPOSE OF THE STUDY

The purpose of this study was to compare the learning process of two groups of students who took a Natural Science course at the I.U.P.E.B. taught by Conventional and A-T methods in the laboratory sessions.

The learning process was determined by means of a study of two main dependent variables. The first variable was the immediate achievement of students after covering a specific amount of subject matter in the course. The second variable related to the level of retention three weeks after the botany content was administered. These two variables were analyzed in relation to two groups of items included in the tests developed to measure the two dependent variables and the referred subordinate dependent variables.

Main Hypotheses

Ho_1: There will be no significant differences between the immediate achievement scores of the students taught by the A-T method and the scores of those taught by the Conventional-Expositive method of laboratory instruction.

Ho_2: There will be no significant differences between the retention scores of the students taught by the A-T method and the scores of those taught by the Conventional-Expositive method of laboratory instruction.

Ancillary Hypotheses

Ho_3: There will be no significant differences between the immediate achievement scores and retention scores of the students taught by the A-T method and the scores of those taught by the Conventional-Expositive method of laboratory instruction, when those comparisons are made on the basis of "memory" questions.

Ho_4: There will be no significant differences between the immediate achievement scores and retention scores of the students taught by the A-T method and the scores of those taught by the Conventional-Expositive method of laboratory instruction, when those comparisons are made on the basis of "analysis" questions.

III. ASSUMPTIONS AND LIMITATIONS OF THE STUDY

The literature suggests that laboratory sessions constitute a critical instructional procedure in both the teaching and learning of science. Assumptions for this investigation are:

1. The laboratory sessions identified for the study are relevant enough in the science teaching-learning process to be investigated separately from the traditional large group lectures or small group discussion sessions.
2. The laboratory environment itself is of great importance for the teaching-learning process. However, it is assumed in this study that the laboratory facility alone does not affect the students' learning process in a short period of time. The investigators' assumption is based on previous teaching experiences in the biology field.
3. It is presumed that all the students in the study showed changes in effort and attitude due to the introduction of new methodology and the use of newer media.

This study must be examined in light of the following limitations:

1. Restricted Population: This investigation involved a sample of twenty-one students enrolled in natural science

courses during the second academic period of 1983. Due to this limitation, generalizations and conclusions made are addressed only to the I.U.P.E.B. and the natural science course.

2. Restricted Sample Size: Because the study was focused traditionally on laboratory size settings, the sample needed to consist of the normal number of students for each laboratory session. Results and recommendations apply only to equivalent laboratory settings at the I.U.P.E.B.

3. Instrumentation: The researcher needed to develop the measurement tests because of the specialized science curriculum in the school and the unavailability of other accurate or standardized types of tests. The investigator, however, considered that the test forms developed measured the content according to the pre-stated objectives. All the students showed consistency on their scores throughout the testing sequence.

4. Test Length: The investigation was conducted by following the same traditional testing procedures in which the students are tested every six weeks in their own laboratory sessions for twenty minutes.

5. Duration of the Study: This investigation took place during the first seven weeks of the second semester of 1983.

6. Instructors: For the purpose of this investigation the Biology Department employed the part-time services of five teaching assistants who were trained with the instructors to participate alternately in both types of laboratory teaching methods used in the study. This may have helped to reduce the instructors' effect on the students' attitude toward the investigation.

IV. NEED FOR THE STUDY

The A-T method has received very little or no attention by science educators in South America. Only a few studies have attempted to examine its effectiveness as an integrated way of instruction. Haakonsen (1969) noted that there was an A-T laboratory in the University of Quito, Ecuador, developed in cooperation with a Division of Burgess Publishing Company. However, no information was mentioned in relation to the results obtained by implementing such a program in Ecuador. A personal interview with Dr. Samuel Postlethwait in June, 1981, revealed that other attempts to establish an A-T laboratory were made in Argentina, Brazil, and Colombia, but no reports have been written whatsoever.

In Venezuela, the first report dealing with the A-T method was done by the Department of Environmental Studies of Simon Bolivar University in Caracas, Venezuela. In her study, Professor Arenas mentioned the development of audio-tapes for lecture sessions only. To date, no attempt has been made in Venezuela to analyze and compare A-T methods in laboratory sessions of science courses.

V. SIGNIFICANCE OF THE STUDY

Many high schools, colleges and universities around the world are still in the process of developing A-T systems.

> The question of improving teaching is no longer merely academic; the inability of higher education to cope with the technological and social change is one cause of world-wide student unrest. When a captured audience is exposed to archaic teaching methods, when original minds are frustrated by ill-conceived testing schemes, when less-than-brilliant students are isolated from opportunities to make significant contributions, re-evaluations of concepts and techniques are urgently in order. Conventional methods of instruction, in coping with overwhelming student numbers, have even lost the appellation of traditional teaching, for the tradition of personal guidance and development of an individual to his maximum potential is all but lost (Berman, 1968, p. 847).

Facing the problem of increasing enrollments, restriction on facilities and minimum level of student activism in science courses, universities need to be forced to re-evaluate the Conventional-Expositive method for laboratory teaching.

As a result of pressures and reactions for instructional changes, many universities in the United States and Australia started to incorporate A-T systems into their instructional learning programs. This integrated approach is a multimedia learning system which utilizes basic audio-tapes as a medium for the instructional process. Such A-T systems:

1. Assure better organization and sequencing of instructional materials;
2. Accommodate diverse student backgrounds, abilities, interests and potentialities;

3. Are considered to be the best opportunity for tutorial assistance from professors or qualified teaching assistants;
4. Permit the students to work at their own pace, and
5. Allow the students to evaluate their learning immediately (Haakonsen, 1969).

Postlethwait and Hurst (1972) described the structure of the A-T system as follows: The A-T system consists of an Independent Study Session (ISS) as the true laboratory approach and main component of the entire instructional approach; the laboratory setting is arranged with independent study carrels, the tutorial settings which include tape-recorders, headphones and other types of media and visuals (printed materials, slides, photographs, etc.) which indeed represent the instructional core of the A-T system. Other study sessions include: a General Assembly Session (GAS) and a Small Assembly Session (SAS). These two were referred to in the original system developed by Postlethwait which was designed especially to handle large and small groups in the instructional system.

For the experimental methodology the present study considered only the ISS session of the original A-T system. The main concern of the investigation was to analyze laboratory teaching methods on science courses. Moreover, previous descriptive research carried out at the I.U.P.E.B. in 1978 by the biology staff showed that teaching weaknesses were referred to the laboratory sessions.

Further analysis indicated that the Conventional-Expositive method was extremely deficient in providing for basic learning concepts. The results of this investigation also revealed that students and instructors indicated deficiencies in the laboratory were focused on:

1. materials and course organization;
2. time restriction;
3. lack of appropriate learning environment;
4. opportunities for the students to clarify concepts and microscope observations;
5. unavailability of visual aids in the laboratory to either accommodate learning styles or simply to reinforce the ideas and concepts related to the subject matter covered (Escalona y Rivero, 1978).

VI. DEFINITION OF TERMS

Following are the definition of terms used in this study:

Attitude: For the purpose of this investigation, the term was used to describe the tendency of the students' feelings about the A-T method as compared to students' feelings about the Conventional-Expositive laboratory method.

Audio-Tutorial: A type of instructional method characterized by self-directed and self-paced instruction in individual settings. (It is related to the original idea developed by S. N. Postlethwait in 1961, or an adaptation of it.)

Conventional-Expositive: A type of instructional method characterized by lectures, group discussions and relatively isolated laboratory experiences (Postlethwait and Russell, 1972).

Critical Thinking: Refers to the individual ability to use logical inquiry and reasoning in new problems and situations (Beyer, 1984).

Immediate Achievement: For this study it is the learning type or behavioral change showed by a student after covering the subject matter of an instructional situation (Rowsey, 1973).

Knowledge and Use of Knowledge Questions: Knowledge questions are those questions which require the recall of memorized facts from the student. For this study, they are called "memory" questions and are used as an indicator of memorization.

Use of knowledge questions requires that the student analyze and/or interpret the results of a procedure and use this knowledge to see relationships among biological concepts. For this study they are called "analysis" questions and used as an indicator of critical thinking (Beyer, 1984).

Pedagógico: Four year teacher college which mainly prepares high school teachers in science, social sciences, Math, Language and Technical education. One of this type of colleges is referred to as I.U.P.E.B. in the study.

Retention: For this study, it is the percentage of subject matter the student can remember correctly after a certain period of time. An ideal teaching method would enable the student to retain in a greater amount of learning for a longer period of time (Rowsey, 1973).

VII. METHODS AND PROCEDURES

Description of Instructional Methods

Two methods of instruction were compared in this investigation. The Conventional-Lecture method was compared to the A-T system which was originally developed by Postlethwait in 1961.

Sample Population

The population consisted of all students (N=144) enrolled in the Natural Science course (DCN010) at the I.U.P.E.B. during the second semester session of 1983. These students were biology majors who were required to take this course as a freshman student. No other undergraduate level was included in the population because the course weas offered for the first time as part of a new curriculum design for students majoring in biology. The population was reduced to N=102 in view of the following developments:

1. Twenty-two students changed major programs in the I.U.P.E.B.;
2. Three students decided to drop the course after the first week;
3. Fifteen students were eliminated before the first week of the semester, presumably for non-academic reasons.

Experimental Design

The design for this investigation utilized two groups of students. Those who were assigned to receive the Conventional-Expositive method in the teaching of laboratory sessions were designated as the control group. The other students, assigned to be taught under the A-T method, were designated as the experimental group.

Instrumentation

Due to the absence of an appropriate instrument designed to evaluate the efficiency of the types of questions included on an ancillary purpose of the investigation, it was necessary to develop such an instrument. In order to gather the information desired for the main variables of the investigation (immediate achievement and retention), two equivalent test forms were developed, Forms A and B (Appendix A).

The achievement instrument was designed to measure student attainment of the educational objectives outlined for each laboratory session. The two equivalent forms had fourteen items each. Both forms covered six units of instruction with an equal number of items assigned in relationship to the time allotted the students to answer the test.

Fourteen items were selected from a file of tests that had been written for previous botany classes and which were evaluated by test developers after previous usage. These test items have been continuously evaluated during the past four semesters of an introductory botany course. An additional field test was conducted by the investigator with the purpose of analyzing the items discrimination on the test.

Lindquist (1959) suggested that for a test to be effective, it must be valid, reliable, representative and feasible and should discriminate adequately between individuals tested. The equivalent tests developed to investigate dependent variables of the study fit these requirements.

Validity checks of test items were done by three different procedures. First, a continuous process of revision of test items during the last four semesters was employed. It allowed test developers the opportunity of modifying or eliminating items that lacked effectiveness in measuring subject matter content and behavioral changes expected on the study. The second procedure was done by a specialist in the plant science field who worked at a different institution than I.U.P.E.B., and who reviewed the test items and judged their content validity. Finally, three A-T assistants and the two instructors who employed the different teaching approaches of this investigation evaluated the entire test to determine if its structure was a valid measure of the prestated educational objectives outlined for the block of subject matter.

A reliability index was calculated in using the appropriate procedures of the two computer packages available for making test analyses. Computerized reliability procedures were available by

Statistical Analysis for Social Science (SPSS) and Laboratory Educational Research Test Analysis (LERTAP). The reliability coefficient obtained by these procedures was 0.57.

Attitude Questionnaire

An "attitude" instrument also was constructed to obtain information concerning students' attitudes toward various aspects of the instructional models used for this investigation. The test consisted of ten items dealing with the following six aspects of laboratory teaching:

1. The students' attitudes towards the instructional mode of laboratory work.
2. The degree of motivation shown by the students in their work. Type of influence given by laboratory setting and organization of the activity.
3. The effect of self-pacing on the laboratory session when it was provided.
4. The students' attitudes toward the assistance provided by the instructors during the laboratory session.
5. The effect of audio-visual aids when they were provided.
6. The degree to which the students were informed about the instructional procedures of the laboratory work provided either orally by the instructor or audio-taped.

Each item of the "attitude" questionnaire was carefully examined by instructors who represented each instructional method in the investigation. Some improvements were included after reviewing the questionnaire several times. The procedures permitted the investigator to test for validation; however, no field test was conducted for this part of the investigation. Reliability was not tested for this instrument during the investigation either because its results were only considered for evaluation of the instructional methods tested in the investigation.

The "attitude" instrument was administered to all students at the completion of the subject matter covered for this study. All students responded to the questionnaire after finishing their sixth laboratory session. A copy of the attitude instrument may be found in Appendix B. Course instructors and teaching assistants were also asked to give reactions concerning the instructional procedures in which they participated. Most of the questions dealt with the same operational components of learning situations used for the students. See Appendix B also for a copy of the instructors' attitude forms.

VIII. ORGANIZATION OF THE STUDY

Chapter II includes an extended review of the literature to introduce A-T principles, concepts, teaching effectiveness on achievement, retention and promotion of critical thinking by A-T and Conventional laboratory approaches.

Chapter III describes the investigation's research design, methods, and experimental procedures for sampling and measurements.

This chapter also discusses the procedures for the development of materials and tests, followed by a description of the collection of data procedures.

Chapter IV analyzes the collected data, including the testing of main and ancillary hypotheses.

Chapter V includes the summary, conclusions, implications and recommendations.

CHAPTER II

REVIEW OF LITERATURE

I. INTRODUCTION

In this chapter the researcher attempted to review the literature to trace the evolution of the general concept of A-T instruction. The concept was initiated at Purdue University in 1961. Since that date, it has been estimated that several programs similar to Postlethwait's have developed throughout the United States, Australia, and England (Postlethwait, 1967).

The researcher also reviewed a great number of investigations that have been conducted to compare teaching and learning effectiveness of independent study methods and other individualized approaches in biological subject matter. However, through this current investigation the reviewed literature emphasized A-T instructional modes. In this chapter it was found that A-T has received more attention than any other individualized approach in terms of the teaching effectiveness of botany content.

In most science courses, laboratory teaching sessions have been considered important activities for the learners. Postlethwait's original design (1963) focused on independent study sessions in which emphasis is placed on maximizing students' learning according to their individual characteristics such as backgrounds and capabilities. For these reasons, the investigator decided to review some of the laboratory teaching approaches used or commonly in use.

A primary concern of this section of the investigation was to examine the literature reported on A-T programs and the previously cited individualized instructional approaches developed on the college level. A review of the literature also revealed closely allied studies related to:

1. students' achievement in A-T instructional settings;
2. A-T system and its influence in developing critical thinking, and
3. students' retention in A-T instructional settings.

II. INSTRUCTIONAL SYSTEMS

Teaching cannot always bring on new and rewarding experiences. In most courses offered in many colleges around the world, the objectives and the goals are vaguely stated. The students' expectancies often differ significantly from the expectancies fostered by mastery learning.

> Most students (perhaps over 90 percent) can master what we have to teach them and it is the task of instruction to find the means which will enable our students to master the subject under consideration. Our basic task is to determine what we mean by mastery of the subject and to search for the methods and materials which will enable the largest proportion of our students to attain such mastery (Bloom, 1968, p. 1).

Benjamin Bloom's concept of mastery learning is a great contribution in the improvement of instructional systems. This author confirms that:

> Mastery learning research and practices have already amply demonstrated that the large majority of students in a class can learn subjects up to as high a level as the most able student in a group (Bloom, 1976, p. 24).

Modern teaching-learning systems have been studied in detail by a number of research studies which emphasized instructional systems and other related factors. Most of these studies have agreed that the effectiveness of teaching-learning systems would depend primarily on the presence or absence of the following conditions:

1. Goals of instruction should be stated clearly in behavioral terms to be evaluated (Mager, 1962);
2. Learning conditions should be structured in such a way as to increase learning transfer and retention and also to motivate additional learning (Bruner, 1960);
3. Educational media should be integrated with specific learning activities (Briggs, 1967);
4. The students should be oriented toward a learning environment from which they choose the learning resources which best meet their needs (Rogers, 1969),
5. The evaluation system should be developed to provide the learner information about his progress and to help the instructor to judge the effectiveness of his teaching methods (Cronbach, 1963).

According to Postlethwait et al. (1977, p. 65), "Education is more than an information dispensing and absorbing process." Today's education requires continuous sharing experiences from teachers to bring out excitement, common interests and hopes between teacher and learner. These synchronized actions can only be achieved through the utilization of technical devices in the development of an instructional system. The usage of educational technology emphasizing teaching-learning problems has been more extensive during the last fifteen to twenty years. This increased emphasis is possible only when media is used as the "instructional bridge," which will properly enhance the personal relationship between student and teacher.

> The purpose of technology in this context is to "capture" to the greatest degree possible the events or activity between the "good teacher" and the student in one to one relationship, so that the product can be duplicated to accommodate many students in a close approximation of the original situation (Postlethwait et al., 1977, p. 66).

In summary, effective instructional systems should be those which integrate methods and media to assist permanently the students in achieving a well-defined set of educational goals. Such systems have stated the instructional objectives clearly; analyzed the students' needs; provided an appropriate environment according to individuals' needs; and developed evaluation procedures which keep the learner informed of his progress. By encouraging an individual learning procedure (individual study), the students can receive and use feedback for better revision of covered subject matter and more meaningful achievement.

Independent Study Methods

In recent years, educational researchers have been studying different instructional approaches which meet audio-visual differences of a large number of students and still maintain higher achievement on learning processes. Several investigators have conducted studies in a number of colleges and universities. The authors have reported that 70% of the institutions used some form of independent study and 30% of those institutions restricted its use to high achievers (Felder, 1964).

Current interest in independent study at various lower educational levels can be traced to the usefulness of such a method at the higher educational levels today. These independent study methods "provided the students with an opportunity to make choices, select options and decide upon alternatives" (Brown, 1968, p. 29). Griffin (1969) presented his concept of independent study in the following definition:

> The term independent study means a learning situation within the school day which allows a student to develop personal competencies through experiences as an individual but in interaction with others when needed. It is characterized by freedom from constant supervision. . . . Independent study emphasizes the individual's role in learning. It implies that all students possess potentialities for self-initiative, self-discipline, resourcefulness, productivity and self-evaluation (p. 2).

Griffin (1969) identified two fundamental features of independent study programs. The first feature facilitates those procedures which enhance the students' opportunity to fully develop personal competencies. The second feature permits students to make and to pursue some of the instructional decisions. A review of literature suggests that these basic features are also fundamental to Individualized Instruction. Several authors in the literature indicated that a variety of interpretations have been made regarding individualization. However, they agreed the process attempted to provide the tailoring of instruction specifically required to meet individual needs.

House (1977) discussed three main approaches characteristic of dualization by:

1. varying rate of learning (self-pacing);
2. having students work without a teacher (independent study,
3. encouraging students to enter into one to one relationships with the teacher (tutoring) (p. 20).

The author also attempted to define the meaning of individualization and to clarify some of the misconceptions of the term. He stressed that individualization:

1. is not a process intended as a substitute for teachers;
2. cannot be conceptualized separately from instruction;
3. is used to increase learning success by means of flexible schedules, appropriate learning materials, etc.;
4. cannot be tested and evaluated with norm reference criteria;
5. needs to be implemented as a whole instructional procedure and not as a part of one. Finally, the author considered this kind of instructional approach as one of the best ways to maximize learning growth (p. 21).

One independent study method that has become popular is the A-T method of instruction. Postlethwait (1963) started dealing with this approach in science courses in 1961. The basic idea was based on a multi-media botany program which "provides a maximum of student freedom for independent study and an opportunity for him to make adjustments for his interest, background, and capacity" (Postlethwait et al., 1969, pp. 7-8).

III. THE AUDIO-TUTORIAL METHOD

Background

The A-T system was initiated in 1961 at Purdue University. The system included:

1. a general assembly--one hour per week
2. a small group assembly--one hour per week;
3. a supervised study with audio-tapes and laboratory materials--four hours per week, and
4. independent home study (Postlethwait et al., 1969, pp. 7 and 8.

The method was so successful that in 1963 Professor Postlethwait restructured the course for three hundred students on this learning method and by 1968 six hundred students took the course. Although the A-T method was ideally suited to biology sciences and related fields, it has been used by different faculties, such as Engineering, Architecture, and Medicine.

Individualized System Approaches to Instruction

Several other titles have been given to the original A-T system such as audio-visual tutorial instruction, "A-T approach" or "AVT" (Fenner and Andrews, 1970). Moreover, the A-T approach has been considered by some instructional method developers as an independent study approach and as individualized instruction by others. The latter categorization seems to be the most favored because it was originally developed to adjust for differences in the students' backgrounds, and it was developed as a guide for individual learning procedures (Fenner and Andrews, 1970).

The A-T system provides a variety of advantages for individual needs such as flexibility relating to the students' background, requirements, capabilities and learning conditions as well. The following conditions are provided by the A-T system:

1. repetition is adjusted for individual needs;
2. better concentration is promoted for a specific learning activity;
3. association of experimental materials with instructor's commentaries is handled in the same learning activity;
4. appropriate size of subject-matter units is developed according to students' capacity, rate of assimilation and working time available;
5. adaptation of the means of communication to the nature of the proposed objectives;
6. accommodation of students' peculiarities to different kinds of communication media;

7. integration of learning activities for enhancement and complementation of each other in order to allow the students to obtain greater achievement.

All these learning conditions are considered to provide the students an opportunity to be involved deeply in the learning situation while obtaining the important ingredients of inquiry and personal contact (Postlethwait, 1970, pp. 32, 33).

Other individualized approaches have followed the A-T instructional design in looking for different modes of instruction to meet the demands of both the students and the learning process. Jenkins and Russell (1970) started the development of instructional modular packages which covered a small unit of subject matter (minicourses). This package is presented in a self-instructional format in which a student controls the rate and intensity of his study. The basic strategy of these individualized instruction models or approaches was to involve the student in learning tasks designed to aid mastery of objectives. Five kinds of involvement were included:

1. tangible involvement was provided by scale modes, preserved specimens and other teaching materials in the learning activity;
2. instruction was given on the audio-tape format;
3. human interaction was programmed for student-student and student-instructor;
4. visuals were presented to enhance individualized instructions;

5. printed materials were available as part of the teaching materials to provide the students immediate reinforcement (pp. 490, 491).

This minicourse by Jenkins and Russell, which focused on individualized instruction coupled with students' freedom and flexibility, concentrated on guiding the student through a more meaningful learning experience.

The student achievement through individualization has been studied by different investigators. Coombs (1975) described results of a study in which the major goal was to produce significant student achievement. Other benefits provided by this individualized approach were responsibility, self-confidence and self-achievement.

Research studies have also confirmed that achievement in subject areas which specified behavioral objectives promoted the use of self-pacing, multi-media, student-teacher interaction and the selection of learning environments are the main attributes of the learning situation (Coombs, 1978).

IV. EVALUATION OF A-T INSTRUCTION AND ITS EFFECTIVENESS IN SCIENCE TEACHING

The first A-T instructional model was conceived by Postlethwait at Purdue University as an attempt to make adjustments for the difference in science backgrounds of students enrolled in the freshman botany course. Although the students had the same intellectual ability, they could not perform equally because of their science background differences (Postlethwait, 1963).

The A-T approach to learning, as described by Postlethwait (1963), was developed as a remedial study to assist the students with different science backgrounds. A taped lecture was developed each week and it was available at the campus Audio Visual Library. The students could "attend" the taped lecture when they wanted to, and they could stop it when directions or explanations were unclear. They also could go back and listen to it again (Postlethwait and Russell, 1972).

After determining that self-pacing was popular with the students who were trying it, Postlethwait was encouraged to try some refinements. He modified previous instructional schemes, including points, living specimens and other teaching materials that the students could look at, touch, smell and/or manipulate. These procedures included the integration of sight and sound features with his experimental A-T instructional model (Postlethwait, 1978).

Feedback from students in the pilot study was used to restructure the course. The original design included three components: a general assembly session, an integrated quiz session and an independent study session. This design has been modified continuously and still the developer is looking for new aspects of instructional designs to provide more flexibility and adaptability to students' needs (Postlethwait, 1978).

After almost twenty-three years of instructional research, most of the literature reviewed cited the following advantages of the A-T system as it is compared to the Conventional lecture method:

1. emphasis is placed on the students' learning process rather than on teaching;
2. the students pace their learning activities according to their abilities to assimilate the information. Repetition is provided for difficult subjects if it is necessary;
3. better students are free to choose other challenging and instructional activities to accomplish the instructional tasks;
4. the students "attend" lectures at their convenience;
5. lectured tapes maximize the attention and minimize distractions;
6. the students receive more individual attention;
7. scheduling problems are reduced;
8. laboratory settings can accommodate more students in less work space with less staff;
9. minimum effort is necessary to set make-up labs, review and testing sessions;
10. the students develop self-confidence and responsibility during their own learning (Postlethwait et al., 1977, pp. 67-69).

The present format is designed to provide the students with different opportunities for human interactions among teachers, teacher assistants and students. The students are able to ask for assistance from trained A-T assistants during the available working time. A-T systems are essentially a self-instructional program that provide tutorial assistance when it is required (Postlethwait and Russell, 1972).

