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This study was designed to evaluate the relative effectiveness of a new college general biology course which utilized an audio-tutorial laboratory as contrasted with a traditional lecture course.

Five biology classes with 720 students at the Kansas State Teachers College in Emporia, Kansas, participated in the study. The five classes were composed of two traditional biology classes and three audio-tutorial classes. Seventy students, 35 male and 35 female, were selected from each of the two biology groups.

The design of the study was a 2 × 2 factorial type. The factors were the two biology courses, audio-tutorial and traditional, and the two sexes. The data were treated by analysis of variance.

Criterion tests used in a posttest situation were the _Test on Understanding Science, Form W_, an _Attitude Scale_, and an investigator prepared _General Biology Test_. The latter test was designed

to measure student comprehension of biology on the basis of ability to recall information, ability to show relationships between bodies of knowledge, ability to apply knowledge in new situations, and ability to use skills involved in understanding of scientific problems. Total test scores for the three criterion tests and subtest scores for the Test on Understanding Science, Form W, and the General Biology Test were compared.

The data presented in this study indicated that the audio-tutorial course was as effective as the traditional course with which it was compared. In general, students in the audio-tutorial classes attained higher scores on the criterion tests than did students in the traditional classes. However, none of the differences were significant.

Results of the analyses indicated that there was a difference between the sexes in ability to show relationships between bodies of knowledge, for the male students in both biology courses scored significantly higher on that level of understanding of biology.

The criterion tests and the various subtests seemed to measure distinctly different understandings about science, levels of comprehension of biology, and attitude toward science; however, there was a strong positive correlation between attitude toward science and ability to apply knowledge to new situations.

# An Evaluation of an Experimental Biology Course Employing Some Cognitive and Noncognitive Achievements as Criteria

by

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# AN EVALUATION OF AN EXPERIMENTAL BIOLOGY COURSE EMPLOYING SOME COGNITIVE AND NONCOGNITIVE ACHIEVEMENTS AS CRITERIA

## I INTRODUCTION

It is common practice among biology academe to cite the population explosion, the increased college enrollments, and the information explosion in biology as the source of obstacles to offering a more effective introductory college biology course. Certainly, these are factors of no small consequence; but man, within limits, will conceive of some means of accommodating numbers alone in the foreseeable future. Another factor, which may well be at least equally important, is the development of a college course that imparts an awareness of the intellectual basis of science and a permanent interest in science. The present rapid increase in biological knowledge should offer a unique opportunity to develop a course that would impart to the student some understanding of the persons and processes responsible for that new knowledge. However, there is no evidence that this is occurring.

That science is and will continue to be a dominant force in our society is a foregone conclusion. Consequently, the task of producing a scientifically literate citizenry is one that is gaining in importance as a responsibility of science teaching. While the term "scientific literacy" may have a multiplicity of meanings, it is generally agreed that understanding the nature of science constitutes a part of scientific literacy (64). The importance of that aspect of science teaching is reasonably well summarized by Glass (31, p. 7) when he states:

> For a scientific society to be democratic, the people must understand the nature of the dominating force in their lives. The problem is that simple. For us, this does not mean teaching just a lot of facts about science, or even a lot of important concepts and principles--that the earth is round and not flat, and that the atom has energy in it, and that the genes control the paths of development. All those things are important. But far more important than any of those facts and concepts is the comprehension on the part of the learner of the <u>nature</u> of the process whereby knowledge increases and whereby man acquires new understandings of life and of his universe.

In general, it is the cognitive changes in learners which most teachers attempt to evaluate. These are also the changes which are most often emphasized in the materials of instruction and the teaching-learning process (28, p. 379). This is not intended to imply that all biology courses have the sole objective of bringing about only cognitive changes in learners. Purcell writes that (67, p. 533):

> It is generally agreed that there are legitimate educational objectives associated with the area of feelings and emotions, the affective domain, which include such things as interests and values.

But achievement tests alone are not adequate to the task of determining the achievement of all objectives. Tests must be constructed and used to evaluate changes in the noncognitive areas. Whenever a school or a subject has goals beyond the acquisition of subject matter, it must be responsible for appraising its pupils' progress in all these areas (91, p. 213).

The importance of the attitude toward a discipline is succinctly stated by Foster when he writes that (26, p. 416):

> The attitude is probably more important than facts. . . . Even though many of the facts will certainly be forgotten, the attitudes tend to remain. This is important enough to justify the time and energy spent on a school subject even though the facts may be forgotten and the skills lost through the passage of time.

Research on the teaching of college biology and on innovations in college biology has been limited in quantity and scope. In summarizing research on college biology curriculum, Van Deventer states that (92, p. 336-337):

> Whereas the physicists have been quite cognizant of the need for curricular change, and the chemists have been moderately active, college biologists have so far done little to meet the challenge posed by the rapid advances in biological knowledge and of new curricular developments in the high school. Although several contributions, mainly from nationally sponsored and financed groups, have set forth the necessity of updated training for prospective teachers, only a few college biology faculties have shown concern for redesigning the general undergraduate offerings.

Even where curricular experiments have been initiated they generally concern themselves with single factors, single instruments, and single dimensions (25).

Regardless of the long history of comparative inactivity in curricular innovations on the part of college biologists, there is concrete evidence that the situation is changing. The organization of the Commission on Undergraduate Education in the Biological Sciences represents an emergent interest in the area of curriculum improvement. As this interest is translated into some kind of revision of existing offerings, it is of utmost importance that the innovations be submitted to an incisive and continuous evaluation. There has been an increase in both the quantity and quality of evaluation techniques and instruments for assessing some innovations.

## Statement of the Problem

The purpose of this study was to compare the understandings about science, attitude toward science, and mastery of biological concepts of students enrolled in a traditional lecture biology course to students enrolled in a newly designed biology course employing an audio-tutorial laboratory at the Kansas State Teachers College in Emporia, Kansas.

More specifically, the following questions were of primary concern in the study:

1. To what extent do students completing a lecture biology course differ from audio-tutorial students in understanding of science as determined by the Klopfer Test on Understanding Science, Form W (TOUS)?
2. To what extent do students completing a lecture biology course

differ from audio-tutorial students in attitudes toward science as determined by an <u>Attitude Scale</u>?

3. To what extent do students completing a lecture biology course differ from audio-tutorial students in the understanding of selected biological concepts as determined by a <u>General Biology Test</u>?

This study was designed to investigate the above questions which were based on the stated objectives of the two introductory college biology courses for non-science majors.

## Importance of the Study

A majority of the students who matriculate at the Kansas State Teachers College prepare for the teaching profession. Three semester hours credit in science is the minimum science requirement for the baccalaureate degree and introductory general biology is the science course most frequently selected in order to satisfy the science requirement. Except for pre-service elementary teachers and physical education and psychology majors, who are required to complete one additional science course, the general biology course is frequently the last formal encounter many students will have with science.

During the 1964-1965 academic year, a curriculum committee consisting of persons from the biology faculty formulated tentative suggestions for an eventual revision of the offerings in biology. The curriculum committee also proposed a revision of the introductory general biology course in order that it would better achieve its stated objectives which are as follows:

1. To develop an understanding of some of the more important concepts and principles of biology.
2. To develop an understanding and appreciation of living things, including life processes.
3. To show how to approach problems scientifically, to be open minded, unprejudiced, critical in thinking, and intellectually honest.
4. To teach technical terms of biology that may be found in literature of everyday life--newspapers, magazines, radio, and television.
5. To help apply a knowledge of biology and the scientific method to the solution of personal and social problems.
6. To develop an interest in biology from an aesthetic, as well as, a practical viewpoint.

The introductory general biology course was taught by means of lectures which were supplemented by films, slides, and study guides. There were two classes of approximately 300 students and one of approximately 75 students each per semester. The laboratory phase of the course for non-majors was deleted in 1959 after a study based on students' ability to recall factual information showed no difference between the lecture and lecture-laboratory course (10). The lack of facilities as enrollment increased influenced the decision to delete the laboratory phase of the course for non-majors. The lecture-laboratory course was retained for biology majors.

Several factors were considered by the curriculum committee prior to recommending a revision of the traditional course. The course objectives were considered adequate and desirable, but it was generally conceded that other means of achieving the objectives should be explored. Although there was evidence that laboratory work made little or no contribution to the learning of factual information, the concensus was that the inclusion of appropriate laboratory activities could make measurable contributions to the achievement of the course objectives. Finally, it was suggested that any changes should be subjected to as objective and comprehensive an evaluation as time and suitable instruments would permit.

Interest in the laboratory phase of the course increased after reviewing the operation of the audio-tutorial type of laboratory designed by Postlethwait at Purdue University (65). In view of the limited facilities, the audio-tutorial laboratory seemed the only feasible means of accommodating all students enrolled in general biology. Subsequently, a pilot course was developed and offered to about 80 students during the spring semester of the 1965-1966 academic year.

The new course, designated audio-tutorial because of the laboratory, differed from the traditional course in several respects. The laboratory consisted of six booths which were provided with all equipment and materials needed for an exercise in addition to instructions which were either tape recorded or mimeographed or both. Problems encountered when attempting to interweave meaningful laboratory activities into a course based on existing textbooks resulted in the decision to abandon the use of existing general biology texts. Instead, two selections The Cell (85) and Adaptations (93) from the Foundations of Modern Biology Series and 25 Scientific American offprints were selected as study material for the pilot course. The audio-tutorial course differed, then, from the traditional course, in that it provided laboratory activities and relied on more diverse sources for the lecture material.

The objectives of the traditional and audio-tutorial courses were intended to serve as guidelines for the teaching and learning of biology. As such, the objectives should serve as the focal point when selecting instruments for the purpose of measuring and evaluating student achievement as well as the effectiveness of the courses for both male and female students. A comparison of the behavioral changes of students who complete the parallel courses should be basic to the subsequent design and choice of the type of course to be offered in introductory biology. The results should provide information which would be of value in establishing guidelines for the eventual revision of other biology courses.

## Definition of Terms

### Understanding Science

Understanding of science means the comprehension a student possesses about the nature of science, about the role of science in our society, and about how scientists behave and operate, both as scientists and as citizens. More specifically, the understanding of science includes the following (14, p. 3-6):

1. Science as an institution: the human element in science, communication among scientists, scientific societies, instruments, international character of science, interaction of science and society.
2. Scientists as people: generalizations about scientists as people, institutional pressures on scientists, abilities needed by scientists.
3. Processes and aims of science: generalities about scientific methods, tactics and strategy of sciencing, theories and models, aims of science, controversies in science, science and technology, unity and interdependence of the sciences.

These are the understandings which define the term "understanding of science" for the purpose of this study.

Attitude

The term "attitude" employed in this study refers to how an individual feels about science. It is an emotionalized feeling, organized through experience, either positive or negative regarding science (24).

## Basic Assumptions

In this study it was assumed that:

1. The Test on Understanding Science, Form W validly and reliably measures selected aspects from the universe of understandings of science.
2. The General Biology Test validly and reliably measures the understanding of selected aspects of biology.
3. The achievement in general biology and understanding of science can be separated into components for the purpose of analytical evaluation.
4. The Attitude Scale validly and reliably measures attitudes toward science.
5. The General Ability Test validly and reliably measures the student's general ability.
6. Understanding of science, attitudes toward science, and understanding of biology are common objectives of the

lecture and audio-tutorial biology courses.

## Hypothesis to be Tested

The stated objectives for the two biology courses being subjected to a comparison in this study are identical. The means of achieving the objectives differ, however. The attainment of the objectives in the lecture course is based on the content of a published textbook while the attainment of the objectives in the audio-tutorial course is based on two books dealing with special topics in biology, periodical articles, and laboratory activities.

The general hypothesis was that students completing the audio-tutorial course would have attained a higher degree of mastery of biological concepts, more positive attitudes toward science, and a higher degree of understanding about science than students completing the traditional course in biology. Therefore, it was predicted that students completing the two different biology courses would differ in their mastery of biological concepts, understandings about science, and attitude toward science.

To test the general hypothesis, the following null hypotheses were established for statistical treatment:

1. There is no difference in attitude toward science between students completing a traditional biology course and the attitude toward science of students completing an audio-tutorial

course based upon scores on the _Attitude Scale_.

(a) There is no difference in attitude toward science between males and females who have completed a traditional and an audio-tutorial course based upon scores on the _Attitude Scale_.

(b) There is no interaction between the type of biology course completed and sex on the attitude toward science based upon scores on the _Attitude Scale_.

2. There is no difference in achievement on the _General Biology Test_ between students completing a traditional biology course and achievement on the _General Biology Test_ of students completing an audio-tutorial course.

(a) There is no difference in achievement on the _General Biology Test_ between males and females who have completed a traditional biology course and an audio-tutorial course.

(b) There is no interaction between the type of biology course completed and sex on achievement on the _General Biology Test_.

3. There is no difference in the ability to recall information based upon scores on the _General Biology Test_ between students completing a traditional biology course and the ability to recall information based upon scores on the _General Biology Test_

of the students completing an audio-tutorial course.

(a) There is no difference in the ability to recall information based upon scores on the General Biology Test between males and females who have completed a traditional and an audio-tutorial course.

(b) There is no interaction between the type of biology course completed and sex on the ability to recall information based upon scores on the General Biology Test.

4. There is no difference in ability to show relationships between bodies of knowledge based upon scores on the General Biology Test between students completing a traditional biology course and the ability to show relationships between bodies of knowledge based upon scores on the General Biology Test of students completing an audio-tutorial course.

(a) There is no difference in the ability to show relationships between bodies of knowledge based upon scores on the General Biology Test between males and females who have completed a traditional and an audio-tutorial course.

(b) There is no interaction between the type of biology course completed and sex on the ability to show relationships between bodies of knowledge based upon scores on the General Biology Test.

5. There is no difference in the ability to apply knowledge in new

situations based upon scores on the General Biology Test between students completing a traditional biology course and the ability to apply knowledge in new situation based upon scores on the General Biology Test of students completing an audio-tutorial course.

(a) There is no difference in the ability to apply knowledge in new situations based upon scores on the General Biology Test between males and females who have completed a traditional and an audio-tutorial course.

(b) There is no interaction between the type of biology course completed and sex on the ability to apply knowledge in new situations based upon scores on the General Biology Test.

6. There is no difference in the ability to use skills involved in understanding scientific problems based upon scores on the General Biology Test between students completing a traditional biology course and the ability to use skills involved in understanding scientific problems based upon scores on the General Biology Test of students completing an audio-tutorial course.

(a) There is no difference in the ability to use skills involved in understanding scientific problems based upon scores on the General Biology Test between males and females who have completed a traditional and an audio-tutorial course.

(b) There is no interaction between the type of biology course completed and sex on the ability to use skills involved in understanding scientific problems based upon scores on the <u>General Biology Test</u>.

7. There is no difference in understanding of science based upon total <u>TOUS</u> scores between students completing a traditional biology course and understanding of science based on total <u>TOUS</u> scores of students completing an audio-tutorial biology course.

   (a) There is no difference in understanding of science based upon total <u>TOUS</u> scores between males and females who have completed a traditional and an audio-tutorial course.

   (b) There is no interaction between the type of biology course completed and sex on understanding of science based upon total <u>TOUS</u> scores.

8. There is no difference in understanding about the scientific enterprise based upon scores on Area I of <u>TOUS</u> between students completing a traditional biology course and understanding about the scientific enterprise based upon scores on Area I of <u>TOUS</u> of students completing an audio-tutorial course.

   (a) There is no difference in understanding about the scientific enterprise based upon scores on Area I of <u>TOUS</u> between males and females who have completed a traditional and an audio-tutorial course.

(b) There is no interaction between the type of biology course completed and sex on understanding about the scientific enterprise based upon scores on Area I of <u>TOUS</u>.

9. There is no difference in understanding about scientists based upon scores on Area II of <u>TOUS</u> between students completing a traditional biology course and understanding about scientists based upon scores on Area II of <u>TOUS</u> of students completing an audio-tutorial course.

(a) There is no difference in understanding about scientists based upon scores on Area II of <u>TOUS</u> between males and females who have completed a traditional and an audio-tutorial course.

(b) There is no interaction between the type of biology course completed and sex on understanding about scientists based upon scores on Area II of <u>TOUS</u>.

10. There is no difference in understanding about the methods and aims of science based upon scores on Area III of <u>TOUS</u> between students completing a traditional biology course and understanding about the methods and aims of science based upon scores on Area III of <u>TOUS</u> of students completing an audio-tutorial course.

(a) There is no difference in understanding about the methods and aims of science based upon scores on Area III of TOUS between males and females who have completed a traditional and an audio-tutorial course.

(b) There is no interaction between the type of biology course completed and sex on understanding about the methods and aims of science based upon scores on Area III of TOUS.

## Limitations of the Study

1. The population was composed of students enrolled in general biology for non-majors during the fall semester of the 1966-67 academic year at the Kansas State Teachers College.
2. The sample for the study was limited to the following groups which were selected from the population:
   (a) A random sample from two traditional classes in general biology for non-majors at the Kansas State Teachers College.
   (b) A random sample of males from the students enrolled in three audio-tutorial classes and all females enrolled in three audio-tutorial classes at the Kansas State Teachers College.
3. The understanding of science, understanding of selected biological concepts, and attitudes toward science were the only factors of concern in this study.

4. The instrument used to measure understanding of science was a 40 minute test limited to the following areas:

   (a) Understandings about the scientific enterprise.

   (b) Understandings about scientists.

   (c) Understandings about the methods and aims of science.

5. The instrument used to measure achievement in biology was a 50 minute test limited to the following areas:

   (a) The ability to recall and reorganize materials learned.

   (b) The ability to show relations between bodies of knowledge.

   (c) The ability to apply knowledge in new situations.

   (d) The ability to use skills involved in understanding scientific problems.

6. The instrument used to measure attitude toward science was a ten minute test consisting of 20 items.

7. Information used to describe the students and to assist in the interpretation of some data was furnished by the Office of the Registrar at the Kansas State Teachers College.

8. Because of the nature of enrollment procedures and class scheduling, the assignment of students to the traditional and audio-tutorial biology classes was non-random.

# II REVIEW OF RELATED RESEARCH

## Introduction

The effectiveness of the teaching of science in the secondary schools has been the subject of a far greater number of experimental studies than the teaching of science at the college level. For this reason, those studies of high school science, especially biology, which evaluated methods or objectives similar to the present study have been reviewed. The same criteria were also used in selecting a few studies of college science courses other than biology.

The related studies were grouped into three categories which were methods of instruction, attitudes toward science, and understanding of science. In those studies which deal with the comparison of instructional methods, the comparison was typically based on the student's acquisition of subject matter knowledge--the cognitive domain. Because the learning of biology comprised an integral part of the evaluation of methods, that aspect of the studies was included with the review of methods of instruction, rather than treated as a separate category.

## Methods of Instruction

A few studies have been made to determine if there is one particular method which is most effective in attaining instructional objectives in college biology.

College General Biology

Barnard (4) reported a study in which he compared the relative effectiveness of a lecture-demonstration method and a problem-solving method of teaching the biological portion of an orientation science course at the college level. The investigator prepared tests to measure four outcomes, which were as follows: recall of specific information, understanding of generalizations, abilities in problem-solving, and scientific attitudes. After analyzing the results, Barnard concluded that (4):

> 1. The lecture-demonstration method had some advantages over the problem-solving method with respect to achievement on tests covering specific information, although the results in all cases are not statistically significant.
>
> 2. Neither method had statistically significant advantages over the other with respect to achievement on tests measuring the understanding of generalizations.
>
> 3. The problem-solving method had statistically significant advantages over the lecture-demonstration method with respect to achievement on tests measuring certain abilities in problem solving.
>
> 4. The problem-solving method had statistically significant advantages over the lecture-demonstration method with respect to achievement on tests measuring scientific attitudes.

Breukleman, Andrews, and Novak (10) reported a controlled experiment in which three biology sections taught in large lecture groups without laboratory were compared with three taught in smaller lecture and laboratory groups. The study was carried on with successive groups of students for a three-year period. An analysis of the entrance tests of ability of the groups revealed no significant difference among them each year or over the three years. The investigators concluded that:

> (a) the lecture-only approach was apparently effective in teaching facts and principles;
>
> (b) lectures must be carefully planned and executed;
>
> (c) a greater proportion of staff hours must be provided for student conferences;
>
> (d) audio-visual aids and distribution of lecture outlines, study questions, and diagrams were needed.

