THE DEVELOPMENT AND RELATIVE EFFECTIVENESS OF INFORMATIVE AND INVESTIGATIVE MODULES TO TEACH PRE-SERVICE ELEMENTARY TEACHERS THE SKILLS NEEDED TO MAINTAIN LIVING ORGANISMS IN A CLASSROOM

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JUANITA THOMAS WHATLEY
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This is to certify that the

thesis entitled

The Development and Relative Effectiveness of Informative and Investigative Modules to Teach Pre-service Elementary Teachers the Skills Needed to Maintain Living Organisms in a Classroom

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ABSTRACT

THE DEVELOPMENT AND RELATIVE EFFECTIVENESS OF INFORMATIVE AND INVESTIGATIVE MODULES TO TEACH PRE-SERVICE ELEMENTARY TEACHERS THE SKILLS NEEDED TO MAINTAIN LIVING ORGANISMS IN A CLASSROOM

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The purpose of the study was twofold: 1) to develop instructional modules for training pre-service elementary school teachers to maintain living organisms in the class; 2) to investigate the relative effectiveness of informative and investigative modules for training pre-service elementary school teachers to maintain living organisms.

As an integral part of the development of the instructional modules, a pilot study was conducted with 57 pre-service elementary teachers enrolled in science methods classes at Michigan State University. Five modules involving the use of seven organisms were tested. As a result of this study more modules involving fewer organisms and testing instructional procedures were developed.

Students enrolled in Biological Science for Elementary Teachers at Michigan State University, Winter term 1973, were subjects for testing the final modules.

These students all received a general skills test designed to determine their general knowledge concerning the germination of seeds, the growth requirements for plants and the environment suitable for survival of animals. The test results were the basis for assigning students to either a high or low skill group.

Within each skill level, subjects were randomly assigned to a group that would determine which organism, plant or animal, they would study first. All students completed an informative module, either plant or animal, during the first week of the study. The next week all students received an investigative module for a different organism.

The evaluation instrument to test the effectiveness of the modules contained one section on the plants used in the study (beans, rye grass, clover) and a second section on the animal used in the study, the Daphnia. Each part of the test was analyzed separately. Three equivalent forms of the evaluation instrument were administered as: 1) a pretest before the informative modules, 2) as an intermediate test, one week later, before the investigative modules, and 3) as a posttest, two weeks later, when the experimentation required for the investigative module was concluded.

The hypotheses were tested at the 0.05 level of significance using a multivariate repeated-measure analysis. The following conclusions were reached:

1) Instructional modules can be developed and used effectively to train pre-service elementary teachers to maintain living organisms in the classroom.

2) Significant differences were found between the investigative and informative modules. The investigative modules were more effective than the informative modules. The animal modules, both informative and investigative, were more effective than the plant modules.

3) There was a relationship indicated between the skill levels and the type of modules. The informative modules were more effective for the high skill level. The low skill level was more successful with the investigative modules.

4) Students who received the plant modules first had significantly higher gain scores than those students who received the animal module first. This order was particularly effective for the low skill level.

5) There was no significant difference found between those students who achieved the objectives of the modules and those who did not. Since the classification was based on written responses it is possible that the classification was based on incomplete data, because many students chose not to answer the questions. However, it

might be inferred from the large number of low skill students who were classed as non-achievers, that this group had more difficulty with keeping and interpreting data sheets.

Three other hypotheses looking for interaction between the independent variables, skill level, order of module presentation and achiever status, were not rejected.

An area for future research is the suggested relationship between the skill levels and the learning processes inherent in the instructional modules. There is a need to determine if college students do, in fact, operate at different intellectual levels of learning. If such an association is found, then, is it possible to decrease the rate of failure and the amount of frustration some students suffer in a difficult learning situation, by providing experiences more compatible with the student's intellectual development.

THE DEVELOPMENT AND RELATIVE EFFECTIVENESS OF INFORMATIVE AND INVESTIGATIVE MODULES TO TEACH PRE-SERVICE ELEMENTARY TEACHERS THE SKILLS NEEDED TO MAINTAIN LIVING ORGANISMS IN A CLASSROOM

By

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CHAPTER I

INTRODUCTION

This study involves the pre-service training of elementary school teachers to maintain living organisms in the classroom but it should not be considered as an isolated entity. Learning to maintain living organisms represents only a small portion in the total training program of elementary school teachers. The subject should be examined, therefore, in light of its contribution to the total training program. For this reason current trends in the education of elementary teachers will be explored as an introduction to teacher training in science and the learning of a specific skill i.e., maintaining living organisms for classroom use.

Current Trends in Elementary Teacher Preparation

Since the decade of the Sixties it would appear as though someone had opened a Pandora's box of teaching ills. All areas of the elementary curriculum are under scrutiny. A plethora of new mathematics, social studies and science programs has emerged.[1] At the same time the old edict of "teach my child to read" flashes brightly in the background.

As if this were not enough the new elementary science programs call for the teacher to step down from her role as the central character in the teaching-learning situation.[2] She must become like a skilled puppeteer who can manipulate a room full of material, including living organisms, and her competencies as a learning facilitator to produce a learning environment with the child as the central character.

But the tale doesn't end there. Each decade must have a theme. And the theme for the Seventies must include: Accountability, Performance-Based Teacher Education, Scientific Literacy and help stamp out pollution! In such a period of trends and counter trends colleges of education are faced with the overwhelming problem of designing a teacher training program that will provide the confidence and competence an elementary school teacher needs to cope with a rapidly changing social order.

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[1]Thomas D. Fontaine, "Federal Programs for the Improvement of Science and Mathematics," Science Education, 54 (3), 1970, pp. 209-212

[2]W. R. Zeitler, "The Changing Role of the Elementary School Teacher," (Paper presented at sixteenth annual convention, National Science Teachers Association, Washington, D.C., March 1968)

Recognizing the problems that face teacher education, the U.S. Office of Education sponsored the Model Teacher Education Project (USOE Model Projects) in the late sixties. In 1968 nine colleges began the development and testing of comprehensive programs for elementary school teacher-preparation. And a challenge was accepted to design programs of teacher education which could prepare persons to teach effectively in new environments.

Florida State University went so far as to state that one of its goals was to prepare a program which would meet the expectations of society in 1978. Their predictions about society for 1978 included an accelerating trend toward urbanization, an increasing challenge to traditional wisdom, the pervasiveness of multiple mass media, and the dominance of science and technology as forces in our lives.[3]

To accomplish the objective of preparing teachers for change, many of the models abandoned traditional course requirements in favor of performance criteria or behavioral models where progress was assessed by demonstrated behavior and not the number of courses completed. A specified performance criteria states the behavior expected of the teacher, the condition under which the behavior will take

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[3]Systems Development Corporation. Analytic Summaries of Specification for Model Teacher Education Programs. Falls Church, Va., October 1969, p. 40

place and how the behavior will be evaluated. For facilitation of performance-based guidelines most of the models relied on the instructional module, organized around a single objective, as the basic unit of curriculum.

At about the same time the USOE Model Projects were being completed the American Association for the Advancement of Science (AAAS) Commission on Science Education was taking a serious look at the preparation elementary teachers were receiving in science. It was recognized that while science in elementary schools had changed completely, the majority of science courses for teachers at the college level had changed little or not at all. From a series of three conferences, in which over sixty leaders in American education participated, came a list of guidelines and standards for improving science instruction for elementary teachers.[4] Modules of instruction along with other training structures were recommended as means for developing desired behavior.

Performance-based Teacher Education (PBTE), considered by some as the most vigorous movement in teacher education today, appears to be a vehicle for carrying out many of the guidelines established by both AAAS and the

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[4]American Association for the Advancement of Science Commission on Science Education. Preservice Science Education Recommendations for Research and Development, Washington, D.C., 1970, p. 1-37

USOE Model Projects. In fact certain elements of a PBTE program as identified by a committee from the American Association of Colleges for Teacher Education (AACTE) could well have come from either the AAAS report or the Model Projects. Some of the essential elements include:

1) Designated competencies (knowledge, skills, behaviors) derived from explicit conceptions of teacher roles.

2) Assessment of student's competency based on predetermined criteria and using performance as the primary source of evidence.

Two implied characteristics of particular interest for this study are: 1) Instruction is individualized and 2) instruction is modularized. A module as defined by AACTE is "a set of learning activities (with objectives, prerequisites, pre-assessment, instructional activities, post assessment and remediation) intended to facilitate the student's acquisition and demonstration of a particular competency."[5]

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[5]Stanley Elam, ed. for American Association of Colleges for Teacher Education Committee on Performance-Based Teacher Education, "Performance-Based Teacher: What is the State of the Art?" Association for the Education of Teachers in Science Newsletter, October 1972, p. 6-9

Need for the Study

The guidelines from AAAS and the USOE Model Projects along with characteristics for PBTE give impetus to three major concerns: 1) identifying the competencies needed by elementary teachers to perform effectively in the classroom; 2) designing instructional instruments and providing learning experiences to teach and evaluate these competencies; 3) evaluating the competencies as they relate to pupil achievement.

Identification of competencies is a sensitive area, since educators have not come up with a list of competencies or crucial skills that a teacher should possess in order to perform successfully in the classroom. What will be accepted as evidence of successful performance by the teacher candidate has not been determined. As stated in the AACTE Committee report on PBTE: "No one can provide an all purpose answer to the evidence question partly because answers are situation-specific, but more fundamentally because our knowledge base is too thin."[6]

The Committee cautions against letting knowledge objectives and very simple skill objectives dominate the training program. It is this writer's contention, however, that in science teaching the knowledge objectives and simple skill objectives are a very important part of the

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[6] Ibid., p. 15

training program. The University of Massachusetts, for example, in its model for teacher education has, as a part of its curriculum design, detailed skills important to science, such as measuring, manipulating materials and preparing visual presentations.[7]

An examination of elementary science textbooks, science programs and supplementary materials on the market revealed that the emphasis for the seventies in elementary school science is on process skills and the discovery approach.