Since the origin of A-T instruction in 1961, many high schools and colleges have become involved in the development of A-T systems. These A-T systems vary in structure and function, according to the needs of particular courses, students, instructors and institutions (Kutty, 1971).

Research on Laboratory Teaching Activities

A relatively large number of studies conducted prior to World War II have been reported on laboratory sessions as a teaching activity for most social and scientific fields. Cunningham (1920) conducted a review of literature in this area in which he listed thirty-seven studies dealing with laboratory activities. Most of these studies compared the effects of teacher demonstrations and individual laboratory experiences on the student's ability to grasp subject matter.

Cunningham (1924) also studied the average time the students needed to complete the experimental activities proposed in a lecture demonstration and in the individual laboratory approaches. He concluded that there is a marked conservation of time in doing work by the lecture-demonstration approach. Phillips (1920) also compared the laboratory and the demonstration methods of instruction. The author measured the students' achievements through different tests;

results showed that laboratory methods had no advantage over the demonstration methods.

Working in the same study area, Kiebler and Woody (1923) showed that the students who had done their work by the laboratory method were better able to attack new problems independently as compared to those instructed by the lecture-demonstration method.

In his dissertation Cooprider (1923) found that when oral directions were given, students made higher scores on immediate tests. On the other hand, in delayed tests, written directions resulted in higher scores in laboratory work situations. However, oral instructions resulted in higher scores in lecture-demonstration approaches.

Anibal (1924) also compared the individual laboratory and the lecture-demonstration method approaches. Results indicated that the lecture-demonstration method produced more skillful students when it is compared with students who had one semester of individual laboratory work.

Because of the above investigations and their results, the investigator reviewed some of the laboratory instructional schemes used in teaching science courses during almost half of the present century. Research findings have indicated that instructional methods, either individual or demonstration, did not show major differences in some of the comparative factors as achievement, self-confidence, retention of knowledge and time to accomplish the instructional activity.

Since the beginning of this century, the expansion of factual knowledge in the natural sciences has made it necessary to examine instructional models. The older teaching modes have stressed memorization of factual details, and a minimum emphasis has been placed on organizing and understanding facts about the way living organisms function (UNESCO, 1977).

New curriculum programmers supported by different institutions, such as the National Science Foundation in the United States, and many others around the world, including the Nuffield Foundation in England, began developing some organized curriculum programs which required new instructional approaches (Haun, 1960). These curriculum projects of the 1960's called attention to the need to update the roles of scientific discovery methods for the learning and understanding of natural science.

Other important contributions were provided by "genetical" psychologists such as Piaget and Bruner, who worked with many other institutions and personalities in developing the rationale for analyzing instructional approaches which would maximize concept learning by the student. By examining new insights into learning processes, Ausubel (1960) opened a pathway to develop instructional designs to facilitate learning for students with a variety of learning aptitudes.

The tremendous impact of educational technology in the process of teaching biology added a new frontier for instructional design developers. Since the end of the nineteenth century and the beginning of the twentieth, various means of conveying information in teaching natural science increased greatly (UNESCO, 1977).

Research on A-T Laboratory Systems

Since Postlethwait initiated the A-T system as a multi-media approach to teaching botany, laboratory sessions were considered part of his original design. In this instructional mode, students were required to attend a supervised study session with audio-tapes and laboratory materials for four hours per week. "The A-T system has never been a set of unchangeable patterns of instructions" (Postlethwait, 1978). For this reason, multiple research studies have been conducted in the secondary and higher education levels.

Himes (1971) cites Westerfeld's use of the A-T system in botany since 1964 at Pennsylvania State University. The author reports that the students have favored the instructional system. The program was developed as a response to increased enrollments, limited time, and not enough faculty members.

Other investigators have indicated similar satisfaction with the A-T program. Shaw and Baker at Utah State University initiated using the system in the botany laboratory. The authors report "that the work was cut one-third through the use of A-T." They also mention that "the system allowed them to cover more material and handle a greater number of students when it is compared to the old classical laboratory system" (Himes, 1971, p. 3).

Surdy (1966) reported an A-T course in bacteriology which was highly successful. The students who enrolled in the course indicated a preference for A-T approach over the Conventional instructional mode of lecture and laboratory.

Latorri (1966) of the University of Quito, Ecuador, has begun using the A-T system under the direction of Professor Postlethwait at Purdue University and the cooperation of A-T Systems Division of Burgess Publishing Company.

Green (1967) developed an A-T program in agronomy. The author reports that it is possible to increase subject matter when the A-T method is used. He stated that the A-T method of instruction was one of the answers for the improvement of instruction. Riddell (1968), Welker (1968), and Syrocki et al. (1969) have also reported positive results with the A-T system.

Druger (1969) used the A-T system for a biology course. An attitude questionnaire revealed that students generally favored the A-T method. The students also stated that the approach provided an effective and efficient way of teaching college biology to a class of over 800 students.

Stuck and Manatt (1970) reported a definite economy of time using the A-T in addition to significantly higher achievement by the A-T students. Several studies have focused their attention on the learning effectiveness of A-T systems in the areas of achievement and retention.

Program Development

Development and implementation of A-T programs have resulted in the enhancement of individual learning strategies. One fundamental need in establishing an A-T program is to have the objectives clearly defined for each segment or lesson (Ehrle, 1970). Mager (1962) has emphasized the need for a clear specification of instructional objectives. Postlethwait (1966) noted that for him to define objectives clearly was the most difficult factor which sometimes accounted for unsuccessful A-T programs. Hahn (1971) has reported an unsuccessful example in which the primary reason for the lack of success on the examination were imprecise objectives, lack of organization in teaching materials, and other errors in planning.

Designing the instructional model is the next step after the specification of the behavioral objectives. In the A-T system the emphasis is placed on the instructional sequence of the audio-taped presentation. This communication medium enables the master teacher to lead the students through a set of learning activities--such as looking at the microscope, performing laboratory investigations, encouraging questions, and viewing pre-programmed presentations, all directed toward the stated objectives. The tapes are structured not as a tape lecture nor as a substitute for laboratory instructions, but as a programming device to tutor the student through a variety of integrated learning experiences put together in a logical and hierarchical sequential unit. Postlethwait characterizes the tapes as follows:

> The product, the tape, tangible items, visuals and printed materials can be duplicated as many times as necessary to accommodate any number of students. . . . The student now

> has access to the clever instructor in more ways than the written word . . . a great teacher to involve a student in a sequence of learning activities on a symphony of learning (Postlethwait et al., 1977, p. 66).

The audio-tape is only one part of the A-T laboratory methods; hence, preparing the A-T tapes solely from old lecture and teaching materials has caused some A-T systems to be unsuccessful (Novak, 1970).

The selection of audio-visual equipment is extremely important for A-T instruction. according to Briggs (1968), in this time when so many media are available, it is the responsibility of the instructor to select and use the various combinations of media to accomplish the most effective instruction. Pacing is one important factor in selecting audio-visual communication devices. Allen (1960) revealed that still pictures such as film strips and slides were as effective as silent or sound motion pictures because of the opportunity for the student to pace his own work. A-T laboratories (often called an A-T Learning Center) commonly have carrels containing the tape recorder, headphones and other laboratory equipment. There are no formal guidelines or restrictions as to appropriate media and equipment for the laboratory. However, the philosophy of the A-T method does have some restrictions. The instructional mode for teaching was conceived as a means of effectively uniting the teacher and student. Media is used to enhance the learning environment (Syrocki et al., 1969). A caution is mentioned by Pressey (1963), when he suggested that media was not intended to eliminate textbooks, guide tests, or any other teaching aids, but to enhance the usefulness of the audio visual materials.

Postlethwait (1978) regards the A-T system as a concept and not a procedure. For this reason it needs to be reviewed and evaluated critically. The system must always be flexible and adaptable to the students' needs. The author concluded by stressing that:

> Audio-tutorial is not an easy way for a teacher to discharge responsibilities to students and then go do research. The A-T approach requires dedication to the basic purpose of all-teacher-helping students learn (Postlethwait, 1978, p. 18).

V. RESEARCH RELATED TO A-T SYSTEM

Achievement

Most of the A-T related research to date has dealt primarily with either attitude(s) or achievement. A major focus relating to achievement has been through comparisons between A-T and Conventional methods of instruction.

One of the first attempts in the comparative methods studies was conducted by Russell (1968) who examined the two instructional approaches in the teaching of biology at the college level. Through analysis of variance, the author examined the effect of sex, standardized placement test scores and successful completion of high school biology on achievement. The study showed no significant differences in any of the tested hypotheses with the exception of the overall achievement, where the control group scored higher than the experimental group, and in the achievement, the females in the control group surpassed the male students.

Grobe (1970) also compared achievement among students of non-science majors enrolled in a biology course taught by A-T and Conventional approaches by using Analysis of Variance; the author reported no significant differences among A-T and conventional sections at the 0.05 level.

Another comparative study was conducted by Nordland et al. (1973) in which the investigators measured the effect of standardized measures on the students' achievement. The achievement was measured by a series of tests after each instructional unit. After analyzing the scores through t-tests, the results indicated that the two types of instructional approaches were equally effective on immediate achievement of scores in biology.

Sparks and Unbehaun (1971) reported a similar comparative study, using the Natural Science portion of the American College Test (ACT) as a pretest and a locally constructed total Biology Test as a post-test. They found by using t-tests that the students enrolled in the A-T sections of a general geology course performed significantly better than the students enrolled in the Conventional laboratory section.

Rowsey (1973) compared A-T and Conventional methods in an animal course. By using Analysis of Variance the author found that the A-T students demonstrated greater "achievement gain" but did not differ significantly from Conventional students in attitude toward the course content.

Rowsey and Mason (1975) compared the achievement scores of two groups taught by the A-T and the Conventional approaches.

Statistical data obtained through t-tests showed significant differences between the comparison groups, indicating better performance of the experimental group in an immediate achievement test as well as a retention test.

Maccini (1969) found that A-T students enrolled in an introductory geology course showed "significant gains" in achievement scores.

McClurg (1971) compared the effectiveness of the A-T method for a college geology laboratory with the Conventional laboratory using the same teaching materials. Analysis of Variance coefficients indicated that there were no significant differences between the two groups at the 0.01 level.

Hunt and Lamking (1975) conducted a research study in order to compare the performance of students receiving immediate reinforcement and feedback within the A-T system with the students in the same A-T system who did not receive reinforcement and feedback. Results indicated that the group who received the immediate reinforcement produced significant and greater gains in cognitive learning compared with the group which had not been reinforced.

Bish et al. (1978) reported a study in which A-T was compared to the usual Laboratory-Lecture (LL) instruction in an introductory biology course for non science students. Mean scores for the A-T sections were significantly higher than those in the Laboratory Lecture instructional approach.

Khan (1980) found a significant increase in cognitive achievement of student teachers in an introductory biology course. A significantly higher level of cognitive achievement was recorded for the experimental group.

Grobe and Sturges (1973) compared A-T and Conventional methods of instruction to test the level of achievement of non-science majors in a biology course. The Conventional group scored higher than the A-T group; however, the mean differences were not significant at the 0.05 level.

Fisher (1976) made a descriptive study in which he attempted to analyze the effectiveness of A-T science teaching. He found that in twenty-five comparative studies on achievement, the A-T method was significantly better than the Conventional approach in most of the comparisons made. Among other instructional factors, the author found that attitude, self-pacing and economy favored the A-T instructional mode also. Finally, the author of this study also reported that lower ability students in the A-T mode learned more than those in the Laboratory-Lecture approach. However, higher ability students performed better when they were taught by the Laboratory-Lecture instructional mode. These findings seemed to support previous results reported by Postlethwait (1972).

Critical Thinking and A-T System

Beyer (1984, p. 486) outlined some of the more significant obstacles for the improvement of thinking skills. In defining this problem, the author listed five of the major reasons why the educators have not devoted enough time to teaching thinking skills:

1. the educators do not agree which thinking skills should be taught;
2. lack of precise definitions for the skills selected in the instructional process;
3. teachers do not provide the kind of instructions they attempted to;
4. school curricula are mostly "skills overload";
5. achievement tests used in many schools may inhibit the teaching and learning of thinking skills.

Beyer (1984, p. 558) defined the practical approaches and discussed five steps that educators can use to produce improvements. The author stressed the use of inappropriate instruction as a common mistake in teaching thinking skills. The author suggested eight basic ways for the students to learn thinking skills. Among the most relevant ones for the instructional technique tested for the present study, the author suggests that the learners:

1. may be consciously aware of what they are doing and how they do it;
2. are not distracted by other elements competing for attention;
3. can see the learning product after the skill is achieved;
4. practice the skills of different learning activities by following individual instructional approaches;

5. use feedback during the teaching activity;
6. can talk about what they have learned;
7. receive permanent guidance on how to use the skill when a goal needs to be accomplished, and
8. have guided activities to practice the skill in other situations different from the one used when the skill was first presented.

The A-T instructional approach has been described as a method which provided for all or most of the needed learning conditions and thinking skills of students. However, the inappropriate testing procedures reported by Beyer (1984) have received little attention by those researchers who have conducted studies dealing with achievement in the A-T settings. Consequently, more research is needed to determine the effect of testing procedures on achievement scores in the A-T method.

Mitchell (1972) carried out an investigation to compare the effectiveness of the A-T and Conventional laboratory approaches in a general biology college course. Two main criteria, critical thinking and recalling of biological concepts, were primarily analyzed. The author concluded, among various other findings, that no significant differences were found in the comparative groups in the areas of critical thinking and recalling outcomes.

Brewer (1974) made an evaluation of the A-T method of learning plant anatomy. Through numerous comparisons for four years, the author compared the students' testing outcomes for recalling comprehension and problem solving on the prescribed subject matter. The findings of this study indicated again a complete superiority of A-T in students' achievement when it was compared to Conventional teaching methods. However, an evaluation of the results of the investigation indicated that the A-T system promoted students to progress from competence in "recall type of knowledge" to competence in comprehension and "problem solving type of knowledge."

Collins (1978) compared the levels of academic achievement of students taught by A-T and Conventional instructional staff instructors. Mastery of subject matter was measured by achievement tests in which recall "knowledge" and "use-of-knowledge" types of items were equally represented in the tests. Findings showed that all the groups had acquired significant knowledge during a teaching period of eight weeks. All students had shown mastery learning regardless of whether a student or staff tutor had been used. However, most of the learning was provided mainly by "knowledge" items rather than "use-of-knowledge" items. Finally, the author also reported that the retention test was given three months after the students were posttested. Results indicated no significant difference in the retention test for all the groups, as well as the students' performance on the two types of questions.

Retention and A-T System

In addition to previously discussed criteria used in A-T related research, the retention of knowledge is another important factor to be considered when students' learning processes need to be improved. One relevant aspect that educational researchers need to examine is how the achieved knowledge can be retained longer.

Hewett (1976) attempted to compare two methodologies in the teaching of complex subjects. The author found in the study that there were no significant differences between the two teaching methods on the level of achievement accomplished by both groups. However, a final phase of the same investigation indicated the experimental teaching methodology was significantly superior in the retention of students' knowledge.

Mentzer (1974) conducted a study which compared the effect of the response mode upon the achievement and retention of a life science course. Findings indicated significant differences among the experimental groups in terms of the degree of mastery learning in achievement and retention variables.

Smith (1977) investigated the effects of various A-T teaching techniques on the retention of mastery-level skills. Through Analysis of Variance and t-tests, the results indicated that the groups taught by A-T related materials showed higher retention than those students who received a "compressed-speedy" lecture.

Varano (1977) compared the effects of "advance organizers" and behavioral objectives on the foundation and retention of knowledge in a biology course. His study showed no significant differences among the groups in immediate learning or retention.

Gabel and Herron (1977) examined the effect of allowing students to pace themselves to achieve mastery. These self-paced students were compared to students who were trying to meet a deadline for completing the subject matter of the Intermediate Science Curriculum Study (I.S.C.S.). Major variables of this study were the learning rate, retention, and attitude. Results showed no significant differences for the groups whether the students had deadlines or were self-paced. However, the effects on retention were significantly different in the groups favoring self-pacing over deadline students.

Moshiri (1981) analyzed the effects of the progressive inclusion of audio-visual media as related to achievement, attitudes, and retention of knowledge in I.S.C.S. subject matter content. This study indicated that instructional methods using a combination of audio visual media in an I.S.C.S. program showed superior achievement and retention in comparison with the groups who had a single audio-visual medium.

Case (1980) studied the effect of modified laboratory instruction (A-T) on college students biology achievement and retention. By using t-tests, the author reported significant differences for achievement and retention in favor of the A-T instructional laboratory method.

VI. SUMMARY

The literature related to the major problems addressed in the present study indicated that:

1. A large number of science materials and new approaches were developed and implemented in the 1950's.
2. Concepts dealing with individualized learning processes which were proposed, in part, by Piaget, Bruner, Rogers, Ausubel, Gagné, Mager and Skinner, were used extensively in the development of individualized instructional approaches.
3. In the biological sciences and particularly in botany, the A-T method has received considerable attention by investigators. Through these studies, it has been shown that the instructional method attempted to accommodate learning conditions in order to maximize student achievement.
4. Related A-T investigations have shown great differences in their findings obtained when comparisons were made between the A-T and Conventional methods of instruction. Some of these studies favored A-T (i.e., Sparks and Unbehaun, 1971; Rowsey, 1973; Rowsey and Mason, 1975; Khan, 1980; and others) in promoting higher achievement than the Conventional methods. Other studies have indicated no significant differences between the scores obtained by using the two methods (Russell, 1968; Grobe, 1970; Nordland et al., 1973; McClurg, 1971, and others). Finally, a few comparisons have indicated that Conventional approaches promoted higher achievement when they are compared to the A-T instructional mode (Bish et al, 1978).

5. The literature indicated that the A-T system has not been proven to be better than the conventional laboratory methods in promoting critical thinking (i.e., Mitchell, 1972; Collins, 1978). However, other investigations indicated that A-T did cause students to show higher competence in "problem solving type of knowledge" than in "recall type of knowledge" (Brewer, 1974).
6. The A-T methods of teaching biology showed better results in the area of retention of mastery knowledge for larger periods of time.

CHAPTER III

METHODS AND PROCEDURES

I. PREPARATION FOR THE STUDY

The study was conducted during the first seven weeks of the second semester of 1983 at the I.U.P.E.B. (see Chapter I). It was implemented in four steps. First, all students in the control and experimental group were given a pretest to measure achievement in the specific content of the investigation. This test was administered after the first laboratory session which was designed to cover only prerequisite activities for laboratory sessions, such as how to handle microscopic mounting of living materials on microscopic slides, etc. These activities were not included in the content to be tested in the study. In the second step, students of both groups were exposed for six weeks to identical content areas related to the plant science field by either the Conventional or A-T instructional methods. In the third step, a posttest was administered to both groups after covering the subject matter at the seventh week. Finally, in the tenth week a retest was given to both groups. All tests given in these different steps were equivalent forms, and twenty minutes were alloted for the respondents to answer all items.

Experimental Design

Wilson (1952) conceived the ideal experiment as one in which all relevant factors are held constant except for the one which is being investigated. Using Stanley and Campbell's (1963) criteria for research designs, it is known that irrelevant factors, which can be controlled, influence the results of an experiment. Kahle (1978) considered the A-T model as a research tool to control internal validity and external validity as well. The research method used for this investigation was a mixed design, Lindquist Type I, which used a repetitive or replicative measurement for a dependent variable. One modification was made in this design, which was the presence of one additional observation for the dependent variable retention. The experimental design is called a Pretest-Posttest Control Group Design with a repeated measured (Huck et al., 1974) or randomized Control Group Pretest-Posttest Design (Van Dalen et al., 1966).

Sampling Procedures

The sample was selected from students enrolled in the Natural Science Introductory course at the I.U.P.E.B. for the second semester of the 1982 academic year. Eight sections were completed for this course involving four morning and four afternoon sections. Due to difficulties in handling previous student choice of sections, it was necessary to take the sample either from the four morning sections or the afternoon sections. By using a random sampling numbers table (Kendall, 1954), the morning sections were selected.

From these four enrolled groups, a final sample was chosen by means of sampling tables. Twenty-four students were selected who were randomly assigned to control or experimental groups. The traditional number of laboratory students was limited to twelve, which made it necessary to keep the sample size small, approximating the number of students who normally work in a laboratory setting at I.U.P.E.B..

During the six weeks study period, three students dropped the course, one of whom was from the control group and two of whom were from the experimental group. The total sample of both the experimental and control groups was composed of twenty-one students.

The Instructors

The investigator designed and prepared all taped lectures which were used during the experimental period. The instructors, including the teaching assistants, shared the responsibility for supervising the laboratories during the times they were in use. Therefore, all of the students were exposed to all of the instructors at various times. The instructors for the study were selected from a group of teachers who taught botany during the last five years and volunteered to participate in the investigation. The instructors were officially approved by the Biology Department. They were given special training sessions to acquaint them with Postlethwait's A-T system. The training program embraced a period of approximately three weeks.

II. METHODS OF INSTRUCTION

The Conventional-Expositive Method

The Conventional method of lecture and lecture-type laboratory activities are the more common methods of teaching biology at the college level. Students enrolled in the course taught by this method met regularly in a typical laboratory setting. The students met once a week for three hours under the direction of a single instructor. The Expositive method of instruction presented by this teacher was the Conventional approach that was used consistently before the investigation. The students under this laboratory method used the same laboratory guide and printed materials as the A-T method group.

The lectures consisted of a descriptive or explanatory approach during which the students were personally involved in passive note-taking. The emphasis was on listening, with no opportunity for question-answer activity by the students due mainly to time restrictions. Students were directed to observe the plant tissue microscope slides and to examine diagrams and "print" photographs on the laboratory guides.

Laboratory work was performed under the direction of an instructor who generally led the group, giving them instructions and time limits to start or stop an activity. The students made observations and drew some conclusions, but not much time was available to answer the questions of the laboratory guide.

The laboratory setting was structured in such a way that the six students were seated facing each other around laboratory tables, sharing common space with the rest of their classmates (Figure 1). This kind of arrangement made it difficult for the instructor to command the students' attention which was a detrimental factor for poorly motivated students.

A-T Method

In contrast to the control group, lectures were presented by means of audio-tapes, using identical content, organization and method of presentation of teaching materials. Students were involved in an independent learning approach, which also involved listening to the lecture (Figure 2). They were assisted as necessary, but almost all of them finished their assignments with little or no help. Students performed the same activities as control group students. In addition, they had time to answer the questions of the laboratory guide.

The laboratory, as mentioned earlier, was provided with twelve carrels for individual sessions (Figure 3). Because of their physical isolation, students' concentration was improved. Members of this group were able to receive any kind of reinforcement from instructors or teaching assistants.

A traditional biology laboratory was modified to contain individual study carrels. The carrels were constructed with veneer board and formica and were equipped with cassette recorders

Figure 1. Exercises of Natural Science Students Showing Conventional Approach.

Figure 2. Illustration of Independent Study at a Special Designed Carrel.

Figure 3. Use of Carrels in Audio-Tutorial Experimental Method.

(see Appendix C). Students attended this laboratory at their normal laboratory schedule (three hours weekly). Upon entering the A-T laboratory, the students sat at the study carrels (Figure 4) which had a mimeographed laboratory guide published weekly and other materials required to fulfill each week's laboratory session. The students also had headphones connected to their cassette decks which operated independently from all other decks in the laboratory (Figure 5). Pre-recorded cassette presentations developed a specific biological concept in a logical and organized format. The students performed the activities required in the weekly laboratory guide under the guidance of the appropriate pre-recorded cassette. In this manner, the content of the cassette presentation was not a simple lecture or a teacher substitute for personal inquiry by the student. This session also provided immediate reinforcement of concepts and compensated for individual differences in learning rates by enabling each student to work at his own pace. Reinforcement was also provided orally by the teacher or teaching assistants whenever it was required. A summarizing multi-media presentation also attempted to provide reinforcement at the end of each laboratory session. This reinforcement package can be operated individually or under the instructors' directions (Figures 6 and 7). The student could also replay any portion of the tape as often as necessary to master the concepts under study. The cassettes and laboratory guides were changed each week.

Figure 4. View of Individual Study Carrel for Restricted Use of Audio-Tutorial Students in Natural Science at the I.U.P.E.B.

Figure 5. Natural Science Students in Audio-Tutorial Session Engaged in Independent Study Activity.

Figure 6. A Natural Science Student Receiving Reinforcement in Laboratory Exercises Through Independent Study Method.

Figure 7. Natural Science Students in Groups Receiving Reinforcement from Instructor.

Differences Between the Two Instructional Methods

All Conventional and A-T laboratory sessions were directed by two different botany teachers and teaching assistants. Students under each of the two methods attended lectures twice a week for one hour each, directed by a third teacher (main subject coordinator). Both lectures and laboratory work were coordinated by the main subject coordinator. However, students who took the course taught by the Conventional approach did not have:

1. Access to pre-programmed instructional cassettes;
2. Continuous reinforcements during the laboratory session;
3. Summarizing multimedia presentation pre-programmed using audio cassettes and 2x2 slides.