They recommended further study of the effect of the lecture-only method on attitudes, ability to solve problems, and retention and understanding of biological concepts.

Olson (61) studied the results of two different methods of teaching in a general-education biology course to four classes. Two classes were taught by a teacher-centered method which used one textbook and audio-visual aids. The other two classes were taught a student-centered method in which the students planned their own work on a problem-approach basis. The latter group used six different textbooks and audio-visual aids. The evaluation instruments were an author-designed test to measure ability to use some of the inductive aspects of scientific thinking, forms X and Y of the Cooperative Biology Test, and Burmeister's Ability to Think Scientifically Test I A. He found that subject matter performance and scientific thinking ability increased significantly under both treatments. There was no significant interaction between either of the treatments and intelligence levels.

Snyder (77) studied the growth in knowledge of biology for 95 college freshmen during the 1959 academic year. In order to compare the relative effects of the introduction of a problem-solving, project technique to the traditional lecture-laboratory method, the population was divided into two statistically matched groups. Form X and Form Y of the Cooperative Biology Test were used as pretest and posttest respectively. Statistical analysis showed little superiority for the experimental method. There was an indication that more biological facts than biological principles were learned by students in the experimental group. The high-ability students seemed to profit more from the experimental method than the lower-ability students.

Dearden (20) reported a study in which six lecture sections under one lecturer were given four different experimental treatments. The contrasting laboratory treatments were (a) conventional individual laboratory, (b) demonstration laboratory, (c) workbook exercises, and (d) term reports. Using a pretest and posttest design he evaluated three outcomes: (a) biological knowledge, (b) scientific thinking, (c) logical attitudes. Although all treatments proved effective in increasing knowledge, none showed statistically significant superiority to the others. No treatment was superior to the others for students at different levels of ability. The three criterion tests were administered to a sample of students three months after completing the course. None of the treatments proved to be more effective from the standpoint of retention.

Gallentine (29) evaluated the effectiveness of utilizing overhead projection in collegiate undergraduate biological science courses in large lecture groups and in small lecture groups as compared to conventional instruction in similar groups using the chalkboard as a means of illustration. The experiment consisted of a comparison of differences on an embryology laboratory practical examination, an association transfer test, and the Watson-Glaser Critical Thinking Appraisal. There was an indication that instruction with overhead projection might have been responsible for an increase in students' ability to think critically.

Televised instruction has been the object of a number of research projects. Syrocki and Wallin (86) compared the effectiveness of the teaching of human biology by means of closed circuit television with teaching by an instructor in the classroom. The two methods were equally effective means of teaching human biology. The students participating in the study recommended the use of television for groups of 40 or more students but preferred small groups to large groups in an auditorium. Stickell (81) analyzed 250 reports of studies of television versus face-to-face instruction in all subject areas. He found that ten were interpretable, 23 partially interpretable, and 217 were uninterpretable. No difference in achievement was the typical conclusion. Miles and Van Deventer (52) reviewed recent studies dealing with televised instruction and concluded that findings of no significant differences in achievement between students taught by television and those taught conventionally were the usual outcomes. They cautioned that these conclusions should not be interpreted to mean that there is no loss when a class is taught by television rather than face-to-face because there is some indication that television seems to be slightly inferior to conventional instruction in most college situations.

Schefler (72) used college freshmen classes in biology to compare an inductive laboratory approach with a lecture-illustrative laboratory approach. The investigator and one other teacher each taught one experimental and one control class during a ten week study of a unit on genetics. There was an indication that the effects of teacher difference was of greater significance than the effects of method difference.

College Biological Sciences

Mattheis (49), in a controlled experiment with prospective elementary school teachers in a college science course, found that students taught in a conventional type laboratory expressed no differences in interest in science from an experimental group which worked on science projects during the laboratory periods. Neither method seemed to have a profound influence on achievement in subject matter.

Novak (58), using equated groups in a 43-student general botany class, sought to determine the effect of labeled photomicrographs supplied in addition to regular outline drawings in the laboratory on student achievement. Tests were administered on the average of every four weeks and the results compared. He found that the group receiving labeled photomicrographs achieved higher test scores in all instances, but the differences were insignificant.

Kuhnen (44) compared the effectiveness of field trips with a traditional laboratory in college general botany in gain in knowledge, in gain in ability to apply principles, and in increase in interest. The data revealed that there was little difference in gain in knowledge, all in favor of the laboratory group. Neither the laboratory nor the field trip contributed significantly to a gain in the ability to apply principles.

Lawson, Burmester, and Nelson (45) reported on the development of a teaching device called a "scrambled book" for natural science. It was primarily a self-administered objective test, with accompanying comments telling why each possible answer is right or wrong. The whole book was arranged like a taxonomic key, telling the student where to go for the next step or alternative. Then the entire instrument was scrambled so that items and explanations did not follow an orderly sequence. The scrambled book supposedly required that the student learn new ideas and that he use these ideas in test situations frequently involving deductive thinking. The scrambled book was used for one week in studying a unit on genetics. The experimental and control groups were given a test to measure ability to reason, analyze, interpret, and apply what had been learned. They concluded that the quality of learning was enhanced by the use of the scrambled book, but most students were not ready to dispense with the instructor.

Frings and Hichar (27) conducted a carefully planned and executed study of three laboratory teaching methods in college general zoology. A regular method using a manual in which identification and description of structures was illustrated with diagrams was compared with another method using unlabeled diagrams and accompanying lists of structures, and yet, another method employing the study of living specimens identical or related to those used in the other two procedures with suggested experiments and questions. The investigators found that the results of all methods were closely similar and suggested that the method used should depend on the preference of the instructor.

Stickley (82) developed three short sequences of programmed instruction to be used in conjunction with short, continuous loop, cartridge-loaded eight mm. motion pictures in medical pharmacology. He evaluated the effectiveness of the methodology by testing the achievement of cognitive goals and obtaining student reactions by means of an attitude scale. There was no significant difference in achievement of cognitive goals between the experimental group and a control group. The students reacted favorably to the programmed materials used in the study.

Postlethwait, Novak, and Murray (65, p. 98-99) and Steiner (80) described a taped audio-tutorial approach in botany. They reported that the approach made it possible to present a greater amount of information in a given period of time, that students reached a higher level of achievement, vanadalism was reduced, and students' attitudes were improved. The only quantitative evidence for the claims was that which showed students received higher grades under the audio-tutorial system than in the previous course. The report did not reveal whether the improved achievement was due to the audio-tutorial method or to the frequency of administering achievement tests or both.

College Physical Sciences

Newman and Gassman (57) described an experimental laboratory course in organic chemistry at the Ohio State University in which the laboratory was conducted similarly to that of Postlethwait. The major difference being that the Ohio State University course seemed to place more emphasis upon student interests and student initiative.

Riggs (69) compared the problem solving abilities of students in a college chemistry class using a laboratory manual with a class which attempted to solve research-like laboratory problems. On the basis of two tests of problem solving and two achievement tests, he concluded that there was no significant difference in problem solving abilities between the two groups.

Bradley (9), in a study of the relative merits of the individual laboratory versus the lecture-demonstration methods in college natural science, found that neither method was superior as measured by pencil and paper tests.

Alterman (2) used experimental and control groups to compare the ability of college students to apply principles of physics to new situations. The experimental method attempted to develop a principle by demonstration and analysis of applications to situations before stating the principle and then proceeded to illustrate and apply it. The former method was labeled the inductive method and the latter, the deductive method. The inductive method produced significantly better results in ability to apply knowledge only for those students rating low on preliminary background tests. He also found a high correlation between ability of students to recall facts and principles with ability to apply principles to new situations. There was a high correlation between ability of students to recall facts and their ability to solve mathematical problems in physics. The ability to solve mathematical problems in physics was moderately correlated with the ability to apply principles to new situations. Stubbs (84), in a similar study in college general chemistry, concluded that the inductive method showed no superiority over the deductive method and that the inductive method held more promise for training students in the use of the scientific method of problem solving and procedure.

Robinson (70) reported on a study of the use of current science articles in teaching a general-education college course in physical science. Fifteen articles, mostly from Scientific American, were used for an experimental group in lieu of certain portions of the text. The articles were selected for appropriateness of content, understandability, and interest to nonscience majors. They were assigned as homework and were discussed in class. A control group used only the text. Using a pretest and posttest design, Form C of A Test of Science Reasoning and Understanding: Natural Science, a locally designed science understanding questionnaire, and a questionnaire intended to reflect scientific interest were administered 12 weeks apart. The science understanding questionnaire was the only instrument which showed a significant difference in gain, and the difference was in favor of the group using science articles.

Miller (53) studied the effectiveness of teaching by the complete use of recorded illustrated lectures and teaching by a combination of recorded illustrated lectures and discussion method of teaching selected topics in a college physical science course. There were indications that recordings were capable of reducing the time a teacher needs to spend with students and that excessive use of recordings lower student achievement. A student questionnaire revealed that there was an extreme objection to the recordings because of boredom and monotony.

<u>Secondary School Science</u>

Herron (34) constructed a chemistry test to compare the gain in cognitive abilities of students in CHEM Study with students in conventional chemistry. The CHEM Study students scored significantly higher on ability to apply knowledge, which led the investigator to infer that conventional chemistry students rely more on lower level cognitive abilities.

Baumel (5) investigated the effectiveness of a method of teaching secondary school biology which involved the critical analysis of research papers of scientists. Comparisons were based on the mastery of biology content, critical thinking ability, and science interests. All three instruments showed no significant differences between the experimental and control groups.

Owens (62) and Crall (16) evaluated secondary school students growth in ability to apply biological principles. They found that students displayed a significant increase in ability to apply scientific principles to new situations when classroom experiences were based on the application of principles.

Stafford (79), using equated groups of high school biology students, taught one group from a textbook and the other with supplemental materials arranged in the same sequence as the text topics. He found that neither group was superior to the other in the learning of biology.

The relative values of lectures, demonstrations, and individual laboratory work in high school have been the subject of numerous investigations. Newman (56) compared the effectiveness of three different lecture-discussion groups. One group had lecture-discussion each day with reading assignments outside of class, another had daily lecture-discussion periods with some time devoted to reading assignments in class, and a third group had daily lecture-discussions with no text or reading assignments whatsoever. No group was superior in ability to recall factual information. Taylor (87) compared the effectiveness of a lecture method with a small-group discussion method in teaching high school biology and found the methods were equally effective in imparting factual information.

Oliver (60) investigated the relative efficiency of three methods of teaching biology in high school. The methods were lecture-discussion, lecture-discussion and demonstration, and lecture-discussion and demonstration with laboratory exercises. On the basis of the tests used, he concluded that regardless of the method, high school students within various ability groups could be expected to learn the same amount of factual information in biology, apply biological principles with about equal facility, and had equally favorable attitudes toward science and scientists.

Coulter (15) conducted an investigation of ninth grade biology in which he compared the amount of learning of students taught by inductive laboratory experiences, by deductive laboratory exercises, and by demonstration of deductive experiments. Outcomes were measured in terms of knowledge and application of principles of biology, scientific attitudes, laboratory technique, and student reaction to the instructor. It was concluded that the inductive treatment produced significantly greater attainment of the attitudes of science and students in the laboratory treatment reacted more favorably to their instruction than did the students receiving the demonstration treatment.

In 1925, Downing (21) analyzed eight studies on lecture-demonstration versus laboratory methods of instruction in high school science. Following the analysis he presented the following summary of the findings (21):

> The lecture-demonstration method of instruction yields better results than the laboratory method in imparting essential knowledge and is more economical of time and expense. This is true for both bright and dull pupils and for all types of experiments. The last two points need additional experimental confirmation.
>
> The lecture-demonstration method appears to be the better method for imparting skill in laboratory technique in its initial stages and for developing ability to solve problems. Again, these two items are tentative conclusions, and further experiments will be required to establish them.
>
> Oral instructions are, in general, more effective than written instructions in lecture-demonstration but less effective in laboratory work.
>
> "What the experiment proves" is the item on which most pupils fail and is evidently the point to be stressed in teaching.
>
> In science teaching we need to concentrate on a few fundamental principles and to curtail the multiplicity of details in order that pupils may retain the instruction. "Teach for keeps" must be the slogan.

In 1946, Cunningham (19) summarized six Doctoral Dissertations, 18 Master's Theses, and 13 articles on lecture-demonstration versus individual laboratory work in science teaching. Most of these studies were concerned with the comparative effects of the two methods on students' ability to grasp subject matter concepts. The studies failed to demonstrate the superiority of either method. According to Cunningham, these earlier studies left much to be desired in the way of experimental design and statistical treatment of data.

Summary

The research on teaching methods and media is too limited and inconclusive to produce valid recommendations. The typical conclusion was that the experimental method or media failed to demonstrate any superiority over a conventional method. In those studies which indicated a possible superiority of one technique as opposed to another, there had been few attempts to improve upon the experimental design by a refinement of the objectives and evaluation instruments, positively identifying factors responsible for minor differences, using a reasonably large sample, and providing sufficient time for a variety of learnings to occur.

Although the laboratory has long been associated with science instruction, research on its effectiveness fail to show a contribution beyond the acquisition of factual information, development of laboratory skills, and retention of learning. It was often assumed that laboratory activities foster an understanding of the processes of science, but there was little in the way of evidence either in the form of laboratory exercises or evaluation instruments to support the assumption. The use of media such as, tape recorders and television for instructional purposes, has stimulated a number of research studies which have produced inconclusive results.

The objectives of general education science courses include the acquisition of knowledge, some facility in using that knowledge, an appreciation of nature, some understanding of science as a process, and an expectation that the students attitude toward science will be modified. However, the acquistion of knowledge is generally the only outcome that is subjected to measurement and evaluation. There is some indication in the more recent research that the other objectives are being subjected to less superficial consideration than in the past.

## Studies Related to Attitudes Toward Science

In summarizing his review of research on the learning of biology, Hurd (37, p. 212) concluded that:

> the objectives of liberal education in biology at both the high school and college levels include an expectation that the students attitudes toward social and personal problems and toward science will be modified as a result of instruction.

In view of the emphasis on changes in attitudes toward science as a desirable outcome of instruction, it seems paradoxical that the area has been the object of so little research effort. Most investigations have been conducted primarily by the designers of attitude measuring instruments and the instruments were usually limited in scope.

White (95) compared the attitudes of pre-service elementary teachers toward elementary school science to determine if the kind of general education science pattern was an influence on attitudes.

He concluded that there was no difference in attitudes toward elementary school science between those students completing a botany-geology science pattern and those completing a biological-physical-science pattern.

Barkley (3) used Thurstone's Attitude Toward Evolution Scale to investigate the changes in attitude toward evolution of women college students taking science and mathematics. There was some indication that the attitudes of students were modified as a result of the two treatments.

Pace (63) reported an analysis of questionnaires from 2,500 alumni of Syracuse University. He assumed that people whose opinions reflected the greatest insight and understanding in various fields would also be more active in those fields. This was true to a limited degree in art, music, literature, and religion, but not true for politics, civic affairs, and science.

Moore and Henderson (54) used a Likert-type scale to measure changes in the attitude of students in junior college physical science classes. They found that students did develop a more favorable attitude when specific attempts were made to influence attitudes. Beardslee and O'Dowd (6) reported that there were data which showed that students entering college have a more favorable view of the scientist than students who have spent a semester in college. Schmidt (73) discovered that twelfth grade students in one study had less positive attitudes toward science than eighth grade students as a group.

In an investigation of the effects of a required mathematics course upon the attitudes of prospective elementary teachers, Gee (30, p. 75) found that there was no significant relationship between students attitudes towards mathematics and change in the understanding of mathematics while enrolled in the course. He found a high relationship existing between attitudes toward mathematics and achievement as reflected in course grade. Powell (66) and Rostrom (71) also reported a significantly positive relationship between student attitudes and performance on achievement tests.

Wick and Yager (96) reported a study of attitudes in science courses in junior and senior high school classes. They found that grades were not of particularly great importance in determining the student's attitude toward a course. The study also showed that students generally show a decrease in course attitude and that the attitude of students toward a course is highly dependent upon the classroom teacher.

Mead (50) conducted a nation-wide survey to determine the high school students' image of the scientist. A representative sample of 35,000 high school students were asked to complete statements relative to science and scientists. The study showed that, in general, students had built up a very positive image of science and the scientist when they were asked to speak without personal career involvements. But when the question became one of personal contact with science, such as a career choice or the choice of a spouse, the image was decidedly negative. The investigator identified the school as having an important role in modifying that attitude.

Stoker (83) surveyed the aptitude and attitudes of 15,000 students toward science and scientists and the relationships of these factors to each other and the personal traits of the students. The students generally expressed favorable attitudes toward science as a social institution. He found a significant relationship between aptitude and attitude toward scientists. The attitude toward science and scientists as people seemed to be influenced by religion, grades in science, education of parents, and their socio-economic status.

Wickline (97) sought to determine if high school students' attitudes concerning science and scientists could be changed as a result of viewing ten motivational films in the Horizons of Science series. Using Allen's Attitude Scale as a pre- and posttest, he found that the attitude of the high school students toward science and scientists were relatively stable.

Belt (8) tested 516 college-bound seniors from 12 New Jersey high schools and found a generally favorable attitude toward science and scientists. The study showed that high ability students had more favorable attitudes toward science and scientists than did a representative cross section of high school students.

In 1957, Allen (1) conducted a study of high school seniors to determine their attitudes toward science and scientific careers. In order to measure if high school seniors who chose scientific careers had more positive attitudes than those choosing nonscience careers, he developed a 93-item reaction inventory. The study was also designed to determine if there was a difference in attitudes toward science between high ability students choosing scientific careers and those choosing nonscientific careers. He concluded that for the group studied the attitudes were favorable toward science when judged by the response rating determined by a jury. Intelligence was found to be positively correlated with the attitude towards science. An item analysis of the instrument indicated that students do not have a clear-cut understanding of the nature of science and scientific work.

Howe (35, p. 205) used a modification of Allen's reaction inventory in a study of biology students in Oregon. The study disclosed that 40 of 51 biology classes evidenced attitude changes in the direction of attitudes held by a jury composed of professors of science at Oregon State University. In a majority of the classes, the attitudes of students changed in the direction of the attitudes of the classroom teacher.

Summary

In general the studies reviewed reveal that instruction in science does change student attitudes. Favorable attitudes were not incidental results of instruction. Rather, they were the results of a teaching method which was designed to achieve a particular attitude. Several studies showed that attitudes were perhaps a function of course grade, intelligence, and the classroom teacher. This was not universally true, however. It was conceivable, that in those studies reporting a low correlation of attitude toward science with course grade, intelligence, and the classroom teacher, the investigators had explored beyond the emotionalized feeling a student has concerning either his last or his most disliked science course. In other words, they may have probed the realm of intrinsic behavior and identified an attitude which was more independent of transitory extrinsic factors.

## Studies Related to the Understanding of Science

Teaching for an understanding of science has been a relatively recent addition to the objectives of science instruction in general education courses. Although the objective evaluation of students' understanding of science has been an innovation of the last two or three decades, considerable progress has been made.

Brown, Michaels, and Bledsoe (11) investigated the use of film slides to supplement the lectures and laboratory exercises in an introductory microbiology course. TOUS was used as one evaluation instrument. Although the group using film slides scored significantly higher on achievement tests in the study, there was no significant difference in gain in TOUS scores over the one semester experimental period. The investigators questioned the validity of using TOUS at the college level because it may have been too easy for the students.

Craven (17, p. 135) conducted a study to determine the extent to which students who were completing planned curricula in science education possessed an understanding of science consistent with that of the practicing scientist. On the basis of significant differences in TOUS scores between science teacher-candidates and freshmen in social science, freshmen in science education, elementary teacher-candidates, and in-service science teachers, he inferred that some factor other than the amount and type of college science studied, scholastic aptitude, and academic achievement was responsible for the differences in the understanding of science. The high mean scores of in-service science teachers on TOUS would indicate that the test may very well lose its discriminating power for upper level undergraduates.