The newer textbooks even challenge the teachers to use the text as a tool for discovery. One publisher goes so far as to say, "lack of recent training in science is no stumbling block to teachers--they simply enjoy discovering science along with their pupils."[8] This is a paper tiger, a sham, to say the least since teachers must be able to create an environment conducive to discovery and must be able to keep the investigation going. Teachers, therefore, must be competent in the process skills in order to help children develop them.

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[7]Systems Development Corporation, Model Programs, 76-77

[8]Comment taken from a 1973 advertisement brochure for Science: Understanding Your Environment published by Silver Burdett

In addition to such management skills as questioning, and offering suggestions for data pooling, a teacher must also possess basic process skills such as: formulating hypotheses, designing and conducting experiments, interpreting, and analyzing data. Mechanical skills involved in just operating and manipulating material cannot be overlooked either. Both experienced and new teachers are often overwhelmed with the wide array of materials that accompany many science programs and the newer textbook series. Research to be discussed in Chapter II supports the argument that students should be given experience with representative materials that are being used in elementary school science today.

Although elementary science programs and textbooks tend to be skill-specific as far as materials are concerned, there are commonalities in certain management and communication skills. In addition, all programs devote some portion of the year or the sequence to the study of plants and animals. For this reason, this study has been designed to investigate the skills needed to maintain plants and animals in the classroom. Not only are living organisms used in most programs, but many of the process and management skills needed to maintain organisms are useful in other areas of science teaching. A list of the skills identified from the life science portion of a select group of textbooks and science programs can be found in Appendix A.

Once the skills have been identified, a second problem is investigating instructional tools for teaching the skills. The AACTE Committee investigating PBTE, AAAS Commission on Science Education and the USOE Model Projects all favor the use of instructional modules.

Since the module has been used successfully in many areas of study its effectiveness is assumed. In this study different kinds of modules have been explored to see if certain students perform better on certain kinds of modules or if there is a relationship between subject matter and the kind of module used.

Also important in the development of the modules is the emphasis placed on evaluation. In many of the modules currently on the market evaluation is not a major concern. The developers' energy, effort and imagination have often gone into producing the materials themselves and not into assessment outcomes.[9]

The third area of concern, evaluating the skills taught pre-service elementary school teachers as they relate to pupil achievement, was not investigated in this study. Such evaluation, a subject for a longitudinal study, will be discussed in Chapter V.

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[9]Elam, "Performance-Based Teacher Education," p. 22

Purpose of the Study

The purpose of this study was twofold: 1) to develop instructional modules for training pre-service elementary school teachers in the maintenance of living organisms in the classroom; 2) to investigate the relative effectiveness of informative and investigative modules for training pre-service elementary school teachers in maintaining those organisms.

Definition of Terms

The following definitions of terms are used throughout the study:

AAAS - American Association for the Advancement of Science.

AACTE - American Association of Colleges for Teacher Education.

Achievers - students in the study who demonstrated mastery of the objectives for the investigative modules as determined by answers to questions on the data sheets.

High Skill Level - students who scored 16 points or more on a twenty-two point skills test designed to determine general knowledge on maintaining plants and animals in a classroom.

Informative modules - modules that supply all the facts needed to maintain an organism in a classroom but do not include specific directions.

Investigative Modules - modules that require observation and experimentation to gather data needed to maintain a living organism in a classroom; initial instructions given, problem situation described.

Low Skill Level - students who scored 15 points or less on the twenty-two point general skills test described previously.

MLOC - Maintaining Living Organisms in the Classroom is the general name used for all the tests: general skills, pretest, intermediate test and posttest.

Module - a self contained and independent unit of instruction with a primary focus on a few well-defined objectives. The substance of a module consists of materials and instructions needed to accomplish these objectives.[10]

Non-Achievers - students in the study who gave no evidence of having achieved the objectives for the investigative modules.

PBTE - Performance-Based Teacher Education.

Pupil - a male or female enrolled in elementary school grades.

SCIS - Science Curriculum Improvement Study, an elementary science program for grades 1-6.

Student - a male or female enrolled in a college level course.

USOE Model Projects - Elementary Teacher Education Project, Bureau of Research, Office of Education, Department of Health, Education and Welfare, Washington, D.C., October 1967.

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[10]Joan G. Creager and Darrel L. Murray, ed. The Use of Modules in College Biology Teaching (Washington, D.C.: Commission on Undergraduate Education in the Biological Sciences, 1971) p. 5

Hypotheses

The following hypotheses were tested in this study:

1. There is no difference between the three repeated measures for the test, Maintaining Living Organisms in the Classroom (MLOC).

2. There is no difference between the High Skill Level group and the Low Skill Level group on the MLOC tests.

3. There is no difference between Order A, students who receive the plant module first and Order B, students who receive the animal module first, as determined by the MLOC tests.

4. There is no difference between Achievers and Non-Achievers as determined by the MLOC tests.

5. There is no interaction between skill levels and order of module presentation for the MLOC tests.

6. There is no interaction between skill levels and achiever status for the MLOC tests.

7. There is no interaction between order of module presentation and achiever status for the MLOC tests.

8. There is no interaction between skill levels, order of module presentation and achiever status for the MLOC tests.

9. There is no difference between the Investigative Modules and the Informative Modules as determined by the MLOC tests.

Assumptions

Since the major concern of this study was to develop modules useful in training pre-service elementary school teachers to maintain living organisms the following assumptions were made:

1. Learning to maintain living organisms for classroom use is a viable skill for elementary school teachers.

2. The learning ability of students enrolled in a course designed for elementary education majors is not related to the students' declared major. Therefore, non-elementary education majors enrolled in the course used for this study will not significantly affect the outcome of the study.

3. While a paper and pencil test is not a completely adequate means of assessing a student's performance with living organisms it is at least an indication that knowledge of the skill has been gained.

Overview

The general organization of the study is as follows:

Chapter II contains a review of current literature with emphasis on pre-service elementary school teachers training in science education, the skills needed and the methods being used to teach these skills. Attention is also given to current thought on the value of using living organisms in the classroom and the teacher training involved.

Chapter III has a summary of the work that preceeded the formulation of this study, the procedure used in developing the modules for the study along with the design plan and analysis model.

Chapter IV includes the analysis and interpretation of the data, while Chapter V contains a summary of the complete study along with implications for further research.

CHAPTER II

REVIEW OF THE LITERATURE

The primary purpose of this study was to develop and test modules to be used in training pre-service elementary school teachers to maintain living organisms. To justify the inclusion of such modules in a science education class the assumption must be made that the basic ideas behind the modules are consistent with current practices and trends in the field of education. With this thought in mind a review of the literature was conducted to seek answers for the following questions:

1) What are current practices in elementary school science?

2) What are the attitudes of teachers toward teaching science and what difficulties do they encounter?

3) What has been done to identify the skills, competencies and knowledge needed by elementary school teachers to meet the challenge of modern elementary science?

4) What methods are being developed for use in building the skills and competencies needed by elementary school science teachers?

5) Should the use of living organisms in the classroom be a part of elementary science and should the teachers be trained to maintain living organisms?

Current Trends in Elementary School Science

The second half of the twentieth century has been characterized by change. Rapid advances in science and technology have prompted the emergence of a new social order beset with gadgets, new medicines, over population and bewilderment. New knowledge is being created faster than it can be disseminated and assimilated by a populace unaccustomed to rapid changes and involvement.

Hurd[1] has said that the amount of scientific knowledge doubles in the time it takes a child to progress from kindergarten to high school. Therefore, our children living in this new world of science must be educated to deal with change. Education, which has often enjoyed the reputation of being fifty years behind the times, has been challenged "to escape the threat of obsolescence."

> To escape the threat of obsolescence, education in the sciences must be based upon the kind of information that has survival value and upon strategies of inquiry that facilitate the adaptation of knowledge to new demands. A curriculum is needed that is oriented toward a period not yet lived, influenced by discoveries not yet made and beset with social problems not yet predicted. The need is for an education designed to meet change, to appreciate

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[1]Paul DeHart Hurd and James J. Gallagher, New Directions in Elementary Science Teaching, (Belmont, California: Wadsworth Publishing Co., Inc., 1968), p. 2

> the process of change and to influence the direction of change.[2]

This directive by Hurd was further reinforced when the National Science Teachers Association (NSTA) set as a major goal of science education in the seventies the development of "scientifically literate and personally concerned individuals with a high competence for rational thought and action."[3] Although the NSTA Position Statement characterized in detail the scientifically literate person, Hurd's general statement summarizes some of the characteristics that have influenced many of the new elementary science programs.

> A person literate in science knows something of the role of science in society and appreciates the cultural conditions under which science thrives. He also understands its conceptual inventions and its investigative procedures.[4]

In the late fifties scientists and educators having observed the successful development of new science programs at the secondary level focused attention on elementary

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[2]Paul DeHart Hurd, "Toward a Theory of Science Education Consistent with Modern Science," Theory into Action: in Science Curriculum Development, (Washington, D.C., National Science Teachers Association, 1964), pp. 7-8

[3]Richard J. Merrill and Glenn D. Berkheimer, "NSTA Position Statement on School Science Education," The Science Teacher, 38 (1971), p. 21

[4]Hurd, Theory of Science Education, p. 9

school science. Many projects and curricular studies were committed to a concept approach, a few set information-giving as a major goal, some wanted to combine science and arithmetic and still others felt that any topic that arouses interest was sufficient.[5]

Each project set its own goals based on diverse philosophical beliefs and used different curricular materials to obtain the goals. However, the projects all agreed that "science learning requires active involvement of the children, who perform experiments, make observations, and draw conclusions. In other words, the elementary school classrooms must become laboratories as well as study halls and the school's (physical) environment must be used for field studies as well as for recreation."[6]

In spite of the fact that evidence has been gathered as to the efficacy of the new science programs and the companion teaching methods, many areas have retained the status quo in both teaching methods and materials at the elementary level. Maben,[7] in a study of approximately

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[5]Hurd, New Directions, 33-34

[6]Robert Karplus and Herbert D. Thier, A New Look at Elementary School Science, (Chicago: Rand McNally, 1967), p. 4

[7]Jerrold Maben, "A Survey of Science Teaching in the Public Schools of the Far West and Great Lakes Region of the United States During the 1970-1971 School Year," (unpublished manuscript Herbert H. Lehman College, The City University of New York, 1973), p. 144

3400 elementary schools in eleven Far West and Great Lakes states during the 1970-1971 school year, reports that the use of science curriculum improvement project material was small.