Furthermore, the A-T method provided individual study carrels and head-phones for the students and allowed them a high degree of concentration. The Conventional laboratory setting permitted the students to distract one another and allowed unrelated outside events to distract their attention. Finally, students taught by the A-T method were provided continuity for related learning activities which was not provided in the Conventional laboratory method.

Subject Matter and Laboratory Settings

The subject matter covered during the six week experimental period concentrated on plant cells and plant tissues (Appendix D). Before the preparation of each lesson, certain objectives were determined. The objectives were used to insure that equal material would be covered in both groups. In addition to the behavioral objectives, the activities included in each laboratory session were clearly explained, as well as their resources. Every week the students received a handout in which objectives, activities, and resources were stated (Appendix E).

Each laboratory room contained two laboratory tables, a blackboard and several models and charts. They were also equipped with twelve Olympus compound microscopes and the necessary ancillary materials such as reagents, dyes, microscope slides, cover glasses, etc. Arrangement of laboratory facilities is presented in Appendix F.

In addition to the materials mentioned, the A-T laboratory contained twelve carrels. Each one of these contained a Sanyo Stereocast Cassette Recorder (Model M4200), a pair of Circle headphones (Model SD300) and the cassettes for the week's lesson. The tapes were approximately 35-45 minutes in length. The two benches in the A-T laboratory were used as demonstration tables on which other complementary materials such as audio-visual equipment were set.

Basically, laboratory settings differed from one another only in their means of providing a maximum environment for an effective teaching situation. However, the A-T laboratory was considered by both students and instructors to have better organization and use of work room.

Materials

All instructional materials were developed by the investigator and colleagues from the I.U.P.E.B. biology staff. Reference materials previously developed in old courses were used as main guides to describe subject matter and activities for the first section on Natural Science (DCN010), which was entitled Plant Cells and Tissues. Other references used for material development were A-T commercial packages published by Purdue University and available from W. B. Sanders Company. A-T laboratory guides from different universities in the United States were also very valuable for the investigator to know as a model for structuring the A-T laboratory slides. At this point, vital decisions were made to adopt the traditional guides to the requirements of the new A-T proposal. After judging and analyzing the organization of the entire course and the goals of this investigation, the entire biology staff determined that laboratory guides needed to be identical for the two experimental teaching methods in each of the six laboratory sessions. On the basis of this decision, the responsibility to develop all instructional materials for the part of the course addressed by the investigation was undertaken by the researcher. A sample of laboratory guides and teaching materials can be found in Appendix G and also see Plate I (In Pocket).

III. APPROACHES FOR THE DEVELOPMENT OF A-T MATERIALS

Different considerations were taken into account for the elaboration of A-T materials. As the initial step in the evaluation process, the process of decision making became crucial at this point of the design. An Instructional Framework designed by the investigator (Figure 8) was a useful reference for the material development process. In the initial stages of the System design, it was necessary to examine course goals and contributions for the entire curriculum program. After evaluating the scope of the course, educational objectives were specified in behavioral terms (Mager, 1962). Subject matter was examined and a content outline was produced to define the detail topics that needed to be covered. It was also necessary to analyze this critical step, the specific instructional unit, since it shows the topics and their hierarchical importance in the course. This process was vital for the course organization, content distribution, planning the lecture sequence for both instructional models and also for identifying the relevant questions to be included in the tests.

Statements of course objectives also were made in light of course requirements and previous students' backgrounds and abilities. Specific objectives identified what the students should be able to do and their minimum performance or acceptance level as well. Each of the six course units were defined and developed by following the same working scheme.

The elaboration of an A-T unit required a series of procedures listed in Figure 9. These had to be related to each other in order to design the unit properly. After following the processes and requirements to produce A-T units, laboratory A-T lectures were prepared for each laboratory session.

INSTRUCTIONAL FRAMEWORK

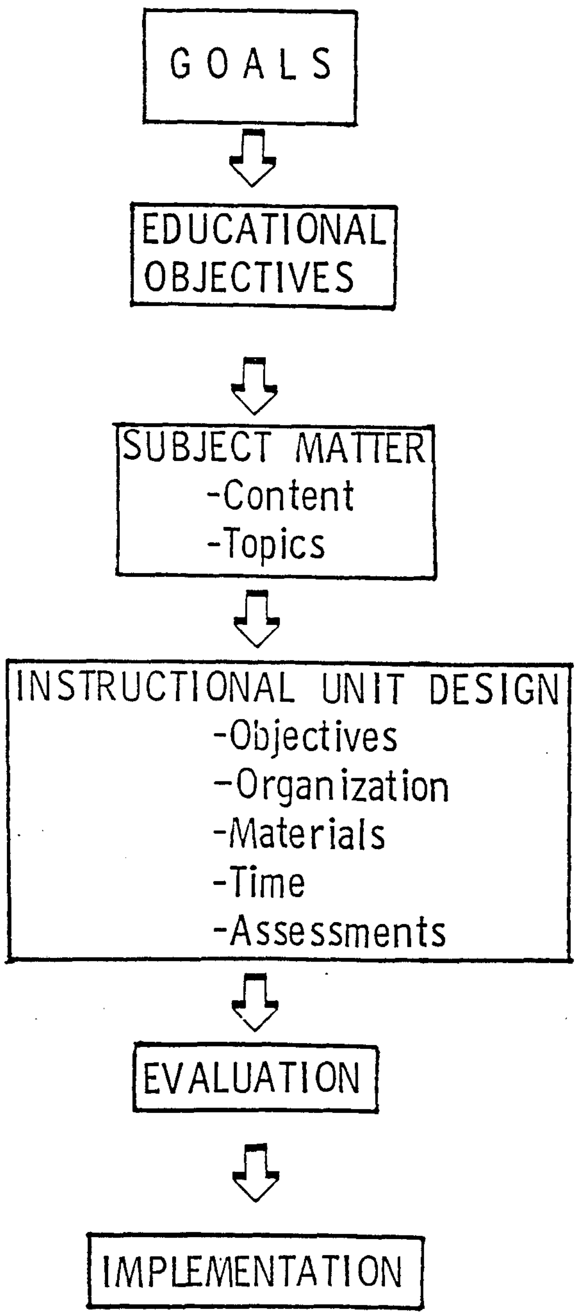


Figure 8. Instructional Framework.

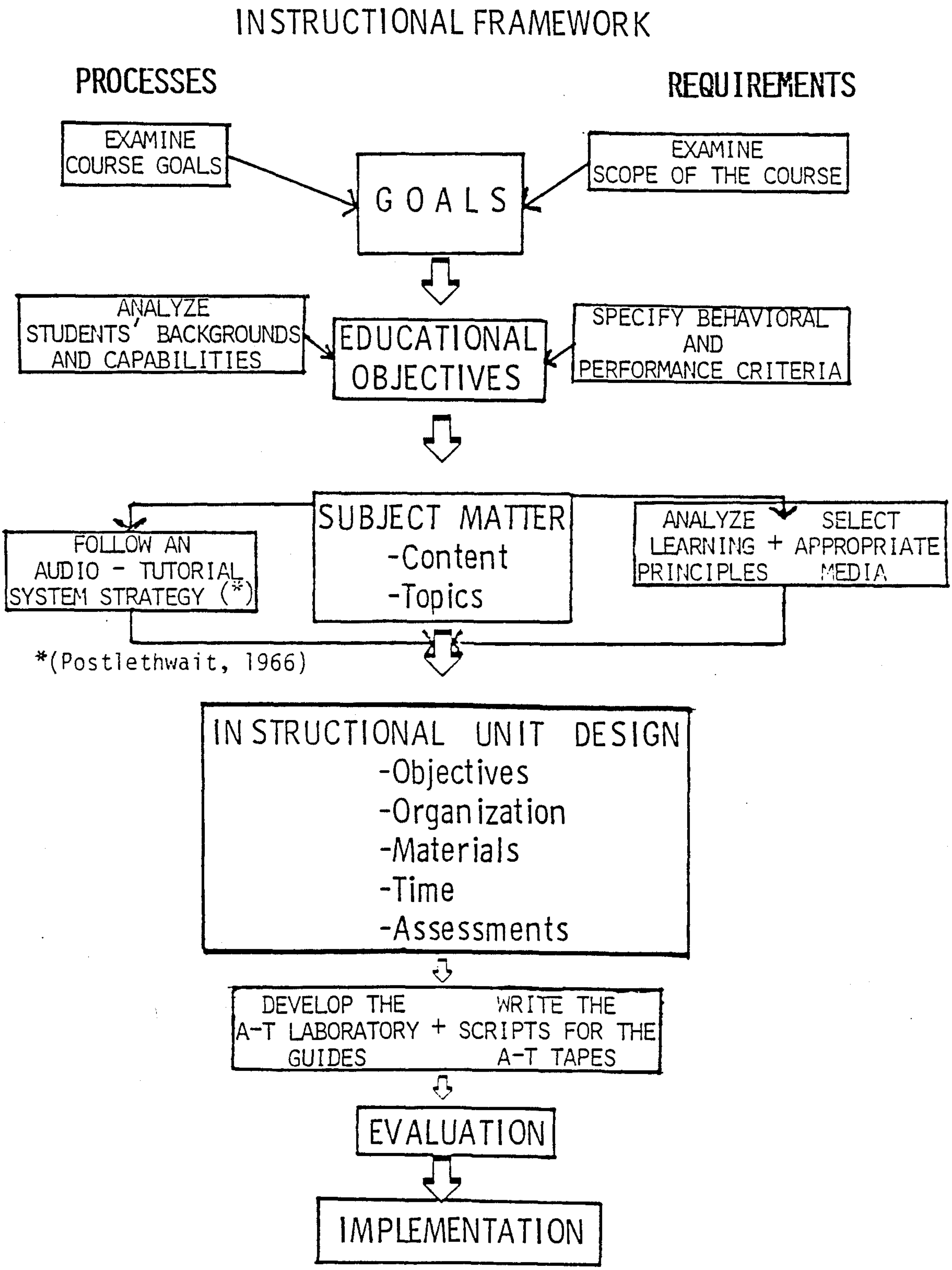


Figure 9. Instructional Framework, Processes and Requirements for the Development of Audio-Tutorial Units.

Learning principles and procedures also were stated for a structural concept of instructional design. Other procedures were concerned with the production of carefully organized materials which would achieve meaningful learning. Ruby (1977) referred to Ausubel and his "advanced organizer principle" since "much of the material presented to students is information which the student is 'merely' required to comprehend." Ruby agreed with Ausubel's idea that "new material must relate to information already acquired by the student." The above consideration revealed that previous knowledge allowed the students to acquire more easily and retain better for meaningful learning (Murray, 1977).

Use of multi-media was considered to be the key step after the design of learning structure. The A-T system provided an opportunity for subject matter to be covered in a wide variety of modes for the students to find the best medium which communicates most effectively for them (Postlethwait, 1972). These final decisions concerning the appropriateness of media were also based upon the effectiveness of the media for the kind of learning the students were involved in. These considerations and arrangements of learning conditions to optimize the learner's internal capabilities are what Gagné (1977) calls instruction. Media selection and integration with previous steps must be effective enough to motivate students at the highest level. It has been shown that modes of material presentation enhanced learning activeness (Postlethwait, 1972).

The writing of scripts followed the unit development procedure. At this point material was properly organized and properly sequenced (Mizell, 1977). The laboratory guide was developed following the script of subject matter covered. As the script was produced, provisions were made to integrate media at the appropriate phases of instruction. Finally, the A-T unit was produced as an integrated learning activity, including all necessary media learning materials.

This integrated package was evaluated and revised by the investigator and colleagues and was pretested in a trial run with a small number of high school students. On the basis of this evaluation, all teaching materials were revised and adjusted using students' comments. Feedback was also requested from other colleagues, and their reactions were considered as well.

IV. PREPARATION OF MATERIALS FOR INTRODUCTORY NATURAL SCIENCE

Materials for this course were developed under the direction of the investigator. The content of this course required six units whose content has been described previously.

Each A-T unit consisted of a script, an audio-tape, a laboratory guide, and whatever other media or materials were required to present each instructional laboratory unit. All the units were structured to be compatible with the students' capabilities. The appropriate size for each unit was also considered to allow students to grasp the amount of subject matter in the appropriate amount of time. Scripts from the plant cell unit and the summarizing multimedia presentation (Appendix H) provide an illustration of the format used in the A-T units.

The scripts adequately presented verbal material as directions and additional information for a particular activity. Incidental notes advised the student of musical interludes and asked the students to complete an assigned learning activity as well as look at the microscope, answer a question, etc.

The master tapes were recorded on reel format in a studio that was well insulated for random external noise. Master tapes made use of musical background and musical interludes. The decision to incorporate music into the tapes was taken from previous A-T experiences in which the students responded favorably to the background music. Cassettes were later dubbed directly from master tapes.

Laboratory guides were designed for experimental groups to be used in conjunction with the audio tape and the information submitted by the instructor in the control group. Each guide was accompanied with a list of objectives which outlined the material and activities covered during the laboratory session. The guides also provided study questions, extra illustrations, a complete glossary, and visuals which correlated with verbal presentations.

V. COLLECTION OF DATA

Data collection started with a pretest given to all twenty-one students before any instruction was introduced. A posttest was administered to all students after the completion of the six week subject matter unit. As a follow-up three weeks later, a retest on the content material was given to both groups of students. The instrument required twenty minutes to complete. The testing program was spaced throughout the time of the study in order to minimize any effects the instruments might have upon subjects. An additional instrument was designed to evaluate the students' and instructors' "attitude" to the instructional laboratory methods used in the investigation.

VI. METHODS OF DATA ANALYSES

All data were coded so they could be handled by computerized statistical procedures run at Empresa Regional de Computación (ERCO) and the University of Tennessee Computer Center (UTCC). The two computer packages available in these computer centers which were used included Statistical Procedures for Social Science (SPSS) and Statistical Analysis System (SAS). Another package, Laboratory Educational Research Test Analysis Package (LERTAP) was also used as an additional and collateral procedure to determine the test reality index. This procedure yielded a coefficient of 0.57.

All data were transferred to computer coding forms and entered into the machine through monitor screens. The files created were checked for accuracy by visual and machine verification. Statistical calculations were done on an IBM System/360 Model computer. Preprogrammed routines in the mentioned computer packages were employed for all the statistical analyses required to test the hypotheses.

Analysis of Variance

In educational research one of the most common applications of the Analysis of Variance is to determine if differences between group means are significant. This technique as used in this study makes it possible to discriminate the variance obtained in the data into parts and to assign each part to its correct source. Since the study looked at the effects of one independent variable (laboratory teaching methods) on two dependent variables (achievement and retention outcomes), the effect of test questioning procedures on these two dependent variables, Analysis of Variance with two-way classification was used. In this manner it was possible to identify differences in the experimental results that were attributed to each variable and the interaction between the independent and dependent variables.

CHAPTER IV

ANALYSIS OF DATA

I. PROCEDURES

The purpose of this investigation was to analyze the achievement of two laboratory groups instructed by a Conventional-Expositive method (control group) and an A-T methodology (experimental group). The outcomes examined were the immediate achievement scores, after covering six weeks of instruction. Examination for the level of retention was made three weeks later.

The two groups received a pretest before the first week of the investigation. This test was used to demonstrate the homogeneity of the groups. A posttest was administered for the two groups to measure the immediate achievement at the sixth week of the study. Finally, the two groups also received a follow-up test (retest) to measure the level of retention. Table 1 shows the raw score on each instrument for each student in the two groups. The individual numbers in each column represent the correct responses by each student in the testing sequences. The number used to designate each student is not intended to rank the student in any way.

As was previously mentioned in Chapter III, Analysis of Variance was used as the main statistical procedure to test null hypotheses and ancillary hypotheses as well. For all statistical

Table 1. Test Sequence Raw Scores[a] of the Students in the A-T and Conventional Instructional Groups.

	Pretest		Posttest		Retest	
Student Number	Memory Questions	Analysis Questions	Memory Questions	Analysis Questions	Memory Questions	Analysis Questions
1	0	0	1	1	1	1
2	0	0	2	1	1	1
3	0	0	2	1	1	1
4	0	1	3	1	1	1
5	1	0	5	1	2	2
6	0	0	5	1	3	1
7	2	0	5	2	3	2
8	0	0	1	1	1	1
9	0	0	1	1	3	1
10	0	0	2	1	1	1
11	1	1	6	4	3	3
12	0	0	1	3	1	3
13	1	0	3	4	2	4
14	0	0	2	4	1	3
15	0	0	2	3	1	3
16	2	0	1	4	2	3
17	1	0	3	5	2	4
18	0	0	2	3	1	2
19	0	0	2	4	1	3
20	2	1	3	7	3	6
21	1	0	3	5	3	5

[a]Each number in the columns indicates the correct answer(s) of the student in each test section.

analyses used in the investigation, the 0.01 significance level was used for testing the hypotheses. These were obtained by using a General Linear Model (GLM) procedure available in the Statistical Analysis Systems (SAS) computer package. This procedure is appropriate when Analysis of Variance is requested for unbalanced designs.

II. PRELIMINARY ANALYSES

Figure 10 shows the cell means of the two compared groups across the testing samples. By contrasting all cell means (Table 2), significant differences may be observed (F=19.84, df=5). This result indicated the degree of variance that accounts for each cell means was significantly different from the other means. In addition, a preliminary analysis was necessary to determine the homogeneity of randomly assigned groups. In Table 2, which compares cells 1 and 4 (see Figure 10), no significant difference for these cell means was found. The control and experimental groups were shown to be equivalent on the pretest scores (F=0.11, df=1) at the 0.01 level.

The first comparison was made to test the effect of the instructional modes of laboratory teaching on the students' total scores. Table 3 shows that for the independent variable, both instructional groups differed significantly from each other for the testing sequence (F=11.45, df=1) at the 0.01 level. This table also indicated that the overall cell means of these testing samples were significantly different (F=42.64, df=2). The results of this

	Cell 1	Cell 2	Cell 3
Control Group	0.54	4.36	3.18
Experimental Group	Cell 4 0.80	Cell 5 6.40	Cell 6 5.30
	Pretest	Posttest	Retest

Figure 10. Overall Cell Means for the Two Groups in the Testing Sequence.

Table 2. Summary Table for Analysis of Variance of General Scores and Contrasting Procedure for the Two Instructional Methods on the Pretest.

Source of Variation	df	Sum of Squares	Mean Square	F
Model	5	294.07	58.81	19.84**
Error	57	169.00	2.97	
Total	62	463.07		
Treatments	1	33.94	-----	11.45**
Cell 1 and 4	1	0.34	-----	0.11

**Significant at 0.01.

Table 3. Summary Table for Analysis of Variance of General Scores of the Instructional Groups on the Testing Sequence for All Tests.

Source of Variation	df	Sum of Squares	Mean Square	F
Model	5	294.07	58.81	19.84**
Error	57	169.00	2.97	
Total	62	463.07		
Treatments	1	33.94	-----	11.45**
Testing	2	252.89	-----	42.64**
Interaction	1	11.62	-----	1.96

**Significant at 0.01.

table indicated that the independent variable showed differences on the students' total scores. However, these findings did not manifest in any degree the instructional effectiveness for either one of the laboratory teaching approaches. The results only indicated the groups were significantly different for the mode of instruction and for each testing activity. A non-significant interaction was evidenced for two groups and the three testing samples. Figure 11 presents the scoring pattern of the two instructional groups over the testing sequence. The patterns show that the two groups have a similar mode of gaining scores for immediate achievement and dropping scores for retention. However, through multiple comparisons, using the Analysis of Variance contrasting procedures, it was shown that the two groups differed significantly in terms of the variables observed in this investigation.

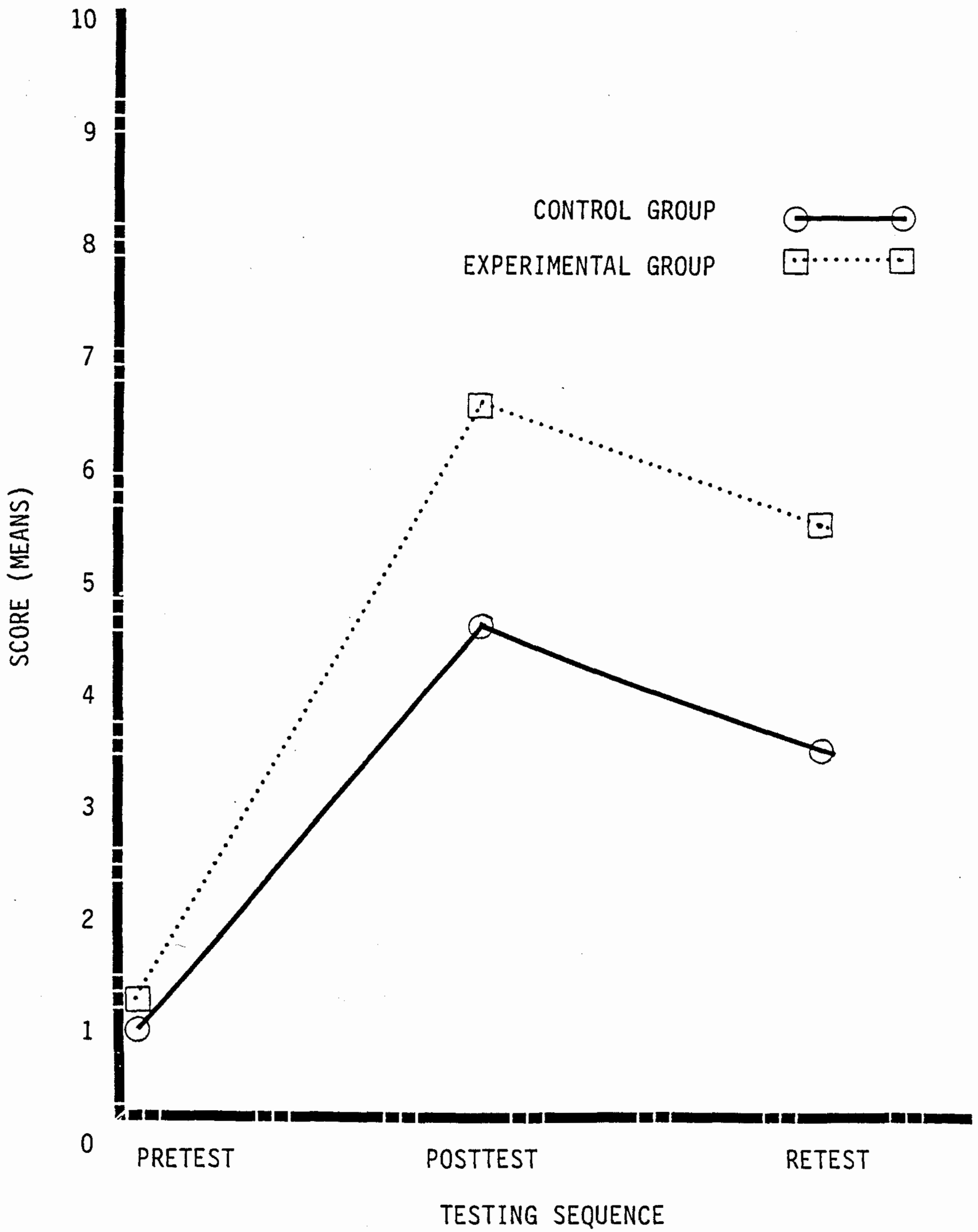


Figure 11. Comparison of the Two Groups' Achievement on Each Testing Activity.

III. TESTS OF HYPOTHESES

In Chapter I, four null hypotheses were stated for this investigation, and this section presents the findings in the same order. The resultant tests of these hypotheses were conducted, and the results are presented as follows.

IV. MAIN HYPOTHESES

First Null Hypotheses

There will be no significant differences between the immediate achievement scores of the students taught by the A-T method and the scores of those taught by the Conventional-Expositive method of laboratory instruction.

Analysis of Variance was utilized to test this hypothesis. Contrasting procedures mechanisms of the GLM computerized procedure were also used to compare the groups' gain scores between the pretest and posttest. Table 4 shows that the control group (cell means 1 and 2) showed a significant increase in the achievement scores on the posttest as compared to the pretest scores ($F=27.04$, $df=1$). This table also indicates that the experimental group (cell means 4 and 5) showed a significant increase in their scores on the posttest as compared to the pretest scores ($F=52.88$, $df=1$). Finally, also in Table 4, an F value of the treatment of main effect (the two instructional methods) showed that the performances of the groups were significantly different from each other in posttest scores (cell means 2 and 5 of Figure 10).

Table 4. Summary Table for Analysis of Variance of the Immediate Achievement and Contrasting Procedures on the Posttest.