Mason (48) reported a study in which he compared a scientific thinking method with a descriptive method of teaching college biology. The scientific thinking method was more effective in teaching scientific attitudes, and he concluded that the ability to think scientifically could be taught more effectively when students were given direct practice in developing such abilities.

O'Dowd and Beardslee (59) used interviews and questionnaires to study student stereotypes of men in various occupations, including scientists. There was a wide agreement that the scientist was highly intelligent and possessed a driving concern to extend knowledge and to discover truth. On the negative side, the scientist was viewed as a person who was uninterested in people and unsuccessful with them, uninterested in art, and a nonconformist and radical with only moderate control of his impulses.

Thomas (88) used <u>TOUS</u> in comparing a one phylum approach to zoology by means of arthropods with a phylogenetic program for the preparation of prospective elementary school teachers. The test was used as part of a pretest and posttest battery. The experimental program did bring about some gain in understanding science.

Zingaro (100) used <u>TOUS</u> as part of a pretest and posttest battery in comparing an inductive laboratory to a conventional laboratory in teaching college sophomores the interrelationship of physiochemical principles in physical science. Statistical analysis produced significant F-values for instructor effect and interaction with respect to the Test on Understanding Science, Form W. This indicated that there were measurable instructor differences in teaching for an understanding of science, even when different instructors were following the same prescribed course.

Schefler (72) conducted a comparative study of the differences between a lecture-illustrative laboratory approach and an inductive approach in college biology. Analysis of the differences in posttest scores on TOUS after a ten week period of instruction indicated no significant differences in understanding science between the experimental and control groups. There was some indication that the effects of teacher differences may be of greater significance than the effects of method differences.

Wilson (98) developed a 26-item questionnaire to determine the opinions and attitudes related to certain aspects of science and its place in our society. The questionnaire was presented to 285 persons in grades eight through the senior year of college who were asked to indicate agreement or disagreement with the items. Although the groups differed considerably in background and training, there was considerable uniformity in their responses to the statements. The investigator concluded that the responses indicated a considerable lack of understanding of science and its role in our society. Behnke (7) arrived at a similar conclusion after analyzing replies from 621 high school science teachers and 70 scientists to 50 tested statements.

Gruber (32) attempted to evaluate the first year, 1957-58, academic year institute of the University of Colorado by measuring gain in knowledge of the history and philosophy of science. While the fellows made adequate academic progress, 92 percent performed below a level considered adequate on a history of science test and made no gain in understanding the philosophy of science. The lack of increase in knowledge about the way scientific knowledge unfolds was attributed to the supposition that the fellows were rarely exposed to such information.

Meinhold (51) designed a 55-item Test on the Methodology of Science which he administered to 1,268 secondary science teachers enrolled in 29 National Science Foundation Institutes in 1960. The test was also administered to a similar number of teachers of other subjects who were graduate students in education. On the basis of test results, the investigator concluded that secondary school science teachers possessed no greater understandings of the methodology and philosophy of science than the secondary school teachers of other subjects.

Withey (99) reported a study of public opinion about science and scientists conducted by the Survey Research Center of the University of Michigan. It was found that probably not more than 12 percent of the adult population really understood what was meant by the scientific approach. Two-thirds of the sample thought science was simply thorough and intensive study. One-fourth freely admitted that they did not know what was meant by studying something scientifically. Only about one-tenth talked at all about controlled experimentation, scientific method, measurement, systematic variation, theory, or similar ideas.

Cooley and Bassett (13) used an experimental instrument to assess student perceptions of science and scientists during a ten week summer science program at Thayer Academy, Braintree, Massachusetts. The instrument was one under development by the Educational Testing Service. The major conclusion from this study was that it was possible to design instruments for research in science education which can detect changes in student behavior in areas other than the mastery of facts and principles.

Klopfer and Cooley (43) conducted a comprehensive study to test the effectiveness of the History of Science Case Studies in changing the understanding of science and scientists of high school chemistry, physics, and biology students. Achievement on previously established tests of appropriate subject matter content and the Test on Understanding Science (TOUS - Form X) were used as criterion instruments in the study. They concluded that the History of Science Case Studies was an effective method of increasing student understanding of science and scientists when used in high school biology, chemistry and physics classes. The significant gains in understanding of science and scientists were achieved without a significant loss of achievement in the usual subject matter content of high school science courses.

Crumb (18) used TOUS in comparing the understanding of science of students completing Physical Science Study Committee Physics Course and students completing conventional physics courses. He found that the PSSC program was significantly more effective in the area of promoting an understanding of science than conventional physics programs. Trent (90) conducted a study similar to that of Crumb and found that PSSC and traditional physics courses were equally effective in attaining student understanding of science as measured by TOUS. Crumb and Trent each noted marked differences in mean pretest scores on TOUS between the traditional and PSSC subpopulations. Crumb hypothesized that the school itself, its staff, and its attitude toward change may be responsible for the initial differences.

Downing (22) designed a test on scientific attitudes in 1936. The analysis of results of the test led him to conclude that the ability to think scientifically was a complex which included a number of abilities and that the abilities develop at varying rates and differently in different communities.

Kazem (39) used a test designed by Keesler to determine the effectiveness of informational expository films and historical dramatic films upon the understanding of the elements of scientific method by tenth grade high school biology students. He reported that the informational expository films made a significantly greater contribution to the understanding of the elements of the scientific method than the historical dramatic films. Both types of films made significant contributions, however.

Using an opinion scale of his own design, Kimball (41) evaluated the changes in the opinions of high school students studying the physics course prepared by Harvard Project Physics. The investigator concluded that the students who spent a year studying Harvard Project Physics expressed opinions about the nature of science which agreed to a significantly higher degree with the postulated model of the nature of science at the end of the year than at the beginning.

Kleinman (42) analyzed the teaching patterns of junior high school science teachers and identified those teachers using critical thinking as part of their respective teaching procedures. She found that high ability students in classes taught by teachers using the critical thinking pattern scored significantly higher on the Test on Understanding Science (TOUS - Form Jy).

Smith (76) appraised the extent to which a group of 36 boys and 24 girls attending an eight-week summer science training program for high school students understood the nature of science and scientists. Using <u>TOUS</u> and the <u>Watson-Glaser Critical Thinking Appraisal</u>, it was found that both boys and girls were below average in perception of science and scientists. The boys possessed a significantly higher understanding of science than did the girls, however. The investigator concluded that the attitudes and mood of science were apparently not getting through by indirect means.

Sorenson (78, p. 122-123) compared a laboratory-centered high school biology program with a lecture-demonstration-centered program. He found significant gains in the understanding of science based on pretest and posttest administration of <u>TOUS</u>. The gains in understanding science differed significantly for the two treatment groups. The investigator also found that <u>TOUS</u> scores were not significantly related to mental ability.

Lepper (46) used <u>TOUS</u> along with the <u>Opinion Attitude and Interest Survey (OAIS)</u> test as criteria for the successful selection of eleventh grade participants in a summer science institute. The 30 academically gifted students scored a mean of 43.5 on <u>TOUS</u> which is 1.6 standard deviations above the mean of the eleventh grade norm group. With respect to <u>TOUS</u> the selection of participants for the institute was considered quite successful.

Carrier (12) reported a study using a 30-item modification of the 1961 edition of the <u>Test on Understanding Science (TOUS - Form</u>

X) to evaluate the use of the History of Science Case instruction method in junior high school. Although there was a significant gain in understanding of the scientific enterprise, about scientists, and about the aims of science as measured by the test, the adaptation of TOUS proved difficult from the standpoint of vocabulary.

Hubbard (36) studied the junior high school students' conception of science as an institution and scientists as an occupational group. He also investigated changes which occurred when selected classes received an introductory unit of instruction relative to the ways of the scientist. Using the Facts About Science Test, Hubbard found that the perceptions of science and scientists held by eighth graders were reasonably accurate concerning some of the aims, limitations, and processes of science, but to a lesser extent concerning the behavior of scientists as people. The group receiving the introductory unit of instruction concerning the ways of the scientist did not perform significantly better on the total test than did the control group.

Kahn (38) used the analysis of current events in science to teach an understanding of the scientist and how he works to seventh and eighth grade boys. He found that the experimental groups scored significantly higher on tests of scientific attitudes than did a comparable control group.

Renner (68) employed a questionnaire technique to obtain data relative to the understandings that junior high school students have about the work of the scientist, the engineer, and the technician. A panel of experts from the respective fields was used to obtain a concensus concerning the definitions of the scientist, the engineer, and the technician. The data for 1,052 junior high school students indicated that junior high school science contributed little to student understanding of the work of a scientist. The investigator concluded that, although junior high school students regress in their understanding of a scientist's work and increase in their understanding of the work of the engineer and technician, they leave junior high school with a more accurate understanding of the work of a scientist than the work of an engineer or technician.

## Summary

From the survey of the literature, it becomes apparent that an understanding of science and scientists and their work can be taught. There is also evidence that the understandings about science and scientists existed in measurable quantities which can be appraised by instruments designed for that purpose. The *Test on Understanding Science* has been used in a variety of research studies and shows considerable promise as a valuable research instrument.

## Summary

There have been a number of attempts to improve the teaching of college general education science courses. The attempts to improve the offerings are in general a consequence of an increase in scientific knowledge, increased enrollments, and a broadening of the objectives of instruction. In addition to the usual content objectives, the general education science courses typically have instructional goals, such as an appreciation of nature and science, an understanding of science, scientific attitudes, a favorable attitude toward science, and an improvement in problem solving ability and the ability to think critically. Despite the statement of multiple objectives for a course, all objectives occupy a remotely minor role when compared to the acquisition of subject matter knowledge.

A review of the literature reveals that many of the intangible outcomes of science instruction have been fairly well described. It further reveals that the intangibles can be taught, but the best methods or procedures for their attainment have not been identified as yet. Although the intangibles have been fairly well described, there is evidence that many of those persons involved in evaluating curricula innovations have not become familiar with existing knowledge in the area.

The development of instruments to appraise the attainment of the intangible outcomes of instruction has paralleled the improved descriptions of the outcomes. There is some evidence that the abilities necessary for attainment of the intangibles are discrete entities. The latter statement is supported by those studies which indicate there are learnings taking place independently of intelligence as measured by intelligence tests and the acquisition of traditional subject matter content. There is evidence that a variety of evaluative instruments of excellent quality are becoming available for research on attitudes and the understanding of science.

# III DESIGN OF THE STUDY

The purpose of this investigation was to evaluate a newly designed college general biology course. The evaluation was based on a comparison of attitudes toward science, understanding of science, and knowledge of biology of the experimental group with a traditionally taught group of students. The general hypothesis of the investigator was that students completing the experimental course would display a greater knowledge of biology, understanding of science, and more favorable attitudes toward science than students in the traditional course. The design of this study was for the purpose of testing the null hypotheses stated in Chapter I using an analysis of variance with multiple classification of data.

## Description of the Setting

The Kansas State Teachers College is a coeducational institution located in Emporia, Kansas. The primary function of the school is the preparation of elementary and secondary teachers. The enrollment for the Fall Semester, 1966, was 6, 731 students. Enrollment for the Spring Semester, 1967, was 6, 372.

The Kansas State Teachers College conferred a total of 1, 378 degrees during 1966. Eight hundred eighty-five persons received baccalaureate degrees, 479 received the degree Master of Science or Arts, and 14 were awarded the degree Specialist in Education. Of the total who received degrees in 1966, 941 or 68.3 percent held teaching assignments in the fall of that year. Four hundred ninety-six, or 56.0 percent, of the 885 people who received baccalaureate degrees in 1966 qualified for teaching. Of this number, 496 or 83.2 percent entered the teaching profession. In addition, 90.0 percent of the persons receiving the Master's degree and 100 percent of those receiving the specialist degree were in teaching in the fall of 1966. One hundred eight, or 12.2 percent, of those receiving the baccalaureate degree were enrolled in graduate school the following fall.

## Description of Biology Courses

The traditional and audio-tutorial biology courses were each one semester, three credit hour courses which were offered each semester and summer session. The traditional course met three times each week for formal lectures. The audio-tutorial course met twice each week for one hour lectures and once each week for laboratory work, intended to require two to three hours.

### Traditional Biology Course

The formal lectures are based on the textbook, Elements of Biology by Paul B. Weisz and published by McGraw-Hill (94). All chapters, except chapters 17, 18, and 19 dealing with "Growth Factors," "The Body Fluids," and "Nervous Coordination" respectively, were studied.

The lectures were generously supplemented with lantern slides, 35 mm slides, and filmstrips. Chalkboard, feltboard, and a few demonstrations were used to illustrate and explain important concepts. One-fourth of the total class time, after deducting time for four tests and the introduction, was devoted to the viewing of 32 instructional films (See Appendix A). Fifty-four different pieces of handout material were distributed to the students. Thirty-two of the 54 were study guides for the instructional films and the remainder dealt with such things as study questions, course objectives, taxonomic outlines, and various summary and illustrative materials.

## Audio-tutorial Course

The audio-tutorial biology course was designed by several members of the biology faculty at the Kansas State Teachers College. In developing the course, special attention was given to the integration of laboratory activities with reading assignments and lectures. A concerted effort was made to minimize repetitious treatment of concepts except in those instances where repetition seemed necessary for reinforcement of learning. The lecture and laboratory schedules are shown in Appendix B.

The reading assignments were based on two small books, The Cell by Carl P. Swanson (85) and Adaptations by Bruce Wallace and Adrian Srb (93). Both books were published by Prentice-Hall. In addition, 20 Scientific American offprints were assigned as required reading. The above constitutes the major reading assignments (see Appendix B). One reason for choosing offprints and, to a lesser extent, the books was the assumption that such reading material would convey something in the way of an understanding of science and how scientific knowledge is gained.

The lecture periods were devoted to a variety of activities other than formal lectures. Laboratory data for the previous week were collated and discussed during the first lecture period of each week. Ten laboratory tests were administered during the second lecture periods of each week. Approximately one-third of the total time for lectures, exclusive of time for testing, was devoted to the viewing of 19 instructional films. Twenty-nine handout sheets, 19 being study guides for films, and the remainder covered such things as course objectives, taxonomic outlines, and illustrative material, were distributed during the lecture periods.

An assistant, either graduate or undergraduate, was on duty at all times when the laboratory was open. In addition to laboratory exercises, a few demonstrations were set up in the laboratory. The labroatory procedures are included in Appendix B.

## The Experimental Design

The purpose of this study was to evaluate the relative effectiveness of a new college general biology course which utilized an audio-tutorial laboratory as contrasted with a traditional lecture course. Since student enrollment in the two biology courses was independent of general ability and background in biology, a posttest only control group design was chosen as the most logical experimental design for the study. Because the biology courses were of one semester duration, it was also necessary to eliminate the disadvantages of an experimenter induced pretest session.

Gage (28, p. 178) describes this design as one of the true experimental designs and designates it as:

| | | |
|---|---|---|
| $R_1$ | X | $O_1O_2O_3$ |
| $R_2$ | | $O_1O_2O_3$ |

where:

$R_1$ represents the random selection of audio-tutorial biology students

$R_2$ represents the random selection of traditional biology students

X represents the variable, in this study, the audio-tutorial biology course

$O_1$ represents the attitudes toward science as measured by the <u>Attitude Scale</u>

$O_2$ represents the comprehension of biology as measured by the General Biology Test

$O_3$ represents the understandings about science as measured by the Test on Understanding Science, Form W.

The sources of internal validity such as history, maturation, testing, instrumentation, regression, selection, mortality, and interaction of selection and maturation are controlled by this design (28, p. 178). The design also controls the interaction of testing and exposure of groups to the experimental variable, a source of external validity.

## Selected Instruments

The first three of the five tests described in this section were used as criterion instruments in determining the relative effectiveness of the audio-tutorial course. They include the Test on Understanding Science, Form W, Attitude Scale, and General Biology Test. The last two tests, General Ability Test and Entrance Biology Test, were utilized in determining whether there existed initial differences between the audio-tutorial and traditional biology groups.

### Test on Understanding Science, Form W

The Test on Understanding Science, (TOUS) Form W, was selected for the purpose of measuring the understandings about science of the students participating in this study. This instrument was developed by Cooley and Klopfer (14) at the Harvard University Graduate School of Education.

TOUS, Form W, published by the Educational Testing Service in 1961 consists of 60 four-choice items. The test requires 40 minutes for administration. Separate answer sheets were provided with reusable test booklets. The test was developed to measure student understanding in three areas of science. The three areas and their component themes were identified by Cooley and Klopfer with the counsel of science educators, science teachers, and numerous professors of science and the history and philosophy of science.

The following is a summary of the themes for which specifications were developed as a basis for TOUS and the number of test items per area (14, p. 3):

Area I The Scientific Enterprise consisted of 18 items based upon seven themes which were as follows:

1. The human element in science
2. Communications among scientists
3. Function of scientific societies
4. Importance of instruments in science
5. Money
6. International character of science
7. Interaction of science and society

Area II The Scientist (18 items). The three themes were:

1. Generalizations about scientists as people
2. Institutional pressures on scientists
3. Abilities needed by scientists.

Area III Methods and Aims of Science (24 items). The eight themes were:

1. Generalizations about scientific methods
2. Tactics and strategy of sciencing
3. Scientific theories and models
4. Aims of science
5. Accumulation and falsification
6. Controversies in science
7. Difference between science and technology
8. Unity and interdependence of the sciences.

Standardization data were obtained by the authors in a study involving 2,535 students (14, p. 10). By applying the Kuder-Richardson Formula 20 to the test data from those students, the reliability of the total test was determined as .76. The reliabilities for Area I, II, and III were determined as .58, .52, and .58 respectively. The three scale reliabilities are adequate for purposes of comparing groups of students (40), but are not high enough to permit confident interpretation for individuals.

A number of consultants both at Harvard and at other institutions criticized the original items as to their validity. Another check on the validity of the preliminary test was provided by a small study carried out in the summer of 1960. TOUS was administered using a pretest posttest technique to 78 talented high school students in two summer science programs. The students in both programs were in active contact with working scientists. It was found that students in both programs made significant changes toward the desired "correct" response to items on TOUS. A similar group of students not participating in such programs did not tend to move toward the correct responses (14, p. 6).

The relation of TOUS to general scholastic aptitude was investigated by administering the Otis Mental Ability Test, Form Am, at the same time that TOUS was given to a sample of 2,980 students in grades 9 through 12 in October, 1960. The range of the product moment correlation was from .64 to .69 for the four classes. These data indicate that only about 40 percent of the score on TOUS is accountable by scholastic aptitude. Thus, it can be concluded that TOUS and the Otis Mental Ability Tests measure different abilities.

## Attitude Toward Science Scale

The Attitude Scale (Appendix C) used in this study was developed by Wilbur H. Dutton of the University of California at Los Angeles in 1962. It is a 20-item checklist developed using the method of Equal-Appearing Intervals proposed by Thurstone and Chave (89). The individual scale items show like or dislike for some particular aspect of science.

The student checks only those statements with which he agrees. The scale values are placed in front of the items checked by each student and a total obtained which yields the average score on the entire scale for each student. Scale values range from 10.3 (extreme like) to 0.3 (extreme dislike). An attitude score greater than 5.9 is considered positive and a score less than 5.0 is considered negative, while a score of 5.0 to 5.9 inclusive is considered neutral. The scaling method is such that equal differences along all parts of the scale have the same meaning. This makes it possible to determine if a student's attitude toward science is positive, neutral, or negative and the strength of the feeling. The scale may be used to provide attitude toward science scores for individuals or groups as well as to study the general pattern of responses for an individual or for a group (24, p. 45).

The reliability of this scale, using the test-and-retest procedure was 0.93. It has been used in a study of 226 prospective elementary teachers by Dutton and Stephens (25).

## General Biology Test

The General Biology Test, which was developed by the investigator, is a 50-item multiple choice test requiring 50 minutes for administration (Appendix D). This instrument was written and tested with biology students during the fall of 1966.