The use of a single science textbook was still high and lecture-discussion was the most used learning activity. He further states that the firm establishment of textbook reading and lecture-demonstration makes very unlikely a strong expression of need for special science facilities, equipment, and supplies that are a part of student activity approaches.

Obviously, the change in elementary school science is slow. It is obvious too that to accelerate this change a new corps of teachers with positive attitudes toward science must be trained in the processes of science and given the knowledge, skills and competencies needed to teach the new elementary science curricula. Hurd's cogent reminder should be kept in mind:

> The adoption of innovative practices is more likely to be impeded by teachers' attitudes, philosophy, and motivation, and an inappropriate climate for change in the school than by a lack of physical resources, teacher experience, or educational training.[8]

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[8]Hurd, New Directions, p. 132

Attitudes Toward Science Teaching

Since the teacher's attitude toward science is a major factor in bringing about change it is important to understand this attitude if we wish to influence what is being taught in the classroom.

Bixler[9] and Soy,[10] support the importance of positive attitudes. In his research Bixler found that teachers who possess favorable attitudes toward science bring about greater positive change in pupil's learning. Soy felt that an elementary school teacher with a genuine liking for science might be more effective in dealing with housekeeping problems involved in such things as growing micro-organisms or in storing many sets of materials.

To show the slow evolution of attitudes and subsequent curriculum changes requires a literature review from the turn of the century. A review of the trends in elementary school science reveals that the subject has advanced from a strong emphasis on nature study in the first half of the twentieth century to the flood of experiment-oriented textbooks in the fifties.[11] Science was not a

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[9]James E. Bixler, Jr., "The Effect of Teacher Attitude on Elementary Children's Science Information and Science Attitudes," Dissertation Abstract, 19 (1959), 2531-2532

[10]Eloise M. Soy, "Attitudes of Prospective Elementary Teachers Toward Science," School Science and Mathematics, 67 (1967), 507-17

[11]Hurd, New Directions, pp. 24-29

subject of great concern and many of the nature studies were adventures in reading. Teachers were reluctant to do much more.

Lammers,[12] in the late forties found that teachers still felt best prepared to teach nature study or biological topics. They felt the lack of time and equipment were the greatest obstacles to the teaching of science.

Maddux[13] and Curtis,[14] in trying to help improve science programs found problem areas to be the lack of: 1) subject-matter training, 2) training in the use and storage of science materials and 3) knowledge of the proper use of visuals, along with a general low interest in science.

In the early sixties Sharefkin[15] showed that only 15.2% of 138 elementary education student teachers in a

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[12]Theresa J. Lammers, "One Hundred Interviews with Elementary School Teachers Concerning Science Education," Science Education, 36 (1949), pp. 292-295

[13]Grace C. Maddux, "Helping the Elementary Science Teachers," School Science and Mathematics, XLIX, (1949), pp. 534-537

[14]William C. Curtis, "The Improvement of Instruction in Elementary Science," Science Education, 34 (1950), pp. 234-247

[15]Belle Drucker Sharefkin, "A Study of the Possession of the Science Abilities by Student Teachers in a Liberal Arts College Preparing to Teach in Grades Four Through Six," Dissertation Abstract, 21 (1961), pp. 3008-3009

New York College were appreciably interested in science. Piltz[16] investigating teacher-recognized difficulties encountered in the teaching of science in the elementary schools of Florida, found that some teachers lacked confidence in teaching science due to personal feelings of inadequacy, psychological blocks, blocks and fear related to natural phenomena.

Wytiaz[17] and Victor,[18] studying a combined population of over 150 elementary teachers in New Jersey and Illinois, respectively, again found that an inadequate background in science was the overriding reason for reluctance to teach science. Most of the teachers felt best prepared to teach plants or biological subjects. Victor's sample seemed more inclined to stress the technological aspect of science rather than underlying principles and philosophy, thus indicating unfamiliarity with accepted science objectives.

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[16]Albert Piltz, "An Investigation of Teacher-Recognized Difficulties Encountered in the Teaching of Science in the Elementary Schools of Florida, "Dissertation Abstracts, 20 (1962), pp. 3937-3938

[17]Patricia L. Wytiaz, "A Study of the Attitudes of Fifth Grade Teachers of Cumberland County New Jersey Toward Science and their Preparation for Teaching it in the Elementary School," Science Education, 46 (1962), pp. 151-152

[18]Edward Victor, "Why are Our Elementary School Teachers Reluctant to Teach Science?" Science Education, 46 (1962), pp. 185-192

Dutton and Stephens[19] found favorable attitudes among 226 prospective elementary school teachers enrolled in curriculum classes at the University of California, Los Angeles. Six statements (centered around field trips, need for science instruction, studying animals and pupil participation) were selected by over 90% of the students. (Twenty-five percent were afraid of bugs, worms, snakes, insects.) Not surprisingly, the aspects of science disliked were lack of participation, work with crawling insects or reptiles and handling dead animals.

Soy,[20] in seeking to discover why only 8% of the prospective elementary school teachers at State College of Iowa chose science as a subject field, uncovered these reasons for the poor showing: lack of interest in the area, difficulty of college science courses and lack of high school background.

These reports carry us through two decades of surveys and questionnaires seeking to ascertain why there is still a reluctance on the part of elementary school teachers to stress science in the classroom. While the sample is limited, the reports are good indicators of trends since they are from a variety of geographical locations.

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[19] Wilbur H. Dutton and Lois Stephens, "Measuring Attitudes Toward Science," School Science and Mathematics, 63 (1963), pp. 43-49

[20] Soy, "Attitudes of Prospective Teacher," p. 517

At the beginning of a new decade we find many of the twenty-year-old reasons and contributing factors still looming dark on the horizon--low level of preparation in science and science education, weak methods courses--as barriers to effective science teaching.[21] Colleges of education, at last alarmed by the fact that teachers cannot teach what they do not understand, are making a determined effort to change their modes of teaching to make them more consistent with the new approaches to science being introduced in the elementary schools.

Many educators support the familiar maxim that "teachers teach as they have been taught." Unfortunately the methods emulated are often antithetical to the teaching style incorporated in the new science programs, Boulos[22] states, "we seem to teach prospective teachers about teaching but we do not help them become effective teachers. We give them a body of knowledge and when they give it back to us on finals, we assume . . . that they automatically will become good teachers."

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[21]Maben, "A Survey of Science Teaching," pp. 131-135

[22]Sami I. Boulos, "Proposal for an Experiment in Training Elementary Teachers," Science Education, 54 (1970), pp. 203-207

Koran[23] argues further that one crucial task facing those who prepare and supervise teachers is not dissemination of information about ways to teach science and new programs, but it is to get teachers to behave in the manner compatible with the style inherent in new materials.

Perkes[24] concluded from his investigation that the common assumption that there is a transfer from instruction on "how to teach" science to actual teaching would appear to be unwarranted. However, results of this investigation do support the proposition that to "promote teaching behavior in ways consistent with new curriculum recommendations is to require teachers to adhere closely to pedagogical directives of a guide."

Identification of Teaching Skills

Since it is not practical to train teachers to use one specific elementary science program, a major task confronting educators is to identify the knowledge,

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[23]John J. Koran, "Two Paradigms for Training of Science Teachers Using Videotape Technology and Simulated Conditions," Journal of Research In Science Teaching, 6 (1969), pp. 22-27

[24]Victor A. Perkes, "Preparing Prospective Teachers of Elementary Science: An Appraisal Between Prospective Involvement and Teaching Behavior," Science Education, 55 (1971), pp. 295-299

competencies and skills and/or behaviors needed by elementary school teachers to perform effectively in any modern science classroom.

Fawcett[25] examined teaching skills within the context of leadership. The teacher "leads," while learning is done by the student. The "leader" is a facilitator, an organizer, a goal setter, capable of specifying the means by which the goal is reached and capable of evaluating learning results.

Henderson and Lanier,[26] in seeking an answer to the question, what knowledge, skills and competencies does a teacher need to teach effectively, make the following assertions:

> Effective teachers need to possess the same product knowledge and performance as their students. This is essential, not only because as human beings they also need survival skills, but because of the powerful modeling effect they have upon their students. They should therefore, be able to demonstrate acquisition of the product knowledge, information processing and problem-solving skills recommended for all learners . . . .

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[25]Claude W. Fawcett, "The Skills of Teaching," A study for the Ford Foundation Teacher Education Project, (University of California, May 1965)

[26]Judith E. Henderson and Perry E. Lanier, "Teaching Competence: Needed Knowledge and Performance Skills," (unpublished manuscript, Michigan State University, March 1972), pp. 36-39

> They must also be able to demonstrate mastery of a set of "professional behaviors", that is, they should be able to demonstrate acquisition of the knowledge and skills required for successful performance of the tasks of teaching.

These statements are followed by a list of the needed product knowledge and performance skills for both non-professional and professional behaviors. However, the authors are quick to caution educators that identification of knowledge, skills and competencies is subject-specific and their work should be considered in that light.

Along the same lines Pereira and Guelcher state that the skills of teaching are not just behaviors, but behaviors which are related to the situation in which they take place. They support their proposition by quoting from James M. Cooper's A Performance Curriculum for Teacher Education.[27]

> But just as the beginning artist must learn to mix his paints, practice his brushstrokes, and perfect certain techniques and skills before he completely develops his own style of painting, so too, does the fledgling teacher need to be trained in particular teaching skills under differing conditions, and to have his effectiveness evaluated.

Research related to the identification and training for skills associated specifically with elementary

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[27]Peter Pereira and William Guelcher, "The Skills of Teaching: A Dynamic Approach," (Graduate School of Education, Chicago University, June 1970)

science is limited. One of the identified skills that has been given the most attention is that of questioning. As explained by Koran:[28]

> An important characteristic of teacher behavior in the new science curricula on both the elementary and secondary level is questioning behavior. The teacher's role here is to foster exploration and explanation rather than to give answers and reinforce facts. Teachers must learn to ask observation questions, since the behavior that these are intended to produce on the part of students--observation--is critical to scientific inquiry and concept formation.