Source of Variation	df	Sum of Squares	Mean Square	F
Model	5	294.07	58.81	19.84**
Error	57	169.00	2.97	
Total	62	463.07		
Treatments	1	33.94	-----	11.45**
Cells 1 and 2	1	80.18	-----	27.04**
Cells 4 and 5	1	156.80	-----	52.88**
Cells 2 and 5	1	21.72	-----	7.33**

**Significant at 0.01.

These procedures demonstrate that the independent variable had an equal treatment effect on both groups, if only gain scores were compared individually. However, these findings were expected for both groups because of their equivalent deficiency of knowledge mastery in the pretest.

The results indicated that the two groups were not significantly different in achievement at the time of the pretest; however, they did differ significantly at the 0.01 level on the posttest scores. Therefore, the null hypothesis was rejected.

Second Null Hypothesis

There will be no significant differences between the retention scores of the students taught by the A-T method and the scores of those taught by the Conventional-Expositive method of laboratory instruction.

The same procedure was used for testing the second null hypothesis as for the first hypothesis. The contrasting procedures in Table 5 indicated that the independent variable had an effect on the second dependent variable-retention. After the students in the two groups were exposed to the instructional methods, their level of retention outcomes dropped considerably.

Also in Table 5 the control and experimental groups (cell means 2 and 3; 5 and 6, respectively of Figure 10, page 75) showed no significant differences in their posttest and retest scores. These comparisons indicated that the two groups showed a loss of mastery of knowledge after the instructional approach was administered. However, this decreasing achievement was not significantly different when cells 2 and 3 (control group) and cells 5 and 6 (experimental group) were compared in Table 5). The F value of the treatment of main effect (the two laboratory methods) is shown in Table 5 demonstrated that the control and experimental groups performed on significantly different levels on the retest (cell means 3 and 6 of Figure 10, page 75).

Through these analyses it might be concluded that when the overall means of retest are compared for the two groups, they differed significantly at the 0.01 level. Therefore, the null hypothesis was rejected.

Table 5. Summary Table for Analysis of Variance of the Level of Retention and Retest Contrasting Procedures.

Source of Variance	df	Sum of Squares	Mean Square	F
Model	5	294.07	58.81	19.34**
Error	57	169.00	2.97	
Total	62	463.07		
Treatments	1	33.94	-----	11.45**
Cells 2 and 3	1	7.68	-----	2.59
Cells 5 and 6	1	6.05	-----	2.04
Cells 3 and 6	1	23.50	-----	7.93**

**Significant at 0.01.

V. THE ANCILLARY HYPOTHESES

Two ancillary hypotheses were stated to study in-depth the effect of laboratory teaching methods on student outcomes. The investigator examined the effect of teaching methods (Conventional-Expositive and A-T) on the two kinds of questions stated in Chapter I.

These two types of questions consisted of an equal number of items on the three testing administrations. The students in the two treatment groups were given these questions an equal number of times. The resulting outcomes were analyzed by Analysis of Variance and by multiple cell means comparisons, following the patterns shown in Figure 12 and in the discussion of the fourth null hypothesis.

	Cell 1	Cell 2	Cell 3
Control Group	0.36	3.00	1.81
	Cell 4	Cell 5	Cell 6
Experimental Group	0.70	2.30	2.00
	Pretest	Posttest	Retest

Figure 12. Overall Cell Means for Memory Questions of the Comparative Groups in the Three Testing Samples.

Third Null Hypothesis

There will be no significant difference between the immediate achievement scores and retention scores of the students taught by the A-T method and the scores of those taught by the Conventional-Expositive method of laboratory instruction when those comparisons are made on the basis of "memory" questions.

This hypothesis was examined by the same statistical procedure used for testing the other hypotheses. The researcher was interested in comparing the outcomes the students obtained on memory questions in the three testing sequences (see Figure 12).

Table 6 shows the first comparison procedure done for the third null hypothesis. By contrasting all cell means of Figure 12, it was found they differed significantly (F=8.82, df=5) at the 0.01 level. Again, this result indicated only that the degree of variance

Table 6. Summary Table for the Analysis of Variance of Mean Scores of the Comparative Groups on "Memory" Questions for the Three Testing Samples.

Source of Variation	df	Sum of Squares	Mean Square	F
Model	5	52.89	10.58	8.82**
Error	57	68.38	1.20	
Total	62	121.17		
Treatments	1	0.06	-----	0.05
Testing	2	48.42	-----	20.18**
Interaction	2	3.27	-----	1.36
Testing 1	1	47.00	-----	39.18**
Testing 2	1	5.75	-----	4.79*

*Significant at 0.05.
**Significant at 0.01.

that accounts for each cell means was significantly different from the other means. For the treatments effect, it was shown in this table that the control and the experimental groups did not differ significantly. However, significant differences were found for the overall outcomes of the pretest, posttest and retest when they were compared to each other. It is also indicated, in Table 6, that most of the differences accounted for in the testing sequence outcomes were for pretest-posttest scores (Testing 1) rather than for the posttest-retest scores (Testing 2). These considerations are supported by significant F values (39.18 and 4.79) at 0.01 and 0.05, respectively. It is also shown in Table 6 that a nonsignificant interaction was found between the instructional methods and the testing sequences.

Table 7 shows all group comparisons across the testing sequences. It is demonstrated that the two instructional groups were equivalent on the pretest for the "memory" questions (cells 1 and 4). In the control group, significant differences (F=31.86, df=1) occurred when the posttest scores were compared to the pretest scores (cells 1 and 2) at the 0.01 level. This group showed a significant increase in the scores on the "memory" questions when they were still under the effect of the Conventional instructional method. After this treatment ceased, the students' scores on this type of questions dropped significantly (F=6.40, df=1).

Table 7. Summary Table for Analysis of the Variance of Mean Scores of the Comparative Groups on "Memory" Questions and Contrasting Procedures of the Three Testing Samples.

Source of Variation	df	Sum of Squares	Mean Square	F
Model	5	52.89	10.58	8.82**
Error	57	68.38	1.20	
Total	62	121.27		
Treatments	1	0.06	-----	0.05
Cells 1 and 4	1	0.59	-----	0.49
Cells 1 and 2	1	38.23	-----	31.86**
Cells 2 and 3	1	7.68	-----	6.40*
Cells 4 and 5	1	12.00	-----	10.67**
Cells 5 and 6	1	0.45	-----	0.38

*Significant at 0.05.
**Significant at 0.01.

For the experimental group, as shown in Table 7, pretest and posttest scores also differed significantly (cells 4 and 5) at the 0.01 level for the "memory" questions. However, no differences were found when this group's posttest and retest scores were compared for retention on the items which require memorization (cells 5 and 6).

Finally, Table 8 shows that when the scores of the two instructional groups were compared on the posttest and retest, they were not significantly different (cells 2 and 5, and cells 3 and 6). As a result of these findings, the researcher accepted the third null hypothesis. The two groups did not differ significantly on the posttest and retest for the "memory" questions.

Table 8. Summary Table for Analysis of Variance of Mean Scores of the Comparative Groups on the "Memory" Questions of Posttest and Retest.

Source of Variation	df	Sum of Squares	Mean Square	F
Model	5	52.89	10.58	8.82**
Error	57	68.38	1.20	
Total	62	121.27		
Cells 2 and 5	1	2.57	-----	2.14
Cells 3 and 6	1	0.17	-----	0.71

**Significant at 0.01.

The groups' gaining and dropping patterns are shown in Figure 13. The patterns indicate the two instructional groups mean scores did not differ significantly across the testing sequences. In relation to the control group, the experimental group scored lower on the pretest, higher on the posttest, and lower on the retest.

Fourth Null Hypothesis

There will be no significant difference between the immediate achievement scores and retention scores of the students taught by the A-T method and the scores of those taught by the Conventional-Expositive method of laboratory instruction, when those comparisons are made on the basis of "analysis" questions.

This hypothesis was also examined by the Analysis of Variance statistical procedure. This time the researcher compared the scores the students obtained in the three testing activities (see Figure 14).

Table 9 shows the preliminary comparison made for this hypothesis. By contrasting procedures, the overall cell means of Figure 14 were found to be significantly different ($F=28.52$, $df=5$) at the 0.01 level. This result indicated only that all cell means were significantly different from each other when they were compared. The two instructional groups also differed significantly across the testing sequence, which is also statistically different at the 0.01 level. It means that the students differed not only when they were under the instructional methods, but also when their total

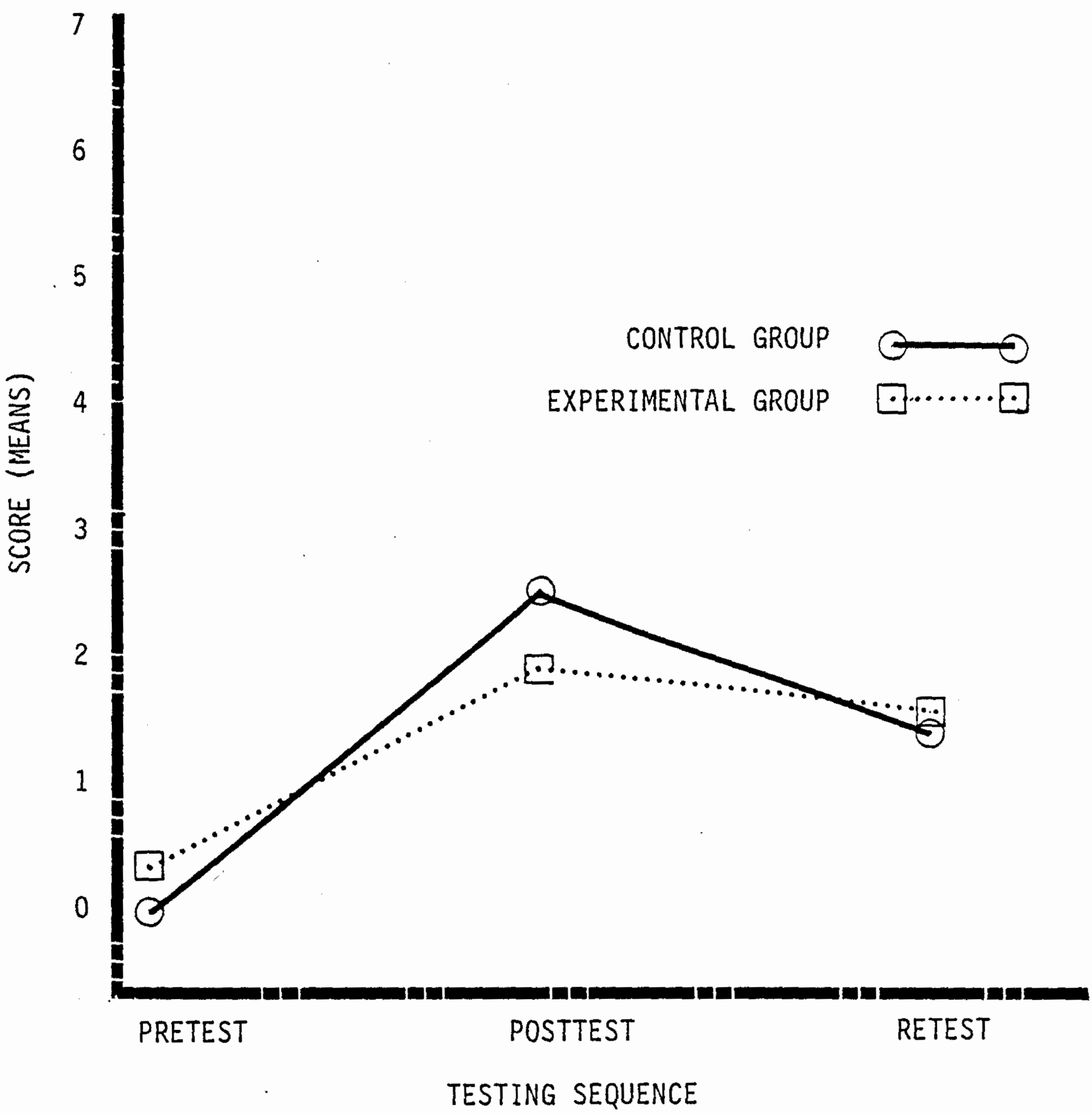


Figure 13. "Memory" Questions Mean Scores of the Comparative Groups on Each Activity of the Testing Sequence.

	CELL 1	CELL 2	CELL 3
Control Group	0.18	1.36	1.36
	CELL 4	CELL 5	CELL 6
Experimental Group	0.10	4.10	3.30
	Pretest	Posttest	Retest

Figure 14. Overall Cell Means for "Analysis" Questions of the Comparative Groups for the Three Testing Samples.

Table 9. Summary Table for the Analysis of Variance or Mean Scores of the Comparative Groups on the "Analysis" Questions of the Three Testing Sequence.

Source of Variation	df	Sum of Squares	Mean Square	F
Model	5	136.64	27.33	28.52**
Error	57	54.63	0.96	
Total	62	191.27		
Treatment	1	36.80	-----	28.30**
Testing	2	81.52	-----	42.53**
Interaction	2	22.10	-----	11.53**
Testing 1	1	70.32	-----	73.38**
Testing 2	1	1.68	-----	1.75

**Significant at 0.01.

Table 10 demonstrates all group comparisons across the testing sequence. It was shown that the two groups were equivalent on the pretest scores for the "analysis" questions (cells 1 and 4). For the control group, significant differences were found when the posttest scores were compared to the pretest scores (cells 1 and 2) at the 0.01 level. The group showed a significant gain in the scores on the "analysis" questions when the students were under the Conventional instructional method of laboratory teaching. After the reatment, the students kept the same mean (cells 2 and 3) for this type of item in the test.

Table 10. Summary Table for Analysis of Variance of Mean Scores of the Comparative Groups on the "Analysis" Questions and Contrasting Procedures of the Three Testing Activities.

Source of Variance	df	Sum of Squares	Mean Square	F
Model	5	136.64	27.33	28.52**
Error	57	54.63	0.96	
Total	62	191.27		
Treatment	1	36.80	-----	38.40**
Cells 1 and 4	1	0.04	-----	0.85
Cells 1 and 2	1	7.68	-----	8.02**
Cells 2 and 3	1	0.00	-----	1.00
Cells 4 and 5	1	80.00	-----	33.47**
Cells 5 and 6	1	3.20	-----	3.34

**Significant at 0.01.

For the experimental group, as shown in Table 10, scores on the pretest and posttest also differed significantly (cells 4 and 5) at the 0.01 level for the "analysis" questions. However, no differences were found for this group when the posttest and retest scores were compared for the level of retention of items which required analysis or further consideration than simple recalling (cells 5 and 6).

Finally, Table 11 shows that when the posttest and retest of the two instructional groups were compared, both groups differed significantly (cells 2 and 5, and cells 3 and 6). Therefore, the researcher rejected the fourth hypothesis. The two groups differed significantly on the posttest and retest for the "analysis" questions.

Table 11. Summary Table for Analysis of Variance of Mean Scores of the Comparative Groups on the "Analysis" Questions of Posttest and Retest.

Source of Variance	df	Sum of Squares	Mean Square	F
Model	5	136.44	27.33	28.52**
Error	57	54.63	0.96	
Total	62	191.27		
Cells 2 and 5	1	39.22	-----	40.92**
Cells 3 and 6	1	19.64	-----	20.49**

**Significant at 0.01.

The groups' gain patterns are indicated in Figure 15. The patterns show that the two instructional groups' mean scores differed significantly across the entire sequence of three tests. However, both groups showed gain scores, but only the experimental group dropped in retention.

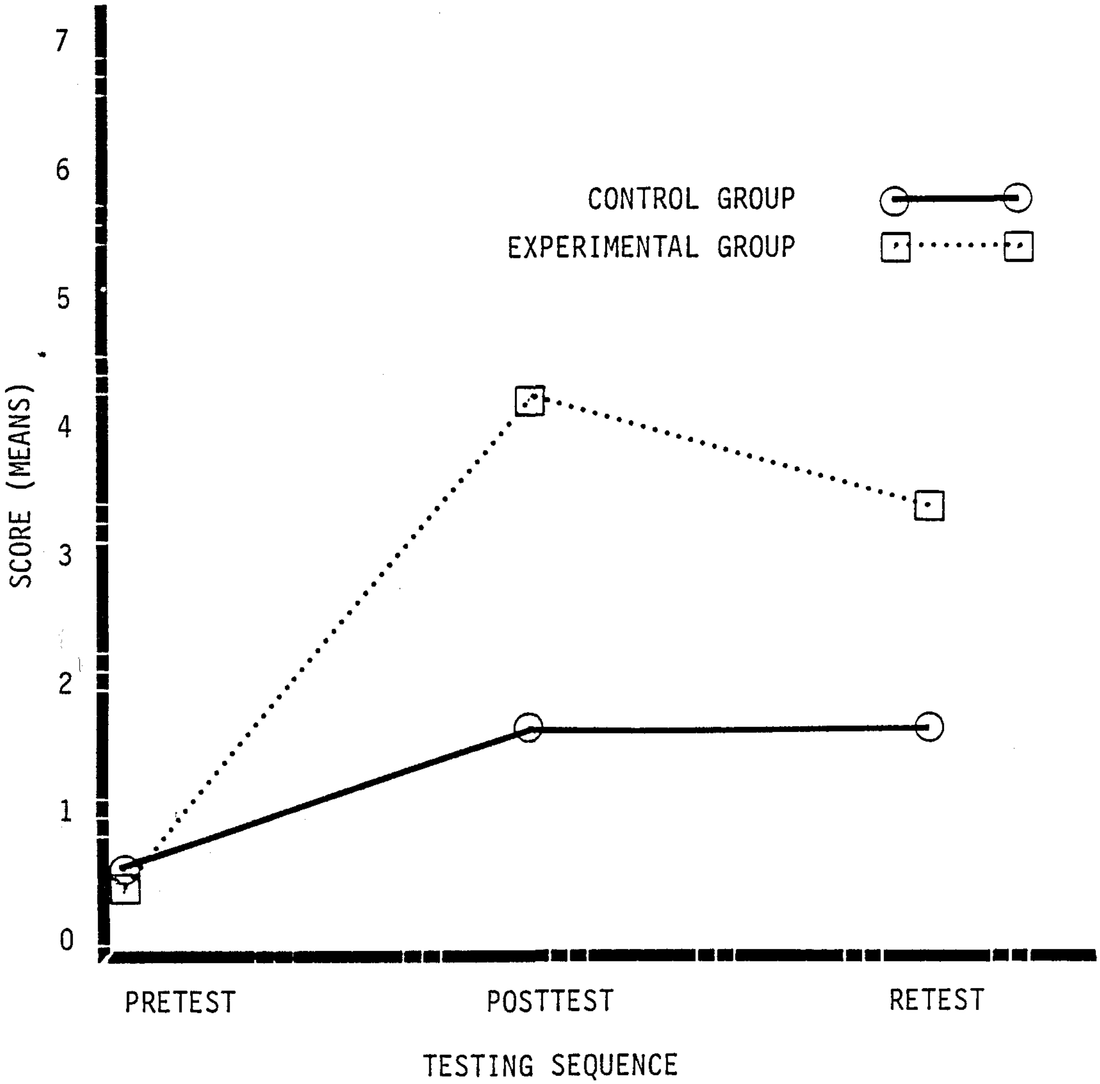


Figure 15. "Analysis" Questions Mean Scores of the Comparative Groups on Each Activity of the Testing Sequence.

VI. ANALYSIS OF ATTITUDE OUTCOMES

The "attitude" of students and teachers toward the instructional methods was a very important factor to be considered in the investigation. An assessment of these "attitudes" allowed the investigator to obtain feedback from students and instructors who participated in the study, which was very useful in the interpretation of achievement findings.

The "attitude" outcomes were measured by means of two forms of evaluation questionnaires (Appendix B) which were given to the students and instructors at the sixth week of the investigation (administered after the investigation). By this time the students and instructors had been exposed to the comparative instructional models. The instructor and teaching assistants also were requested to make observations and report them at the end of each instructional activity. The observations dealt with the degree of motivation and activeness in the laboratory, working rates, and other factors related to those listed in Chapter I for the attitude questionnaire.

All of the questions and answers in the "attitude" instrument were analyzed by the investigator and the instructional team, including the teaching assistants. A summary of the results and conclusions generated by the teaching team is presented in the charts contained in Figures 16 and 17.

Item No.	Conventional Laboratory Approach	A-T Laboratory Approach
1	-The group reported no difference between the previous laboratory method and this approach.	-The students agreed that the A-T approach was completely different from prior laboratory instructional modes.
2	-All the students felt that they were motivated in the laboratory sessions; however, they also agreed that their motivation always depended on the teachers.	-All the students found that they were motivated in the laboratory sessions, mainly because they found themselves very involved in the learning situation.
3	-The students described their participation as passive. They listened to the instructor's instructions and completed their activities.	-The students stated that they learned by themselves in a very active manner.
4	-The general opinion of this group was that they felt compelled to begin and end each activity with the teachers.	-This group was hesitant to initiate activities early in the session, but they initiated activities on their own later in the session.
5	-This group felt that they needed the instructor's assistance almost constantly.	-The students in this group agreed that assistance was required only at the beginning of the session.
6	-The students rated the audio-visual aids very effective during their lecture sessions.	-The group evaluated the use of audio-visual aids as the key instructional element in the A-T laboratory sessions.
7	-There was a general agreement that procedures and subject matter provided in the laboratory sessions were not as precise as they should be.	-The students reported that procedures and subject matter provided by audio-tapes were always given precisely at the proper times.

Figure 16. Students' Responses in Natural Science Courses to the "Attitude" Questionnaire.

Item No.	Conventional Group	A-T Group
1	-The instructors reported the activities caused many fluctuations in the students' motivation, and were very difficult to control.	-The instructors stated the A-T group maintained a high motivation level from the time they started working on the activities.
2	-The instructors reported that this group never completed the entire assignment on time. These students had to be given extra time to complete their work.	-Students in this group had enough time to complete and review the assignments and to receive extra reinforcement during the laboratory session.
3	-The working rate for this group averaged approximately 25 minutes for each assignment.	-The working rate for this group averaged approximately 15 minutes for each assignment.
4	-The instructors reported that each student in this group required help at least twice on each activity.	-The students in this group received assistance only twice during the entire laboratory session.
5	-The students in this group did not seem to develop a high degree of self-confidence or responsibility during the experimental study.	-After the recorded A-T session, the students became more self-confident and responsible in their laboratory activities.
6	-The instructors observed that the students were more concerned about competing with each other than they were about completing their assignments by their own effort.	-The students worked individually and completed the assignments by their own efforts.
7	-The instructors reported that the students were distracted by many factors (external and internal random noises) which may have affected their working effectiveness.	-Because of the way these students approached their activities, they had fewer distractions.

Figure 17. Instructors' Responses in Natural Science Courses to the "Attitude" Questionnaire.

VII. SUMMARY

Based on the analysis of the results included in this chapter, a list of findings is presented as a summary of the data analysis procedures. The major findings are as follows:

1. each of the two instructional methods produced about the same amount of increment in achievement and retention of mastery knowledge in laboratory teaching sessions;
2. the A-T instructional group scored significantly higher than the Conventional-Expositive group on the posttest;
3. the A-T instructional group scored significantly higher than the Conventional group on the retest;
4. the A-T group remembered about 10% more of the mastery knowledge tested by the retest;
5. the A-T group did not achieve at as high a level as those using the Conventional method on "memory" items. However, the A-T group retained about 50% more knowledge on memorization than the Conventional group;
6. the A-T method resulted in higher achievement on "analysis" items when compared with the Conventional method. On the retention level, however, the Conventional group retained the same mean score, whereas the A-T group retained 80% of the posttest mastery knowledge.

The "attitude" questionnaire responses from the students and teachers who used the A-T method indicated the following:

1. it promotes higher motivation because of the student's involvement in the instructional process;
2. the students liked to work at their own pace;
3. the students required minimum assistance; therefore, the instructors were able to work longer with the slow achievers;
4. instructions and procedures related to subject matter are given precisely when the A-T system is used;
5. the students required less time to complete an assignment; therefore, they had more time to review and obtain reinforcement;
6. the students became self-confident and responsible because of their role in the A-T approach,
7. the students enjoyed working individually and being less distracted.

CHAPTER V

SUMMARY, CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

I. SUMMARY

This investigation was conducted as an exploratory review of laboratory teaching methods in the Biology Department of the I.U.P.E.B. Students who were taking a new Natural Science course served as subjects for the study. The students' immediate achievement and retention level for the content of six plant science units were measured by two equivalent test forms developed by the investigator. The test included two types of questions: items which required a low cognitive knowledge level involving simple recall or memorization, and other types of questions (referred in this study as "analysis" items) which required a knowledge of relationships, application of terms or other higher levels of knowledge.

There were four hypotheses in the study. They were concerned with:

1. the effect of the use of two laboratory instructional methods on the students' immediate achievement;
2. how the students' level of retention was affected by the two laboratory approaches;
3. the groups' higher or lower number of correct responses on "memory" questions during the testing sequence of the study;

4. the higher or lower number of correct answers on the "analysis" items during the testing samples of the investigation.