Before writing the test items, the written materials for the traditional and audio-tutorial courses were perused and the concepts in each were identified and placed on cards. This resulted in the identification of approximately 175 concepts for each course. Each concept was then coded according to its placement on a two dimensional grid where one axis represented content areas and the other axis represented organizational levels. The 11 content areas were diversity of type and unity of pattern, energetics, form and function, behavior, genetics, development, systematics, evolution, organism and environment, history and philosophy, and homeostasis. The 12 organizational levels were the molecule, organelle, cell, tissue, organ-system, organism, species, population, community, ecosystem, biome, and biosphere. The coding facilitated the matching of concepts from the two courses. It was found that the two courses shared 105 of the approximately 175 concepts found in each.

The preliminary form of the test, which was essentially based on an adaptation of items from the portfolio of Dressel and Nelson (23), consisted of 100 items. The test items were developed around the concepts which were common to the two courses. The 100-item test was a summation of four 25-item tests based on the cognitive levels according to Schwab (75, p. 457-458).

The following is a summary of the four cognitive levels which were used as guidelines for developing the General Biology Test items (75, p. 457-458):

I. The ability to recall information and to make minor reorganizations of materials learned.

II. The ability to show relations between different bodies of knowledge learned at different times or in connection with different topics.

III. Understanding of materials learned as demonstrated by ability to apply knowledge in new situations. This level has two subdivisions which are:

1. Ability to apply nonquantitative bodies of knowledge.
2. Ability to apply and manipulate quantitative materials.

IV. Ability to use skills involved in an understanding of scientific problems. The subdivisions in this level are:

1. Ability to discern problems.
2. Ability to discern and screen useful hypotheses.
3. Ability to infer what data to seek in testing hypotheses.
4. Ability to plan experiments appropriate to a problem.
5. Ability to interpret data (draw appropriate conclusions).
6. Ability to identify assumptions and principles.

The preliminary test was divided into two 50-item tests each of which contained an equal number of questions from the four cognitive levels and administered to 223 introductory biology students at a college in Minnesota near the end of Fall Quarter, 1966. The preliminary test was further divided into four 25-item tests and administered to groups of 12, 18, 40, and 40 introductory biology students per test at an Oregon college at the same time. Thirty-five of the items were selected for inclusion in the final test in introductory biology at another Oregon college at the end of the Fall Quarter. The latter group was composed of approximately 265 students. Phi coefficients or discrimination indexes were computed for each item on each test according to the recommendations of Guilford (33, p. 502) and Nedelsky (55, p. 97). Difficulty indexes were also calculated for each item on each test according to the suggestions of Nedelsky (55, p. 97). The items were also checked against the text material used in the try-out schools to determine which items students in those schools should be able to answer.

Using discrimination indexes, difficulty indexes, and appropriateness of the items for the try-out groups as criteria, 50 test items were selected for the final General Biology Test. The 50 items were representative of each of the cognitive levels. Items were selected which had a discrimination index of about .30 or more on the preliminary tests and a difficulty index of about .50. Because the test was a part of the final examination for the students at the Kansas State Teachers College, efforts were made to omit those items with a low difficulty index, although the discrimination index was within the acceptable range of about .30 or more. Reliability coefficients were calculated after the final administration of the test (see Chapter 4).

## Criterion of Academic Ability

Scores on the Schrammel General Ability Test were used as a criterion of academic ability. According to the Manual of Directions (74, p. 1-2) the test is an adaptation and revision of the Army Alpha Intelligence Test. The original Army Alpha Test was devised by the Pyschology Committee of the National Research Council for the purpose of testing men for army classification during World War I. After the war the Bureau of Educational Measurements of the Kansas State Normal (now Kansas State Teachers College) was granted permission on November 7, 1919, to adapt the test for school and college use. De Voss, then director of the Bureau, computed norms and published directions for the test.

In 1927 the norms were revised and a new manual was published. In 1936 Schrammel and Brannan published the Schrammel-Brannan Revision of the Army Alpha Examination. In 1947 an adaptation was made of previous editions of the Army Alpha Test which could be used with a separate answer sheet and IBM scored. Because the test was to be used as an entrance test for examining all students entering the Kansas State Teachers College of Emporia, the obsolete and less valid items were deleted as were three of the parts. For the parts retained, a few additional items were added.

The 1947 edition was used annually from 1947 to 1952 for examining all undergraduate students of the college as well as for examining graduate students applying for admission for masters degree candidacy. Studies of the results were made each year and suggested revisions were incorporated in each succeeding edition.

The Schrammel General Ability Test is a 50 minute test which is designed for use with high school, college, and graduate students. The scores may be converted to an intelligence quotient. Reliability coefficients for all forms, based on college freshmen, are .90 or greater. A correlation between the scores made on the test by 110 students on entering college in September, 1952, and grades made by those students for the 1952-53 school year yielded a coefficient of .65 plus or minus .04. These data suggest that the test ranks high in respect to both reliability and validity. The test is administered to all students entering the Kansas State Teachers College as part of a battery of tests.

The Schrammel General Ability Test consists of three equivalent forms: A, B, and C. The three forms are equal in the number of parts, type and number of items in each part, and item content. Statistical studies have shown the three forms to be as nearly equal in difficulty as it is possible for three forms to be. A fourth form, D, has separate norms.

The Schrammel General Ability Test scores were used as a control to determine if there was an initial difference in ability between the experimental and control populations. The ability scores were also used to determine if there were any initial differences between the samples selected for the experimental and control groups.

The scores were taken from student records.

### Criterion of Biology Background

The percentile rank on the biology test designed by the biology department was used as an indicator of student knowledge of biology at the time of entering college. The test was administered by the college as part of the pre-enrollment battery of tests. The percentile rank on the test served as a control to determine if there was an initial difference in the knowledge of biology of students in the sample selected for the study.

The percentile ranks on the test were taken from student records.

## Selection of the Sample

The population for this study was composed of those students completing General Biology 100 A, 100 B, 100 E, 100 F, and 100 G at the Kansas State Teachers College during the fall semester of the 1966-67 academic year and for whom <u>General Ability Test</u> scores were available. General Biology 100 C was not considered because it was a traditional course with conventional laboratory offered only to freshmen who intend to major in biology. One small traditional class, General Biology 100 D, of 78 students was eliminated because the instructor also taught one of the three audio-tutorial classes.

The population totaled 764 students. There were 654 traditional and 110 audio-tutorial students in the original population. The following Tables I and II indicate the grade classification and male and female composition of the population.

Table I. Number and Percentage by Sex and Class of Audio-tutorial Students.

| Class | Male | | Female | | Total | Percent of total |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | | |
| Freshman | 54 | 77.1 | 29 | 72.5 | 83 | 75.5 |
| Sophomore | 7 | 10.0 | 6 | 15.0 | 13 | 11.8 |
| Junior | 6 | 8.6 | 4 | 10.0 | 10 | 9.1 |
| Senior | 1 | 1.4 | 0 | .0 | 1 | .9 |
| Special | 2 | 2.9 | 1 | 2.5 | 3 | 2.7 |
| Total | 70 | 100.0 | 40 | 100.0 | 110 | 100.0 |

Table II. Number and Percentage by Sex and Class of Traditional Biology Students.

| Class | Male | | Female | | Total | Percent of total |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | | |
| Freshman | 170 | 71.7 | 282 | 75.6 | 452 | 74.1 |
| Sophomore | 50 | 21.1 | 72 | 19.3 | 122 | 20.0 |
| Junior | 13 | 5.5 | 18 | 4.8 | 31 | 5.1 |
| Senior | 4 | 1.7 | 1 | .3 | 5 | .8 |
| Special | 0 | .0 | 0 | .0 | 0 | .0 |
| Total | 237 | 100.0 | 373 | 100.0 | 610* | 100.0 |

*Number reduced by eliminating Biology 100 C.

The discrepancy in the male-female ratio between the two groups was a consequence of enrollment procedures. Enrollment in the audio-tutorial course increased in later registration period and there was a greater number of males than females enrolling during the later period.

The two groups were alphabetized into four groups on the basis of biology course and sex and assigned a number progressively. In order to obtain four equal size groups for which complete data were available, the data were recorded for the smaller group of 40 audio-tutorial females. Complete data were available for 35, thus establishing the number of students necessary for each of the other three groups. The remainder of the sample was drawn using Li's Table of Random Sampling Numbers (47, p. 589-598) to first select 40 students for each of the three groups. The number in each group was reduced to 35 by first eliminating those students with incomplete data and, secondly, by omitting students in reverse of the order of selection. Minimum sample sizes were determined in discussion with the Statistics Department at Oregon State University, and, each sample exceeds the minimum.

The population sample was composed of 140 students, 70 from each of the two groups divided equally as to sex. The following Table III indicated the grade classification of the samples.

Table III. Number and Percentage by Sex and Class of Samples Used in the Study.

| Class | Audio-tutorial | | | | Traditional | | | |
|---|---|---|---|---|---|---|---|---|
| | Male | | Female | | Male | | Female | |
| | N | % | N | % | N | % | N | % |
| Freshman | 27 | 77.1 | 24 | 68.6 | 26 | 74.3 | 29 | 82.9 |
| Sophomore | 4 | 11.4 | 6 | 17.1 | 5 | 14.3 | 6 | 17.1 |
| Junior | 2 | 5.7 | 4 | 11.5 | 2 | 5.7 | 0 | .0 |
| Senior | 1 | 2.9 | 0 | .0 | 2 | 5.7 | 0 | .0 |
| Special | 1 | 2.9 | 0 | .0 | 0 | .0 | 0 | .0 |
| Total | 35 | 100.0 | 35 | 100.0 | 35 | 100.0 | 35 | 100.0 |

Other characteristics of the population and samples are analyzed and discussed in Chapter 4.

## Procedures Used in Collecting Data

### Obtaining Test Scores

The Attitude Scale, Test on Understanding Science, Form W, and the General Biology Test were administered to the biology students in January, 1967. The tests were given to all students by the class teachers, not by the investigator, in three consecutive class meetings. All teachers followed the same instructions regarding the administration of the tests so as to insure similar test conditions. The Attitude Scale was administered first and the General Biology Test was administered last as part of the final examination of 100 multiple choice type items. The sample tests were sorted from the tests for the population, after scoring.

### Obtaining Other Relevant Data

The following data were obtained from the student records:

1. The score from the Schrammel General Ability Test.
2. The percentile rank on the pre-enrollment biology test.
3. The sex of the students.
4. The grade level classification of the students.

The biology course grades for students were obtained from the biology teachers.

## Statistics Used in Analysis of Data

A t test for unequal groups was used to determine if there was an initial significant difference in general ability between the traditional and audio-tutorial students in the population on the basis of the General Ability Test scores. The same test was used to determine if there was a significant difference in ability between males and females in the smaller audio-tutorial group. The formula for the t test is as follows:

$$t = \frac{(X_1 - X_2)\sqrt{\frac{N_1 N_2}{N_1 + N_2}}}{\sqrt{\frac{S_1^2 (N_1 - 1) + S_2^2 (N_2 - 1)}{N_1 + N_2 - 2}}}$$

where t is the t value,

X is the mean score on the criterion,

N is the number of scores,

$S^2$ is the variance.

The samples from the traditional and audio-tutorial groups were compared on the basis of General Ability Test scores and percentile ranks on the Entrance Biology Test. An analysis of variance with a two × two factorial design was used for this comparison. One factor represented the type of biology course and the other represented the sex of the students.

Coefficients of reliability $r_{tt}$ were computed for the investigator designed biology test according to the Hoyt version of the Kuder-Richardson formula (33, p. 496). This formula depends upon a single administration of a test and is probably an underestimator of the reliability. Using this formula, coefficients of reliability were determined for the entire test and each of the four levels, and also for each of the two groups in the study which resulted in the computation of 15 $r_{tt}$ values. Since the test was a 50 minute test and each of the four parts represented 12 to 13 minute tests, all $r_{tt}$ values were converted to R values where R is the reliability which a test would have if lengthened to one hour. In computing the R values it was assumed that each of the 50 items on the test would require one minute of student time. The formula for the conversion was as follows (55, p. 223):

$$R = \frac{r_{tt}}{r_{tt} + t(1-r_{tt})}$$

where $r_{tt}$ is the coefficient of reliability,

t is the length of the test in hours.

The Hoyt method also provided the means for determining if the investigator prepared biology test and each subtest possessed discriminatory value. F ratios were computed along with each $r_{tt}$ on the basis of an analysis of variance of scores and items correct among the upper, middle, and lower groups in the samples. Significant F ratios indicated that a test has discriminatory power between high and low scoring students on a test. A condensed form of the Hoyt formula (33, p. 496) is as follows:

$$r_{tt} = \frac{n}{n - 1}\left[\frac{NX^2 I^2 - X(XN)}{NX^2 - (X)^2}\right]$$

where X is a score in the test,

I is the number of right answers for an item,

N is the number of scores,

n is the number of items in a test.

Simple correlation coefficients were computed for the data for each variable in order to determine if there were indications of linear relationships. Other correlations were also computed and were reported.

In order to obtain an empirical estimate of whether the subtests of the <u>General Biology Test</u> measured different levels of understanding of biology, the correlations of the subtests with each other were corrected for attenuation. Correlations corrected for attenuation which have values less than one indicate that the subtests measure different abilities. The formula for the correction is as follows (55, p. 116):

$$\text{Correction} = \frac{r_{12}}{\sqrt{r_{11}\, r_{22}}}$$

where $r_{12}$ is the coefficient of correlation between subtests,

$r_{11}$ is the coefficient of reliability of one subtest,

$r_{22}$ is the coefficient of reliability of one subtest.

For this study a correlation coefficient, $r$, with a value less than .50 was interpreted as lacking significant predictive properties. The basis for this interpretation was the coefficient of determination, $r^2$, which, when multiplied by 100, gives the percentage of the variance in one variable that is associated with or determined by variance in its correlate. Thus, $r$ indicated the strength of relationship while $r^2$ represents an expression of predictive value. It was felt that any $r$ which was an effective predictor in less than 25 percent of the cases was insignificant.

Chi square was used to determine if any of the differences between group responses to individual items on the Attitude Scale were significant.

To test the null hypotheses a two $\times$ two factorial analysis of variance was used. The two way interaction error mean square was used as the denominator in all instances for the computation of $F$ ratios. The same factorial design was used for other analyses of variance which were reported. Analysis was based on the .01 and .05 levels of significance.

## Processing of the Data

Data for the computation of coefficients of reliability for the biology test were tabulated on data forms. The coefficients of reliability and General Biology Test F ratios were computed with a desk calculator. The t test was also computed on a desk calculator. All computations were checked in order to assure accuracy.

The test scores and other data for each student were entered on data forms and then punched on IBM cards for analysis. The data punched on IBM cards were verified by a second key punch operator. A Fortran 3300 program specifically designed for execution on the CDC 3300 machine was used to determine the mean, standard deviations, analysis of variance, and correlation coefficients used in this investigation.

These programs were computed at the Computer Center on the Oregon State University Campus. At least one calculation from the computer and a stack deck was checked on a desk calculator in order to assure accuracy of the computer program and results.

# IV PRESENTATION AND INTERPRETATION OF FINDINGS

It was the purpose of this investigation to evaluate a newly designed general education biology course on the basis of student attainment of the major objectives of instruction. The objectives were: (1) the comprehension of biology, (2) attitude toward science, and (3) understanding of science. Students in the newly designed audio-tutorial classes were compared to traditional biology students by means of scores on selected evaluation instruments using a post-test only experimental design.

The data for the study were obtained by administering the Test on Understanding Science, Form W, an Attitude Scale, and an investigator designed General Biology Test. The investigation was conducted during the Fall Semester of the 1966-67 academic year at the Kansas State Teachers College in Emporia, Kansas. The tests were administered during the last three class meetings in January, 1967. Data were also collected from school records and from biology instructors. Data from the criterion tests and student records were tabulated on data sheets and punched on IBM cards for statistical analysis.

The data from school records were used as controls to determine if there were initial differences between the traditional and audio-tutorial students. These data as well as course grades were further analyzed by means of correlations with scores on the criterion instruments.

The null hypotheses to be tested were listed in Chapter I, and are considered later in this chapter when the null hypotheses are individually examined. The criterion measure in each of the tests of the null hypotheses was the group mean on the Test on Understanding Science, Form W, Attitude Scale, and General Biology Test.

## Analysis of the Data

This subdivision is concerned with an examination of the data which were either used in the correlation studies or in the testing of the null hypotheses. It also involves an analysis of scores on the General Ability Test and Entrance Biology Test to determine the nature of the group under investigation. The investigator designed General Biology Test is analyzed to determine its discriminating power and coefficient of reliability. Student responses to the criterion instruments are also analyzed to provide information relevant to the purpose of the investigation. Course grades of the audio-tutorial and traditional biology students are compared.

### Indicators of a Homogeneous Group

General Ability Test as an Indicator. Table IV provides information regarding the mean General Ability Test scores of students in the population. The mean score of the traditional biology students was slightly higher than the mean of the audio-tutorial students. The mean score of the audio-tutorial females was higher than the mean of the audio-tutorial males.

T tests were computed to ascertain whether differences in group means were significant. Table IV shows that the t-values were too small to indicate a significant difference at the .05 level. Hence, it was assumed that there was no real differences in ability, as measured by the General Ability Test, between students enrolled in traditional and audio-tutorial biology and between males and females enrolled in either course.

Table IV. Comparison of Groups within the Population Based upon Scores on the General Ability Test.

| Group | n | Mean | n.d.f. | t value | Level of Significance |
|---|---|---|---|---|---|
| Population | | | | | |
| Traditional | 654 | 108.32 | 653 | 1.62 | - |
| Audio-tutorial | 110 | 105.88 | 109 | | |
| Audio-tutorial | | | | | |
| Male | 70 | 105.21 | 69 | .63 | - |
| Female | 40 | 107.05 | 39 | | |

t (762 d.f.) .05 = 1.96
t (108 d.f.) .05 = 1.96

One hundred and forty students, 70 audio-tutorial and 70 traditional, were randomly selected for statistical comparison. Table V shows that the means and ranges of General Ability Test scores for the groups within the sample were similar. In order to determine if any of the differences were statistically significant, the data were subjected to an analysis of variance using a two factor design where sex was one factor and type of biology course represented the other factor.

The calculated F ratios, shown in Table VI, indicate that there is no significant differences in ability between the audio-tutorial and lecture groups, and still a smaller difference between male and female students. The insignificant F ratio for interaction indicates that there were no real differences in ability of males and females in the audio-tutorial and lecture groups. On the basis of no statistically significant differences in ability scores, the groups were considered to be comparable for the investigation.

Table V. Means and Ranges of General Ability Test Scores of Sample.

| Group | n | Mean | Range |
|---|---|---|---|
| Class | | | |
| Traditional | 70 | 107.800 | 60-135 |
| Male | 35 | 108.114 | 60-135 |
| Female | 35 | 107.486 | 73-131 |
| Audio-tutorial | 70 | 106.329 | 72-132 |
| Male | 35 | 106.314 | 76-132 |
| Female | 35 | 106.343 | 72-129 |
| Sex | | | |
| Male | 70 | 107.214 | 60-135 |
| Female | 70 | 106.914 | 72-131 |
| Total* | 140 | 107.064 | 60-135 |

*Standard Deviation of total = 15.115

Table VI. Analysis of Variance of General Ability Test Scores of of the Sample.

| | d.f. | SS | MS | F ratio | Level of Significance |
|---|---|---|---|---|---|
| Class (a) | 1 | 79.7786 | 75.7786 | .3383 | - |
| Sex (b) | 1 | 3.1500 | 3.1500 | .0135 | - |
| a × b interaction | 1 | 3.7785 | 3.7785 | .0162 | - |
| Error | 136 | 31,673.7143 | 232.8950 | | |

F (1, 136 d.f.) .05 level of significance = 3.9201

Entrance Biology Test as an Indicator. Table VII provides information regarding the nature of the sample based upon scores on the Entrance Biology Test as a criterion of knowledge of biology prior to enrollment in college.

Table VII shows that traditional biology students made slightly higher scores on the Entrance Biology Test than did the audio-tutorial students. It also shows that the male students in all groupings scored higher than did female students. To determine if any of the differences were statistically significant, F ratios were computed using analysis of variance in a factorial design. Table VIII shows that none of the F ratios approach the .05 significance level (3.9201). Thus, it was concluded that the groups were comparable in knowledge of biology at the beginning of the experiment. Since the F values for type of biology, sex, and interaction were not significant, the conclusion was not biased by the factor of either sex or method and was not influenced by an interaction between sex and type of biology course selected by the student.