Studies were conducted by McDonald and Koran using written and film-mediated models to train teachers in the acquisition of questioning skills. In the McDonald and Koran study[29] three treatment groups were used; a film-mediated modeling treatment (film portrayal of analytic questioning), a written modeling treatment (a text of the film sound track) and a control treatment which received no model. The findings suggested that the rate and level of learning of a specific teaching strategy varies as a function of model presentation (film mediated modeling most effective, no modeling least effective); and that the

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[28]Koran, "Two Paradigms for Training Teachers," p. 23

[29]Frederick J. McDonald and Mary Lou Koran, "The Effect of Individual Differences on Observational Learning in the Acquisition of a Teaching Skill," (Final Report, Project No. 81073, United States Office of Education, March 1969)

effectiveness of instructional methods varies from subject to subject with differences being related to trainee aptitudes.

Koran,[30] who did a similar experiment and obtained similar results concluded however, that both training methods had merit for training pre-service elementary science methods students. Since there was some indication of aptitude-model interaction Koran felt the model chosen should depend on the conditions (aptitude of students) and constraints (finance) at hand.

Menzel,[31] studied the effects of four different procedures for training 110 methods students in two processes of science: measuring and classifying. The four procedures were: 1) active laboratory-oriented work, 2) passive reading-centered study, 3) alternating, active followed by passive and 4) intermittent, active, passive, active, etc. The control group had no instruction in the two processes. Menzel found no difference among treatment groups and control on classifying but did find some differences among groups on measuring using a Process Measure instrument.

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[30]John J. Koran, "A Study of the Effects of Written and Film-Mediated Models on the Acquisition of a Science Teaching Skill by Preservice Elementary Teachers." Journal of Research in Science Teaching, 8 (1971), pp. 45-49

[31]Ervin W. Menzel, "A Study of Preservice Elementary Teacher Education in Two Processes of Science," (Doctoral Dissertation, Temple University, Philadelphia, Pa., 1968)

The work done by Beisenherz[32] was the only reference found that dealt specifically with biological skills. Although his work is concerned with high school teachers it does have implication for elementary science teachers. He identified skills needed by prospective high school biology teachers and recommended a special course to teach the skills.

In a later study Beisenherz and Probst[33] validated the skills from the previous study by having 52 high school biology teachers indicate whether the skills were used or usable in their teaching. Thirty-five techniques from a list of 154 were identified by 40 or more of the 52 teachers as those in which mastery prior to teaching was advisable. While only a few of the identified skills are useful at the elementary level the studies do indicate that similar research is needed for elementary science.

Skill Development Methods

Closely associated with identifying teaching skills and competencies is the study of methods being used to train

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[32]Paul C. Beisenherz, "The Need for a Special Course in Biologic Skills and Techniques," The American Biology Teacher, 32 (1970), pp. 219-221

[33]Paul C. Beisenherz and C. J. Probst, "Mastery of Biological Techniques: A Model for Teacher Education," (paper presented at the 21st meeting of the National Convention of the National Science Teachers Association, Detroit, Michigan, April 1973)

teachers in these skills and competencies. Two such studies have already been discussed. With the strong emphasis on performance/competency-based teacher education, methods are being explored that lend themselves to evaluating specific behaviors, individualization and allowance for individual differences.

In this investigation particular attention was given to expository and investigative activities as they pertain to training elementary teachers. Although the value of laboratory work has been debated by both scientists and educators there seems to be a consensus that some activity does contribute to learning. Now the question becomes what kind of activity is the most suited for elementary science methods courses.

Raun and McGlathery[34] investigating the ongoing concern as to elementary school teachers indicate a dislike or fear of science, inferred that teachers do not understand the nature of science. It was suggested that such a lack of understanding was the result of exposure to the products of science and little or no exposure to the processes of science. This conclusion was used by Raun and McGlathery as a justification for the conceptualized model of a methods course based on active student

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[34] Chester E. Raun and Glenn E. McGlathery, "Elementary School Science Methods: One View and One Approach," Science Education, 54 (1970), pp. 213-216

involvement and performance which demonstrated achievement and understanding.

Michals,[35] in evaluating and constructing science education courses, found that objectives for preparing elementary teachers are best achieved when students are actively participating in class activities on relevant topics, as compared to lecture-demonstrations on the same objectives.

Ricker and Hawkins,[36] while testing the effectiveness of science education proficiency modules for training college students, brought out information pertinent to the idea of activity oriented courses. In this research students who were responsible for acquiring certain performance behavior (competency) could select the learning activity desired. Reading, laboratory practicum, small group sessions and individual help sessions could be selected. Interestingly, all students chose to do at least some of the practicum and only 15% chose to do the readings which have been considered by some authorities as an efficient learning method for college students.

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[35]Bernard E. Michals, "The Preparation of Teachers To Teach Elementary School Science," Science Education, 47 (1963), pp. 122-131

[36]Kenneth S. Richer and Michael L. Hawkins, "Testing a Science Education Proficiency Module with College Students," GEM Bulletin 69-12, (University of Georgia, Athens, 1969)

Mattheis,[37] investigated the effect on the competence of pre-service teachers for teaching science produced by two different types of laboratory experiences. He tested the assumption that laboratory experience in science is necessary if the pre-service education of elementary school teachers is to be successfully accomplished. The experimental group used a science-project approach to laboratory work, while the control group was taught by the conventional replication-verification method.

Mattheis found that, with respect to knowledge of science, the project approach was more efficient for students who exhibited strong interest and a proficient knowledge of science. However, students who were not interested and who did not know very much about science learned more science when they were in the control group.

A study completed by Hoffman and Druger,[38] while not directly concerned with training elementary school teachers, was of interest since the focus was on methods of audio-tutorial instruction similar to methods used for this study. The population of 90 students chosen at

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[37]Floyd E. Mattheis, "A Study of the Effects of Different Approaches to Laboratory Experiences in College Science Courses," University Microfilms, Ann Arbor, 1962

[38]Frederic E. Hoffman and Marvin Druger, "Relative Effectiveness of Two Methods of Audio-Tutorial Instruction in Biology," Journal of Research in Science Teaching, 8 (1971), pp. 149-156

random from a group of 800 students enrolled for the first semester of the 1968-1969 general biology course at Syracuse University was randomly divided into two experimental groups: the direct group and the indirect.

The direct group received lessons of a descriptive or expository nature that usually required passive participation by the students. Little or no question-and-answer activity was required. Observations were guided and answers were provided for all laboratory work. In contrast, the indirect group was taught by a lecture-question-answer method during which the student proceeded toward the objectives in an investigatory manner. Although film-loops, slides, demonstration materials and laboratory work were the same for both groups, to accomplish the objectives the indirect group was free to make its own observations, develop answers to questions and reach its own conclusions.

There was no difference found between the groups with respect to total achievement, critical thinking abilities or retention. However, a significant difference was found in favor of the indirect group with respect to problem-solving abilities.

Not enough evidence has yet been presented to make a strong statement on the aptitude-treatment interaction suggested by Koran and Mattheis or the idea that investigation or activity is useful in obtaining only certain kinds of objectives, as suggested by Hoffman, Druger and Menzel. What the literature does decry is hasty decisions based on weak evidence. Shulman and Tamir reiterate this caution after reviewing current research being done with new science curriculum studies.[39]

The Use of Living Organisms in the Elementary Science Classroom

The last but most significant topic of interest for this study is the value of training elementary school teachers to maintain living organisms. This part of the literature search was to find answers to these questions: Why include the study of living organisms in the elementary science curriculum? Do teachers need special training in order to be able to maintain living organisms?

Unfortunately, the answer to the "why" question must be based on the generally expressed opinion of "experts" since specific research studies are limited. Pratt[40] expresses the idea that "a classroom equipped with plants and animals can become a laboratory for problem

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[39]Lee S. Shulman and Pinchas Tamir, "Research on Teaching in the Natural Sciences," (Preliminary manuscript prepared for the Second Handbook of Research on Teaching, R.M.W. Travers, Editor), pp. 51-54

[40]Grace K. Pratt, How to: Care For Living Things in the Classroom, (Washington, D.C.: National Science Teachers Association, 1965), p. 1

solving, reflective thinking and testing. Familiarity with animals through daily contact overcomes gradually the fear which some children may have of them."

Mayers,[41] concerned with the study of biology becoming the study of necrology at the high school level, speaks of values, in studying living organisms, that could well be applied to elementary school. He maintains that one objective of biology has been to inculcate a respect for life and an understanding of the conditions necessary for its perpetuation. Also the emphasis on environment makes it imperative that students experience the environmental necessities for maintaining life. These objectives can best be obtained by using living organisms. "The principles of animal care with respect to nutrition, cleanliness, space, exercise, and similar parameters can be extrapolated to the requirements for maintaining human beings in dignity and within a proper environment."

As Pratt explains it:

> Plants and animals may stimulate speculation among older children and lead them to the use of scientific methods in conducting controlled experimentation. Through these processes they learn something of the tested limits of human control, such as how diet changes behavior and appearance or how the lack of light affects plants and animals.

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[41]William V. Mayers,"Biology: Study of the Living or the Dead?" The American Biology Teacher, 35 (1973), p. 27

> The differentiation between "self", and others is frequently clarified through the relationships of children and animals. Biological sameness and difference are exemplified.

Orlans,[42] also concerned with the use of living organisms in the high school, was surprised to find that little attention had been paid to finding out just what kinds of plants and animals were most used. She wished to discover reasons why the use and diversity of living organisms was limited. (Dr. Orlans is completing a book for BSCS on the care and maintenance of live animals in the classroom, to be published in the fall 1973.)

An indirect support for the use of living organisms in the elementary science classroom is the volume of articles published by scientists, science educators and teachers on plants and animals suitable for classroom use. Articles range from helpful hints on raising plants to detailed instructions on how to plan lessons to use vivariums.