II. CONCLUSIONS

Twenty-one students were selected to participate in the study. They were pretested in the first week of the investigation, post-tested in the sixth week, and retested in the ninth week. The following conclusions in this study are based on the three Natural Science tests and on an "attitude" questionnaire:

1. Students in the A-T system performed more efficiently and at a higher level of achievement, in equally timed laboratory sessions, than those in the Conventional-Expositive group. This conclusion is based on the consistently superior scores achieved by students using the A-T method of instruction.
2. The A-T students' level of retention, as based on post-test and retest scores, was affected positively by the use of the A-T instructional approach.
3. Students using the A-T method gained more self-confidence and autonomy as a result of using this method.
4. The individualized nature of the A-T approach created a more favorable learning environment in the laboratory sessions.

5. Higher test scores for "memorization" questions were achieved by students in the control group using the Conventional-Expositive method.
6. Higher test scores for "analysis" questions were achieved by students in the experimental group using the A-T system.

III. IMPLICATIONS

An examination of goals, objectives and processes related to the design of the science curriculum in the Natural Science area was initiated by the staff at the I.U.P.E.B. The investigator who, also, was involved in the study carefully examined the instructional process. Findings from the resulting research investigation suggested the following implications:

1. if "analysis" items, problem-solving, and other related higher level concepts are to be stressed in the science curriculum, then the A-T method should be seriously considered as the primary instructional mode;
2. if, on the other hand, low level items stressing "memory" of scientific facts and other low level cognitive ideas constitute the primary objective, then the Conventional-Expositive method might well be continued;
3. more specialized instruments would seem to be needed in order to measure precisely the level of understanding of students who enroll in the Natural Science courses which emphasize biology;

4. if the A-T method should be adopted as the preferred approach to the teaching of biology laboratories, then serious consideration should be given to:
   a. revision and updating laboratory facilities to provide for carrels, tape recorders, additional utilities, etc.
   b. acquisition of other up-to-date types of materials needed for independent studies;
5. instructors using the A-T method should have special in-service training in the philosophy and implementation of the A-T instructional system;
6. evaluation of the A-T method should be studied from the standpoint of the number and type(s) of tests needed for the assessment of achievement and retention of science knowledge.

IV. RECOMMENDATIONS

The findings obtained in this investigation raise some additional recommendations which need to be addressed by further research studies. They are the following:

1. It is recommended that future studies involve the A-T method in other science areas which use a traditional laboratory approach. Research studies in the biological science (Fisher, 1976) areas have indicated that when the two laboratory approaches have been compared for

learning, diverse findings have been obtained with some favoring the A-T method while others favored the Conventional system.

2. Future research should be addressed to deal with the individual effects that the pre-programmed reinforcing unit has on the A-T group. Several studies (Briggs, 1968; McKeachie, in Postlethwait, 1977) have compared the effect of immediate reinforcement using media presentations. These and other studies indicate that feedback "will produce positive changes in performance if it provides new information . . ." (McKeachie and Kulik, in Postlethwait, 1977, p. 109). McKeachie also stated: "the effect depends upon amount of feedback and if students know to use that knowledge" (in Postlethwait, 1977, p. 109).
3. Further investigations might examine the effect of multimedia, pre-programmed presentations used for the A-T group by isolating the reinforcing activity and testing its effect on Conventional-Expositive students as well.
4. Further study of the operational costs of laboratory teaching should be conducted. For the purpose of the investigation, the cost of operation for A-T was not discussed. However, many studies have addressed cost figures and the initial expenditures as main objectives

of the investigation. Research studies (Nance, 1973) have found that the A-T system was more expensive initially but decreased in cost after two to three years. White and Barnes (1978) also analyzed the cost effect of A-T and Conventional instruction by comparing instructors' salaries, equipment and instructional supplies, and maintenance service figures. These authors concluded that the greater the number of students using the laboratory facilities each week resulted in lower instructional cost for each student involved.

5. The experimental group in this study showed favorable responses to the A-T laboratory environment and also showed improved motivation and greater independence in completing assignments. Further investigations should examine the effect on teaching conditions and facilities in the process of learning. McKeachie (in Postlethwait, 1977) showed that smaller working groups (classes) showed higher levels of motivation and cognitive achievements.
6. Additional information is required for a complete understanding of the relationships between laboratory facilities and their effects on the learning process.
7. Finally, the limitations of the study described in Chapter I undoubtedly call for further investigation. The investigator will replicate the experiment in the first semester of 1985. The replication of the study

should include larger samples, more comprehensive and longer test instruments and other adjustments in laboratory and teaching conditions. The effects of modified follow-up studies ultimately will allow science educators to understand better the effectiveness of A-T science teaching.

BIBLIOGRAPHY

BIBLIOGRAPHY

Allen, W. H. "Audio-Visual Communications Review." Encyclopedia of Educational Research, ed. C. W. Harres. New York: Macmillan Company, 1960.

Anibal, F. G. A Comparative Study of the Effectiveness of Teaching High School Chemistry Through Individual Laboratory Experimentation and Lecture Demonstration. Unpublished Master's Thesis, University of Chicago, 1924.

Arenas, Z. de. "La Metodología Audio-Tutorial en la Enseñanza de Estudios Ambientales en la Universidad Simón Bolívar." Ed. ASOVAC I Convensión Nacional. Caracas, 1982.

Ausubel, D. P. "The Use of Advance Organizers in the Learning and Retention of Meaningful Verbal Material. Journal of Educational Psychology, 51: 267-272, 1960.

Berman, A. "Questions/Answers About Seminar/Auto-Lecture." Audio-visual Instruction, 13: 847-857, 1962.

Beyer, B. K. "Improving Thinking Skills--Defining the Problem." Phi Delta Kappan, 65: 486-490, 1984.

__________. "Improving Thinking Skills--Practical Approaches." Phi Delta Kappan, 65: 556-560, 1984.

Bish, J. T., B. L. Browman, and A. Sarachek. "Lecture-Laboratory vs. Structured Audio-Tutorial Approaches: Student Achievement." Journal of College Science Teaching, 8: 168-171, 1978.

Bloom, B. S. "Learning for Mastery." Evaluation Comment, Center for the Study of Evaluation of Instructional Programs, University of California at Los Angeles, 1, 1968.

Bloom, B. J. Human Characteristics and School Learning. New York: McGraw-Hill Publishing Company, 1976.

Blommers, P. and E. F. Lindquist. Statistical Methods in Psychology and Education. Boston: Houghton Mifflin Company, 1960.

Brewer, I. M. "Recall, Comprehension and Problem Solving." Journal of Biological Education, 8: 101-112, 1974.

Briggs, L. J. "Learner Variables and educational Media." Review of educational Research, 28: 160-173, 1968.

Briggs, L. L. Instructional Media Final Report. Pittsburgh: Instructional Methods Program of CREATE, American Institute for Research, 1967.

Brown, F. D. Educational by Appointment: New Approaches to Independent Study. West Nyack: Parker Publishing Company, 1968.

Bruner, J. S. The Process of Education. Cambridge: Harvard University Press, 1960.

Campbell, D. and J. Stanley. Experimental and Quasi-Experimental Designs for Research. Chicago: Rand McNally College Publishing Company, 1963.

Case, C. L. "The Influence of Modified Laboratory Instruction on College Student Biology Achievement." Journal of Research in Science Teaching, 17: 1-6, 1980.

Collins, B. G. "The Effects of Mastery Learning and Student Tutors Upon Achievement in an Audio-Tutorial College Biology Program." Journal of Biological Education, 12: 27-32, 1978.

Cook, T. C. and D. T. Campbell. Quasi-Experimentation: Design and Analysis Issues for Field Settings. Boston: Houghton Mifflin Company, 1979.

Coombs, R. E. "Student Achievement Through Individualization." The American Biology Teacher, 37: 171-173, 1975.

__________. "Individualization and Student Freedom to Choose." The American Biology Teacher, 40: 365-368, 1978.

Cooprider, J. L. "Laboratory Methods in High School Science." School Science and Mathematics, 23: 526-530, 1923.

Cronbach, L. J. Educational Psychology. New York: Harcourt, Brace and World, 1963.

Cunningham, H. A. "Under What Conditions, in High School Science, Is Individual Laboratory Preferable and When Does the Lecture Demonstration Give Better Results?" The Proceedings of the High School Conference of November, 18, 1920.

__________. "Laboratory Methods in Natural Science Teaching." School Science and Mathematics, 24: 70-715, 848-851, 1924.

Druger, M. "Audio-Tutorial Course in College Biology." Paper given at NSTA meeting in Dallas, Texas, March, 1969.

Ebel, R. L. Essentials of Educational Measurement. Englewood Cliffs: Prentice-Hall, Inc., 1979.

Ehrole, E. "Avoiding the Audio-Tutorial Mistake." Washington, D.C.: Office of Biological Education of the American Institute of Biological Sciences, 1970.

Escalona, F. and R. Rivero. "Analisis de la Enseñanza de la Botánica en el I.U.P.E.B. desde 1959 hasta 1977." Congreso Venezolano de Botánica. Barquisimeto, 1978.

Felder, D. "Independent Study Practices in Colleges and Universities." Journal of Higher Education, 35: 331-338, 1964.

Fenner, P. and T. F. Andrews. Audio-Tutorial Instruction: A Strategy for Teaching Introductory College Geology. Washington, D.C.: Council on Education in the Geological Sciences, 1970.

Fisher, K. M. "A-T Science Teaching: How Effective Is It?" Bioscience, 26: 691-697, 1976.

Gabel, D. and J. D. Herron. "The Effects of Grouping and Pacing on Learning Rate, Attitude, and Retention in ISCS Classrooms." Journal of Research in Science teaching, 14: 385-400, 1977.

Gagné, R. M. The Conditions of Learning. New York: Holt, Rhinehart and Winston, 1977.

Green, D. E. "The Development of an Audio-Tutorial System of Instruction in Agronomy 114A at Iowa State." National Association of Colleges and Teachers of Agronomy Journal, 11: 55, 1967.

Griffin, W. H. Schedules, Bells, Groups, and Independent Study. D. W. Beggs III and E. G. Buffie (Eds.). Bloomington: Indiana University Press, 1969.

Grobe, C. H. Comparisons in College Biology Achievement Between the audio-Tutorial and Conventional Methods of Instruction for Nonscience Majors. Unpublished Doctoral Dissertation, University of North Dakota, 1970.

__________ and A. W. Sturges. "The Audio-Tutorial and Conventional Methods of College-Level Biology for Non-Science Majors." Science Education, 57: 65-70, 1973.

Haakonsen, H. O. An investigation of the relationships between selected psychological characteristics of students and performance in Audio-Tutorial. Unpublished Doctoral Dissertation, Syracuse University, 1969.

Hahn, T. C. "Audio-Tutorial Instruction: A Case Study." Bioscience, 21: 814-819, 1971.

Haun, R. R. (ed.). Science in General Education. Dubuque: C. Brown, 1960.

Hewett, H. J. "Retention: A Case for Experimental Methodology in Teaching Complex Subjects." Educational Research Quarterly, 1: 30-37, 1976.

Himes, C. L. An Exploratory Study of Audio-Tutorial Approach in the Teaching of General Biology at the College Level. Unpublished Doctoral Dissertation, University of Pittsburgh, 1971.

House, P. A. "Individualization: What Is It Really?" The Science Teacher, 44: 20-21, 1977.

Huck, S. W. et al. Reading statistics and Research. New York: Harper and Row, Publishers, 1974.

Hunt, T. D. and B. Lamking. "An Analysis of Reinforcement and Feedback Within an Audio-Tutorial Plant Taxonomy Module." Journal of Research in Science teaching, 12: 121-125, 1975.

Jenkins, J. R. and J. D. Russell. "Involving Students in Individualized Instruction." The American Biology Teacher, 33: 489-492, 1970.

Kahle, J. B. "A-T Instruction: A Perspective and a Prediction." The American Biology Teacher, 4: 17-20, 1978.

Kendall, M. G. and B. Smith. Tables of Random Sampling Numbers, Tracts for Computers, No. 27. Cambridge: Cambridge University Press, 1954.

Khan, A. G. "Effects of Audio-Tutorial and Conventional Instructional Techniques on Cognitive Achievements." Journal of Research in Science teaching, 17: 47-53, 1980.

Kiebler, E. W. and C. Woody. "The Individual Laboratory Versus the Demonstration Method of Teaching Physics." Journal of Educational Research, 7: 50-58, 1923.

Kutty, M. N. "The Audio-Tutorial System--A New Trend in Science Education." Biology News, 1: 15-18, 1971.

Latorri, F. A-T in Quito, Ecuador. Minneapolis: Burgess Publishing Company, 1966.

Lindquist, E. F. A First Course in Statistics. Cambridge: The Riverside Press, 1942.

__________. Educational Measurement. Minasha: George Banta Publishing Company, 1959.

Maccini, J. A. Evaluation of an Audio-Visual Tutorial Laboratory Serving College-Level Introductory Laboratory Geology. Unpublished Doctoral Dissertation, Ohio State University, 1969.

Mager, R. Preparing Objectives for Programmed Instruction. Palo Alto: Fearon Publishers, 1962.

McClurg, J. E. The Development and Experimental Evaluation of Our Open-Scheduled Audio-Tutorial Geology Laboratory. Unpublished Doctoral Dissertation, University of Michigan, 1971.

Mentzer, D. S. The Effect of Response Mode Upon the Achievement and Retention of Student Nurses Taught Life Science by Audio-Tutorial Instruction. Dissertation Abstracts International, 35 (1974), 2053-2054.

Mitchell, D. W. A Comparative Study of Audio-Tutorial and Conventional Laboratory Approaches in College Biology. Dissertation Abstracts International, 32 (1972), 1882.

Mintzes, J. J. "The A-T Approach 14 Years Later--A Review of Recent Research." Journal of College Science teaching, 4: 247, 1975.

Mizell, A. P. "Learning Hierarchies: Robert Mills Gagné." In S. N. Postlethwait and Associates, eds. Exploring Teaching Alternatives. Minneapolis: Burgess Publishing Company, 1977.

Moshiri, S. T. A Quasi-Experimental Study on the Effect of Audio-visual Media Instruction on Student Achievement, Retention, and Attitude in the ISCS Program. Dissertation Abstracts International, 41 (1981), 3974.

Murray, D. L. "The Learning of Biology: A Structural Basis for Future Research." The American Biology Teacher, 39: 415-419, 1977.

Nance, J. B. "Operations Research Analysis of Audio-Tutorial Systems." Educational Technology, 13: 64-66, 1973.

Nordland, F. G. and J. B. Kahle. "Audio-Tutorial Instruction and Learning Deficiencies." Paper presented at the Fifth Annual International Audio-Tutorial Congress Conference. Ohio State University, 1973.

Novak, J. D. "Relevant Research on Audio-Tutorial Methods." School Science and Mathematics, 70: 777-784, 1970.

Phillips, T. D. "A Study of Notebook and Laboratory Work as an Effective Aid in Science Teaching." School Review, 28: 451-453, 1920.

Postlethwait, S. N. "A System Approach to Botany." Audio-Visual Instruction, 8: 243-244, 1963.

____________. How to Prepare an Audio-Tutorial Lesson. Report by Audio-Tutorial Systems. A Division of Burgess Publishing Company, Frederick, Maryland, 1966.

____________. "Teaching Tools and Techniques: An Audio-Tutorial Approach to Teaching." Pacific Speech, 1: 57, 1967.

____________. "The Audio-Tutorial System." The American Biology Teacher, 32: 31-33, 1970.

____________. "Students Are a Lot Like People!" University Vision, 8: 1-6, 1972.

____________. "The Audio-Tutorial System." In S. N. Postlethwait and Associates (eds.), Exploring Teaching Alternatives. Minneapolis: Burgess Publishing Company, 1977.

____________. "Principles Behind the Audio-Tutorial System." National Society for Programmed Instruction Journal, 18: 3-4, 1978.

____________, S. Novak, and H. Murray. An Integrated Experience Approach to Learning. Minneapolis: Burgess Publishing Company, 1969.

____________ and Associates. Exploring Teaching Alternatives. Minneapolis: Burgess Publishing Company, 1977.

____________ and R. N. Hurst. "The Audio-Tutorial System: Incorporating Mini Courses and Mastery." Educational Technology, 12: 35-37, 1972.

____________ and J. D. Russell. "Minicourse--The Style of the Future." Report from The Commission of Undergraduate Education in the Biological Sciences, 31, 1972.

Pressey, S. L. "Teaching Machine (and Learning Theory) Courses." Journal of Applied Psychology, XLVII: 1-6, 1963.

Ray, W. S. An Introduction to Experimental Design. New York: The Macmillan Company, 1960.

Riddell, R. A-T in Canada. Minneapolis: Burgess Publishing Company, 1968.

Rogers, C. R. Freedom to Learn. Columbus: Charles E. Merrill Publishing Company, 1969.

Rowsey, R. E. A Comparative Study of Two Methods of Instruction in a University Animal Biology Course: Audio-Tutorial with Conventional Lecture-Laboratory. Unpublished Doctoral Dissertation, Auburn University, 1973.

____________ and W. H. Mason. "Immediate Achievement and Retention in Audio-Tutorial Versus Conventional Lecture Laboratory Instruction." Journal of Research in Science Teaching, 12: 393-397, 1975.

Ruby, D. "David P. Ausubel and the Advanced Organizer." In S. N. Postlethwait and Associates (eds.), Exploring Teaching Alternatives. Minneapolis: Burgess Publishing Company, 1977.

Russell, W. B. Some Comparisons of the Audio-Tutorial Method wit the Conoventional Method in Introductory College Biology. Unpublished Doctoral Dissertation, North Texas State University, 1968.

Smith, H. G. The Effects of Various Audio-Tutorial Review Techniques on the Retention of Mastery-Level Skills. Dissertation Abstracts International, 29 (1977), 4118.

Sparks, P. D. and L. M. Unbehaun. "Achievement of Audio-Tutorial and Conventional Biology Students: A Comparative Study." Bio-Science, 21: 574-576, 1971.

Stuck, D. L. and R. P. Manatt. "A Comparison of Audio-Tutorial and Lecture Methods of Teaching." Journal of Educational Research, 63: 414-418, 1970.

Surdy, T. E. "An Audio-Tutorial Bacteriology Course at Kansas State Teachers College." CUEBS News, 2: 8-9, 1966.

Syrocksi, B., et al. Audio-Video Tutorial Program in Principles of Biology. Minneapolis: Burgess Publishing Company, 1968.

Syrocky, J. B., C. Thomas, and G. Fairchild. "The Audio-Visual Tutorial Program." The American Biology Teacher, 3: 91-96, 1969.

UNESCO. New Trends in Biology Teaching. Edinburgh: Duculot Press Company, 1977.

Van Dalen, D. and W. Meyer. Understanding Educational Research. New York: McGraw-Hill Company, 1966.

Varano, S. P. The Effects of Advance Organizers and Behavioral Objectives on the Facilitation of Learning and Retention of a Biology Unit. Dissertation Abstracts International, 29 (1977), 7131.

Welker, J. Audio-Tutorial Biology at Olney Community College. Minneapolis: Burgess Publishing Company, 1968.

White, J. M., and R. D. Barnes. "A Cost Analysis of Audio-Tutorial and Conventional Instruction." AIBS Education Review, 7: 10-11, 1978.

Wilson, E. B. An Introduction to Scientific Research. New York: McGraw-Hill Book Company, Inc., 1952.

APPENDIXES

APPENDIX A

FORMS OF COGNITIVE TEST

MINISTERIO DE EDUCACION

INSTITUTO UNIVERSITARIO PEDAGOGICO EXPERIMENTAL

DEPARTAMENTO DE CIENCIAS EXPERIMENTALES

AREA DE BIOLOGIA

BARQUISIMETO

NOMBRE Y APELLIDO: ______________________________ C.I. ______________

ANALISIS EXPLORATORIO No. 1

Estimado alumno (a):

La finalidad del presente análisis exploratorio es el de conocer los conocimientos, que debes tener sobre algunos aspectos fundamentales de las ciencias naturales. En particular de la célula vegetal y sus posibles modificaciones en los diferentes órganos de la planta.

Por tal motivo, te solicitamos contestes objetivamente a las catorce (14) preguntas que componen el mencionado análisis exploratorio. Esta información será de valiosa ayuda para las evaluaciones y consideraciones que se pueden formular con relación al programa de carácter experimental que se ha contemplado en la asignatura Ciencias Naturales.

Muchas gracias.

B-1

ESTIMADO ALUMNO

A continuación se les presentan 14 preguntas acerca de tópicos básicos *relacionados con la Célula y Téjidos Vegetales.*

Con ellas procederás de la manera siguiente:

a) Las oraciones serán completadas con la palabra o palabras que hacen su significado correcto.

b) Los cuadros serán completados con una palabra que satisfaga lo exigido en cada uno de ellos.

c) En el dibujo señalarás las estructuras solicitadas con su función respectiva.

Relee tus respuestas para asegurarte que realmente llenan los requisitos que se te exigen en cada respuesta.

1.- El **Citoplasma**, además de mantener el equilibrio funcional de la Célula vegetal, es el sitio donde se localizan ______________________________.

2.- La **Célula Vegetal**, unidad básica de todo organismo es estudiada por la **Citología:** mientras que la **Histología** analiza ______________________________.
y la **Anatomía** la estructura interna de las plantas.

3.- Las **Células Epidermicas** de forma alargada y con función protectora se denominan ______________________________.

4.- Los tres principales **sistemas de téjidos** presentes en las plantas son:

______________________________, ______________________________,

______________________________.

5.- En los ambientes **Xerofíticos**, debido a la reducida disponibilidad hídrica, las células del **mesófilo** se compactan para formar: ______________________________.

6.- El **mesófilo** de la hoja con grandes espacios intercelulares se denomina:

____

7.- En los ambientes acuáticos, las plantas presentan en sus hojas un conjunto de células de tipo ____________________________________ denominado **Aerénquima.**

8.- Células con paredes lignificadas que dan rigidez y sostén a los cordones vasculares de todos los órganos vegetales se denominan:

____

9.- Las dos principales **sustancias de reserva** formadas por la célula son:

1) ____________________________________ la cual se forma en los **plastidios** y

2) ____________________________________ sintetizadas en las **vacuolas.**

10.- Entre los tipos de **pigmentos vegetales** podemos señalar:

1) ____________________________________ encontrándose incluidos en **plastidios** y

2) ____________________________________ situándose en el **citoplasma** o en las **vacuolas.**

11.- Los principales componentes básicos de la **membrana celular** son:

____________________________________ - ____________________________________

____________________________________ y grasas.

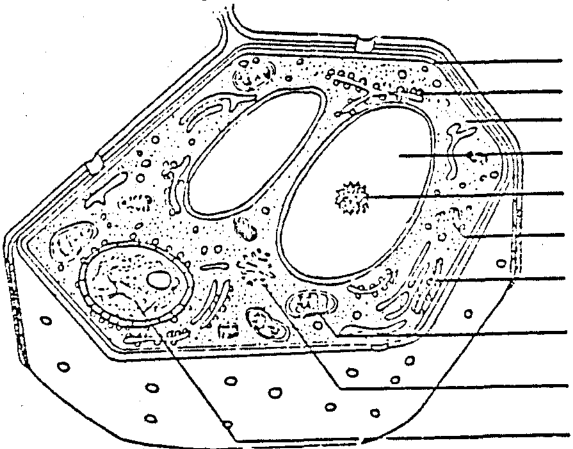
12.- En el siguiente cuadro establezca la diferencia entre la célula Animal y Vegetal al señalar la **presencia o ausencia** de las estructuras abajo indicada.

	PARED CELULAR	VACUOLAS	PLASTIDIOS
CELULA ANIMAL			
CELULA VEGETAL			

13.- A continuación se presenta el siguiente gráfico en el que indicarás en los espacios respectivos, los señalamientos que se preguntan en las columnas 2,3,4 en referencia a los téjidos que aparecen en la columna 1.

COLUMNA 1	COLUMNA 2	COLUMNA 3	COLUMNA 4
TEJIDO	Ausencia o Presencia de cloroplastos	Función en la planta	Capa Embrionaria que lo origina
EPIDERMICO			
PARENQUIMATICO			
VASCULAR			

14.- Identifica en el siguiente gráfico, 5 componentes de la unidad celular vegetal. Coloca un **número** (1 al 5) al lado de las líneas que indican cada estructura y el **nombre** de ellas en el cuadro que aparece debajo de la representación celular. Señala igualmente la **función** que dichos elementos cumplen en la célula vegetal.



NOMBRE DE LA ESTRUCTURA	FUNCION
1)	
2)	
3)	
4)	
5)	

MINISTERIO DE EDUCACION
INSTITUTO UNIVERSITARIO PEDAGOGICO EXPERIMENTAL
DEPARTAMENTO DE CIENCIAS EXPERIMENTALES
AREA DE BIOLOGIA
BARQUISIMETO

NOMBRE Y APELLIDO: ______________________________ C.I. ________________

ANALISIS EXPLORATORIO No. 1

Estimado alumno (a):

La finalidad del presente análisis exploratorio es el de conocer los conocimientos, que debes tener sobre algunos aspectos fundamentales de las ciencias naturales. En particular de la célula vegetal y sus posibles modificaciones en los diferentes órganos de la planta.