Table VII. Means and Ranges of Percentile Rankings of the Sample on the Entrance Biology Test.

| Group | n | Mean (Percentile) | Range (Percentile) |
|---|---|---|---|
| Class | | | |
| Traditional | 70 | 49.414 | 2-98 |
| Male | 35 | 51.314 | 2-98 |
| Female | 35 | 47.514 | 7-84 |
| Audio-tutorial | 70 | 45.214 | 2-94 |
| Male | 35 | 49.186 | 2-94 |
| Female | 35 | 43.371 | 3-92 |
| Sex | | | |
| Male | 70 | 49.186 | 2-98 |
| Female | 70 | 45.443 | 3-92 |
| Total* | 140 | 47.314 | 2-98 |

*Standard Deviation of Total = 26.99

Table VIII. Analysis of Variance of Percentile Rankings of the Sample on the Entrance Biology Test.

| | d.f. | SS | MS | F ratio | Level of Significance |
|---|---|---|---|---|---|
| Class (a) | 1 | 617.4000 | 617.4000 | .8386 | - |
| Sex (b) | 1 | 490.3143 | 490.3143 | .6663 | - |
| a × b interaction | 1 | .1143 | .1143 | .0002 | - |
| Error | 136 | 100,120.3429 | 736.1790 | | |

The preceding information provided evidence regarding the composition and characteristics of the sample. Based upon the test scores for ability and previous knowledge of biology, the audio-tutorial and traditional biology students were judged to be comparable for the study.

General Biology Test

Table IX provides information regarding the discriminating property and reliability of the investigator designed General Biology Test. The discriminating power of the test and subtests was determined by an analysis of variance of scores of students ranking in the upper, middle, and lower groups on the test. As shown in Table IX the F ratios are all in the critical region which indicates there are significant differences among the means for students scoring in the upper, middle, and lower groups. Hence, the test and each of the four subtests were judged capable of discriminating between individuals in the audio-tutorial and traditional groups, as well as, individuals in the total sample.

Table IX also shows the reliability coefficients for the 50 minute test and each of the four subtests or levels for the audio-tutorial students, traditional biology students, and total sample. Levels I and III each consist of 12 items, while Levels II and IV are composed of 13 items each. All $r_{tt}$ values, except for Level III, either equal or exceed .50 which is generally considered a minimum value for group comparisons. Because of the small number of items in the subtests and because test reliability is a function of test length, R values were computed. The R values indicate the reliability coefficient which the test and subtests would have if they had been lengthened by adding similar items to make up a one hour test. Each computed R value indicates that the General Biology Test and its subtests have adequate reliability for group comparisons.

Table IX. F ratios, Coefficients of Reliability, and Adjusted Coefficients of Reliability for the General Biology Test Based upon Scores of Audio-tutorial and Traditional Biology Students.

| | d.f. | | F Ratio | Level of Significance | $r_{tt}$ | R |
|---|---|---|---|---|---|---|
| Total Biology | 59, | 2891 | 6.1408 | .005 | .84 | .86 |
| Audio-tutorial | 29, | 1421 | 7.8211 | .005 | .87 | .89 |
| Traditional | 29, | 1421 | 5.4006 | .005 | .81 | .84 |
| Level I | 59, | 649 | 3.1358 | .005 | .68 | .92 |
| Audio-tutorial | 29, | 319 | 3.9922 | .005 | .75 | .94 |
| Traditional | 29, | 319 | 2.5453 | .005 | .61 | .89 |
| Level II | 59, | 708 | 2.4214 | .005 | .58 | .86 |
| Audio-tutorial | 29, | 348 | 2.8580 | .005 | .65 | .89 |
| Traditional | 29, | 348 | 2.0971 | .005 | .50 | .82 |
| Level III | 59, | 649 | 1.7703 | .005 | .44 | .79 |
| Audio-tutorial | 29, | 319 | 1.8379 | .01 | .46 | .81 |
| Traditional | 29, | 319 | 1.7622 | .025 | .43 | .79 |
| Level IV | 59, | 708 | 2.3253 | .005 | .57 | .86 |
| Audio-tutorial | 29, | 348 | 2.3558 | .005 | .58 | .86 |
| Traditional | 29, | 348 | 2.2795 | .005 | .56 | .85 |

Table X shows correlations for the subtests which have been corrected for attenuation. All corrected correlations are less than one which indicates that the various subtests measure different abilities or levels of understanding of the students in the sample (see Chapter III).

Table X. General Biology Test Subtest Correlation Coefficients Corrected for Attenuation.

| Subtest | Correlation | Correction |
|---|---|---|
| Level I × Level II | .61 | .98 |
| Level I × Level III | .53 | .98 |
| Level I × Level IV | .52 | .84 |
| Level II × Level III | .49 | .98 |
| Level II × Level IV | .47 | .81 |
| Level III × Level IV | .48 | .96 |

Attitude of Students toward Science

The attitude of the students toward science was measured by an Attitude Scale (see Appendix C). The means and ranges of attitude scores for the audio-tutorial and traditional biology students are shown in Table XI. Both groups showed positive attitudes toward science based upon the instrument used. The audio-tutorial students indicated a slightly more favorable attitude toward science than did the traditional biology students. Male students within each group showed a slightly more favorable attitude than female students within groups; however, female students in the audio-tutorial group indicated about the same degree of positive attitudes as male students in the traditional group.

The standard deviation of .817 indicates that the attitudes for the total sample were grouped closely around the mean of 7.67. Five students, two audio-tutorial and three traditional, indicated a neutral attitude toward science, while two students, one audio-tutorial and one traditional, indicated a negative attitude toward science. All other attitude scores were positive.

Table XI. Means and Ranges of Student Scores on the Attitude Scale.

| Group | n | Mean | Range |
|---|---|---|---|
| Class | | | |
| Traditional | 70 | 7.62 | 4.21 - 9.18 |
| Male | 35 | 7.63 | 4.21 - 9.18 |
| Female | 35 | 7.60 | 5.64 - 8.81 |
| Audio-tutorial | 70 | 7.73 | 4.81 - 8.86 |
| Male | 35 | 7.85 | 6.25 - 8.86 |
| Female | 35 | 7.62 | 4.81 - 8.48 |
| Sex | | | |
| Male | 70 | 7.74 | 4.21 - 9.18 |
| Female | 70 | 7.61 | 4.81 - 8.81 |
| Total* | 140 | 7.67 | 4.21 - 9.18 |

*Standard deviation of total = .817

Table XII shows the frequency of student responses on the Attitude Scale. As noted in Table XI, there were only slight variations in responses between either classes or sexes. The chi square was used to determine whether the differences were statistically significant only when the frequency in each category was equal to or exceeded five and when inspection of the data indicated a possible significant difference. On that basis, analysis of Item 17, "Science is interesting, but not as important as other subjects," produced a chi square value of 5.260 which was significant at the .05 level. Thus, a significantly greater number of traditional biology students than audio-tutorial students expressed that opinion.

As noted in Table XII, items with the higher scale values were checked most frequently. The students indicated a favorable attitude towards field trips, Item 1, although that activity was not a part of either biology course. Ninety-four percent of the students indicated that, "science is important in this scientific age in which we live," Item 15. Items 1, 3, 5, 8, 9, 10, 12, 14, 15, and 19 were checked by, at least, 50 percent of the students. Although the students generally displayed favorable attitudes toward science, the 31 percent response to Item 13, "Scientists are people who invent something to improve everyday life," would seem to indicate that a considerable number of students have misconceptions about what a scientist does.

Table XII. Frequency of Responses of Audio-tutorial and Traditional Biology Students to the Attitude Scale Items.

| Item No. | Scale* Value | Traditional Male | Traditional Female | (N=70) Total | Audio-tutorial Male | Audio-tutorial Female | (N=70) Total |
|---|---|---|---|---|---|---|---|
| 1 | 8.5 | 33 | 32 | 65 | 32 | 30 | 62 |
| 2 | 1.3 | 4 | 0 | 4 | 2 | 1 | 3 |
| 3 | 8.1 | 18 | 26 | 44 | 17 | 23 | 40 |
| 4 | 2.5 | 3 | 4 | 7 | 1 | 6 | 7 |
| 5 | 7.4 | 28 | 31 | 59 | 31 | 32 | 63 |
| 6 | 2.7 | 10 | 7 | 17 | 6 | 13 | 19 |
| 7 | 7.7 | 23 | 28 | 51 | 25 | 29 | 54 |
| 8 | 4.7 | 20 | 28 | 48 | 22 | 23 | 45 |
| 9 | 8.9 | 24 | 24 | 48 | 29 | 25 | 54 |
| 10 | 9.6 | 19 | 14 | 33 | 19 | 19 | 38 |
| 11 | 1.6 | 2 | 5 | 7 | 0 | 6 | 6 |
| 12 | 10.1 | 26 | 32 | 58 | 27 | 26 | 53 |
| 13 | 6.5 | 12 | 14 | 26 | 10 | 8 | 18 |
| 14 | 7.3 | 21 | 22 | 43 | 23 | 22 | 45 |
| 15 | 10.3 | 30 | 34 | 64 | 33 | 34 | 67 |
| 16 | 6.8 | 9 | 7 | 16 | 7 | 7 | 14 |
| 17** | 4.4 | 7 | 10 | 17 | 5 | 1 | 6 |
| 18 | 0.3 | 1 | 1 | 2 | 1 | 1 | 2 |
| 19 | 8.4 | 21 | 13 | 34 | 24 | 23 | 47 |
| 20 | 5.8 | 16 | 20 | 36 | 16 | 17 | 33 |

*Using a scale on which 10.3 represents most favorable responses and .3 represents least favorable response

**Chi square (1 d.f.) audio-tutorial vs. traditional equal 5.260 significant at the 5% level

Biological Knowledge of Students

The biology knowledge of students upon completing the biology courses was measured by scores on the investigator designed General Biology Test. The means, standard deviations, and ranges of scores for the total sample are shown in Table XIII. The mean of 29.33 for the 50 item test represents an average score of 58.66 percent correct. The means, on a percentage correct basis, range from 57.3 percent for Level II to 60.0 percent correct for Level III. The standard deviations indicate a uniform variance for the four subtests. The ranges of the scores on the total test and subtests, along with the standard deviations indicate a fairly wide distribution of scores. Perfect scores of 12 were obtained by two students on the Level I subtest and one student on the Level III subtest.

Table XIII. Means, Standard Deviations, and Ranges of Total Sample Scores on the General Biology Test.

| Test | Mean | Standard Deviation | Range |
|---|---|---|---|
| Total | 29.33 | 7.50 | 13 - 44 |
| Level I* | 7.05 | 2.60 | 1 - 12 |
| Level II** | 7.45 | 2.54 | 1 - 12 |
| Level III | 7.20 | 2.08 | 2 - 12 |
| Level IV | 7.63 | 2.14 | 2 - 12 |

*Levels I and III composed of 12 items each
**Levels II and IV composed of 13 items each

Table XIV shows the mean scores and ranges of mean scores of the audio-tutorial and traditional biology students. The audio-tutorial students obtained slightly higher mean scores on the total test, Level I, and Level IV, while the traditional biology students scored slightly higher on Levels II and III. The ranges of the scores were similar for both groups of students.

Table XIV. Mean and Range of Mean Scores of Audio-tutorial and Traditional Biology Students Based upon the General Biology Test.

| | Audio-tutorial | | Traditional | |
|---|---|---|---|---|
| | Mean | Range | Mean | Range |
| Total | 29.39 | 13 - 44 | 29.27 | 13 - 41 |
| Level I | 7.07 | 2 - 12 | 7.03 | 1 - 12 |
| Level II | 7.40 | 2 - 12 | 7.50 | 1 - 12 |
| Level III | 7.03 | 2 - 11 | 7.37 | 3 - 12 |
| Level IV | 7.89 | 2 - 12 | 7.37 | 3 - 12 |

Table XV shows the mean scores of male and female audio-tutorial and traditional biology students on the General Biology Test. Male students in each group attained slightly higher total mean scores than did the female students. The traditional biology students, both male and female, obtained slightly higher mean scores on the Level III subtest. Both sexes in the audio-tutorial group indicated slightly higher mean scores on the Level IV subtest than did either sex in the traditional biology group.

Table XV. Mean Scores of Male and Female Audio-tutorial and Traditional Biology Students on the General Biology Test.

| | Audio-tutorial | | Traditional | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| Total | 30.43 | 28.34 | 30.14 | 28.40 |
| Level I | 7.49 | 6.66 | 7.06 | 7.00 |
| Level II | 7.43 | 7.06 | 8.09 | 6.91 |
| Level III | 7.20 | 6.86 | 7.49 | 7.26 |
| Level IV | 8.00 | 7.77 | 7.51 | 7.23 |

## Students Understanding of Science

The understanding of science of the students was measured by the Test on Understanding Science, Form W. Table XVI shows the means, standard deviations, and ranges of scores of the total sample on the test and its three areas or subtests. The mean of 33.89 for total sample represents a mean of 56.5 percent correct responses. The mean score on the test is slightly greater than the tentative norm of 32.25 established for 12th grade students. The mean scores for Areas I, II, and III represent a mean of 60.2, 64.2, and 47.9 percent respectively of correct responses. The students were considerably less knowledgeable in Area III dealing with the understandings about the methods and aims of science than in the other two areas based upon the mean percentage of correct responses.

As noted in Table XVI the range of the scores for the total test and subtests was wide. A few students failed to attain a score of 25 percent or chance score on the total test and subtests. The high score of 49 on the test would indicate that the test could discriminate between individuals with a better understanding of science than the students in the sample being investigated; however, the ceiling was approached in Areas I and II.

Table XVI. Means, Standard Deviations, and Ranges of Total Sample Scores on the Test on Understanding Science, Form W.

| Test | Mean | Standard Deviation | Range |
|---|---|---|---|
| Total | 33.89 | 6.25 | 13 - 49 |
| Area I* | 10.84 | 2.54 | 4 - 16 |
| Area II** | 11.56 | 2.49 | 5 - 16 |
| Area III*** | 11.51 | 2.93 | 3 - 19 |

*Area I consists of 18 items
**Area II consists of 18 items
***Area III consists of 24 items

Table XVII shows the means and ranges of scores of the audio-tutorial and traditional biology students on the Test on Understanding Science, Form W. The means for the audio-tutorial students are slightly higher on the total test and Areas I and II, but the differences in means did not exceed .60 in favor of either group on any of the subtests.

Table XVII. Means and Ranges of Scores of Audio-tutorial and Traditional Biology Students on the Test on Understanding Science, Form W.

| | Audio-tutorial | | Traditional | |
|---|---|---|---|---|
| | Mean | Range | Mean | Range |
| Total | 34.14 | 13 - 49 | 33.63 | 20 - 47 |
| Area I | 10.97 | 4 - 16 | 10.71 | 5 - 16 |
| Area II | 11.84 | 5 - 16 | 11.27 | 6 - 16 |
| Area III | 11.37 | 3 - 18 | 11.64 | 6 - 19 |

Table XVIII. Mean Scores of Male and Female Audio-tutorial and Traditional Biology Students on the Test on Understanding Science, Form W.

| | Audio-tutorial | | Traditional | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| Total | 34.49 | 33.80 | 33.14 | 34.11 |
| Area I | 10.83 | 11.14 | 10.57 | 10.86 |
| Area II | 11.97 | 11.71 | 11.00 | 11.54 |
| Area III | 11.69 | 11.06 | 11.57 | 11.71 |

Table XVIII shows the mean scores for male and female audio-tutorial and traditional biology students on the Test on Understanding Science, Form W. The means for male audio-tutorial students were slightly higher than the means for female audio-tutorial students in all categories except Area I. In the traditional biology group the female students scored slightly higher than male students in all categories. Female students in the total sample scored .14 of a score higher than did the males. The differences between means for all classifications were less than one point.

## Grades as Measures of Achievement

The biology course grades of the students were analyzed to determine if there were any relationships between course grades and the type of biology course and the sex of the students. The mean grade for the total sample was 2.96 where 3 represents a "C" grade. The highest mean grade, 3.171, was attained by the females in the traditional biology group. The lowest mean grades were 2.886, which were attained by both the female audio-tutorial and male traditional biology students.

Table XIX. Analysis of Variance of Biology Course Grades of the Total Sample.

| | d.f. | SS | MS | F Ratio | Level of Significance |
|---|---|---|---|---|---|
| Class (a) | 1 | .5786 | .5786 | .6623 | - |
| Sex (b) | 1 | .5786 | .5786 | .6623 | - |
| a × b interaction | 1 | .8643 | .8643 | .9894 | - |
| Error | 136 | 118.8000 | .8735 | | |

Table XIX shows the analysis of variance of the biology course grades for the total sample. The F ratios were too small to indicate any significant differences in course grades between the groups or interaction between sexes and biology courses. Hence, it was assumed that neither the type of biology course nor the sex of the student influenced the grades received by the students.

Correlation Studies

Correlation coefficients for each set of data with every other set of data were computed to determine the presence or absence of relationships. These computed r values are indicated in Table XX. For this study only r values of about .50 or greater were considered large enough to have significant predictive values.

The General Ability Test scores correlated significantly with scores on the Entrance Biology Test, course grades, total biology test, and Levels II and IV of the General Biology Test. General Ability Test correlation with TOUS was fairly strong but weaker for each of the three areas within TOUS. The General Ability Test did not correlate well with the Attitude Scale which indicates a weak relationship between these two sets of data.

The Attitude Scale showed a low correlation with all sets of data except for the high correlation with Level III of the General Biology Test. Level III was designed to measure the ability to apply knowledge in new situations. The low correlation of the Attitude Scale with other sets of data would indicate that the scale was measuring an outcome which was fairly distinct from all the others.

The General Biology Test correlated significantly with all sets

Table XX. Coefficients of Correlation between All Sets of Data for Total Sample.

| | Entrance Biology | Course Grade | Area III | Area II | Area I | Total TOUS | Level IV | Level III | Level II | Level I | Total Biology | Attitude Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| General Ability | .57 | .54 | .39 | .28 | .46 | .49 | .54 | .45 | .51 | .44 | .60 | .14 |
| Attitude Score | .26 | .30 | .19 | .10 | .40 | .16 | .13 | .81 | .29 | .23 | .24 | |
| Total Biology | .66 | .73 | .42 | .43 | .41 | .54 | .76 | .76 | .82 | .85 | | |
| Level I | .58 | .69 | .32 | .38 | .35 | .45 | .52 | .53 | .61 | | | |
| Level II | .55 | .65 | .37 | .33 | .24 | .41 | .47 | .49 | | | | |
| Level III | .49 | .48 | .32 | .32 | .32 | .41 | .48 | | | | | |
| Level IV | .50 | .51 | .33 | .36 | .41 | .47 | | | | | | |
| Total TOUS | .49 | .52 | .80 | .72 | .80 | | | | | | | |
| Area I | .34 | .41 | .49 | .41 | | | | | | | | |
| Area II | .38 | .37 | .32 | | | | | | | | | |
| Area III | .42 | .43 | | | | | | | | | | |
| Course Grade | .65 | | | | | | | | | | | |

of data except the TOUS subtests and the Attitude Scale. The high correlation with course grade is partially due to the use of student scores on the General Biology Test in determining student grades. The high correlation of the test with each of the four subtests indicates a reasonably high test validity.

The four levels of the General Biology Test correlated significantly with the Entrance Biology Test and course grades with Level III correlations bordering on significance. Levels I and II, ability to recall information and show relationships between bodies of knowledge respectively, correlated the highest of the four levels with the Entrance Biology Test and course grades. None of the subtests of the General Biology Test correlated significantly with TOUS and its subtests; however, Level IV, the ability to use skills involved in understanding scientific problems, approached a significant correlation with total TOUS. Level I correlated significantly with the other three levels, but correlated the highest with Level II. The other correlations between levels were only slightly below the .50 r value for significance. The modest correlations of the subtests of the General Biology Test with other sets of data indicates that the subtests were measuring different levels of understanding of biology.