A survey was made of one of the more popular elementary science publications, Science and Children, for January 1968 - May 1972 to get an idea of how educators felt about using living organisms. These articles support the idea already expressed that with living plants and animals in the classroom a skillful teacher can cover the

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[42]F. Barbara Orlans, "Live Organisms in High School Biology," The American Biology Teacher, 34 (1972), p. 343

the gamit from promoting interest to teaching scientific concepts, even mathematics and social science. For a listing of the articles found in Science and Children, see Appendix B.

The fact that science educators are concerned about the limited use of living organisms in the classroom gives credence to the belief that teachers need training in the use of live specimens to encourage their use in the classroom. Secondary school science teachers responding to a survey conducted by Orlans at the NSTA March 1970 national convention gave these reasons why they did not keep live organisms for use in their classrooms:[43] they did not know how to keep them, that caring for them is too much trouble; that plants and animals take up too much space; that physical conditions in the classroom are not suitable and that the school cannot afford them.

Orlans further explained that all too often, teachers receive no instruction or information on selecting, caring for, and using particular species. The teachers affirmed that they needed more information in order to diversify the species they kept and to improve their standards of animal care and use.

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[43]Ibid, p. 344

Reed[44] in a more recent article held many of the same opinions:

> Another factor (that prevents the use of living materials) is the attitude of the school personnel, which can act to discourage even the most knowledgeable teacher. The principal may object to the presence of animals in the classroom. The custodians complain about the "mess" of pots and cages. Money is usually available for athletic equipment but seldom can be found for soil and seeds.
>
> The textbook materials may have procedures that don't work. They may present dull and pedestrian topics for classroom use which the teacher, because of a lack of basic information, cannot develop or revise.

Reed's work with the Minnesota Mathematics Science Project, which sought to relate mathematics and science, gave much insight into why many of the new curricular projects dealing with living organisms often fail. Her conclusions:[45]

> The average elementary school education major, who has had little pratical experience and who may not be a biologist at heart, needs help. The basic information this person needs is facts about whole organisms in their environments, with the addition of practical examples as to how this information can be used in the classroom. Naturally the emphasis should be on the basic principles.

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[44]Elizabeth W. Reed, "The Place to Begin," <u>AIBS Education Review</u>, 2, June 1973, p. 44

[45]Ibid, p. 45

Mayers also gave strong support to the need for teacher training. He remarks:[46]

> Many of our teacher-preparation institutions gloss over this segment (proper handling of living organisms) of the curriculum: they indicate that animal-keeping would be a nice thing to do, but they do not tell how it should be done. We need, therefore, to incorporate in all our teacher-training processes information on the care and maintenance of organisms in the laboratory and on ways in which they become productive contributors to the academic program.

Summary

The survey of the literature was to find justification for training elementary school teachers to maintain living organisms in the classroom.

This is what was found:

1. Educational visionaries have developed programs designed toward teaching skills for coping with change through problem solving. Nevertheless, single science textbooks and the lecture-discussion format continues to dominate the science program in many elementary schools.

2. The attitude of elementary school teachers toward science is generally one of reluctance toward teaching the subject. Inadequate preparation in science and science methods contribute to this reluctance.

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[46]Mayers, "Study of Living or Dead," p. 29

Colleges of education seeking to alleviate the problem are developing competency-based programs setting performance criteria consistent with the new approaches to science being introduced in the modern elementary science curriculum.

3. The specific skills and competencies needed by an elementary school teacher to perform effectively in teaching science have not been validated. Many educators agree, however, that teachers need to develop science process skills as well as the professional skills needed to manage a classroom. The skill of questioning deemed essential in modern science has been investigated by many educators.

4. Methods being studied to train teachers in the skills and competencies needed to teach science include: 1) film-mediated model versus written model, 2) active laboratory-oriented work versus passive reading-centered study, 3) science-project approach to laboratory work versus conventional replication-verification method and 4) audio-tutorial instruction using the direct group (passive participation) versus the indirect group (active investigation).

5. While the value of studying living organisms at the elementary school level cannot be substantiated with research studies the success experienced by science educators and classroom teachers seems to warrant their

use. Living organisms can help develop an appreciation for life and an understanding of relationships between plants, animals and man in a total environment. Both teachers and those working with teachers agree that there is a need for more training in the basic principles of plant and animal growth, care and maintenance in the classroom.

Much of the literature reported represented only the viewpoints of science educators. The implication is clear that much research is needed to validate these widely accepted viewpoints.

CHAPTER III

DESCRIPTION OF THE STUDY

The twofold purpose of this study was to develop and to investigate the relative effectiveness of informative and investigative modules for training pre-service elementary teachers to maintain living organisms in the classroom.

General Background Information

To identify the general teaching skills needed by elementary school teachers for the life science portion of elementary science, a survey of several elementary science textbook series and science curriculum programs was completed in the spring 1972. A questionnaire prepared from this survey was given spring term 1972 to 77 students enrolled in Biological Science 202, Biological Science for Elementary Teachers, to determine which of these skills had been developed by these pre-service elementary school teachers. These students strongly indicated that more skill was needed in the maintenance of animals, particularly invertebrates. (See Appendix A for questionnaire results.)

Since all textbook series and curriculum programs examined advocated the use of living materials it seemed feasible to pursue the development of this skill. Modules were decided on as the vehicle for training since they are easily adjusted to individual differences, they can be completed individually and they require a minimum amount of supervision.

Development of the Modules

The development of the modules was started in the summer 1972. One elementary science program, Science Curriculum Improvement Study (SCIS), which devotes half of each year grades 1-6 to the study of living organisms was used as a guide for choosing the organisms to study. Initially five modules were prepared for testing: The Aquarium, Daphnia and Chlamydomonas, Drosophila (Fruit Fly), Tenebrio beetles (Mealworms) and the Terrarium with the Chameleon.

These modules were concerned with training pre-service teachers to establish and maintain environments suitable for survival of specific animals. The design was to give step by step directions for establishing the habitat without including excessive details on the organisms themselves. Information was included that would help the student recognize and correct conditions that threatened the existence of the organisms.

A pilot study using the five modules was conducted fall term 1972. Subjects were 57 students enrolled at Michigan State University in Education 325F, Teaching Science in Elementary School.

The results indicated that the modules could be used successfully to train pre-service teachers to establish habitats for the survival of organisms for at least a two-week period. Several changes were made in the overall experimental design to eliminate irregularities apparent during the pilot study.

Being a firm believer in the adage that teachers tend to teach as they are taught the writer was dissatisfied with the cook-book type instructions given in the modules. Even though students did accomplish the objective of establishing a suitable environment for the organism to survive and there was a significant change in knowledge about the organism as measured by pre- and posttest comparisons, the method of instruction was unquestionably out of date.

A space and logistics problem developed from having so many different organisms established at the same time in the same room. Also, there was no control over student interaction between groups studying different organisms. For example, a student who did not establish a fruit fly culture could show an increase in knowledge on the fruit fly simply by observing and discussing the culture with his neighbor. While this practice would work well in the general classroom, it would tend to give misleading test data for the effectiveness of a particular module.

The following decisions were made based on results from the pilot study:

1) Develop and test modules more in line with accepted practices for inquiry or discovery type learning.

2) Choose organisms that could be used in small containers to reduce space requirements.

3) Use only two organisms, one plant and one animal, at the same time to reduce the amount of interaction.

4) Choose a classroom setting that would allow for more individualized work and reduce student-student interaction.

These decisions meant that only one of the originally developed modules would be a part of the final experimental design. The modules that were eliminated are included in Appendix C and will be discussed in Chapter V.

General Design of the Test Modules

Two types of modules were used in the study: informative and investigative. Basically, the informative modules present facts while the investigative modules require the student to discover the facts through experimentation. The investigative and informative modules covering the same subject were developed from the same set of behavioral objectives to insure that the only differences were in method of presentation rather than in material covered.

The modules were designed as self instructional units. Each consists of taped information or directions for the experiment, printed matter to accompany the tape and any materials needed to carry out the experiment suggested in the investigative module. The organisms used for the plant modules were common plants used in elementary science such as grass, beans and clover. Daphnia was chosen for the animal modules since it is becoming a popular organism for classroom use.

The Informative Plant Module contained information on the characteristics of seeds along with requirements for germination of seeds and growth of plants. Pictures of common seeds and ways to establish germination studies accompanied the taped material. The Investigative Plant Module required students to study the characteristics of a sample set of seeds and to investigate factors that affect germination of seeds and growth of plants. In addition to the pictures of the seeds that were studied and of ways to study germination, each subject received a guide sheet for monitoring the plants over a two-week period. Data sheets with questions designed to aid observations and to help in interpretation of the data were also provided.

For the Informative Animal Module, environmental conditions required for Daphnia survival and the procedure for culturing green algae as food for Daphnia were described. Other sources of food were also discussed. The Investigative Animal Module posed the problem of food sources for the Daphnia and led the student through a study of environmental conditions necessary for Daphnia survival and reproduction. Both modules contained a picture of the Daphnia along with a detailed description of the identifying features. A data sheet with questions to guide interpretation of data and a guide sheet for maintaining the Daphnia for two weeks accompanied the investigative module.

Description of Sample

The participants in the study were enrolled at Michigan State University in Biological Science 202, Biological Science for Elementary Teachers, during winter term 1973.

While the population of interest for this study was pre-service elementary school teachers at Michigan State University, the students enrolled in Biological Science 202 were chosen as subjects for two reasons:

First, the "student" could be used as the experimental unit since the laboratory work was done on an individual basis. Second, the students who are primarily elementary education majors were least likely to have taken any other biology course during their college career and few if any would have completed a science methods course.

The assumption is that the learning ability of students enrolled in a course designed primarily for elementary education majors does not differ from that of students who are elementary education majors. Therefore, the non-education majors in the course would not significantly affect the outcome of the study.

Biological Science 202 is a general biology course that follows an audio-tutorial format. The heart of the program is the Independent Learning Session, often referred to as the laboratory session, which is arranged by the student to fit his time schedule.