Por tal motivo, te solicitamos contestes objetivamente a las catorce (14) preguntas que componen el mencionado análisis exploratorio. Esta información será de valiosa ayuda para las evaluaciones y consideraciones que se pueden formular con relación al programa de carácter experimental que se ha contemplado en la asignatura Ciencias Naturales.

Muchas gracias.

A-1

ESTIMADO ALUMNO

A continuación se le presentan 14 preguntas acerca de tópicos básicos relacionado con la Célula y Téjidos Vegetales.

Con ellas procederás de la manera siguiente:

a) Las oraciones serán completadas con la palabra o palabras que hacen su significado correcto.

b) Los cuadros serán completados con una palabra que satisfaga lo exigido en cada uno de ellos.

c) En el dibujo señalarás las estructuras solicitadas con su función respectiva.

Relee tus respuestas para asegurarte que realmente llenan los requisitos que se te exigen en cada respuesta.

1.- La **célula vegetal**, unidad básica de todo organismo es estudiada por la **Citología**; mientras que la **Histología** analiza ______________________________, y la **Anatomía** la estructura interna de las plantas.

2.- El **Citoplasma**, además de mantener el equilibrio funcional de la célula vegetal, es el sitio donde se localizan ______________________________.

3.- Los tres principales **sistemas de téjidos** presentes en las plantas son:

______________________________, ______________________________

______________________________.

4.- Las **células epidérmicas** de forma alargada y con función protectora se denominan:

______________________________.

5.- El **mesófilo** de la hoja con grandes espacios intercelulares se denomina:

____

6.- En los ambientes **Xerofíticos,** debido a la reducida disponibilidad hídrica, las celulas del **mesófilo** se compactan para formar:

____

7.- Las dos principales **sustancias de reserva** formadas por la célula son:

1) ______________________________ la cual se forma en los **plastidios** y

2) ______________________________ sintetizadas en las **vacuolas**.

8.- Entre los tipos de **pigmentos vegetales** podemos señalar:

1) ______________________________ encontrándose incluidos en **plastidios** y

2) ______________________________ situándose en el **citoplasma** o en las **vacuolas**.

9.- Los principales componentes básicos de la **membrana celular** son:

______________________________, ______________________________

______________________________ y grasas

10.- Las **células** con paredes lignificadas que dan rigidez y sostén a los cordones vasculares de todos los órganos vegetales se denominan:

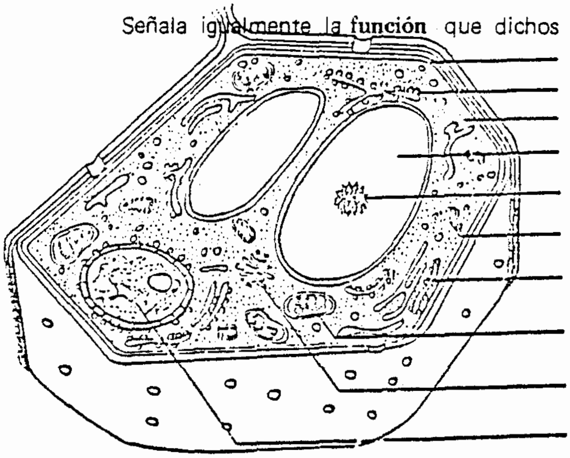
____

11.- En los ambientes acuáticos, las plantas presentan en sus hojas un conjunto de células de tipo ______________________________ denominado **Aerénquina**.

12.- En el siguiente cuadro establezca la diferencia entre célula Animal y Vegetal al señalar la **presencia** o **ausencia** de las estructuras abajo indicada.

	PARED CELULAR	VACUOLAS	PLASTIDIOS
CELULA ANIMAL			
CELULA VEGETAL			

13.- Identifica en el siguiente gráfico, 5 componentes de la **unidad celular vegetal.** Coloca un **número** (1 al 5) al lado de las **líneas** que indican cada estructura y el **nombre** de ellas en el cuadro que aparece debajo de la representación celular. Señala igualmente la **función** que dichos elementos cumplen en la célula vegetal.



NOMBRE DE LA ESTRUCTURA	FUNCION
1)	
2)	
3)	
4)	
5)	

14.- A continuación se presenta el siguiente gráfico en el que indicarás en los espacios respectivos, los señalamientos que se preguntan en las columnas 2,3,4 en referencia a los téjidos que aparecen en la columna 1.

COLUMNA 1	COLUMNA 2	COLUMNA 3	COLUMNA 4
TEJIDO	**Ausencia o Presencia** de cloroplastos	**Función** en la planta	**Capa Embrionaria** que lo origina
EPIDERMICO			
PARENQUIMATICO			
VASCULAR			

APPENDIX B

"ATTITUDE" QUESTIONNAIRE

FORMS

INSTITUTO UNIVERSITARIO PEDAGOGICO EXPERIMENTAL
DEPARTAMENTO DE CIENCIAS EXPERIMENTALES
AREA DE BIOLOGIA
BARQUISIMETO

FORMA EVALUATIVA DE LA ACTIVIDAD DE LABORATORIO No. 1.

(Por favor complete ésta forma antes de retirarse, colocando una equis(X), en el espacio respectivo).

1.- ¿Disfrutó Ud. de la actividad semanal?

_____Sí _____No.

2.- ¿Tuvo a su disposición todo el material que necesitaba?

_____Sí _____No.

3.- ¿Finalizó Ud. sus actividades de laboratorio en el tiempo disponible?

_____Sí _____No.

4.- ¿Estuvo la actividad de laboratorio bien organizada?

_____Sí _____No.

5.- ¿Le gustó el método utilizado para la realización de esta actividad práctica?

_____Sí _____No.

6.- ¿Consultó Ud. a su profesor-asistente hoy?

_____Sí _____No.

7.- ¿Si la respuesta anterior fué afirmativa, señale Ud. aproximadamente, el número de veces?

__________Veces.

8.-¿La utilización de Recursos audiovisuales (proyector de dispositivas, gráficos, modelos, etc.) considera Ud. son elementos motivantes para su aprendizaje?

_____Sí _____No.

FORMA EVALUATIVA DE LA ACTIVIDAD DE LABORATORIO No. 1. (continued)

9.- ¿Consideras fuerón precisas las informaciones suministradas por tu instructor al igual que fuerón efectivas las consideraciones hechas en relación al material que observavas?

_____Sí _____No.

Por favor, señale a continuación algunas sugerencias, críticas u observaciones que pudiera Ud. tener en relación a la actividad de laboratorio de esta semana. No coloque su nombre. Gracias por su colaboración.

INSTITUTO UNIVERSITARIO PEDAGOGICO EXPERIMENTAL
DEPARTAMENTO DE CIENCIAS EXPERIMENTALES
AREA DE BIOLOGIA
BARQUISIMETO

FORMA EVALUATIVA DE LA ACTIVIDAD DE LABORATORIO No. 1.

(Por favor complete ésta forma antes de retirarse, colocando una equis(X), en el espacio respectivo).

1.- ¿Disfrutó Ud. de la actividad semanal?

_____Sí _____No.

2.- ¿Tuvo a su disposición todo el material que necesitaba?

_____Sí _____No.

3.- ¿Finalizó Ud. sus actividades de laboratorio en el tiempo disponible?

_____Sí _____No.

4.- ¿Estuvo la actividad de laboratorio bien organizada?

_____Sí _____No.

5.- ¿Cual fué el número del puesto de aprendizaje donde realizó su trabajo?

Puesto número _____

6.- ¿Le gustó el método utilizado para la realización de actividad práctica?

_____Sí _____No.

7.- ¿Consultó Ud. a su profesor-asistente hoy?

_____Sí _____No.

8.- ¿Si la respuesta anterior fué afirmativa, señale Ud. aproximadamente, el número de veces?

__________ Veces.

FORMA EVALUATIVA DE LA ACTIVIDAD DE LABORATORIO No. 1. (continued)

9.- ¿La utilización de Recursos audiovisuales (proyector de diapositivas, gráfico, modelos, etc.) considera Ud. son elementos motivantes para su aprendizaje?

_____Sí _____No.

10.-¿Consideras fueron precisas las informaciones suministradas por tu instructor (grabación) al igual que fueron efectivas las consideraciones hechas en relación al material que observavas?

_____Sí _____No.

Por favor, señale a continuación algunas sugerencias, críticas u observaciones que pudiera Ud. tener en relación a la actividad de laboratorio de esta semana. No coloque su nombre. Gracias por su colaboración.

____

____

____

____

____

INSTITUTO UNIVERSITARIO PEDAGOGICO EXPERIMENTAL
DEPARTAMENTO DE CIENCIAS EXPERIMENTALES
AREA DE BIOLOGIA
BARQUISIMETO

FORMA EVALUATIVA DE LOS INSTRUCTORES
DE LA ACTIVIDAD PRACTICA No. 1

(Convencional)

(Por favor complete ésta forma antes de retirarse, colocando una equis(X), en el espacio respectivo.)

1.- ¿Solicitaron los estudiantes su asistencia en tal frecuencia que le dificultaba su trabajo como asistente en el laboratorio?

_____Sí _____No.

2.- ¿En caso de la pregunta 1 ser afirmativa, indique el número de veces promedio que el alumno requirió su asistencia?

__________Veces.

3.- ¿Observó Ud. que había alumnos que solicitaban asistencia con mayor frecuencia que otros que la hicieron al comienzo de le actividad ó que simplemente no requirieron de tal asistencia?

_____Sí _____No.

4.- ¿Si su respuesta es positiva en la pregunta 3, indique el número de alumnos que Ud. observó que requirian asistencia continua e indique el sexo de los mismos?

_____ Alumnos.
_____ Sexo masculino.
_____ Sexo femenino.

5.- ¿Considera Ud. que la asistencia a la práctica prestada por su persona, facilitó y de alguna forma incrementó la velocidad de trabajo demostrada por los alumnos?

_____Sí _____No.

FORMA EVALUATIVA DE LOS INSTRUCTORES DE LA ACTIVIDAD PRACTICA No. 1 (Convencional) (continued)

6.- ¿Si su respuesta fué afirmativa en la pregunta 5 y pudo Ud. observar detalladamente el ritmo de trabajo de los alumnos, indique aproximadamente la velocidad de trabajo (promedio) de un alumno para realizar un ejercicio?

________ Minutos

7.- ¿Cree Ud. que el recurso audiovisual, fué para los alumnos un elemento determinante en la motivación en la actividad-práctica?

_____Sí _____No.

8.- ¿Considera que la dotación del laboratorio (ambiente físico y mobiliario) fué apropiado para el desarrollo de la actividad-práctica?

_____Sí _____No.

Señale a continuación algunas sugerencias, críticas u observaciones que pudiera Ud. tener en relación a la actividad de laboratorio de esta semana. Por favor indique su nombre al final del cuestionario.

____

____

____

____

____

INSTITUTO UNIVERSITARIO PEDAGOGICO EXPERIMENTAL
DEPARTAMENTO DE CIENCIAS EXPERIMENTALES
AREA DE BIOLOGIA
BARQUISIMETO

FORMA EVALUATIVA DE LOS INSTRUCTORES
DE LA ACTIVIDAD PRACTICA No. 1.

(Audio-Tutorial)

(Por favor complete ésta forma antes de retirarse, colocando una equis(X), en el espacio respectivo.)

1.- ¿Considera Ud. que hubo reacción de los estudiantes ante la metodología utilizada?

_____Sí _____No.

2.- ¿Observó Ud. que el estudiante, luego de iniciada la actividad práctica, mostró naturalidad en su trabajo?

_____Sí _____No.

3.- ¿Solicitaron los estudiantes su asistencia en tal frecuencia que la dificultaba su trabajo, como instructor en el laboratorio?

_____Sí _____No.

4.- ¿En caso de la pregunta 3 ser afirmativa, indique el número de veces promedio que un alumno requirió su asistencia?

__________ Veces.

5.- ¿Observó Ud. que había alumnos que solicitaban asistencia con mayor frecuencia que otros que la hicieron al comienzo de la actividad ó que simplemente no requirieron de tal asistencia?

_____Sí _____No.

6.- ¿Si su respuesta es positiva en la pregunta 5, indique el número de alumnos que Ud. observó que requerían asistencia continua e indique el sexo de los mismo?

_____ Alumnos.
_____ Sexo masculino.
_____ Sexo femenino.

FORMA EVALUATIVA DE LOS INSTRUCTORES DE LA ACTIVIDAD PRACTICA No. 1.
(Audio-Tutorial) (continued)

7.- ¿Considera Ud. que la asistencia a la practica prestada por su persona facilitó y de alguna forme incrementó la velocidad de trabajo demostrada por los alumnos?

_____Sí _____No.

8.- ¿Si su respuesta fué afirmativa en la pregunta 7, y pudo Ud. observar detalladamente el ritmo de trabajo de los alumnos, indique aproximadamente la velocidad de trabajo (promedio) - de un alumno para realizar un ejercicio?

________ Minutos

9.- ¿Cree Ud. que el recurso audiovisual, fué para los alumnos un elemento determinante en la motivación en la actividad-práctica?

_____Sí _____No.

10.-¿Considera que la dotación del laboratorio (ambiente físico y mobiliario) fué apropiado para el desarrollo de la actividad práctica?

_____Sí _____No.

Señale a continuación algunas sugerencias, críticas u observaciones que pudiera Ud. tener en relación a la actividad de laboratorio de esta semana. Por favor indique su nombre al final del cuestionario.

____

____

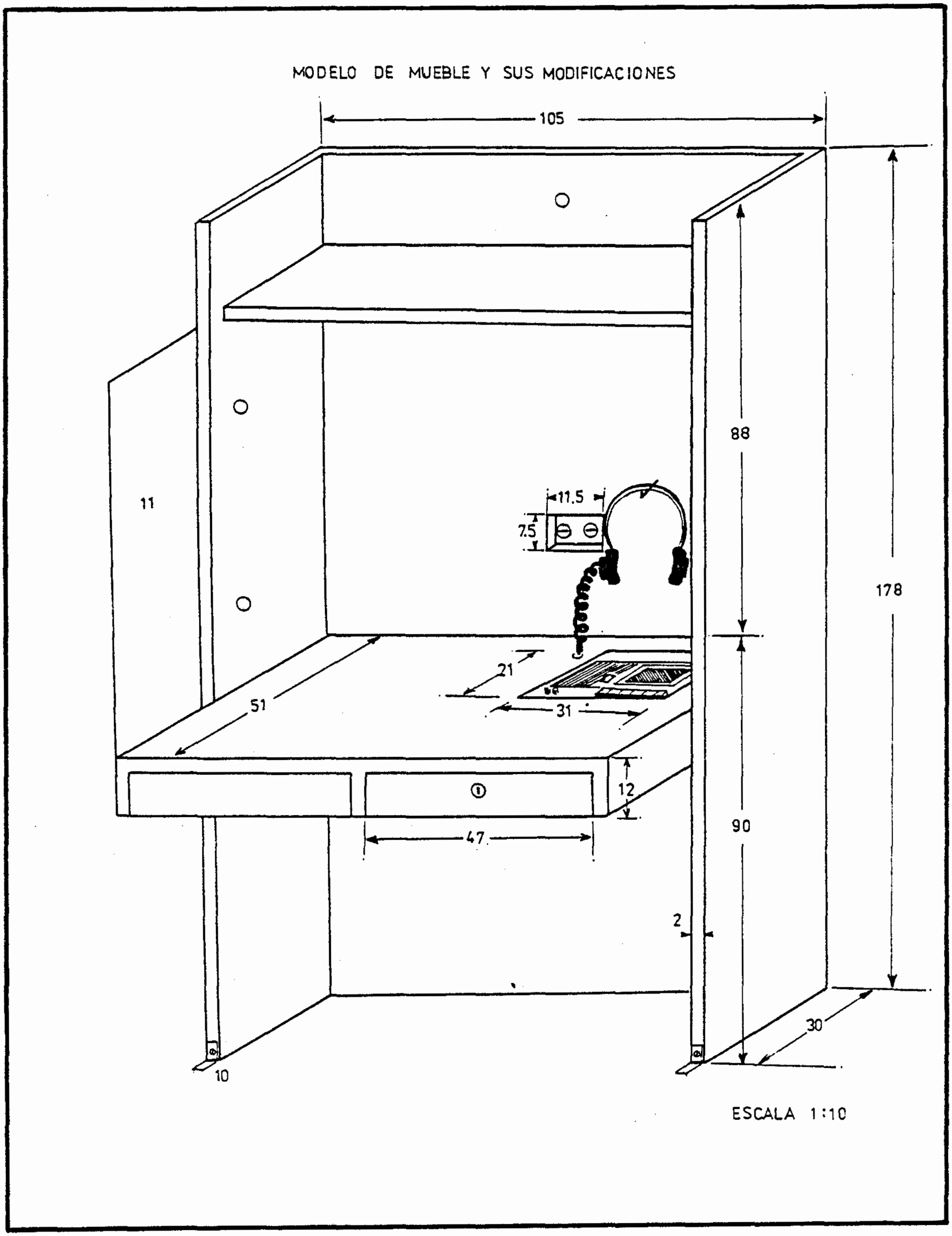
____

____

____

APPENDIX C

CARREL DESIGN FOR A-T STUDENTS



Note: Specifications shown in metric scale.

APPENDIX D

COURSE OUTLINE OF BOTANY CONTENT FOR NATURAL SCIENCE DCN010

OUTLINE OF BOTANY CONTENT FOR

NATURAL SCIENCE DCN010[a]

Unit	Week	Topics
I	2	Development of the Seed Plant. The embryo; seedling and germination.
II	3	Apical Meristems and Their Derivative Plant Tissues. Differentiation; specialization and morphogenesis.
III	4	The Plant Cell. Differences between plant and animal cells; cell organelles and their main presence in plant cells; summary of types of cells and tissues.
IV	5	The Dermal Tissue System. Composition; development and function of stomata, trichomes and other dermal structures in plants.
V	6	The Fundamental or Ground System. Parenchyma, collenchyma and schlerenchyma cell types; distribution in the plant; cell structure and function.
VI	7	The Vascular Tissue. Xylem and Phloem cell types; distribution in the plant; cell structure and function.

[a]Designated code number for the course.

APPENDIX E

EDUCATIONAL OBJECTIVES FOR AN INSTRUCTIONAL LABORATORY UNIT

INSTITUTO UNIVERSITARIO PEDAGOGICO EXPERIMENTAL
DEPARTAMENTO DE CIENCIAS EXPERIMENTALES
AREA DE BIOLOGIA
BARQUISIMETO

ACTIVIDAD DE LABORATORIO No. 1
CELULA VEGETAL

OBJETIVOS	ACTIVIDADES	RECURSOS
Al finalizar la sesión teórica-práctica semanal estarás en capacidad de:	Realiza las siguientes actividades:	Precisa los siguientes recursos:
1.- Definir las diferencias básicas entre: Anatomía, Histología y Citología vegetal.	1.1.- Lectura de la introducción de la guía y otras orientaciones señaladas por su profesor-asistente.	- Guía de laboratorio. - Introducción. - Glosario. - Profesor-asistente.
2.- Enumerar, al menos tres diferencias básicas entre célula vegetal y animal.	2.1.- Orientaciones y observaciones introductorias a la ejercitación de la práctica semanal. Lectura del material señalado por el profesor-asistente.	- Guía de laboratorio. - Gráfico "A" - Gráfico "B" - Profesor-asistente.
3.- Identificar al menos cinco, de los componentes básicos de la célula vegetal e indicar su función en la dinámica operativa de la unidad celular.	3.1.- Observaciones realizadas en un montajes de hoja de Elodea (ejercicio No. 1) y bulbo de cebolla.	- Guía de laboratorio. - Gráfico "A". - Profesor-asistente. - Material fresco.
4.- Explicar al menos una de las funciones vitales del citoplasma, en la célula vegetal.	4.1.- Observacione de la célula típica en las hojas de Elodea.	- Guía de laboratorio. - Profesor-asistente. - Material fresco.

ACTIVIDAD DE LABORATORIO No. 1 (continued)

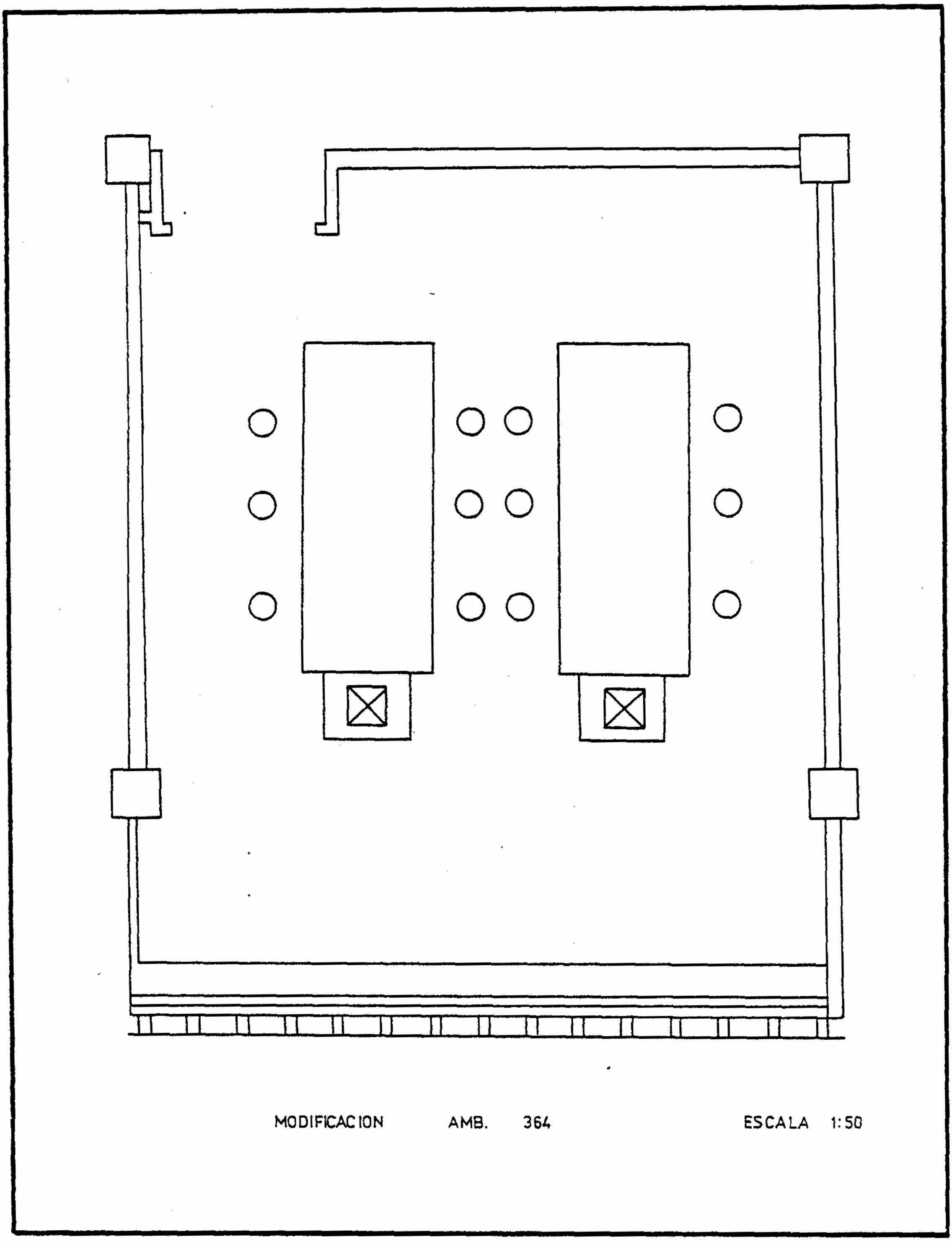
OBJETIVOS	ACTIVIDADES	RECURSOS
Al finalizar la sesión teórica-práctica semanal estarás en capacidad de:	Realiza las siguientes actividades:	Precisa los siguientes recursos:
5.- Señalar, al menos dos de los componentes de la membrana celular indicando las características que tales componentes aportan a citada estructura.	5.1.- Orientaciones generales suministradas por el profesor-asistente.	- Guía de laboratorio. - Profesor-asistente.
6.- Comparar al menos tres de los tejidos constituyentes de la planta, indicando su estructuración típica celular y su origen embrionario.	6.1.- Observaciones realizadas en los ejercicios de la guía de laboratorio y orientaciones suministradas por tu profesor-asistente.	- Guía de laboratorio. - Profesor-asistente. - Material fresco.
7.- Evaluar al menos una de las funciones básicas para cada tipo celular y tejidos observados durante la actividad práctica.	7.1.- Observaciones realizadas en los ejercicios de la guía de laboratorio y orientaciones suministradas por tu profesor-asistente.	- Guía de laboratorio. - Profesor-asistente. - Material fresco.
8.- Establecer al menos tres relaciones entre la presencia y función que tienen algunas células en diferentes órganos vegetales.	8.1.- Orientaciones informativas suministradas por tu profesor-asistente.	- Guía de laboratorio. - Profesor-asistente. - Material fresco.