The correlations of total TOUS scores with the three areas of the test were highly significant. Total TOUS scores correlated significantly with the Entrance Biology Test and course grades. TOUS subtest correlations with each other, the Entrance Biology Test, and course grades were not significant.

Course grade correlation with all sets of data, except TOUS subtests and the Attitude Scale were either significant or else bordered on significance. The higher correlation of course grades with the General Biology Test and the Entrance Biology Test indicate that slightly over 40 percent of the course grade is accountable to, or associated with, student knowledge as indicated by scores on those two tests.

## Tests of Null Hypotheses

In the tests of null hypotheses, the statistical model used was the posttest only design as recommended by Gage (26, p. 178). The design of the study was a 2 × 2 factorial type. The factors were the two different biology courses, audio-tutorial and traditional, and the sex of the students. Instruments used in the investigation were the Attitude Scale, Test on Understanding Science, Form W, and an investigator designed General Biology Test. Total mean individual scores on the Attitude Scale were used in the computations, while total scores and part scores were used in the calculations for the other two instruments. Data were treated by an analysis of variance.

In this chapter, tests of null hypotheses which were stated in

Chapter I are presented and discussed. F ratios were computed to determine whether differences in group means on the tests were statistically significant.

Attitude Toward Science

1. There is no difference in attitude toward science between students completing a traditional biology course and the attitude toward science of students completing an audio-tutorial course based upon scores on the Attitude Scale.

The results of the attitude test scores for the audio-tutorial and traditional biology students are found in Table XXI. The mean score of the audio-tutorial students was compared to the mean score of the traditional biology students.

Table XXI. Analysis of Variance of Attitude Scale Scores of Audio-tutorial and Traditional Biology Students.

| | d.f. | SS | MS | F*** Ratio | Level of Significance |
|---|---|---|---|---|---|
| Class (a)* | 1 | .4686 | .4686 | .6973 | - |
| Sex (b)** | 1 | .6338 | .6338 | .9431 | - |
| a × b interaction | 1 | .3168 | .3168 | .4714 | - |
| Error | 136 | 91.4023 | .6721 | | |

*Class = audio-tutorial versus traditional biology courses
** = male students versus female students
*** F(1, 136 d.f.) .05 level = 3.9201

The audio-tutorial students had the highest mean attitude score. However, the F value of .6973 was too small to be a significant difference, so the null hypothesis was accepted indicating no real difference between the two groups in attitude toward science as measured by the Attitude Scale.

(a) There is no difference in attitude toward science between males and females who have completed a traditional and an audio-tutorial course based upon scores on the Attitude Scale.

The results of the attitude test scores for male and female students in the total sample are found in Table XXI. The mean score of the male students was compared to the mean score of the female students. The male students had the highest mean attitude score. However, the F value of .9431 was too small to be a significant difference, so the null hypothesis was accepted indicating no real difference between the two sexes in attitude toward science as measured by the Attitude Scale.

(b) There is no interaction between the type of biology course completed and sex on attitude toward science based upon Attitude Scale scores.

The results of the attitude test scores for interaction between biology courses and sexes are found in Table XXI. The mean scores of male and female students in two different biology courses were compared. The male audio-tutorial students had the highest mean attitude score. However, the F value of .4718 was too small to be a significant difference, so the null hypothesis was accepted indicating no interaction between the two sexes and two courses in attitude toward science as measured by the Attitude Scale.

Knowledge of Biology

2. There is no difference in achievement on the General Biology Test between students completing a traditional biology course and achievement on the General Biology Test of students completing an audio-tutorial course.

The results of the General Biology Test scores for the audio-tutorial and traditional biology students are found in Table XXII. The mean score of the audio-tutorial students was compared to the mean of the traditional biology students. The audio-tutorial students had a slightly higher mean score. However, the F value of .0081 was too small to be a significant difference. Hence, the null hypothesis was accepted.

Table XXII. Analysis of Variance of General Biology Test Scores of Audio-tutorial and Traditional Biology Students.

| | d.f. | SS | MS | F Ratio | Level of Significance |
|---|---|---|---|---|---|
| Class (a) | 1 | .4571 | .4571 | .0081 | - |
| Sex (b) | 1 | 128.2571 | 128.2571 | 2.2644 | - |
| a × b interaction | 1 | 1.0286 | 1.0286 | .0182 | - |
| Error | 136 | 7703.1427 | 56.6408 | | |

(a) There is no difference in achievement on the General Biology Test between males and females who have completed a traditional biology course and an audio-tutorial course.

The results of the General Biology Test scores for the male and female biology students are found in Table XXII. The mean score of the male students was compared to the mean score for the female students. Male students had the higher mean score. However, the F value of 2.2644 was too small to be a significant difference, so the null hypothesis was accepted indicating no real difference between the two groups in achievement as measured by the General Biology Test.

(b) There is no interaction between the type of biology course completed and sex in achievement on the General Biology Test.

The results of the General Biology Test scores for interaction between biology courses and sexes are found in Table XXII. The mean scores of each sex in two different biology courses were compared. The male audio-tutorial students had the highest mean General Biology Test score. The low F value indicates that the means are too uniform for significant interaction, so the null hypothesis was accepted.

3. There is no difference in the ability to recall information based upon scores on the General Biology Test between students completing a traditional biology course and the ability to recall information based upon scores on the General Biology Test of the students completing an audio-tutorial course.

The results of the ability to recall information test scores for the audio-tutorial and traditional biology students are found in Table XIII. The mean score of audio-tutorial students on the subtest was compared to the mean score of the traditional biology students. The mean for the audio-tutorial group was slightly larger than the mean for the traditional biology group, but the small F value indicates that there was no significant difference between the groups in ability to recall information. Hence, the null hypothesis was accepted.

Table XXIII. Analysis of Variance of Ability to Recall Knowledge Scores of Audio-tutorial and Traditional Biology Students.

| | d.f. | SS | MS | F Ratio | Level of Significance |
|---|---|---|---|---|---|
| Class (a) | 1 | .0643 | .0643 | .0094 | - |
| Sex (b) | 1 | 6.8643 | 6.8643 | 1.0054 | - |
| a × b interaction | 1 | 5.2071 | 5.2071 | .7627 | - |
| Error | 136 | 928.5143 | 6.8273 | | |

(a) There is no difference in the ability to recall information based upon scores on the General Biology Test between males and females who have completed a traditional and an audio-tutorial course.

The results of the ability to recall information test scores for the male and female biology students are found in Table XXIII. The mean score of male students was compared to the mean score of female students. While the male students had a higher mean score, the F ratio was too small to indicate a significant difference between the groups. Hence, it was accepted that there was no real difference in ability to recall information between the groups based upon scores on the Level I subtest of the General Biology Test.

(b) There is no interaction between the type of biology course completed and sex on ability to recall information based upon scores on the General Biology Test.

The results of the ability to recall information test scores are found in Table XXIII. The mean scores of sexes in the two biology courses were compared. The audio-tutorial males had the highest mean score and the females of the same group had the lowest mean score. The F value of .7627 was too small to indicate lack of uniformity of mean scores among the groups, so the null hypothesis was accepted.

4. There is no difference in ability to show relationships between bodies of knowledge based upon scores on the General Biology Test between students completing a traditional biology course and the ability to show relationships between bodies of knowledge based upon scores on the General Biology Test of students completing an audio-tutorial course.

The results of the ability to show relationships between bodies of knowledge subtest scores for the audio-tutorial and traditional biology students are found in Table XXIV. The mean score of the audio-tutorial students was compared to the mean score of the traditional biology students. The traditional biology students had a slightly higher mean score. There was no significant difference between the groups based upon subtest scores as seen in the caluclated F value, so the null hypothesis was accepted.

(a) There is no difference in ability to show relationships between bodies of knowledge based upon scores on the General Biology Test between males and females who have completed a lecture and an audio-tutorial course.

The results of the ability to show relationships between bodies of knowledge subtest scores for these groups are found in Table XXIV. The mean score of the male students was compared to the mean score of the female students. Male students in the audio-tutorial and traditional biology classes had higher mean scores than did the female students in either group. The F value of 4.7160 indicates a significant difference between males and females in ability to show relationships between bodies of knowledge, so the null hypothesis was rejected.

Table XXIV. Analysis of Variance of Ability to Show Relationships between Bodies of Knowledge Scores of Audio-tutorial and Traditional Biology Students.

| | d.f. | SS | MS | F Ratio | Level of Significance |
|---|---|---|---|---|---|
| Class (a) | 1 | .3500 | .3500 | .0552 | - |
| Sex (b) | 1 | 30.1786 | 30.1786 | 4.7610 | F < .05 |
| a × b interaction | 1 | 2.0643 | 2.0643 | .3257 | - |
| Error | 136 | 862.0571 | 6.3387 | | |

(b) <u>There is no interaction between the type of biology course completed and sex on ability to show relationships between bodies of knowledge based upon scores on the General Biology Test.</u>

The results of the ability to show relationships between bodies of knowledge subtest scores for these groups are found in Table XXIV. The mean scores of sexes in the two biology courses were compared. Male students in the traditional biology course had the highest mean score and females in the same group had the lowest mean score. The small F ratio indicates that achievement of the sexes on the subtest was neither influenced by the type of biology course nor by the interaction of sex and type of biology course. Hence, the null hypothesis was accepted that there was no interaction between sex and type of biology course completed on ability to show relationship between bodies of knowledge.

5. <u>There is no difference in the ability to apply knowledge in new situations based upon scores on the General Biology Test between students completing a traditional course and the ability to apply knowledge in new situations based upon scores on the General Biology Test of students completing an audio-tutorial course.</u>

The results of the ability to apply knowledge in new situation subtest scores for the audio-tutorial and traditional biology students are found in Table XXV. The mean score of the audio-tutorial students was compared to the mean score of the traditional biology students. The mean score of the traditional biology students was slightly higher than the mean for the audio-tutorial students but the F ratio of .9431 indicates that the difference was not significant. Hence, the null hypothesis was accepted.

(a) <u>There is no difference in the ability to apply knowledge in new situations based upon scores on the General Biology Test between males and females who have completed a traditional and an audio-tutorial course.</u>

The results of the ability to apply knowledge to new situations subtest scores are found in Table XXV. The mean score of the male students was compared to the mean score of the audio-tutorial students. Although the male students had the higher mean score, the difference was not significant; hence, it was accepted that there was no significant difference between the ability to apply knowledge in new situations of these groups based upon scores on the General Biology Test.

Table XXV. Analysis of Variance of Ability to Apply Knowledge to New Situation Scores of Audio-tutorial and Traditional Biology Students.

| | d.f. | SS | MS | F Ratio | Level of Significance |
|---|---|---|---|---|---|
| Class (a) | 1 | 4.1143 | 4.1143 | .9431 | - |
| Sex (b) | 1 | 2.8571 | 2.8571 | .6549 | - |
| a × b interaction | 1 | .1143 | .1143 | .0262 | - |
| Error | 136 | 593.3143 | 4.3626 | | |

(b) <u>There is no interaction between the type of biology course completed and sex on the ability to apply knowledge in new situations based upon scores on the General Biology Test.</u>

The results of the ability to apply knowledge in new situations subtest scores are found in Table XXV. The mean scores of the sexes in the two biology courses were compared. The mean score for male traditional biology students was slightly higher than the means for the other three groups. The small F value indicates that the differences were too small to denote interaction between sex of the students and the type of biology course, so the null hypothesis was accepted that there was no difference in ability of the sexes to apply knowledge in new situations as determined by the General Biology Test.

6. There is no difference in the ability to use skills involved in understanding scientific problems based upon scores on the General Biology Test between students completing a traditional biology course and the ability to use skills involved in understanding scientific problems based upon scores on the General Biology Test of students completing an audio-tutorial course.

The results of the ability to use skills involved in understanding scientific problems subtest scores for the audio-tutorial and traditional biology students are found in Table XXVI. The mean score of the audio-tutorial students was compared to the mean score of the traditional biology students. The mean score of the audio-tutorial students was higher than the mean of the traditional biology students. However, F value of 2.0141 was too low to be significant at the 5 percent level so the null hypothesis was accepted.

Table XXVI. Analysis of Variance of Ability to Use Skills Involved in Understanding Scientific Problems Scores of Audio-tutorial and Traditional Biology Students.

| | d.f. | SS | MS | F Ratio | Level of Significance |
|---|---|---|---|---|---|
| Class (a) | 1 | 9.2571 | 9.2571 | 2.0141 | - |
| Sex (b) | 1 | 2.3143 | 2.3143 | .5035 | - |
| a × b interaction | 1 | .0286 | .0286 | .0062 | - |
| Error | 136 | 625.0857 | 4.5962 | | |

(a) There is no difference in the ability to use skills involved in understanding scientific problems based upon scores on the General Biology Test between male and female who have completed a traditional and an audio-tutorial course.

The results of the ability to use skills involved in understanding scientific problems subtest scores for these groups are found in Table XXVI. The mean score of the male students was compared to the mean score of the female students. The mean score of the male students was slightly higher than the mean of the female students. The F value indicates that the difference was not significant, so the null hypothesis was accepted.

(b) There is no interaction between the type of biology course completed and sex on the ability to use skills involved in understanding scientific problems based upon scores on the General Biology Test.

The results of the ability to use skills involved in understanding scientific problems subtest scores for these groups are found in

Table XXVI. The mean scores of the sexes in each of the biology courses were compared. The mean score of the male audio-tutorial students was higher than the mean for other groups. However, the low F value indicates that there was no interaction between sex and type of biology course. The null hypothesis was accepted.

Understanding of Science

7. There is no difference in understanding of science based upon total TOUS scores between students completing a traditional biology course and understanding of science based upon total TOUS scores of students completing an audio-tutorial biology course.

The results of the understanding of science scores for the audio-tutorial and traditional biology students are found in Table XXVII. The mean score of the audio-tutorial students was compared to the mean score of the traditional biology students. The mean score of the audio-tutorial group was higher than the mean for the traditional biology group. However, the F value was too low to indicate a significant difference in understanding of science between the groups, so the null hypothesis was accepted.

Table XXVII. Analysis of Variance of Understanding of Science Scores of Audio-tutorial and Traditional Biology Students.

| | d. f. | SS | MS | F Ratio | Level of Significance |
|---|---|---|---|---|---|
| Class (a) | 1 | 9.2571 | 9.2571 | .2334 | - |
| Sex (b) | 1 | .7143 | .7143 | .0180 | - |
| a × b interaction | 1 | 24.0286 | 24.0286 | .6058 | - |
| Error | 136 | 5394.1714 | 39.6630 | | |

(a) There is no difference in understanding of science based upon total TOUS scores between males and females who have completed the traditional and audio-tutorial courses.

The results of the understanding of science scores for these groups are found in Table XXVII. The mean score of the male students was compared to the mean of the female students. Female students had a slightly higher mean score than did the male students. The low F value indicates that the difference is not significant so the null hypothesis was accepted that there is no difference in understanding of science between the sexes based upon total TOUS scores.

(b) There is no interaction between the type of biology course completed and sex on understanding of science based on total TOUS scores.

The results of the understanding of science test scores for these groups are found in Table XXVII. The mean scores of the sexes in each biology course were compared. Male students in the audio-tutorial course had the highest mean score and male students in the traditional course had the lowest mean score. The low F value indicates that student scores were not biased by sex nor influenced by the type of biology course. Hence, the null hypothesis was accepted.

8. There is no difference in understanding about the scientific enterprise based upon scores on Area I of TOUS between students completing a traditional biology course and understanding about the scientific enterprise based upon scores on Area I of TOUS of students completing an audio-tutorial course.

The results of the understanding about the scientific enterprise scores for the audio-tutorial and traditional biology students are found in Table XXVIII. The mean score of the audio-tutorial students was compared to the mean score of the traditional biology students. The audio-tutorial group had the highest mean score. The computed F value was not large enough to provide evidence for a significant difference. Hence, the null hypothesis was accepted.

(a) There is no difference in understanding about the scientific enterprise based upon scores on Area I of TOUS between males and females who have completed a traditional and an audio-tutorial course.

The results of the understanding about the scientific enterprise scores for these groups are found in Table XXVIII. The mean score of the male students was compared to the mean of the female students. The mean score of the females was slightly higher than the mean for the males. The small F value indicates that there was no significant difference between the sexes in understanding about the scientific enterprise. The null hypothesis was accepted.

Table XXVIII. Analysis of Variance of Understanding about the Scientific Enterprise Scores of Audio-tutorial and Traditional Biology Students.

| | d.f. | SS | MS | F Ratio | Level of Significance |
|---|---|---|---|---|---|
| Class (a) | 1 | 2.3143 | 2.3143 | .3539 | - |
| Sex (b) | 1 | 2.8571 | 2.8571 | .4369 | - |
| a × b interaction | 1 | .0000 | .0000 | .0000 | |
| Error | 136 | 889.3714 | 6.5395 | | |

(b) <u>There is no interaction between the type of biology course completed and sex on understanding about the scientific enterprise based upon scores on Area I of TOUS.</u>

The results of the understanding about the scientific enterprise scores for these groups are found in Table XXVIII. The mean scores of each sex in the two biology courses were compared. The mean score of the female audio-tutorial students was slightly higher than the mean for the other three groups. The F ratio of .0000 indicates that the means were too uniform to indicate any interaction. Hence, the null hypothesis was accepted.

9. <u>There is no difference in understanding about scientists based upon scores on Area II of TOUS between students completing a traditional biology course and understanding about scientists based upon scores on Area II of TOUS of students completing an audio-tutorial course.</u>

The results of the understanding about scientists scores for the audio-tutorial and traditional biology students are found in Table XXIX. The mean score of the audio-tutorial students was compared to the mean score of the traditional biology students. The audio-tutorial students had the higher mean score, but the F value was too small to be significant at the 5 percent level. Hence, the null hypothesis was accepted.

Table XXIX. Analysis of Variance of Understanding about Scientists Scores of Audio-tutorial and Traditional Biology Students.

| | d.f. | SS | MS | F Ratio | Level of Significance |
|---|---|---|---|---|---|
| Class (a) | 1 | 11.4286 | 11.4286 | 1.8486 | - |
| Sex (b) | 1 | .7143 | .7143 | .1155 | - |
| a × b interaction | 1 | 5.6000 | 5.6000 | .9058 | - |
| Error | 136 | 840.8000 | 6.1824 | | |

(a) There is no difference in understanding about scientists based upon scores on Area II of TOUS between males and females who have completed a lecture and an audio-tutorial course.

The results of the understanding about scientists scores for these groups are found in Table XXIX. The mean score of male students was compared to the mean of the female students. The mean score of the females was slightly higher than the mean for the males. The small F value indicates that the difference was too small to be significant at the 5 percent level. Hence, the null hypothesis was accepted.

(b) <u>There is no interaction between the type of biology course completed and sex on understanding about scientists based upon scores on Area II of TOUS</u>.

The results of the understanding about scientists scores for these groups are found in Table XXIX. The mean scores of the sexes in the two biology courses were compared. The male audio-tutorial students had the highest mean score, while the males in the traditional biology group had the lowest mean score. The computed F value was too small to indicate a lack of uniformity among the mean scores, so the null hypothesis was accepted.

10. <u>There is no difference in understanding about the methods and aims of science based upon scores on Area III of TOUS between students completing a traditional biology course and understanding about the methods and aims of science based upon scores on Area III of TOUS of students completing an audio-tutorial course</u>.

The results of the understanding about the methods and aims of science scores for the audio-tutorial and traditional biology students are found in Table XXX. The mean score of the audio-tutorial students was compared to the mean score of the traditional biology students. The mean score of the traditional group was slightly higher than the mean for the audio-tutorial students. The computed F value was too small to be significant at the 5 percent level, so the null hypothesis was accepted.

TABLE XXX. Analysis of Variance of Understanding about the Methods and Aims of Science scores of Audio-tutorial and Traditional Biology Students.

| | d.f. | SS | MS | | Level of Significance |
|---|---|---|---|---|---|
| Class (a) | 1 | 2.5786 | 2.5786 | .2969 | - |
| Sex (b) | 1 | 2.0643 | 2.0643 | .2377 | - |
| a × b interaction | 1 | 5.2071 | 5.2071 | .5996 | - |
| Error | 136 | 1,181.1429 | 8.6849 | | |

(a) There is no difference in understanding about the methods and aims of science based upon scores on Area III of TOUS between males and females who have completed a traditional and an audio-tutorial course.