The Learning Center or laboratory is open three days a week usually from 8 A.M. to 9 P.M. The amount of time a student spends at the Learning Center listening to tapes, viewing films, filmstrips or demonstrations and performing experiments depends on his background and his individual rate of progress in reaching the objectives set for each week.

Other phases of the course include: 1) a weekly one hour General Assembly Session for lectures or long movies, 2) the Small Assembly Session for weekly discussion of biological topics and activities related specifically to elementary school science and 3) the one hour weekly Evaluation Session for oral and written examinations.

Although the experimental modules used in this study were included as a part of the required activities to be completed at the Learning Center, many students were under the impression that the work was optional and did not participate. Then too, because the nature of the course allows a student to control his own learning activities, it was difficult to maintain a firm control on participation.

Perhaps for these reasons only 137 of the 163 students enrolled for winter term actually began the experimental study by taking the pretest and the first treatment module. Other students were subsequently eliminated if they omitted one required treatment or test.

A total of 98 students received all treatments and completed all required assessments. Of this sample, sixty-three percent were elementary education majors, 20 percent were from the College of Human Ecology with majors in Child Development, 8 percent were majoring in Social Work, while the others were from varied curricula such as social science and mathematics. There were equal distributions of juniors and sophomores who constituted 87% of the sample. Over 85% of the participants were female.

It should be kept in mind that the main emphasis for this study was to investigate the effectiveness of modules for teaching a biological skill using living organisms. The effect of this skill development on the teaching ability of elementary school teachers was not of primary interest. Therefore, the use of subjects who were not prospective teachers would not invalidate the results obtained.

Instrumentation

Four measuring instruments developed by the investigator were used in the study. A skills test designed to measure general knowledge concerning the growth and maintenance of plants and animals was administered. The general skills test was used only as an instrument for dividing the students into high and low skill levels. The data from this test is not used in any other part of the analysis.

Three equivalent forms of a specific skills test, Maintaining Living Organisms in the Classroom (MLOC), were used for criterion measures. One part of the test covered the germination of seeds and the growth requirements for plants used in the study while the other section sought specific requirements for survival of the Daphnia. The tests were given before the first treatment (informative modules) as a pretest, as an intermediate test one week later before the second treatment (investigative modules) and as a posttest two weeks later at the conclusion of the experimental study required for the investigative modules. (Copies of all tests used are included in Appendix D.)

The reliability or coefficient of internal consistency for the test instruments was computed using the Kuder-Richardson formula #20. Using this formula as the sample becomes more homogeneous, the reliability is lowered. As the index of difficulty increases the reliability decreases. Since the length of the test also influences the size of the reliability coefficient the Spearman-Brown prophecy formula[1] was applied to the calculated reliability to predict the reliability if the tests were tripled in length. Summary data and resulting reliability coefficients are found in Table 1. Detailed data for the measuring instruments are in Appendix E.

Design of the Study

The design used was an incomplete repeated measures design. It was like a factorial design in that

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[1]N. M. Downie, Basic Statistical Methods, (New York: Harper & Row Publishers, 1959), pp. 218-221

TABLE 1.--SUMMARY DATA AND RESULTING RELIABILITY COEFFICIENTS

	Pretest	Intermediate Test	Posttest
Mean Item Difficulty	57	47	44
Mean Item Discrimination	29	32	28
Variance	8.08	6.86	5.93
Kuder-Richardson Reliability #20	.4803	.4490	.2857
Spearman-Brown Predicted Reliability	.7349	.7096	.5397

several independent variables were superimposed in order to study their independent and interactive effect on a dependent variable.[2]

There were four factors with two levels each used in the study. This means there were 2^4 or sixteen possible treatment combinations. Since it was not practical to use this many combinations, an incomplete design was used. A decided disadvantage of this design obviously is the loss of partial or total information on one or more treatment comparisons that might be linked together (mixed up) and are thus said to be confounded.[3] However, such a

[2]B. J. Winer, Statistical Principles in Experimental Design, (New York: McGraw-Hill Book Company, 1962), p. 325

[3]R. Lowell Wine, Statistics for Scientists and Engineers, (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1964), p. 480

design does allow a reduction in experimental effort, it gives a somewhat broader scope for inferences and the results of one sequence will indicate if the next sequence is feasible.[4]

The design (A) notation below, modeled after Stanley and Campbell,[5] represents the block from the complete design that was investigated in this study. Model B, C, D with notation for testing not indicated are the other possible blocks that could be investigated if the results from A indicate that such is warranted.

Model A	B	C	D
H O_1 X_P O_2 Y_A O_3	X_P X_A	Y_P Y_A	X_P Y_P
H O_1 X_A O_2 Y_P O_3	X_A X_P	Y_A Y_P	X_A Y_A
L O_1 X_P O_2 Y_A O_3	X_P X_A	Y_P Y_A	X_P Y_P
L O_1 X_A O_2 Y_P O_3	X_A X_P	Y_A Y_P	X_A Y_A

Legend:

O_1 - Pretest; O_2 - Intermediate Test; O_3 - Posttest

X_P - Plant module, Informative Y_P - Plant Module, Investigative

X_A- Animal module, Informative Y_A - Animal module, Investigative

H - High skill level L - Low skill level

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[4]Winer, <u>Statistical Principles</u>, p. 676

[5]Donald T. Campbell and Julian C. Stanley, Experimental Designs for Research, (Chicago: Rand McNally & Company, 1963)

Figure 1 further clarifies the experimental design. The subjects were divided into a high and a low skill level group based on scores from the general skills test. Subjects who scored sixteen points or higher on the twenty-two point test were assigned to the high skill level group while the remaining ones were placed in the low skill group. The scores for the high skill level group ranged from 21-16 points with a mean of 17.5. The mean for the low skill level group was 12.7 with a range from 15-6 points. There were forty-nine students assigned to each skill level.

Within each skill level the subjects were randomly assigned to one of the two subgroups. Subgroup one, Order A, received the informative plant module first, followed the next week by the investigative animal module. Those in subgroup two, Order B, received the informative animal module first, followed the next week by the investigative plant module.

Each subgroup was further divided at the end of the study as achievers and non-achievers. Students whose answers to questions on the data sheets indicated that they had completed the experiment and had accomplished the objectives set for the modules were classed as achievers. All others were placed with the non-achievers.

			PREPLA	PREANI	INTPLA	INTANI	POSPLA	POSANI	N
High Skill Level	Order A	Achiever							
		Non-Achiever							
	Order B	Achiever							
		Non-Achiever							
Low Skill Level	Order A	Achiever							
		Non-Achiever							
	Order B	Achiever							
		Non-Achiever							

Legend: PREPLA--Pretest Plant
PREANI--Pretest Animal
INTPLA--Intermediate test Plant
INTANI--Intermediate test Animal
POSPLA--Posttest Plant
POSANI--Posttest Animal

FIGURE 1.--GENERAL DESIGN OF THE STUDY

Treatment Procedure

During the first two class meetings in the Small Assembly Sessions the general skills test was administered. Group assignments were made as described previously and cards were prepared for each student indicating which module, plant or animal, the student was to receive when the experimental portion of the study began.

When a subject reported to the Learning Center during week six and requested tape three, he was given a sheet briefly explaining the plant and animal study and a pretest, Maintaining Living Organisms in the Classroom (MLOC). When the answer sheet and test were returned to the desk attendant, the student was given a tape for either the Informative Plant or Informative Animal Module, depending on his group assignment, and the printed material to accompany the tape. The cover sheets were color coded to prevent some confusion: pink for animal study, green for plant study.

For week seven all students were to receive an investigative module. If a student had received the animal study the week before he would receive the plant module during week seven and vice versa. When a student was ready for the plant or animal study he was again given a test to be completed before starting the module.

With the investigative module a student received the appropriate tape, a box of materials required for the investigation and printed matter that included the same pictures used for the informative modules on the same subject. Also included were data sheets with questions, and a sheet giving directions on how to monitor the organisms being studied for the next two weeks. (A copy of the objectives, scripts for the tapes, materials required and printed matter used for weeks six and seven are included in Appendix F.)

During the next two weeks students watered plants, added food for the Daphnia, made observations and recorded data. At the end of the two weeks subjects were instructed to complete and return data sheets and dismantle experimental set ups. The posttest was then given during week nine in either the Small Assembly Session or the Evaluation Session.

Hypotheses

The following hypotheses were tested in this study:

1. There is no difference between the three repeated measures for the test, Maintaining Living Organisms in the Classroom (MLOC).

2. There is no difference between the High Skill Level group and the Low Skill Level group on the MLOC tests.

3. There is no difference between Order A, students who receive the plant module first and Order B, students who receive the animal module first, as determined by the MLOC tests.

4. There is no difference between Achievers and Non-Achievers as determined by the MLOC tests.

5. There is no interaction between skill levels and order of module presentation for the MLOC tests.

6. There is no interaction between skill levels and achiever status for the MLOC tests.

7. There is no interaction between order of module presentation and achiever status for the MLOC tests.

8. There is no interaction between skill levels, order of module presentation and achiever status for the MLOC tests.

9. There is no difference between the Investigative Modules and the Informative Modules as determined by the MLOC Tests.

The hypotheses were analyzed using the data in three different ways: combined plant and animal data, plant data alone and animal data alone. For the combined data the following six variables were tested for each hypothesis:

1) Grand Mean

Symbolically: $P_1 + P_2 + P_3 + A_1 + A_2 + A_3$

2) Pretest - Posttest

Symbolically: $(P_1 + A_1) - (P_3 + A_3)$

3) Intermediate - Posttest

Symbolically: $(P_2 + A_2) - (P_3 + A_3)$

4) Plant tests - Animal tests

Symbolically: $(P_1 + P_2 + P_3) - (A_1 + A_2 + A_3)$

5) Interaction: Pretest x Posttest

Symbolically: $(P_1 - A_1) - (P_3 - A_3)$

6) Interaction: Intermediate x Posttest

Symbolically: $(P_2 - A_2) - (P_3 - A_3)$

With the separate data four variables were used for each hypothesis:

1) Grand Mean

Symbolically: $P_1 + P_2 + P_3$ or $A_1 + A_2 + A_3$

2) Pretest - Posttest

Symbolically: $P_1 - P_3$ or $A_1 - A_3$

3) Intermediate - Posttest

Symbolically: $P_2 - P_3$ or $A_2 - A_3$

4) Difference in gain scores

Symbolically: $(P_1 - P_2) - (P_2 - P_3)$ or $(A_1 - A_2) - (A_2 - A_3)$

Analysis Model

Multivariate analysis of variance with repeated measures was used to analyze the data. The analysis model was three-way with two dependent variables and three repeated measures. The independent variables were skill levels, order of module presentation and achiever status. The fourth independent variable, module type, was not a part of the analysis model since its effect was determined in a separate analysis from gain scores. The two dependent variables were the plant test and the animal test. The three repeated measures were pretest, intermediate test and posttest.