ACTIVIDAD DE LABORATORIO No. 1 (continued)

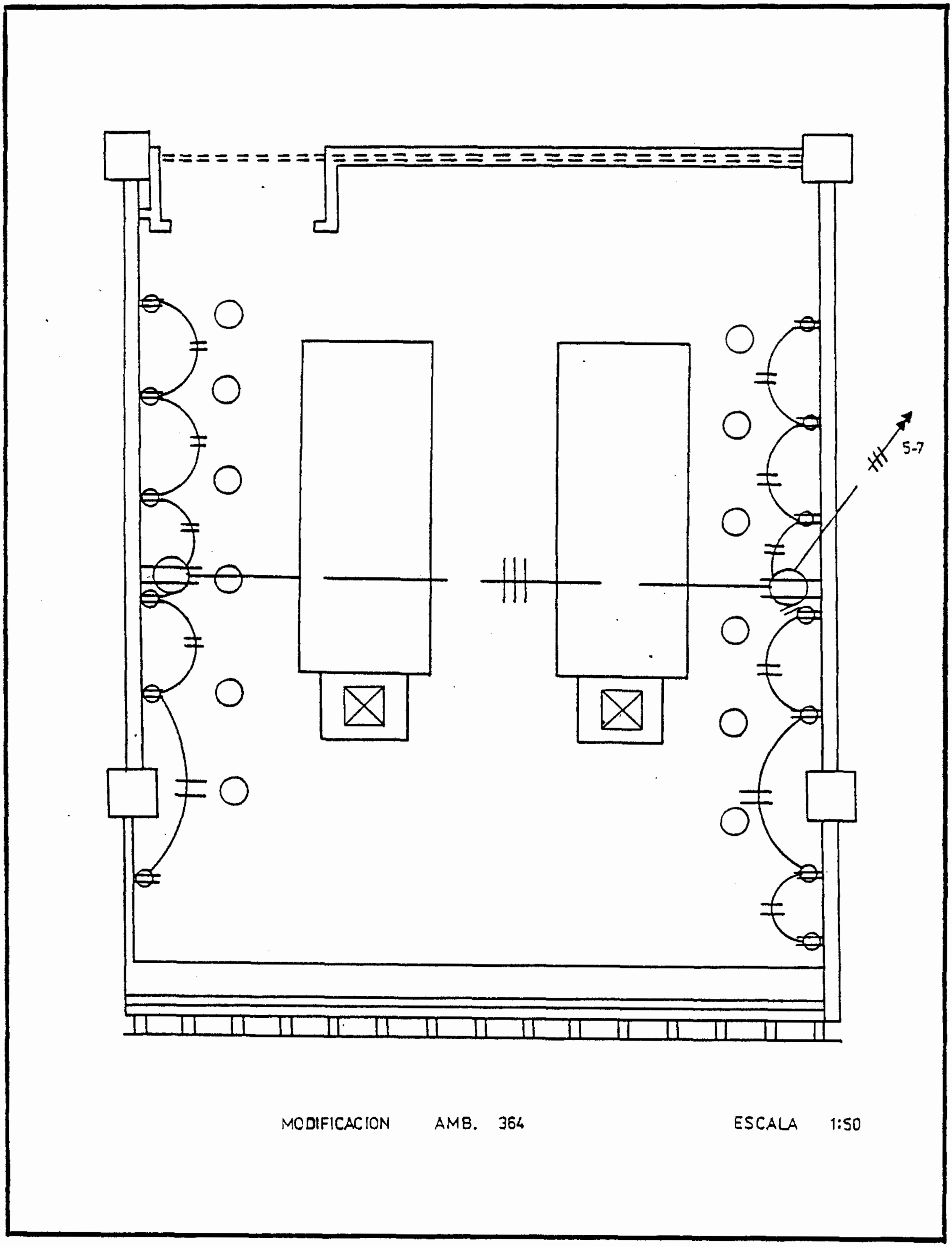
OBJETIVOS	ACTIVIDADES	RECURSOS
Al finalizar la sesión teórica-práctica semanal estarás en capacidad de:	Realiza las siguientes actividades:	Precisa los siguientes recursos:
9.- Relacionar al menos dos de los tipos celulares estudiados con el ambiente natural donde los mismos se han modificado como producto adaptativo.	9.1.- Observaciones realizadas en los ejercicios de la guía de laboratorio y orientaciones suministradas por tu profesor-asistente.	- Guía de laboratorio. - Profesor-asistente. - Material fresco.
10.-Señalar al menos dos, de los tres principales sistemas de tejidos vegetales.	10.1.- Observaciones realizadas en los ejercicios 1, 2, 3 y 4 de la guía de laboratorio.	- Guía de laboratorio. - Profesor-asistente. - Material fresco.
11.-Comparar al menos dos de las principales sustancias orgásticas celulares y la función de la misma en la célula.	11.1.- Observaciones realizadas en el ejercicio 5 de la guía de laboratorio.	- Guía de laboratorio. - Profesor-asistente. - Material fresco.
12.-Justificar al menos dos de las funciones de los pigmentos celulares y su disposición en las células vegetales.	12.1.- Observaciones realizadas en el ejercicio 6 de la guía de laboratorio.	- Guía de laboratorio. - Profesor-asistente. - Material fresco.

APPENDIX F

LABORATORY FACILITIES AND ARRANGEMENT



Laboratory Arrangement for Conventional Instructional Mode



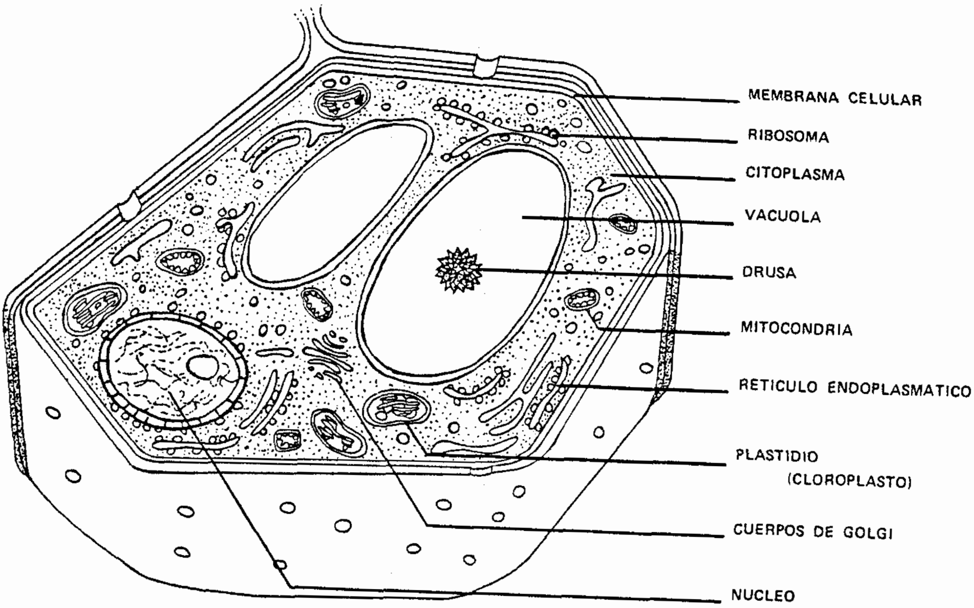
Laboratory Arrangement for Audio-Tutorial
Instructional Mode

APPENDIX G

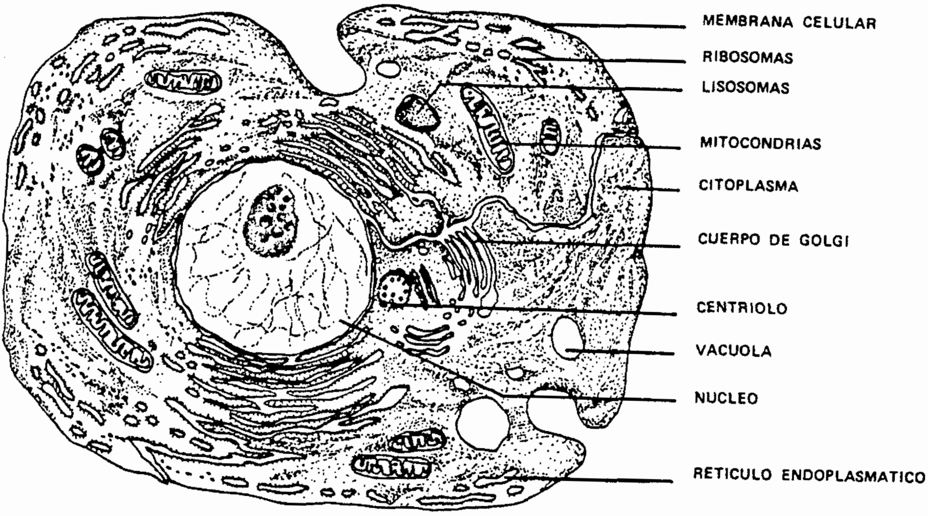
TEACHING MATERIAL SAMPLES DEVELOPED FOR THE STUDY

GRAFICO A

COMPONENTES BASICOS DE UNA CELULA VEGETAL Y ANIMAL



CELULA VEGETAL



CELULA ANIMAL

GRAFICO 8

DIFERENCIAS BASICAS ENTRE CELULA
ANIMAL Y VEGETAL

ESTRUCTURAS	CELULA VEGETAL	CELULA ANIMAL
MEMBRANA CELULAR	PRESENTE	PRESENTE
PARED CELULAR	PRESENTE	AUSENTE
NUCLEO	PRESENTE CON POSICION ACROCENTRICA	PRESENTE CON POSICION CENTRICA
RETICULO ENDOPLASMATICO	PRESENTE	PRESENTE
MITOCONDRIA	PRESENTE	PRESENTE
PLASTIDIOS	PRESENTES	AUSENTES
RIBOSOMAS	PRESENTES	PRESENTES
CUERPOS DE GOLGI	PRESENTES	PRESENTES
LISOSOMAS	AUSENTES	PRESENTES
VACUOLAS	PRESENTES, GRANDES, SOLO UNA EN CELULAS MADURAS.	PEQUEÑAS O AUSENTES
CENTRIOLOS	AUSENTE, EN LA MAYORIA DE PLANTAS	PRESENTE

(Traducido y adaptado de Biology of Plants de Raven, Evert y Curtis; Worth Publishers, Inc., 2a. ed. New York, 1976)

APPENDIX H

SCRIPTS OF AUDIO-TUTORIAL LABORATORY SESSION AND PRE-PROGRAMMED REINFORCEMENT ACTIVITY

INSTITUTO UNIVERSITARIO PEDAGOGICO EXPERIMENTAL
DEPARTAMENTO DE CIENCIAS EXPERIMENTALES
AREA DE BIOLOGIA
BARQUISIMETO

CELULA VEGETAL
(GUION)

Hola! Bienvenidos a la primera sesión de laboratorio de esta asignatura Ciencias Naturales. Como verás es una nueva forma de realizar actividades prácticas, dirijidas y orientadas por medio de grabaciones magnetofónicas. Esto te permitirá estar continuamente asistido en las actividades en las que te ejercitarás posteriormente e inclusive volver atrás, si las mismas no han sido de tu total comprensión.

Cada uno de los ejercicios que aparecen en el manual de laboratorio que tienes ahora, corresponden a los objetivos listados en tu puesto de aprendizaje. Es conveniente que antes de iniciar cualquiera de los ejercicios prácticos, precises correctamente qué, cómo y donde obtendrás el conocimiento que se aspira tú obtengas en las situaciones de aprendizaje.

Para la consecución del material vegetal que tendrás que seccionar para las actividades de laboratorio, tu profesor y los asistentes te indicarán en que forma hacerlo. De igual manera ellos te asistirán en el manejo del microscopio o en cualquier otra eventualidad, que tuvieses en la actividad práctica.

La estructuración de la guía de laboratorio está hecha de tal manera que además de la ejercitación correspondiente a observación de estructuras e identificación de las mismas, puedes resumir algunas ideas de los comentarios e indicaciones que te haremos en referencia al material vegetal que estás analizando. Comenzaremos entonces a hacer referencia del contenido teórico de la actividad práctica a realizar, pero antes quiero que sepas que al oir esta señal (SONIDO) debes hacer una pausa y detener el grabador, presionando la tecla STOP, luego seguir las direcciones señaladas en la guía para completar la actividad indicada. Cuando hayas terminado tu trabajo, podras continuar escuchando esta grabación presionando la tecla PLAY de tu grabador. A continuación debes leer detenidamente la introducción del manual de laboratorio lo cual te guiará a precisar el objetivo fundamental de la actividad práctica de esta semana: Célula Vegetal.
(SEÑAL)

En esta actividad analizaremos la constitución básica de la célula vegetal, y sus organelos citoplasmáticos. La célula es la unidad estructural y funcional de cualquier ser vivo quien puede a su vez tener una estructuración y organización constituida por una sola célula o por miles de éstas con funciones y formas diversas. Debido a la presencia o ausencia de esta diversidad celular, los organismos han esperimentado especialización; gracias a las capacidades adaptativas que han podido mostrar como producto de la efectiva potencialidad celular tanto en las formas citológicas presentadas como en las funciones realizadas.

Los organismos unicelulares (formados por una sola célula) tal como algunas algas y otros organismos animales, han tenido que estructurar su constitución para cumplir todas las funciones básicas (alimentación, digestión, excresión, etc.). Por sus parte, los organismos pluricelulares (constituidos por muchas células) han organizado grupos de éstas llamados tejidos para cumplir una sola función en forma efectiva. Los organismos vegetales que estudiaremos en esta oportunidad son todos pluricelulares, con una histología y organografía bien definida.

Comencemos, entonces el estudio de la célula vegetal mediante la observación del gráfico A, colocado al frente de tu puesto de trabajo (SEÑAL). Podrás haber observado entonces que una célula esta totalmente cubierta por una membrana celular, la cual controla totalmente el paso de materiales hacia dentro y fuera de la célula y así entonces intercambiar con el medio que la rodea. Dentro de esta membrana está el citoplasma y dispersos en éste, los organelos citoplasmáticos (núcleo, cloroplastos, vacuolas, etc.).

Ahora antes de ir en detalle al estudio de estos últimos, debemos saber que hay diferencias notables entre una célula vegetal y una animal (observa el gráfico B) (SEÑAL). La célula vegetal esta rodeada por una pared celular, la cual envuelve la membrana celular o membrana plasmática. La unidad viva por dentro de la pared celular es conocida como protoplasma (citoplasma y núcleo). La posición de este organelo citoplasmático (núcleo) es quizás otra diferencia básica de la célula animal y vegetal, siendo en la primera céntrica y en la segunda acéntrica. Finalmente, la presencia de ciertos organelos citoplasmáticos o el número incrementado de otros pudieran ser otras de las diferencias. Por ejemplo, las células vegetales tienden a tener mayor cantidad de mitocondrias, vacuolas y además poseen exclusivamente plastidios.

Veamos ahora, con la ayuda de ejercitación y la observación que practicarás en dichas actividades, como puede modificarse la constitución básica de la célula vegetal en las diferentes plantas o sus órganos integrantes donde esa unidad estructural forma parte.

Ejercicio 1. Lee cuidadosamente los comentarios introductorios a esta unidad y realiza el montaje correspondiente (SEÑAL). Una célula de una hoja de Elodea (Figura 1), muestra que la sustancia básica o citoplasma está constantemente en movimiento al igual que los organelos y otros elementos suspendidos en dicha sustancia básica. Este movimiento es conocido como corriente citoplasmática o ciclosis. La razón de este tipo de movimiento, no es totalmente conocido, sin embargo, se sabe que el proceso es necesario para el intercambio nutricional entre la célula y el medio que la rodea. La velocidad del movimiento depende entonces de la temperatura ambiental y de otros elementos presentes en el medio. Es por ello que, el agua en que actualmente cubra las células de Elodea de su montaje, ha reducido la velocidad de la corriente citoplasmática; la misma a ido acelerándose a medida que la luz que incide sobre ella, procedente de tu microscopio, ha ido calentando el agua a la temperatura óptima de su medio.

La parte periférica celular esta totalmente llena de cloroplastos, corpúsculos de forma ovoide y de color verde que aparecen entre la pared celular y membrana vacuolar. La presencia de estos plastidios y su número dependerá de la función fotosintética (mecanismo para la elaboración de sustancias alimenticias), éstos abundan en aquellas células vegetales que participan como unidades constituyentes de tejidos asimiladores como el mesófilo de las hojas.

El citoplasma en la mayoría de estas células representa una pequeña porción localizada hacia la periferia de la célula. Ello se debe a que prácticamente la vacuola, llega a ocupar un 90% del volumen celular en las células máduras. Las células jóvenes, contienen solo pequeñas, pero numerosas vacuolas. La sustancia citoplasmática esta formada principalmente por agua y otros componentes como sales, azúcares y proteinas. Esta constitución podrá variar en las plantas, dependiendo de su estado funcional. Aún en condiciones desfavorables el citoplasma posee propiedades físico-químicas que contrarestan en lo máximo la adversidad del medio, tratando en lo posible mantener el equilibrio óptimo funcional.

Las células de la hoja de Elodea posee una membrana externa o pared celular y una más interna la membrana plasmática. La pared celular esta constituida principalmente por celulosa. Esta sustancia le da rigídez a la unidad celular vegetal. El grosor y composición de la pared celular varía de célula a célula, dependiendo de su función. Otros componentes básicos son: hemicelulosa, sustancias pécticas, grasas y lignina. Las dos últimas sustancias serán estudiadas posteriormente en otro ejercicio de esta actividad de laboratorio. Se señaló anteriormente el poder de rígidez de las sustancias constituyentes, pero es necesario añadir la plasticidad conferida por los componentes pécticos, la elasticidad dada por la hemicelulosa y el incremento de rígidez aportado por la lignina. Procede a dar respuesta a las preguntas referidas al ejercicio No. 1 y coloque los nombres de las estructuras que aparecen en la página No. 3 (SEÑAL).

Ejercicio 2. Lee cuidadosamente los señalamientos en tu guía de laboratorio y realiza el montaje que corresponde. Compara tus observaciones con las realizadas en el ejercicio anterior (SEÑAL). La célula típica de este tejido indica que las estructuras más resaltantes son la pared celular, el núcleo y el citoplasma (añada unas gotas de iodo para lograr un mayor resalte de estas estructuras en su preparación). También observará que no se trata de un tejido asimilador sino de protección (Ver figura 1) (SEÑAL).

Es conocido, entonces, este tipo de tejido protector como epidermis y se caracteriza por ser un sistema histológico que se forma en el cuerpo primario y básico de la planta a partir de un meristemo primario: dermatógeno. Es entonces la epidermis la capa externa protectora que cubre el cuerpo primario de la planta y de cualquiera de sus órganos. Funcionalmente y estructuralmente las células epidérmicas son un tanto variables. Además del tipo celular de forma cilíndrica, más larga que ancha, con un núcleo y pared celular bien definidos y sin cloroplastos (Ver figura 2), existe otro tipo de células epidérmicas; las estomáticas, como las que aparecen en seriación continua en la figura 3, y otras en forma de apéndices, tricomas pelos, escamas y vesículas, representados en las figuras 4, 5, 6, 7, 8 7 9. (SEÑAL).

Además de la función de protección mecánica que tiene la epidermis en las plantas, cumplen éstas una función reguladora del recurso hídrico (agua) en la planta. Así, en aquellas partes expuestas del vegetal al medio ambiente, se producen secresiones de sustancias que sirven como material aislante en la célula. De esta manera se forma una cutina que por acumulación progresiva produce una membrana gruesa llamada cutícula.

Conjuntamente con los mencionados reguladores del elemento agua en las plantas, las células estomáticas que a diferencia del resto de células epidermicas poseen cloroplastos, regulan por medio de un poro estomático, la salida y entrada de vapor de agua y ciertos gases, en las hojas y tallos jóvenes. Haga las anotaciones correspondientes en referencia al contenido descrito del ejercicio No. 2, y dé lectura a los comentarios señalados en las figuras 4, 5, 6, 7, 8, 9, 7 27. (SEÑAL).

Ejercicio 3. Detalladamente, lee las indicaciones señaladas para esta actividad y entonces realiza el montaje que se refiere (SEÑAL). Nuevamente, estás observando el órgano foliar de la planta (una hoja) y como recordarás en los ejercicios anteriores señalamos la importancia y constitución del tejido epidérmico. Deciamos anteriormente que cutina, es una sustancia grasulenta que actua como aislante para impedir la transpiración excesiva de la planta y con ello la prdida innecesaria de agua. En algunas ocasiones, además de la cutina, la epidermis presenta una serie de prolongaciones aciculares, redondeadas, etc., que señalabamos previamente como tricomas, pelos o escamas, que también colaboran en la función reguladora del agua. Todas estas estructuras se han originado de la epidermis y forman parte de ese tejido.

Los estomas, con sus células oclusivas y el proceso regulador del poro estomático por medio de procesos fisiológicos particulares de tales células, complementan el mecanismo controlador del agua y algunos gases como el anhídrico carbónico y el oxígeno los cuales son indispensables para el mecanismo fotosintético realizado por la planta. En este corte podrás observar que la epidermis inferior es múltiple, pero presenta ciertas invaginaciones (hundimientos de las capas externas), donde se localizan los estomas protegidos a su vez, por tricomas. El conjunto, la envaginación con las estructuras que allí se encuentran recibe el nombre de criptas estomáticas. La forma de disponerse los estomas, en estructuras hundidas de la epidermis, es propia de plantas de ambientes xerofíticos. Esto representa una respuesta de la planta para evitar en todo momento, la transpiración excesiva y el ahorro de agua, la cual es limitada en su ambiente natural. De respuesta a las preguntas señaladas en la página No. 6 (SEÑAL).

En este órgano que estás estudiando, una hoja, prácticamente es el lugar que la planta ha asignado para la ejecución de la función fotosintética, por tal motivo, observarás que en la sección histológica de esa hoja, aparece una estructuración bien definida y que pudiesemos referir de la siguiente manera (Ver figura 10): Una epidermis superior múltiple de varias capas o estratos y una gruesa cutícula. Esta disposición es propia también de aquellas plantas de ambientes secos (xerofíticos). Luego en la parte media superior, observas, uno o dos estratos de un tejido cuyas células se caracterizan por ser columnares (más largas que anchas) y tener numerosos cloroplastos. Este grupo de células es parte del mesófilo observado en el ejercicio 1 (hoja de Elodea). En esa ocasión recuerda que no había diferenciación alguna de las células del mesófilo. Aquí en esta hoja de Berbería, si hay diferenciación de células en cuanto forma y tamaño. Las células columnares forman parte del tejido parenquimático y que por su disposición compactada se ha denominado parénquima en empalizada (una empalizada en el sentido criollo es una cerca de palos colocados en posición vertical uno al lado del otro). Luego hacia la parte inferior media, se localizan nuevamente células parenquimáticas esta vez de forma esférica u ovoide, y dispuestas en forma menos compactada. Esta disposición del parénquima es propia de un parénquima esponjoso (Asociándose con una esponja). Como verás la cantidad de espacios libres, forman como una cámara de aire por los numerosos espacios intercelulares. Debes saber que la citada cámara de aire, debe estar en intimo contacto con los estomas, quienes como ya conoces, son los encargados de controlar la salida de gases y otros elementos necesarios para la realización de fotosíntesis en las hojas de una planta.

Por supuesto no todas las hojas presentan la misma disposición del mesófilo en parénquima en empalizada y esponjoso, todo depende de los requerimientos de la planta y las adaptaciones de ésta en el medio donde vive. Por ejemplo, recuerda que Elodea es una planta acuática, donde el elemento agua está a su alrededor y en abundancia para sus necesidades. En cambio berbería es una planta terrestre que ha tenido que adaptar estructuras controladoras de las limitadas cantidades del elemento agua en su interior. Si comparas la forma de disponerse los tejidos de esta hoja con una de Maíz, verás que también hay diferencias, entre las cuales pudiesemos notar la presencia de estomas en la epidermis superior e inferior en la hoja de Maíz (el maíz crece en ambientes más húmedos llamados mesofíticos). Esto último también incide en el arreglo del mesófilo, el cual se observa con numerosos espacios intercelulares. Así que el número de estomas y su posición dependerá definitivamente de las necesidades de la planta y de los requerimientos de ésta en relación a su ambiente.

El mesófilo de una hoja está totalmente irrigado por haces vasculares o venas, los cuales estan conectados al sistema vascular del tallo (Ver modelo 1 en el mesón No. 1) (SEÑAL). Podrás haber observado que no hay célula del mesófilo a la que no le llegue irrigación vascular o que no esté en las proximidades de una de tales venas. Un haz vascular es entonces la representación transversal de una de las tantas venas que recorren una hoja, tallo o raíz paralelamente al eje de cualquiera de tales órganos. El arreglo y disposición de las venas caracteriza entonces el tipo de venación: paralela (por ejemplo en el maíz) o reticulada (como en berbería).