The results of the understanding about the methods and aims of science scores for these groups are found in Table XXX. The mean score of the male students was compared to the mean score of the female students. The male students had the higher mean score of the two groups, but the low F value indicates that the difference was not significant. Hence, the null hypothesis was accepted.

(b) There is no interaction between the type of biology course completed and sex on understanding about the methods and aims of science based upon scores on Area III of TOUS.

The results of the understanding about the methods and aims of science scores for these groups are found in Table XXX. The mean scores of the sexes in the audio-tutorial and traditional biology course had a slightly higher mean score than did the other three groups. The low F value indicates that scores on Area III of TOUS were not influenced by an interaction between sex and type of biology course, so the null hypothesis was accepted.

## Summary

Analysis of data from the school records indicates that the audio-tutorial and traditional biology students were comparable in academic ability and background knowledge upon enrolling in college.

Analysis of student responses to the investigator prepared General Biology Test indicates that the test items possessed adequate reliability and discriminating power. There was evidence that the subtests measure distinctly different abilities, have adequate discriminating power, and are sufficiently reliable for group comparisons. However, the low reliability coefficient for the Level III subtest indicates that the results of the comparisons based on that subtest should be interpreted with some caution.

Appraisal of the coefficients of correlation provided some evidence that the General Biology Test and the Test on Understanding Science, Form W, are valid instruments. The correlations also provide evidence which supported the basic assumption that these tests could be separated into component parts for analytical evaluation.

Student responses to the Test on Understanding Science, Form W, and the General Biology Test indicate that the participants have a reasonably good understanding of science and comprehension of biology. Responses to the Attitude Scale indicate that in general the participants were positively disposed toward science.

Comparison of group mean scores of audio-tutorial and traditional biology students on the criterion instruments and subtests failed to reveal any significant differences between the two groups. The comparison of the total male sample with total female sample resulted in the rejection of one null hypothesis. Based on Level II subtest scores, male students were significantly superior at the .05 level to females in ability to show relationships between bodies of knowledge. However, there was no evidence that either sex performed at a significantly higher level in either of the biology courses. That is to say, there was no interaction between the sexes and biology courses.

# V SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

## Summary

This study was designed to evaluate a newly designed general education college biology course on the basis of student comprehension of biology, attitude toward science, and understandings about science. The evaluation was facilitated by comparing the performance of students in the new biology course to students in a traditional course on the basis of performance on selected criterion tests. Seventy audio-tutorial and 70 traditional biology students were involved in the investigation. All were students enrolled in general education college biology at the Kansas State Teachers College during the Fall Semester, 1966, and were randomly selected.

Students were posttested during the last three class meetings of the semester. The criterion tests used were the Test on Understanding Science, Form W, Attitude Scale, and General Biology Test.

To determine whether student enrollment in either of the biology courses was influenced by academic ability or knowledge of biology, student pre-enrollment scores on the General Ability Test and Entrance Biology Test were analyzed. Analysis of the mean scores of the population and the sample based on the above criteria indicated no significant differences between the audio-tutorial and traditional biology students in academic ability and knowledge of biology. On the basis of the analysis, the groups were considered to be comparable for the investigation.

The General Biology Test and subtests designed for this study were analyzed to determine the presence or absence of discriminating power, reliability, and whether the subtests measured different abilities. Total test scores and total scores for each subtest, rather than individual scores, were used as the unit of analysis since it was groups of test items and not the individual items which were under consideration.

Analysis of variance was used to compute F ratios and coefficients of reliability for the total test and each subtest. The F ratios indicated that the General Biology Test and each of its four subtests were capable of discriminating between high and low ability students. On the basis of scores of the total sample, the reliability coefficient for items on the entire test was .84. The coefficients of reliability for the subtests were somewhat smaller, but considered adequate for tests used in comparing groups. The low r value for Level III, the ability to apply knowledge to new situations, indicated that any conclusions based on that subtest should take into account the possibility that the results could be biased by low reliability. However, the computation of adjusted r values, which are predictors of the performance of similar one hour tests, resulted in a minimum R value of .79 which indicated that each subtest had sufficient reliability for group comparisons.

Coefficients of correlation between each set of data were all positive. Correction of the correlations between the General Biology Test subtests for attenuation provided some evidence that each subtest measured a distinctly different ability. The high correlation of TOUS and the General Biology Test with their subtests indicated a relatively high validity for each test.

Student scores on the Attitude Scale and TOUS showed a relatively weak, but positive relationship with student grades. The Attitude Scale correlated significantly, r of .81, with only one measure, Level III of the General Biology Test. Other than the correlations of subtests with total tests, only the correlation between the General Biology Test and course grades and the correlation between the Attitude Scale and Level III of the General Biology Test yielded coefficients of determination of at least 50 percent.

Analysis of the final course grades received by students in the sample showed that the traditional biology students, female students as a group, and female traditional biology students received slightly higher course grades. However, none of the differences were statistically significant; and there was no interaction between biology course and sex. It was interesting to note that, although the audio-tutorial students scored slightly higher than traditional biology students in all categories of the three criterion instruments except General Biology Test, Levels II and III, and TOUS, Area III, the audio-tutorial students received slightly lower final grades. Males, as a group, also, scored slightly higher in all categories including the General Ability Test and Entrance Biology Test than did the females, except TOUS, Area II, however the males received slightly lower final grades.

Analysis of variance was used in a two place factorial design to statistically determine any significant differences in performance on the criterion instruments between the audio-tutorial and traditional biology students. Analysis was based on the .01 and .05 levels of significance.

Based on scores on the Attitude Scale, the participants in the study had positive attitudes toward science. Audio-tutorial students showed a more positive attitude than did the traditional biology students. Male students as a group showed a more positive attitude toward science than did the female participants while audio-tutorial males showed the most positive attitude of all groups. However, none of the differences were statistically significant.

The General Biology Test sampled the student's comprehension of biology. Analysis indicated that audio-tutorial students performed better than traditional biology students on the test as a whole and Levels I and IV. Conversely, the performance of the traditional group was superior to that of the audio-tutorial group on Levels II and III. None of the differences between the two groups were significant. The F ratio of 2.0141 for Level IV was the only F ratio that approached the .05 level of significance.

Male participants in the study, regardless of type of biology course, obtained higher mean scores than did the females on the General Biology Test and each of the four subtests. Statistical comparison of group mean scores resulted in an F value of 4.7160 for Level II, the ability to show relationships between bodies of knowledge, which was significant in favor of males at the .05 level. No significant differences were noted between the sexes on the basis of the other comparisons.

The Test on Understanding Science, Form W, sampled the students' understandings about science. Analysis indicated that the audio-tutorial students had a better over-all understanding about science than did the traditional group; however, the latter group obtained a higher mean score on the Area III subtest. Male students obtained higher mean scores on the entire test and Areas I and III while the female students had a higher mean score on Area II. The differences between the groups on the Test on Understanding Science, Form W, and the subtests were not significant.

## Conclusions

Thirty null hypotheses were tested in this study (stated on pages 11 through 17). The three null hypotheses relating to attitudes toward science were tested and accepted. Fourteen of the 15 null hypotheses relating to comprehension of biology were tested and accepted. The following null hypothesis was rejected:

> There is no difference in the ability to show relationships between bodies of knowledge based upon scores on the General Biology Test between males and females who have completed a lecture and an audio-tutorial course.

The calculated F value of 4.7610 indicated a significant difference at the .05 level between male and female students, with males attaining the higher scores. The 12 null hypotheses relating to understanding of science were tested and accepted. (Statistical analysis of the null hypotheses was presented in Chapter IV.)

The following conclusions were deduced from the data presented in this investigation:

1. Students participating in the study indicated a moderately positive attitude toward science; however, there was no significant difference in attitude toward science as measured by the Attitude Scale between audio-tutorial and traditional biology students. The comparison was not biased by the sex of the students.
2. Evidence was obtained which indicated that students' attitudes

toward science as measured by the Attitude Scale had a strong positive relationship to student ability to apply biological knowledge to new situations as measured by a subtest of the General Biology Test.

3. There was no significant difference in general comprehension of biology, ability to recall information, ability to apply knowledge in new situations, and ability to use skills involved in understanding scientific problems as measured by the General Biology Test either between audio-tutorial and traditional biology students or between male and female biology students.
4. Male students participating in the study indicated a significantly greater ability to show relationships between bodies of knowledge as measured by the General Biology Test than did female students participating in the study. There was no significant difference in that category between audio-tutorial and traditional biology students.
5. There was no significant difference in general understandings about science as measured by the Test on Understanding Science, Form W, either between audio-tutorial and traditional biology students or between male and female biology students.
6. There was no significant difference in understandings about the scientific enterprise, about scientists, and about the methods and aims of science as measured by the Test on Understanding

Science, Form W, either between audio-tutorial and traditional biology students or between male and female biology students.

7. Data were analyzed which indicated that the audio-tutorial biology course could, with some revision, demonstrate significant superiority to the traditional biology course in enhancing students' abilities to use skills involved in understanding scientific problems and understandings about scientists. On the basis of comparisons the differences between the audio-tutorial and traditional biology groups were relatively larger in those two areas.

8. Evaluation of either new or existing biology courses could be improved by measuring a broad range of outcomes. Data from the comparisons in this study indicated that some groups were realizing greater achievement in single learning areas.

9. Evaluation of student achievement, and subsequently, instruction in biology could be improved by measuring a broad range of outcomes. Data from the correlation studies indicated that the relationship between course grades and evaluative criteria became progressively weaker as the measures progressed from the ability to recall factual information to more sophisticated ability levels and understandings about science.

10. Although analysis of the data revealed that male students

performed slightly better on the criterion instruments, female students received slightly higher grades in biology.

11. Evidence was obtained which indicated that differences in responses to the criterion instruments between male and female participants were of a magnitude which was very similar to the differences between audio-tutorial and traditional biology students.

12. Although most of the data indicated that the audio-tutorial course was slightly superior to the traditional course, the differences were not significant.

## Recommendations

On the basis of this investigation, the following recommendations are presented:

1. A comparable evaluation of the audio-tutorial course be conducted in other institutions of higher learning.
2. A comparable evaluation of the audio-tutorial course be done using other but similar criterion instruments.
3. A comparable evaluation of the audio-tutorial course be conducted over a longer period of time.
4. A study be done to analyze specifically the influence of the laboratory phase of the audio-tutorial course on student attitudes toward science, comprehension of biology, and

understandings about science.

5. A study be done to analyze specifically the influence of <u>Scientific American</u> articles on student understandings about science.
6. A comparable study be conducted utilizing a pretest-posttest design and include a comparable group of students not enrolled in science.
7. A longitudinal follow-up study be conducted to determine the stability of student attitude toward science and understandings about science.
8. A comparable study be conducted to evaluate student attainment of other instructional objectives.
9. An investigation be done to analyze more specifically the influence of the audio-tutorial course on student ability to use skills involved in understanding scientific problems and understandings about scientists.
10. An investigation be done to analyze more thoroughly the indication that male biology students were more capable than female biology students in ability to show relationships between bodies of knowledge.

The foregoing statements do not include all of the recommendations that the investigation might suggest. However, each of the recommendations do seem to be relevant to the evaluation of a biology course.

In the interest of subsequent revisions of the audio-tutorial course, it is recommended that the course objectives be outlined in considerably more detail than at present. The identification of a population of expected outcomes would serve as guidelines for the selection of appropriate teaching and learning experiences, thereby reducing the reliance on an intuitive approach to content selection. Along with the identification of more specific objectives, it is recommended that evaluation instruments be designed which measure achievement of the outcomes with a higher degree of specificity.

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# APPENDICES

## APPENDIX A

Instructional Films Used in the Traditional Biology Course

| | | |
|---|---|---|
| 1. | Characteristics of Plants and Animals | Indiana U. |
| 2. | Cell: Structural Unit of Life | Coronet |
| 3. | Bacteria: Friend or Foe | EBF* |
| 4. | The Single-Celled Animals-Protozoa | EBF |
| 5. | Worms: the Annelida | EBF |
| 6. | Mollusks: A Story of Adaptation | McGraw-Hill |
| 7. | Birth of the Soil | EBF |
| 8. | Digestion of Foods | EBF |
| 9. | Asexual Reproduction | Indiana U. |
| 10. | Human Reproduction | McGraw-Hill |
| 11. | Heredity | EBF |
| 12. | The Grasslands | EBF |
| 13. | Simple Plants-the Algae | EBF |
| 14. | Fungi | EBF |
| 15. | Origin of Land Plants-Liverworts and Mosses | EBF |
| 16. | Gymnosperms | McGraw-Hill |
| 17. | Angiosperms | EBF |
| 18. | Joint-Legged Animals: Arthropods | EBF |
| 19. | What is a Fish | EBF |
| 20. | What is a Bird | EBF |
| 21. | Growth of Plants | EBF |
| 22. | Photosynthesis | EBF |
| 23. | DNA-Molecule of Heredity | EBF |
| 24. | Gene Action | EBF |
| 25. | Mitosis | EBF |
| 26. | Meiosis: Sex Cell Formation | EBF |
| 27. | The Chick Embryo: From Primitive Streak to Hatching | EBF |
| 28. | The Community | EBF |
| 29. | Succession: From Sand Dune to Forest | EBF |
| 30. | The Sea | EBF |
| 31. | The Temperate Deciduous Forest | EBF |
| 32. | Natural Selection | EBF |

*EBF = Encyclopedia Britannica Films

# APPENDIX B

Lecture and laboratory schedules, reading assignments, laboratory procedures, and list of instructional films for the audio-tutorial course

GENERAL BIOLOGY (A-T)

Lecture and Laboratory Schedule Fall 1966

| Week | Day | Date | Lecture | Lab |
|---|---|---|---|---|
| | | Sept | | |
| 1 | T | 13 | Introduction | No Lab. |
| | Th | 15 | Laboratory Procedures | |
| 2 | T | 20 | Diversity of Life (Monera Protista) | Use of the Microscope |
| | Th | 22 | " " " (metaphyta) | |
| 3 | T | 27 | " " " (Metazoa) | Habitat Samples |
| | Th | 29 | Ecology | |
| | | Oct | | |
| 4 | T | 4 | " | Limits of Tolerance |
| | Th | 6 | " | |
| 5 | T | 11 | " | Succession |
| | Th | 13 | TEST I | |
| 6 | T | 18 | The Cell | (a) Examination of Cells |
| | Th | 20 | | (b) Drosophila |
| 7 | T | 25 | Biological Energetics | Photosynthesis |
| | Th | 27 | " " | |
| | | Nov. | | |
| 8 | T | 1 | " " | Aerobic Respiration |
| | Th | 3 | | |
| 9 | T | 8 | Reproduction: mechanism | |
| | Th | 10 | " " | Anaerobic Respiration |
| 10 | T | 15 | TEST II | Genetics |
| | Th | 17 | Reproduction: genetics | |
| 11 | T | 22 | " | Genetics |
| | Th | 24 | THANKSGIVING | |
| 12 | T | 29 | Growth: embryology | |
| | | Dec. | | |
| | Th | 1 | " " | Seed Germination |
| 13 | T | 6 | " : life cycles | |
| | Th | 8 | " " " | Embryology and Life Cycles |
| 14 | T | 13 | Control Systems | Auxins and Hormones |
| | Th | 15 | " " | |
| 15 | T | 20 | TEST III | No Lab. |
| | Th | 22 | | " |
| 16 | T | 27 | CHRISTMAS | " |
| | Th | 29 | | " |
| | | Jan. | | |
| 17 | T | 3 | | " |
| | Th | 5 | Control Systems | " |
| 18 | T | 10 | Evolution | Adaptation and the |
| | Th | 12 | " | Fossil Record |
| 19 | | | FINAL EXAM | |

# GENERAL BIOLOGY (A-T)
## Reading Assignments

These assignments refer to material covered in lecture and lab for that week and should be read before class and lab of the week indicated.

| Week | | | |
|---|---|---|---|
| 2 | Offprints: | 2. | Viruses |
| | | 115. | Molds and Men |
| 3, 4, 5 | Offprints: | 144. | Ecosphere |
| | | 114. | Ecology of Desert Plants |
| | | 159. | Ecological Effects of Radiation |
| 6 | The Cell | Chaps. 1 thru 4 | |
| | Drosophila Guide: | pp. 1-16 | |
| 7 | Offprints: | 34. | Photosynthesis |
| | | 107. | Light and Plant Development |
| 9 | The Cell: | Chaps. 5 and 6 | |
| | Offprints: | 119. | Messenger RNA |
| | | 104. | How Do Genes Act |
| | | 153. | Genetic Code II |
| | | 93. | How Cells Divide |
| 10 | Adaptation: | Chaps. 1 thru 4, 9 and 10 | |
| 12 | The Cell: | Chaps 7 and 8 | |
| | Offprint: | 117. | Germination |
| 13 | Offprints: | 53. | Circulatory System of Plants |
| | | 112. | Flowering Process |
| | | 116. | What Makes Leaves Fall |
| 14 | Offprints: | 13. | Great Ravelled Knot |
| | | 158. | Lymphatic System |
| 18 | Adaptation: | Chaps. 5 thru 8, 11 and 12 | |
| | Offprints: | 71. | Radiation and the Human Cell |
| | | 609. | The Present Evolution of Man |
| | | 867. | Crises in the History of Life |

## LABORATORY PROCEDURES

A. Where lab is located

The lab is located on the top floor of this building, in the center of the west side. There is a sign above the entrance which states "Audio-tutorial Lab."

B. Lab open 9:30 a.m. to 10:00 p.m. Monday-Friday

Do not START a lab after 9 p.m. Okay to come in any time to make measurements, etc.

C. Sign up

1. Sign up for 2 hour block of time for the initial lab. (No need to sign up for repeats or taking extra data unless you wish that time and space reserved).

2. Sign up sheets will be in notebook in booth in anteroom to 104 (lab.)
   a. a sheet for each booth
   b. current week and following week.

3. Come promptly--don't stay overtime if someone has signed for the period following yours!!!

4. Drop in whenever you wish. If a booth is vacant for a sufficient length of time for you to complete your work, use it.

D. Check In

1. Check-in cards for everyone will be kept in a file box in first booth just inside door of lab. anteroom.
2. Remove your card and put date and time in on back of card.
3. Place card in holder provided in booth--in slot (pocket) for the number of the booth you will use. This provides a readily visible reference to availability of booths.
4. When you leave lab, remove card and place time out on back of card, then give card to assistant on duty.

E. Lab Tests

1. There will be 10 tests; 25 points each; total 250 points.
2. Tests will be administered on Thursdays of next week after lab.
3. May be objective, subjective, or both.
4. Lab test will be posted on the check-in card. (grades)
5. Material covered on tests will be any reading or lecture pertinent to the lab in question AND any of the lab techniques, processes, or principles.

F. NO SMOKING IN LAB. If you wish to smoke, there are ash trays and seats outside of the lab on the top floor and also in the basement. ALSO: do not bring food or drinks to lab.

G. Work

1. May extend over two weeks, several weeks, or most of semester.
2. Demonstrations.
3. In any one week there may be more than one thing going on.
4. Many experiments "open-ended" - everyone will not get same results.
5. Necessary to be careful in measurements, cleanliness, data-taking, and care of equipment and materials.
6. Sometimes certain writeups will be required, graphs drawn, and/or conclusions reached.
7. Always bring all lab data for all labs to each Tuesday discussion session.
8. Clean up booth and equipment when through with experiment. Also, rewind tape.
9. Assistant on duty at all times to get more materials, answer questions, or to help.
10. Do not kid around. This is a work area. If you want to gab, go outside.
11. May be hand-out sheets, glossaries, diagrams, etc., in conjunction with tapes.
12. If anything goes wrong with equipment or tapes, report it immediately to the assistant.
13. Bring "text", pertinent offprints, paper, pencil, ruler each time.
14. There is no "write up" required for labs--other than graphs, etc., which will be specified at certain times.