Multivariate analysis is necessary when looking at more than one dependent variable at a time. The F-ratio for the multivariate test for each hypothesis represents the simultaneous test of equality of mean vectors for all variables being considered. Univariate analysis was then conducted for each variable to yield a univariate F-ratio which determined the significance of each variable independently as a post hoc procedure.

To determine the relationship of the variable a step-down F-ratio was computed. This ratio gives indications as to the effect of each variable upon the multivariate analysis results. The order in which the variables are listed is important, as the dependence of the differences is read from the bottom up.

For example, if from a list of three variables a significant value is found for variable three, this would indicate that the significance was conditioned upon the other two variables. To determine which variable was contributing to the significance, the order of the list of variables would have to be changed. If the step-down F-ratio for more than one variable is significant two factors must then be considered. If the univariate analysis for the variables in question is highly significant and the correlation between the variables is low, then it can be concluded that these variables have contributed equally to the significance of the multivariate analysis.

In Chapter IV, the significance obtained using the step-down F-ratio will be used in discussing the meaning of the multivariate analysis results for each hypothesis rejected. The univariate analysis for each variable will be used to discuss the graphic presentation of means for each independent variable where significance was found.

Summary

The subjects used in the study were students enrolled at Michigan State University in Biological Science 202, Biological Science for Elementary Teachers, during winter term, 1973.

The treatment consisted of two types of modules, informative and investigative, being used to examine their relative effectiveness in training students to maintain living organisms in the classroom. All students received informative modules first. One half studied plants while the other half studied an animal. The following week all students used the investigative module to set up either a plant or animal habitat and to determine from data collected the optimum conditions for survival of the organism.

The measures used for analysis were three equivalent forms of a specific skills test, MLOC, administered as a pretest before the informative modules, as an intermediate test before the investigative modules and as a posttest at the completion of the investigative modules.

A repeated measures design was used to test for the main effect and interactive effect of four independent variables: 1) high - low skill level group, 2) Order A, plant module first - Order B, animal module first, 3) Informative - Investigative modules, and 4) Achievers - Non-achievers.

Multivariate analysis of variance for repeated measures was used to analyze data collected. The analysis model was a three-way design with two dependent variables. The significance of univariate and step-down F-ratio values were used to interpret results from the multivariate analyses.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF THE DATA

The two-fold purpose of this study was to develop modules to train preservice elementary school teachers in the maintenance of living organisms and to test the relative effectiveness of informative and investigative modules to teach the skills needed in maintaining organisms. The data collected as described in Chapter III is reported and analyzed in this chapter.

A multivariate repeated-measure analysis was conducted using the Control Data 6500 computer system at Michigan State University. The specific program used was the univariate and multivariate analysis of variance, covariance and regression. A three-way design with two dependent variables and three repeated measures was the basis for the analysis scheme. The alpha level was set at 0.05.

The three independent variables were: 1) High and Low Skill Levels, 2) Order A, informative plant module first followed by investigative animal module, and Order B, informative animal module first followed by investigative plant module, and 3) Achievers, subjects who demonstrated mastery of objectives, and Non-Achievers, mastery of objectives uncertain.

The test instruments contained one section on plants and one on animals. Each test is, therefore, treated as two measuring instruments. The three repeated measures then are: Pretest Plant (PREPLA), Pretest Animal (PREANI); Intermediate test Plant (INTPLA), Intermediate test Animal (INTANI); Posttest Plant (POSPLA), Posttest Animal (POSANI). The first treatment, informative plant module for Order A (P → A) and informative animal module for Order B (A → P), was given after the pretest. The second treatment, investigative animal module for Order A and investigative plant module for Order B, was given after the intermediate test.

In Table 2 the cell means computed from raw scores and cell means based on percentage scores are presented. Percentage scores were computed to adjust for differences due to an unequal number of items in the tests. An overview of the mean scores gives an indication of some areas other than the hypotheses tested that should be investigated in more detail.

For example, differences between plant and animal scores gradually decrease from pretest to posttest leading to speculation over why there was a greater gain

TABLE 2.--OBSERVED CELL MEANS, PERCENTAGE SCORES AND CELL FREQUENCIES

VARIABLES			PREPLA		PREANI		INTPLA		INTANI		POSPLA		POSANI		N
			M	P	M	P	M	P	M	P	M	P	M	P	
High Skill Level	Order A P → A	Achiever	5.20	47.2	5.20	43.1	6.87	68.7	5.27	52.7	6.73	61.3	6.87	68.7	15
		Non-Achiever	5.20	47.2	4.90	40.7	6.60	66.0	4.80	48.0	7.20	65.7	6.30	63.0	10
	Order B A → P	Achiever	5.18	47.0	5.82	48.4	5.73	57.3	6.91	69.1	6.54	59.6	5.82	58.2	11
		Non-Achiever	4.69	43.0	5.69	47.4	5.46	54.6	6.07	60.7	6.92	63.1	6.08	60.8	13
Low Skill Level	Order A P → A	Achiever	5.44	56.9	3.44	28.7	5.33	53.3	2.78	27.8	7.22	65.9	6.11	61.1	9
		Non-Achiever	5.25	55.1	4.17	34.7	5.67	56.7	3.58	35.8	6.50	59.2	5.83	58.3	12
	Order B A → P	Achiever	5.83	49.5	4.83	40.3	5.50	55.0	4.83	48.3	6.83	62.2	6.83	68.3	6
		Non-Achiever	4.86	47.8	4.36	36.4	4.82	48.2	5.00	50.0	6.04	55.0	5.59	55.9	22

Legend: PREPLA--Pretest Plant
PREANI--Pretest Animal
INTPLA--Intermediate Test Plant
INTANI--Intermediate Test Animal
POSPLA--Posttest Plant
POSANI--Posttest Animal

N--Frequency

M--Mean Raw Scores

P--Percentage Scores

on the animal test. Also, since there appears to be little difference between groups on posttest scores, the question of what treatment or combination of factors apparently erased the differences should be answered.

Inter-test Correlation

The correlations between the measuring instruments in Table 3 reveal some interesting relationships. The rank order of correlations is: PREANI & PREPLA (.38), INTPLA & POSPLA (.35), and POSANI & POSPLA (.29). The low correlation between INTANI & INTPLA (.01) indicates probable differences in the tests.

Results of Multivariate and Univariate Analyses for Combined Data

The F-Ratio for multivariate test of equality of mean vectors is reported in Table 4 for the hypotheses tested using multivariate analysis. The data for the first analyses represent combined scores from the plant tests plus the animal tests. The following hypotheses were rejected at a 0.05 level of significance:

1. There is no difference between the three repeated measures as determined by the tests, Maintaining Living Organisms in the Classroom (MLOC) ($F = 717.48$, $p < .0001$).

TABLE 3.--INTER-CORRELATION MATRIX

	PREPLA	PREANI	INTPLA	INTANI	POSPLA	POSANI
PREPLA	1.000					
PREANI	.382	1.000				
INTPLA	.182	.067	1.000			
INTANI	.001	.029	.010	1.000		
POSPLA	.098	.095	.348	.064	1.000	
POSANI	-.021	.149	.130	.055	.288	1.000

Legend: PREPLA--Pretest Plant
PREANI--Pretest Animal
INTPLA--Intermediate test Plant
INTANI--Intermediate test Animal
POSPLA--Posttest Plant
POSANI--Posttest Animal

TABLE 4.--MULTIVARIATE REPEATED-MEASURE ANOVA TABLE: COMBINED PLANT AND ANIMAL DATA

Source	df	f	p
Grand Mean	6, 85	717.4810	.0001
Skill Levels	6, 85	6.4401	.0001
Order	6, 85	5.2236	.0002
Achiever	6, 85	0.6287	.7069
Skill x Order	6, 85	0.6181	.7153
Skill x Achiever	6, 85	1.0726	.3854
Order x Achiever	6, 85	0.2638	.9523
Skill x Order x Achiever	6, 85	0.5550	.7649

2. There is no difference between the high skill level and the low skill level as measured by the MLOC tests ($F = 6.44$, $p < .0001$).

3. There is no difference between Order A and Order B as measured by the MLOC tests ($F = 5.22$, $p < .0002$).

The univariate analysis for each of these hypotheses was examined for further significance. The complete data from the analyses are found in Appendix G. The significance for the Step Down F-Ratio will be discussed as the more meaningful analysis rather than the one-way analysis F-ratio which treats each variable separately. For the Step Down F, variables are considered in order from the bottom up. Once a significant $p < 0.05$ is reached, any significance found from this point on is possibly related to this first significant variable and must be considered with this relationship in mind. A summary of probability values for the rejected hypotheses is in Table 5.

For the first hypothesis, the test of difference between the repeated measures, the only variable of interest is the interaction between the pretests and posttests with a p less than .0338. The other variables showed no significant differences.