Cada vena está formada por dos tipos de células o tejidos principales los cuales se originan de un meristemo primario: el procambium. El primer tejido que podrás identificar es denominado Xilema, localizado generalmente hacia la parte adaxial de la hoja o hacia la periferia de la raíz, tallo o fruto. El segundo tejido componente del tejido vascular es el Floema, localizado por la parte abaxial de la hoja ó hacia dentro de los otros órganos vegetales citados anteriormente. Procede a dar respuesta a las preguntas y a colocar el nombre de las estructuras que aparecen en la página No.7. (SEÑAL).

Los tejidos vasculares de las venas están raramente expuestos en forma total a los espacios intercelulares del mesófilo. Las venas principales de una hoja estan rodeadas por células parenquimáticas las cuales contienen pocos cloroplastos, mientras que las venas cortas estan rodeadas por una o más capas de células compactadas y entonces forman una envoltura del haz vascular. Las células de esta envoltura, a menudo parecen unidades citológicas del mesófilo. Estas se extienden de extremo a extremo de las venas del tal manera que no queda parte del tejido vascular expuesto a la cámara de aire que dejan las células del mesófilo. Así se controla el paso de sustancias primas (agua y sales minerales), o elaboradas (azúcares, proteinas, grasas, etc.) que atraviezan la envoltura cuando pasan a través del xilema y floema respectivamente.

Es importante conocer la anatomía, histología y citología del pecíolo, es decir, la porción alargada que une la lámina foliar al tallo. Debe tener por su función tejido lo suficiente flexible para facilitar el movimiento continuo de las hojas por el viento y los pequeños giros que éstas realizan en respuesta a la búsqueda de fuente de energía lumínica: el sol. En la sección transversal del pecíolo que realizastes, y que debes comparar con las figuras 13 y 14, observarás que existe una epidermis que cubre totalmente el pecíolo, una gran masa de tejido central, atravesada por varios haces vasculares separados. (Añada, una gota de safranina para mejor observación). Si observas detenidamente la sección transversal del pecíolo, detallaras que existe una capa por debajo de la epidermis, caracterizada por tener células con espesamientos irregulares en su pared celular primaria (Figura No. 14) la cual no es lignificada, característica ésta que lo capacita para soportar órganos jóvenes o en crecimiento. El conjunto de estas células conforma el tejido colenquimático el cual se deriva de un sistema histológico primario: meristemo fundamental. Al igual que el parénquima es un tejido con componentes celulares que poseen un lumen considerable en el que se encuentran algunos de los organelos citoplasmáticos comunes (núcleo, retículo endoplasmático, mitocondrias, etc.).

Otros de los nuevos tejidos, asociados comúnmente al tejido vascular es el esclerenquimático. Este sistema histológico es también primario y se origina del mismo meristemo que el parénquima y colénquima. Estas células son comunes tanto en partes de vegetal con crecimiento primario, como también en los secundarios; por lo general carecen de protoplasto en su estado maduro. Las células esclerenquimáticas tienen paredes secundarias lignificadas. Es por ello que aportan rígidez y soporte en aquellas partes del vegetal que han cesado su elongación, es decir su crecimiento en longitud. De respuesta a la pregunta que en relación al ejercicio No. 3 aparecen en la página No. 8, y haga algunas anotaciones de su interés, correspondientes a la información hecha en referencia a este ejercicio.

Ejercicio 4. Lee cuidadosamente las indicaciones señaladas y realiza el corte que se especifica. (SEÑAL). Cuando tomaste la muestra del tallo u hoja de Auyama, sentiste al tacto la gran cantidad de pelos epidérmicos que revisten a tales órganos. Estas estructuras se derivan, como se dijo anteriormente, de la epidermis considerándose parte de ese sistema histológico. Generalmente los tallos carecen de estomas, aunque éstos están presentes en algunos tallos jóvenes u otros adultos donde tales estructuras son necesarias para realizar sus funciones vitales de transpiración e intercambio gaseoso. Haga las anotaciones correspondientes y de respuesta a la pregunta formulada en la página No. 8, en referencia al ejercicio 4.

Por debajo de la epidermis se situa una o dos capas de células colenquimáticas, las cuales le dan rígidez a la condición herbacea de la planta. A continuación una gran porción o zona de tejido parenquimático. Una parte externa con células muy activas en las funciones de asimilación, denominada corteza. Luego una interna, limitada, que finaliza hacia la parte central del tallo, dejando así una zona hueca. Esta región también constituida por células parenquimáticas, es llamada médula. Esta zona participa también, aunque en menor grado, en las funciones de asimilación, siendo más efectiva en la acumulación de sustancias de reserva. De respuesta a las preguntas que se indican en la página No. 9 y coloque el nombre a las estructuras que aparecen en dicho gráfico. (SEÑAL).

Esparcidos por toda la zona central observas numerosos haces vasculares dispuestos en forma concéntrica. Si detallas uno de estos haces vasculares con los objetivos de 10 ó 40X del microscopio, observarás los principales componentes histológicos de este sistema vascular. (SEÑAL). Primero, hacia la parte central una serie de células conductoras grandes con espesamientos de lignina en sus paredes (añada safranina para una mejor observación). Estas células son parte del xilema son denominadas vasos y constituyen uno de sus elementos básicos que lo conforman. Los vasos están formados a su vez por miembros del vaso o elementos traqueales del xilema (su nombre se asocia al parecido con la traquea de nuestro aparato respiratorio). Otros componentes del xilema son las traqueidas. Estas últimas también son células elongadas con paredes engrosadas y sin protoplastos al igual que los miembros del vaso. Finalmente al xilema se añaden, células parenquimáticas que almacenan diferentes sustancias.

El floema, en este haz vascular, está representado por dos porciones una externa (Ver figura 16) y una interna. Los haces vasculares caracterizados por esta disposición son denominados bicolaterales. El floema es entonces el componente vascular responsable de la conducción de las sustancias elaboradas. Sus principales células conductoras son los elementos cribosos los cuales pueden ser células cribosas, y miembros de los tubos cribosos. El término criba se refiere a una serie de poros que abundan en la unión de dos elementos cribosos continuos. Este conjunto de poros, denominado área cribosa permite entonces la continuidad de los protoplastos de tales elementos cribosos. Por su parte en los miembros de tubos cribosos, además de áreas cribosas, aparecen zonas con poros de mayor diámetro localizados generalmente en los extremos; las placas cribosas. Entonces la unión de varios miembros de tubos cribosos, interrumpidos por las placas cribosas, forman los tubos cribosos, quienes son realmente los verdaderos elementos conductores del floema. Finalmente las células parenquimáticas, también se asocian a los elementos floemáticos en su constitución. Ubique cada una de las estructuras de las que se han hecho referencia en los gráficos 16 y 17 de la página No. 10 (SEÑAL).

Observa las figuras 17, 18, 19, 20, 21, 22, 23 y 24. Lee cuidadosamente las referencias de cada figura (SEÑAL). Podrás haber notado que los elementos xilemáticos y sus constituidos, los vasos, presentan espesamientos diversos. Así en los períodos de elongación o expansión de los órganos, las primeras estructuras xilemáticas, originadas del procambium constituyen el xilema primario. Las células xilemáticas, formadas inicialmente y de diámetro menor (Ver figuras 11, 12, 15, 16 y 17), forman el protoxilema. (SEÑAL). Los vasos de este tipo de xilema tienen espesamientos de lignina en forma anillada, o espirilada, los cuales, como se dijo anteriormente son comunes en regiones en pleno crecimiento. Los espesamientos anulares y espirilados son destruidos durante los procesos de elongación. El metaxilema, es decir el resto de xilema primario formado posteriormente se caracteriza por tener células conductoras de mayor diámetro y además membranas más gruesas que el protoxilema; es decir son más lignificadas. Los vasos que constituyen este tipo de xilema, suelen ser escaleriforme, reticulados o punteados (Ver figura 20 y 24), los cuales estan presentes en zonas que han cesado su alargamiento. (SEÑAL). Todas estas estructuras xilemáticas son de origen primario y constituyen en sí un sistema vascular primario, originado como se sabe del procambium. El sistema vascular secundario se origina del cambium y está presente en aquellas plantas que exhiben un crecimiento secundario durante su desarrollo. Este sistema será analizado posteriormente en otra actividad práctica.

Ejercicio 5. Procede a leer detenidamente los señalamientos indicados en este ejercicio y realiza las actividades que referimos (SEÑAL). Muchos tallos y raíces se han adaptado para el almacenamiento de algunas sustancias alimenticias elaboradas por la propia planta. La predominancia de células parenquimáticas en estos órganos de reserva es una característica aún más convincente de la función específica de estas partes del vegetal. Toda esa masa de parénquima está totalmente irrigada por tejido vascular. Esto asegura tanto el suministro de la materia prima para la asimilación (agua y sales minerales), como el transporte de pequeñas cantidades de las sustancias elaboradas por ese órgano a otras zonas de la planta donde se requiere tal producto para el continuo desarrollo. La actividad de suministro de materia prima es función del xilema, en cambio, que el transporte del material elaborado lo realiza el floema. Finalmente debes saber que el crecimiento en grosor de este tipo de órgano de almacenamiento, es producto de la actividad de zonas de cambium las cuales, además de producir tejido vascular, forman células parenquimáticas adicionales que incrementan así el volumen y el grosor del órgano vegetal. (Ver figuras 25 y 26) (SEÑAL).

La mayoría de estos órganos de reserva, almacenan sustancias orgásticas; compuestos que se forman como producto del metabolismo, es decir, las funciones digestivas de la célula. El <u>almidón</u>, es una de esas sustancias orgásticas, que se desarrolla en forma de granos en los plastidios de la célula. Particularmente este elemento de reserva se forma en los cloroplastos durante el proceso fotosintético. Los granos de almidón varian en forma y tamaño. Comúnmente presentan como capas concéntricas, que parten de un punto central denominado <u>hilo</u> (Ver figura 25). La seriación de capas concéntricas se debe a la forma alterna en que se disponen los componentes básicos de la molécula de almidón y la secuencia parece estar determinada tanto por factores externos e internos del órgano donde los gránulos se forman. Entonces el almidón, constituye una verdadera sustancia de reserva que pueden ser utilizados tanto por la propia planta para el sustento como por otros muchos organismos vivos y entre éstos nosotros los humanos. Para nuestra dieta, es esencial y se encuentra depositado principalmente en el parénquima, corteza, médula y tejidos vasculares de raíces, tallos, hojas, frutos, semillas, etc. De respuesta a las preguntas que se señalan en la página No. 13 y ubica en las figuras 25 y 27 las estructuras que se han indicado en referencia al ejercicio 5 (SEÑAL).

<u>Ejercicio 6</u>. Cuidadosamente lee las indicaciones de este ejercicio. Realiza el montaje señalado (SEÑAL). Como producto de las múltiples funciones de la célula vegetal, pueden formarse <u>cristales</u>, los cuales son generalmente acumulación de <u>Oxalto de Calcio</u>. Pueden tomar varias formas y tamaños; alargados en forma de lanzas o agujas llamados <u>rafidios</u>; rectangulares o primáticos denominados <u>prismas</u>; agregados de cristales primáticos llamados <u>drusas</u> entre los más importantes. Los rafidios son comunes en pecíolos o tallos, los prismas en hojas y las drusas en cladolios de cactus, raíces u hojas.

Otro compuesto químico que participa en la formación de cristales en la célula vegetal es el <u>Carbonato de Calcio</u>. Estas formaciones no son tan comunes como las de Oxalato de Calcio. Los compuestos carbonatados están asociados generalmente a la pared celular, formando cuerpos prismáticos denominados <u>cistolitos</u> (Ver figura 28) (SEÑAL). Todos los tipos de cristales referidos se desarrollan generalmente en las vacuolas de la célula. Son considerados como productsos que se forman en el metabolismo y reciclaje del calcio.

Anteriormente, en nuestras consideraciones hechas en relación a los plastidios y los pigmentos que estos encierran, nos faltó comentar uno de estos colorantes vegetales: <u>las antocianinas</u>. Estos pigmentos son los responsables de las coloraciones azuladas, moradas, rojos escarlatas y púrpura de algunas células vegetales. A diferencia con los otros pigmentos como la clorofila, las antocianinas son solubles en agua (observe el fenómeno al colocar la epidermis de Suelda con suelda en su montaje con una gota de agua). Este pigmento está disuelto en el <u>jugo celular</u>, es decir en los contenidos líquidos de las vacuolas.

Tienen que ver también estos pigmentos en el cambio de coloración de los frutos al madurar. Finalmente, participan directamente, enmascarando los pigmentos clorofílicos de las hojas, en el multicolor evento que presentan la mayoría de formas arbóreas de las zonas templadas durante el otoño, poco antes de perder totalmente sus hojas. De respuesta a las preguntas que se señalan en la página 15 y ubica en las figuras 27 y 28 las estructuras que se han indicado en referencia al ejercicio 6. (SEÑAL).

Ejercicio 7. Procede a dar lectura a las indicaciones que se señalan en este ejercicio. Realiza luego el montaje correspondiente. (SEÑAL). Entre los tejidos fundamentales, el colénquima y el esclerénquima son de extraordinaria importancia en la planta y que básicamente son ellos los que contribuyen mayormente a dar rígidez y soporte al órgano vegetal. Por su parte el esclerénquima tiene como se indicó, pared celular lignificada (coloque una gota de safranina para la observación en su preparado). Frecuentemente se encuentran asociadas este tipo de células con tejidos vasculares (Ver figura 30) o con otras células de tipo parenquimático (Ver figura 29) (SEÑAL). Este tipo de asociación es continuo y ha creado cierto problema en delimitar la identidad del tejido esclerenquimático. Ello obedece, principalmente, a que hay células parenquimáticas que se esclerifican, es decir endurecen su pared celular como una célula esclerenquimática.

Las células esclerenquimáticas pueden ser de dos tipos: esclereidas y fibras. Las primeras (Ver figuras 29 y 31) se encuentran distribuidas en todo el cuerpo de la planta y varía generalmente en su forma. (SEÑAL). Están agrupadas generalmente en masas formando parte de diversos órganos vegetales (tallos, hojas, frutos y semillas), se denominan Idioblastos, cuando se encuentran aisladas. Estas células son por lo general ramificadas, encontrándose comúnmente en los espacios intercelulares presentes en el mesófilo diferenciado de muchas hojas (Ver figura 31) (SEÑAL). En los frutos ocupan zonas considerables, entremezclados con la parte carnosa de estos órganos vegetales. Su dureza se siente fácilmente al masticar parte de esa masa comestible del órgano. Por tal razón son denominadas células pétreas. Le dan entonces consistencia, rígidez y soporte a la estructura frutal. De respuesta a las preguntas formuladas en la página 17 (SEÑAL).

Las fibras, como se dijo anteriormente, estan en varias partes de la planta, preferiblemente, asociadas con los tejidos vasculares (Ver figura 30) (SEÑAL). Le dan consistencia y firmeza tanto al floema y xilema que constituyen los haces vasculares (fibras xilares). Otro tipo de fibras no asociadas al xilema, denominadas entonces extraxilares (fuera del xilema), pueden estar ligadas al floema, a la corteza ó a la periferia del cilindro vascular. Cualquiera que sea su situación en el órgano vegetal, las fibras se caracterizan por ser células alargadas con su pared secundaria más o menos engrosada. Estas entonces constituyen las "fibras" comerciales y suelen ser duras y blandas. Las duras son generalmente fibras de hojas como la del Sisal, Cáñamo, etc., las cuales tienen membranas muy lignificadas y textura dura y rígida. Las fibras blandas pueden o no estar lignificadas, pero todas son suaves y flexibles como en el Lino, Ramio, etc. Ubique las estructuras referidas en este ejercicio en las figuras que aparecen en la página 18. (SEÑAL).

Para concluir esta sesión de laboratorio permítanme darles algunas ideas recapitulantes. Aunque has observado una gran variedad de células vegetales, cada una de ellas es el resultado de modificaciones estructurales de un tipo básico celular para cumplir entonces funciones diferentes en la planta. Los botánicos han reconocido três sistemas de tejidos: el fundamental, el vascular y el dérmico. El sistema fundamental consiste de los siguientes tejidos: parénquima, colénquima y esclerénquima. El vascular lo constituyen el xilema y floema. Finalmente el dérmico, está constituido por la epidermis. A continuación podrás observar un montaje realizado, identificado en el mesón No. 2, el cual tendrás oportunidad de ver con la compañía de uno de los asistentes quien estará en capacidad de aclararte cualquier duda que se te presente. Al concluir esta actividad regresa a tu puesto para informarte de la actividad final (SEÑAL).

Antes de retirarse, esté seguro de haber completado, repito completado, satisfactoriamente los requerimientos indicados en los objetivos específicos que tienes en tu puesto de trabajo.

Hasta la próxima oportunidad, y no olvides realizar el análisis exploratorio No. 2 antes de abandonar el laboratorio. Tendrás un poco de música para acompañarte, mientras limpias y recoges tu puesto de trabajo. Hasta luego (SEÑAL).

INSTITUTO UNIVERSITARIO PEDAGOGICO EXPERIMENTAL
DEPARTAMENTO DE CIENCIAS EXPERIMENTALES
AREA DE BIOLOGIA
BARQUISIMETO

GUION PARA EL MONTAJE AUDIO - VISUAL.

La célula y los tejidos de una planta se derivan generalmente de un cigoto, es decir a partir de la fusión de las células sexuales masculinas y femeninas. Posteriormente, mediante diferentes fases de su desarrollo, el cigoto forma una estructura multicelular denominada embrión. Bajo numerosos procesos embrionarios se va formando un cuerpo vegetal diferenciado en tejidos, sistemas y órganos que en sí van dando conformidad a la planta adulta. Los meristemos, es decir el conjunto de células embrionarias con altas capacidades de dividirse y originar nuevas estructuras celulares con formas y funciones diversas, son las unidades responsables para iniciar los procesos de diversidad celular e histología en una planta a partir de las zonas meristemáticas que se forman en el embrión. (Observe la proporción del núcleo en relación con el tamaño de la célula). Las principales regiones en las que se localizan los meristemos son entonces, los extremos del cuerpo embrionario. Así, se forma un meristemo apical del tallo y otro de la raíz. Los demás órganos de la planta, hojas, flores y frutos se asocian al meristemo apical del tallo para su total o parcial desarrollo.

La célula vegetal, ya con características morfológicas y funcional es específicas, adquieren posiciones y propiedades en relación a su ubicación en la planta. Así, algunas, células tienen un lumen grande, un citoplasma bien esparcido, núcleo delimitado, cloroplastos distribuidos en el citoplasma con membrana celular y pared celular demarcadas. Tales características coinciden con la descripción de la unidad celular básica. Cualquiera que sea la estructuración de la forma celular, ésta siempre deriva de agregados celulares que a la vez constituyen las unidades básicas del cuerpo de la planta. Estas se han denominado sistemas de tejidos, entre éstos se encuentran el sistema dérmico, el vascular y el fundamental.

El Sistema dérmico, conformará la epidermis, es decir la capa externa protectora que cubre el cuerpo de la planta. Las células epidérmicas varian en forma pero amenudo son tubulares con membranas delgadas, protoplasto vivo y pueden almacenar varios productos de la actividad celular. Algunas células epidérmicas contienen plastidios con poco actividad fotosintética, además de contener antocianinas, en sus vacuolas. Otras células epidérmicas especializadas estan representadas por las células oclusivas de los estomas, los cuales como se sabe son estructuras controladoras del intercambio gaseoso e hídrico en la planta.

El sistema fundamental, incluye aquellos tejidos básicos que conforman el cuerpo vegetal. Aquí se incluyen principalmente las células parenquimáticas. Estas unidades celulares forman los tejidos que constituyen la corteza y médula de la raiz y el tallo, al igual que el mesófilo de las hojas. Las células parenquimáticas tienen protoplastos vivos con altas potencialidades para la división celular. Estas varian en forma; a menudo son poliédricas, pero pueden hacerse elongadas y hasta de forma estrellada en el aerénquima de algunas plantas acuáticas.

Las células colenquimáticas, estructuras citológicas con paredes engrosadas en forma irregular, se derivan del mismo sistema fundamental, por lo que se consideran que tienen parentezco con las células parenquimáticas. Este tipo de células se localizan en los tallos, pecíolos y a lo largo de las venas de las estructuras foliares. Principalmente, actuan estas células en el soporte de órganos que todavía experimentan desarrollo y crecimiento. Por su parte, las células esclerenquimáticas, con paredes aún más lignificadas que las unidades celulares del colénquima, participan en forma más efectiva en la dotación de soporte y rígidez en los elementos maduros de la planta. Generalmente se asocian con los cordones vasculares de todos los órganos vegetales. Las células esclerenquimáticas carecen de protoplastos en su estado maduro, exhibiendo variantes en su forma desde elongadas hasta poliédricas.

El sistema vascular contiene dos clases de tejidos conductores, el xilema encargado de la conducción de agua y sales disueltas y el floema que se encarga del transporte de sustancias alimenticias elaboradas por la planta. El tejido xilemático consiste de diversas unidades o elementos celulares para sus funciones de conducción, almacenamiento y soporte. Las traqueas o vasos cumplen dicha función, mediante las diversas configuraciones de la pared celular, formando así estructuras elongadas (vasos) con espesamientos anulares, espiralados, reticulados y punteados. Cada uno de estos vasos se asocian en los sistemas vasculares de la mayoria de órganos vegetales y su presencia o ausencia dependerá de la actividad de crecimiento que se realice en el órgano vegetal en cuestión.

Otra de las estructuras celulares del xilema que participa activamente en la conducción de agua son las traqueidas las cuales son células más o menos elongadas sin protoplasto vivo, pero a diferencia de las traqueas o vasos, carecen de perforaciones, pero al igual que los vasos poseen punteaduras por donde ocurre el paso de agua de célula a célula, en este tipo de componentes xilemáticos.

Células esclerenquimáticas, también forman parte del xilema. Particularmente las fibras con formas elongadas y paredes lignificadas se asocian al sistema vascular para incrementar la rígidez, mientras el mencionado sistema participa efectivamente en la conducción de agua y sales disueltas. Finalmente, células parenquimáticas se encuentran presentes en el xilema y su composición y función será estudiado posteriormente en otra sesión de laboratorio.

El tejido floemático está constituido por varios tipos de células y está presente en toda la planta. Su función es entonces la conducción y almacenaje de sustancias alimenticias y dándole soporte también a las células especializadas que participan en dicha función. Las principales células son las células cribosas y los miembros de los tubos cribosos.

Todas estas unidades de conducción tienen sus protoplastos bien modificados para facilitar así una mejor actividad de transporte. Las paredes celulares de un elemento criboso varian en grosor con poros de diferentes diámetros tanto en las paredes como en los extremos de los elementos cribosos, formando entonces las áreas cribosas. Las zonas perforadas localizadas entre los extremos de dos elementos cribosos se denomina placas cribosas. Estas estructuras son homólogas a las perforaciones presentes en las paredes de los miembros de los tubos del xilema. La diferencia en cuanto a la sustancia constituyente de tales poros o perforaciones es que en los primeros se denomina calosa un polisacárido, y en los segundos la lignina, un polímero.

Células esclerenquimáticas también se asocian al floema. En este caso encontramos una mayor diversidad celular de este constituyente en comparación con el xilema. En este caso las esclereidas se agregan a las fibras tradicionales que constituyen el tejido floemático. Por último, las células parenquimáticas también integran al floema y sus funciones, además de la de almacenamiento, serán estudiadas en próximas actividades prácticas.

VITA

Raúl Enrique Rivero was born in Barquisimeto, Venezuela on March 25, 1951 to Guillermo and Conchita Rivero. He attended elementary and secondary schools in Barquisimeto, and enrolled at the Instituto Universitario Pedagógico Experimental de Barquisimeto (I.U.P.E.B.) in July, 1969. He completed his teacher preparation program in biology in this college in July, 1973.

After a two-year college teaching experience in Venezuela, he began studying toward a Master's degree in Science Education at The University of Tennessee, Knoxville. This degree was awarded in 1976.

Raúl taught botany at the Instituto Universitario Tecnológico de las Llanos at Calabozo, Venezuela and the I.U.P.E.B. where he is employed as an Associate Professor of the Natural Science and Mathematics Department. He began his doctoral studies at The University of Tennessee, Knoxville, in 1979, and received the Doctor of Education with a major in Curriculum and Instruction in June 1984. Emphasis in his program was in Science Education and Botany. While enrolled at The University of Tennessee, Knoxville, he was supported by the "Gran Mariscal Ayacucho" Venezuelan Foundation.

The author has presented research papers to Botanical and Environmental Congresses in Venezuela. He is a member of the National Association for the Advancement of Science in his country and a member of the American Fern Society, Inc., in the United States.