## APPENDIX B

## INSTRUCTIONAL FILMS USED IN THE AUDIO-TUTORIAL COURSE

| | | |
|---|---|---|
| 1. | The Single-Celled Animals-Protozoa | EBF* |
| 2. | Fungi | EBF |
| 3. | The Joint-Legged Animals: Arthropods | EBF |
| 4. | What is Ecology | EBF |
| 5. | Distribution of Plants and Animals | EBF |
| 6. | The Community | EBF |
| 7. | Succession: From Sand Dune to Forest | EBF |
| 8. | Cell: Structural Unit of Life | Coronet |
| 9. | The Nine Basic Functional Systems of the Human Body | Bray |
| 10. | Photosynthesis | EBF |
| 11. | Photosynthesis: Chemistry of Food-Making | Coronet |
| 12. | DNA-Molecule of Heredity | EBF |
| 13. | Mitosis | EBF |
| 14. | Asexual Reproduction | Indiana U. |
| 15. | Meiosis: Sex Cell Formation | EBF |
| 16. | Heredity | EBF |
| 17. | The Chick Embryo: From Primitive Streak to Hatching | EBF |
| 18. | Origin of land Plants-Liverworts and Mosses | EBF |
| 19. | Simple Plants-the Algae | EBF |

*EBF = Encyclopedia Britannica Films

# APPENDIX C

## Attitude Scale

Seat Number ______

Name ______________________________ Sex ______
(Last) (First) (Middle) M or F

______________________________ ______
(course number and section) (date)

DIRECTIONS: The following is a list of statements relating to science. Place an X in the box before those statements with which you agree. Leave all others blank.

1. Field trips to such places as botanical gardens or observatories make science an interesting subject.

2. Science is unrelated to life experiences.

3. I wish I had been given more science instruction in elementary school.

4. I could never see anything through a microscope.

5. It is very helpful to know the basic facts about animal life.

6. Science seems to be "over my head".

7. Possibilities for student participation make science an interesting subject.

8. The study of science doesn't bore me, but I would never pursue it independently.

9. It is fascinating to study live specimens in the classroom.

10. I am always interested in learning more about science.

11. I just hate mice, worms, bugs, and any other small, crawling things.

12. Science education is a "must" at this time.

13. Scientists are people who invent something to improve everyday life.

14. Science learnings are often the basis of a good hobby.

15. Science is very important in this scientific age in which we live.

16. A lizard is an interesting and attractive classroom pet.

17. Science is interesting, but not as important as other subjects.

18. Science is boring.

19. I like to do science experiments.

20. Elementary school science should be taught to groups of children with approximately the same I. Q.

# APPENDIX D

## General Biology Test

Kansas State Teachers College of Emporia
GENERAL BIOLOGY TEST FINAL FALL 1966

DIRECTIONS: For each item from 1-50. blacken the space on the answer sheet that corresponds to the best answer. Do not make any other marks on the answer sheet. If you change your mind, erase the first mark completely, so that the scoring machine will not record it.

1. The greatest number of different kinds of elements occurs in: 1. fats, 2. proteins, 3. starches, 4. sugars, 5. cellulose.

2. In view of the evidence that environments vary over long periods of time, what must happen within populations of organisms if such populations are to survive? 1. new phyla must be created, 2. the reproductive rate must increase, 3. genera of stressed populations must crossbreed with genera of another population, 4. the ability to produce numerous offspring must be enhanced, 5. suitable mutations must occur and be perpetuated.

3. The relationship between carbon dioxide and the pores of a leaf is comparable to the relationship between water and which one of the following? 1. xylem, 2. glucose, 3. osmosis, 4. root hairs, 5. cellular respiration.

4. The statement that, "As many more individuals of each species are born than can possibly survive in the struggle for existence, it follows that any individual organism which varies however slightly in a manner better adapted to the environment will have a better chance of surviving", best illustrates: 1. natural selection, 2. mutation, 3. isolation, 4. the theory of inheritance of acquired characteristics, 5. hybridization.

5. The statement that, "If the pollen from a plant with white flowers is placed on the pistil of a plant with red flowers, the seeds that are produced give rise to a plant with pink flowers" best illustrates: 1. natural selection, 2. mutation, 3. isolation, 4. the theory of inheritance of acquired characteristics, 5. hybridization.

Questions 6 and 7 are based on the following:

Three beakers, each containing 500 grams of wheat were treated as follows:
In beaker No. 1 the wheat seeds were killed by steaming. In beaker No. 2 the wheat was soaked in water, allowed to germinate, and kept in the dark for ten days. In beaker No. 3 the wheat was untreated. At the end of ten days all three samples were ovendried, cooled, and weighed. NOTE: Wheat contains large amounts of starch which is readily converted to glucose. Weight of each sample after drying was as follows:

Sample No. 1 ............... 475 grams
Sample No. 2 ............... 420 grams
Sample No. 3 ............... 474 grams

6. In the above situation, the variable factor between the two experimental samples and the one control sample is: 1. the percentage of starch at the beginning of the experiment, 2. the occurrence of cellular respiration during the experiment, 3. the occurrence of weight loss from drying, 4. the amount of oxygen consumed during the experiment, 5. the amount of heat needed to dry the three samples.

7. On the basis of the data given above, one might logically infer that: 1. the wheat in the three samples contains different amounts of respiratory enzymes, 2. all the samples, dead or alive; lose weight during storage, 3. loss in weight can be attributed to the using up of glucose, 4. loss in weight is due entirely to the evaporation of water, 5. cellular respiration occurs in all organisms at all times.

8. Organisms which live at great depths in the ocean are usually animals. Green plants are unable to live there because: 1. they have no place to anchor their roots, 2. they cannot manufacture foods in deep water, 3. the oxygen concentration is too low, 4. they are unable to move about as animals do, 5. the carbon dioxide concentration is too low.

9. There are two different fossil forms, each representing a different class, found in undisturbed rock layers of a cliff. One of these is an early amphibian, Onychopus. It is found in a rock layer near the top of the cliff. The other form found in the rock layers below the amphibian would most likely be: 1. a primitive dog, 2. a primitive reptile, 3. a primitive bird, 4. a primitive fish, 5. a primitive horse.

10. Certain species of desert lizards excrete their wastes in dry forms. This represents: 1. a limiting factor of the organism, 2. adaptation of organism to environment, 3. a protective device against enemies, 4. the result of malnutrition, 5. none of these.

11. Which of the following is the most complex compound? 1. a protein, 2. an amino acid, 3. glucose, 4. ribose, 5. ammonia.

12. Cell differentiation is concerned with the observational evidence that: 1. cells remain the same shape during the subsequent development of the organism, 2. cells change from one basic type to specialized types, 3. cells change from one type to another because they have different genetic characteristics, 4. cell division alone accounts for changes occurring in cells, 5. all the possible cell changes which occur do so before the gastrulation stage.

13. A process which operates to eliminate individuals less well adapted than their competitors in a given environment is: 1. gene mutation, 2. natural selection, 3. isolation, 4. genetic recombination, 5. genetic drift.

14. The following statements: "Undoubtedly the first living things reproduced asexually, and sexual reproduction resulted from a chance change that came later. The change probably occurred independently several times among primitive organisms", best illustrates: 1. natural selection, 2. mutation, 3. isolation, 4. the theory of inheritance of acquired characteristics, 5. hybridization.

15. In the food chain, wheat-mouse-owl, the original source of energy used for the life process of the owl came from: 1. wheat, 2. sun, wheat, and mouse, 3. sun and mouse, 4. sun, 5. wheat and mouse.

16. The essential process of respiration is most similar to: 1. the rolling of a stone down a hill, 2. the movement of materials through a plasma membrane, 3. a reaction in which simple molecules combine to form complex molecules, 4. the burning of a fire, 5. the transportation of nutriment in a plant.

Questions 17 through 20. Read carefully the following discussion of the inheritance of coat color and horns in cattle and the PROBLEM which follows it. Then for each question, select the most appropriate answer from the KEY provided.

A certain breed of cattle comes in three colors: red, white or roan (a mixture of red and white). This breed also shows two horn conditions: horned and hornless. It is known that:

I. Matings between red cattle of this breed yield only red offspring.
II. Matings between white cattle of this breed yield only white offspring.

III. Matings between a red animal and a white animal of this breed yield only roan colored offspring.

IV. Matings between two roans may produce red, roan or white offspring.

V. Matings between two horned cattle of this breed always result in horned offspring.

VI. Matings between two hornless cattle of this breed may yield either hornless or horned offspring.

VII. A mating between a hornless bull and a horned cow yielded a horned male calf.

PROBLEM: What is the mode of inheritance of coat color and horns in this breed of cattle?

For questions 17 through 20 select the most appropriate answers from the following KEY.

1. Given and needed to solve the problem,
2. An assumption that bears on the solution of the problem,
3. A conclusion that is supported by the experimental results,
4. A conclusion that is contradicted by the experimental results,
5. (I don't know the answer).

17. Red is dominant over white.
18. This breed of cattle comes in three colors and in two different horn conditions.
19. Referring to the statement VII above, the hornless parent was pure line, that is, he had two genes for hornlessness.
20. White cattle of this breed, when mated together, produce only white offspring.
21. In 1956 a city sprayed DDT on city dumps and other breeding areas of flies. This was immediately effective in reducing the number of house flies in the whole city area. Although the spraying was repeated each year, the number of flies gradually increased, approaching the former (1955) level in 1963. Which of the following best explains the situation? 1. Each new generation of young flies grew up with DDT as part of their environment and gradually developed immunity, 2. Flies gradually found new breeding areas not contaminated by DDT, 3. Flies exposed to non-lethal concentrations of DDT quickly learned to avoid food and other matter sprayed with DDT, 4. Flies from nearby, non-sprayed areas soon migrated to the city area, 5. DDT-resistant flies survived to breed, as did their offspring, until more of each year's flies were DDT-resistant.
22. Mutualism is represented by an association such as that involving: 1. tapeworm and man, 2. leather and mildew, 3. malaria organism and man, 4. termite and intestinal protozoa, 5. penicillium mold and bread.
23. Knowing that environments vary over long periods of time, what must happen within populations of organisms if such populations are to survive? 1. New phyla must be created, 2. Genera of such populations must cross breed with genera of another population, 3. The reproduction rate must increase, 4. the potential to produce offspring must increase, 5. Suitable mutations must occur and be perpetuated.
24. The protoplasmic component that is chiefly responsible for coordinating and controlling the chemical and physical changes which result in the production of more protoplasm is the: 1. nucleus, 2. plasma membrane, 3. cytoplasm, 4. mitochondria, 5. cell wall.
25. After reading a number of scientific articles on the cell, a biologist would be correct in accepting all of the following EXCEPT: 1. a cell is the unit of structure in living organisms, 2. the cell is unit of function in living organisms, 3. all cells come from pre-existing cells, 4. all cells have some means of locomotion, 5. the cell is the minimum organization of matter that is capable of those processes we refer to as life.
26. The theory of evolution state that: 1. all animals have developed directly from viruses. 2. man evolved from the apes, 3. change occurs in the organic world, 4. life may have originated on another planet, 5. life arose spontaneously.

27. At some point in the life cycle of sexually reproducing organisms the diploid number of chromosomes must be reduced to the haploid number because: 1. otherwise in each generation, the number of chromosomes would double, 2. the sperm cell must have the same number of chromosomes as the egg cell, 3. mitosis cannot take place without such a reduction occurring, 4. all body cells have the same number of chromosomes, 5. a change in the number of chromosomes in body cells occur only as a result of mutation.
28. Non-green plants, like those living in a dead log, may be a nuisance to man because they: 1. appear unappetizing, 2. decompose the log, 3. absorb water, 4. kill livestock, 5. may spoil food and lumber.
29. The primary reason that man has been able to distribute throught the world is his ability to: 1. change his body temperature to that of his environment, 2. live solely from inorganic materials, 3. maintain a constant temperature regardless of his environment, 4. utilize carbon dioxide, sunlight, and water to synthesize food, 5. regulate his metabolic rate at will.
30. The dependence of red clover on bumble bees. the Smyrna fig on wasps, and the yucca plant on a certain moth are examples of the generalization that: 1. organisms evolve together, 2. flowers always need insects for pollination, 3. insects prefer blossoms to plant stems for food, 4. organisms have particular food habits, 5. pollination by insects is least effective.
31. On the basis of the various ecological, environmental, anatomical, and physiological factors involved, which of the following organisms would most likely be found living in the vicinity of either the North or South Pole? 1. Protozoa, 2. Frogs, 3. Turtles, 4. Water Snakes, 5. Alligators.
32. "When a person speaks of life he has certain concepts in mind. The power of moving about is associated with life but all living things do not possess this power. Plants are alive and yet many of them do not move about. Crystals grow, hence growth cannot be a characteristic which is restricted to living things. Respiration is considered by some to be the best criterion, but respiration is oxidation or burning, a phenomenon also found in the burning of oil, wood, or coal." The major problem presented in the above paragraph is: 1. do all living things move about? 2. is growth restricted to living things? 3. can any except non-living substances be oxidized? 4. do all people interpret life in the same way? 5. what is life?

Questions 33 and 34 are based on the following statement:

In the Nevada desert there is small pool of water about 30 feet below the surrounding desert. Here is found a type of fish known as the pupfish which has the smallest range of any known vertebrate and which has apparently existed in this pool since the Ice Age ended.

33. The limited range of this species is probably due to: 1. geographical isolation, 2. hybridization, 3. genetic drift, 4. survival of the fittest, 5. mutation.
34. Change in the anatomy and physiology of this species of fish is: 1. impossible because if it were going to change it would have changed by now, 2. possible only if the fish were changed to another habitat, 3. possible only if the fish were crossed with another species, 4. impossible because genes do not change, 5. possible only if the fish were crossed with another genera.

Questions 35 and 36 relate to the cause of a disease in sheep.

35. A researcher injects some blood from a diseased sheep into a healthy sheep. If the healthy sheep develops the same disease, which of the following conclusions is most justified? 1. A microorganism causes the disease, 2. Something in the blood definitely caused the disease, 3. The blood from a diseased sheep will cause the disease in a second healthy sheep into which it has been injected, 4. The disease is caused by some food both sheep have eaten, 5. There is insufficient evidence to reach any of the above conclusions.
36. The researcher isolates a pure strain of a microorganism from the blood of a diseased sheep. Following injection of the microorganism into a group of fifty sheep, forty of them contract the disease. Of the following, it is most reasonable to conclude that: 1. the microorganism

did not get into the blood of the ten sheep that remained healthy, 2. the microorganism is not the cause of the disease, 3. the strain of microorganism was too weak to cause the disease, 4. the ten sheep which remained healthy were naturally immune to the disease, 5. the forty sheep that got the disease ate something poisonous.

37. Cellular respiration in protoplasm takes place at temperatures which are much lower than those for the combustion of non-living material because: 1. more oxygen is used by the protoplasm, 2. less carbon is present in protoplasm than in in non-living material, 3. enzymes are present in protoplasm, 4. hormones are present in protoplasm, 5. protoplasm releases less carbon dioxide during respiration than do non-living things.

38. Changes in climate and the surface of the earth are thought to have an effect upon the evolution of organisms when: 1. the climatic changes cause genes to mutate, 2. they cause the death of all existing organisms and spontaneous generations of new ones, 3. organisms adapt themselves to the changes and these adaptations are inherited, 4. mutations result in organisms better adapted to these changes, 5. the climate and surface changes occur abruptly.

39. Which one of the following five conditions would NOT produce a significant reduction in the photosynthesis rate in a geranium plant if the other four factors were kept at the optimum? 1. Removal of soil water, 2. Removal of atmospheric oxygen, 3. Allow no light to reach the plant, 4. Removal of atmospheric carbon dioxide, 5. Reduce the temperature to $2^{o}$ above freezing.

40. An albino corn plant lacks chlorophyll and therefore cannot manufacture its own food. This genetic characteristic continues to occur in corn plants because: 1. the albino stocks can breed true, 2. the albino plants can live without chlorophyll, 3. the albino plants can be produced through self-pollination of homozygous normal plants, 4. the character is carried by normal plants, 5. although stunted, the albino plants produce a few seeds.

41. The only organisms listed below which are <u>not</u> directly dependent on external sources of organic materials for food are: 1. spiders, centipedes, and snakes, 2. termites, 3. oak and elm seedlings, 4. mold and mushroom plants, 5. saprophytic and parasitic fungi.

42. The most striking evidence that great climatic changes have occurred in the past is provided by the: 1. magnitude of tropical rain forests, 2. thickness of the Eskimo dog's fur, 3. lava deposits in the vicinity of extinct volcanoes, 4. climatic data records kept by the U. S. Department of Agriculture, 5. coal deposits discovered in Antartica.

Questions 43 through 45 are based on the following statement:

A lodgepole pine-ponderosa pine forest area was studied over a period of time. The forest area was rather dense and thus the undergrowth was not well developed. Bearberry, violets, and bedstraw made up a part of the green plants. (v) There were also Indian pipe and coral root, leafless plants which derive their food from decaying plant and animal tissues on the forest floor. (w) Growing on some of the trees were types of lichesn. (x) There were a few barberry plants near the edge of the forest. A nearby wheat field was found to be affected by wheat rust, a fungus growth. This rust must live a part of its life cycle on the barberry bushes, the rest on wheat. The animals found in the area were quite varied. (y) They include animals such as deer, porcupine, ground squirrel, and mice; birds of many kinds: insects such as beetles, flies and ants. The ants are important in aerating the soil. (z) There are also beetles found here which feed upon remnants of animals killed by others for food or animals which have died by other means.

43. The best control measure for the wheat rust would be to: 1. clear barberries from the area, 2. clear pine trees from the area, 3. discontinue growing of wheat, 4. prevent the pollination of rust, 5. burn over the area.

44. Those animals in the area which feed on animals only are: 1. carnivores, 2. herbivores, 3. symbionts, 4. parasites, 5. scavengers.

45. The beetles indicated in sentence (z) are considered: 1. carnivores, 2. saprophytes, 3. parasites, 4. herbivores, 5. scavengers.
46. A student carrying on experimental work in genetics is breeding Holstein-Friesian cattle. He knows from reliable hereditary records that for at least eight generations the cattle with which he is working have been black with white markings. The last calf to be born is marked with a red and white coat. He states that the calf is a mutant. Which of the following statements most nearly fits the situation? 1. If this animal were mated with a black and white animal and the offspring were all black and white, it would prove that the animal is not a mutant, 2. If another similar red calf were born in a herd somewhere else in the world it would prove his statement correct, 3. a character may skip several, but never more than five generations, 4. The situation is improbable, 5. The student is reasoning from insufficient evidence.
47. An albino corn plant appears in an ordinary corn field. Which of the following is the most likely fate of this organism? 1. Growth to flowering only, 2. Growth until reserve food is exhausted, 3. No growth of such a plant, 4. Continued independent existence, 5. Growth to seed production.

Questions 48 and 49 are based on the following:

Dodder, an orange-colored parasitic plant, twines around other plants and obtains nourishment from them through tube-like outgrowths from the stem. If it is living upon a long-day plant, such as Calendula, it will flower only when the days are long. If it is living upon a short-day plant, such as Cosmos, it will flower only when the days are short.

48. From the foregoing evidence, it can be tentatively concluded that dodder: 1. is a long-day plant, 2. is a short-day plant, 3. determines whether its host will be a long-day or a short-day plant, 4. has no stimulative effect on its host, 5. probably obtains growth hormones as well as food from the host.
49. The evidence further suggests that: 1. parasites usually destroy their host, 2. enzymes pass from host to parasite, 3. adjustment to day length is fixed for all plants--a plant is either a long-day or a short-day plant, 4. a hormone produced in one plant can effect a change in another plant, 5. the dodder is a very wide-spread menace to crops in the United States.
50. Purine is related to DNA as amino acid is related to: 1. molecule, 2. sugar, e. fat, 4. RNA, 5. protein.

Level I questions 1, 2, 11, 12, 13, 22, 23, 24, 25, 26, 37, 38

Level II questions 3, 4, 5, 14, 15, 16, 27, 28, 39, 40, 41, 42, 50

Level III questions 6, 7, 8, 9, 21, 29, 30, 31, 32, 47, 48, 49

Level IV questions 10, 17, 18, 19, 20, 33, 34, 35, 36, 43, 44, 45, 46