TABLE 5.-- SUMMARY OF PROBABILITY VALUES FOR HYPOTHESES REJECTED IN MULTIVARIATE ANALYSES OF COMBINED SCORES, PLANT SCORES AND ANIMAL SCORES

Analysis Scores	Hypotheses Rejected	Multivariate Analysis p	Variables	Step-Down Univariate Analysis p
Combined Plant & Animal Scores	Repeated Measures	.0001	GRANDM	.0001
			PRE - POS	.1567
			INT - POS	.8318
			PLA - ANI	.7462
			PRE X POS*	.0338
			INT X POS*	.0802
Plant Scores	Repeated Measures	.0001	GRANDM	.0001
			PRE - POS	.4625
			INT - POS	.8934
Animal Scores	Repeated Measures	.0001	GRANDM	.0001
			PRE - POS	.0300
			INT - POS	.0049
Combined Plant & Animal Scores	Skill Levels	.0001	GRANDM	.0001
			PRE - POS	.3003
			INT - POS	.0048
			PLA - ANI	.0399
			PRE X POS*	.0507
			INT X POS*	.7323

Plant Scores	Skill Levels	.0183	GRANDM PRE - POS INT - POS	.0761 .0836 .0487
Animal Scores	Skill Levels	.0001	GRANDM PRE - POS INT - POS	.0001 .8146 .1220
Combined Plant & Animal Scores	Module Order	.0002	GRANDM PRE - POS INT - POS PLA - ANI PRE X POS* INT X POS*	.7956 .5403 .0215 .0005 .8457 .0028
Plant Scores	Module Order	.0601	---------	-----
Animal Scores	Module Order	.0002	GRANDM PRE - POS INT - POS	.0060 .7535 .0003

*Interaction

The difference between the high skill level and the low skill level is primarily related to the difference between the three plant measures and the three animal measures ($F = 4.36$, $p < .0399$) for each skill level. The next significant value above this one, p less than .0048, for the difference between intermediate tests and posttests for the skill levels is very likely related to the difference between plant and animal scores. A rearrangement in the order of the variables would be necessary to show otherwise. The significance for the grand mean ($F = 17.39$, $p < .0001$) has no meaning for this hypothesis.

Difference between Order A and Order B is affected primarily by interaction between intermediate tests and posttests. Differences between plant and animal measures ($F = 13.23$, $p < .0005$) and intermediate tests minus posttests ($F = 5.48$, $p < .0215$) have also contributed to the rejection of this hypothesis.

Apparently, differences between the plant and animal test results and the differences between intermediate tests and posttests contributed to the difference between skill levels and the effect attributed to difference in the order of module presentation. Therefore, a further analysis of the data looking at the plant and animal data separately and examining in greater detail intermediate and posttest differences was conducted.

Multivariate and Univariate Analysis of Plant Data

When the data from the plant tests alone were subjected to a multivariate repeated-measure analysis only two of the eight hypotheses were rejected: There is no difference between the repeated measures for the plant data ($F = 860.52$, $p < .0001$) and there is no difference between the high skill level and the low skill level for the plant modules ($F = 3.52$, $p < .0183$). See Table 6 for complete listing of F-ratio and p values from analysis of all hypotheses.

TABLE 6.--MULTIVARIATE REPEATED-MEASURE ANOVA TABLE: PLANT DATA

Source	df	F	p
Grand Mean	3, 88	860.5165	.0001
Skill Levels	3, 88	3.5228	.0183
Order	3, 88	2.5607	.0601
Achiever	3, 88	0.5169	.6718
Skill x Order	3, 88	0.6403	.5911
Skill x Achiever	3, 88	0.9777	.4071
Order x Achiever	3, 88	0.3954	.7567
Skill x Order x Achiever	3, 88	0.2221	.8809

An examination of the univariate analysis for the two hypotheses rejected gives a clue as to how the plant test scores have influenced the total results. Probability values for rejected hypotheses are in Table 5 for the plant data. The differences from pretest to posttest ($F = .54$, $p < .4625$) and from intermediate test to posttest ($F = .02$, $p < .8934$) for the three repeated measures were not significant for the plant data. Only the grand mean is significant ($F = 2623.05$, $p < .0001$). This gives no meaningful information other than that the mean of the three measures was greater than zero.

The only significant difference in the univariate analysis of the skill levels is from intermediate to posttest ($F = 3.996$, $p < .0487$). Complete data for the univariate analyses are in Appendix H.

Multivariate and Univariate Analysis of Animal Data

The results from the multivariate analysis of the animal data found in Table 7 indicates that the animal tests results probably had a greater influence on the differences for combined data than did the plant tests results. The same three hypotheses rejected using combined data were also rejected using the animal tests results. Significant differences are apparent for: the three repeated measures (F = 950.15, p < .0001), between skill levels (F = 9.06, p < .0001) and between order of module presentation (F = 7.86, p < .0002). Complete multivariate data in Appendix I.)

TABLE 7.--MULTIVARIATE REPEATED-MEASURE ANOVA TABLE: ANIMAL DATA

Source	df	F	p
Grand Mean	3, 88	950.1536	.0001
Skill Levels	3, 88	9.0603	.0001
Order	3, 88	7.8561	.0002
Achiever	3, 88	0.6490	.5857
Skill x Order*	3, 88	0.4809	.6964
Skill x Achiever*	3, 88	1.2050	.3128
Order x Achiever*	3, 88	0.2310	.8764
Skill x Order x Achiever*	3, 88	0.8796	.4550

*Interaction

A univariate analysis of the first hypothesis shows that differences for INTANI-POSANI (F = 8.33, p < .0049), PREANI-POSANI (F = 4.87, p < .0300) and Grand Mean (F = 2512.85, p < .0001) are significant for the three repeated measures. Since the univariate analyses for the variables are highly significant and the correlations low, each variable probably contributed equally to the overall results for the multivariate analysis.

The univariate analysis for the skill levels suggests that the significance of the multivariate analysis for high skill level versus low skill level in the animal modules is due to the grand mean differences only ($F = 24.55$, $p < .0001$) and not PREANI-POSANI ($F = .06$, $p < .8146$) or INTANI-POSANI ($F = 2.44$, $p < .1220$). The differences between order of module presentation appears to be attributable to intermediate-posttest differences ($F = 14.397$, $p < .0003$). The probability values for all hypotheses rejected after multivariate analysis of the animal data are in Table 5.

A separate multivariate analysis of the plant and animal data was conducted to establish the effectiveness of the informative and investigative modules. The variable of concern was the difference in gain scores. This means: (pretest-intermediate) - (intermediate test-posttest). This variable was tested for the three hypotheses that had been rejected using multivariate analysis: differences in repeated measures, differences in high and low skill levels and differences in order of module presentation. The following results were obtained:

1) For repeated measures there was no significant difference between gain scores for pretest-intermediate test minus gain scores for intermediate test-posttest for the plant data. There was a highly significant difference for the animal data ($F = 7.31$, $p < .0082$).

2) For skill levels there was a significant difference between gain scores for the plant data ($F = 7.10$, $p < .0091$) but the difference was not significant for the animal data.

3) For order of module presentation there was a difference in gain scores for the animal data ($F = 13.20$, $p < .0005$). The hypothesis was not rejected for the plant data. (Complete multivariate and univariate analysis for this variable is in Appendix J.)

Discussion and Interpretation

A comparison of analysis results from plant and animal tests scores using Table 5 gives a clue to factors affecting the overall results. Both plant and animal modules appear to contribute equally to the significant differences between the three repeated measures for hypothesis one. The interaction between the pretest and the posttest for the combined data could well be related to the difference observed between pretest-posttest for animal data but not found significant for the plant data.

For the skill levels the difference found between combined plant and animal scores is probably due more to the differences between intermediate-posttest for plant data since the only differences in the animal scores are in the grand mean. The rejection of the hypothesis ($F = 5.22$, $p < .0002$) on order of module presentation seems to be affected more by the animal modules since the hypothesis was not rejected for the plant data.

A graphic presentation of the data will clarify many of the explanations made thus far. Only the separate data for the plant and animal modules will be discussed since the combined data was designed only to show trends and to test the overall efficacy of the modules.

Grand means for plant and animal scores are plotted in Figure 2. The significant difference between plant and animal scores reported earlier for combined data evidently is related to differences at the pretest and intermediate test levels. The numerical differences between points on the graph, reported in Table 8, indicate that the difference between animal and plant scores changes very little from pretest (9.2) to intermediate test (8.4). The first treatment, informative module, is almost equally

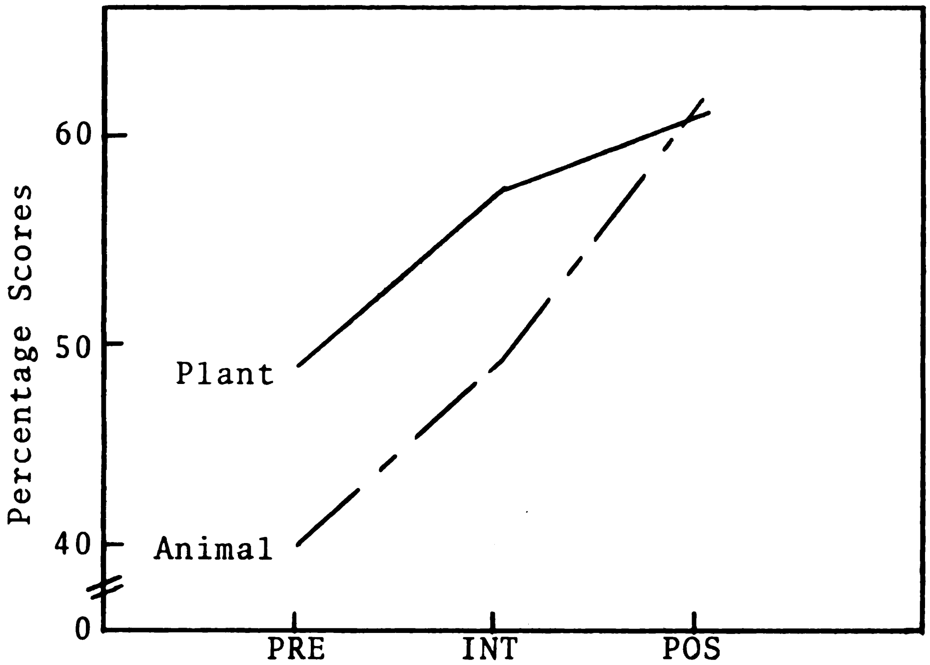


FIGURE 2.--TOTAL EFFECT OF PLANT AND ANIMAL MODULES

effective for plant scores (8.3 point change) and animal scores (9.1 point change). However, since the posttest scores are separated by only .3 point, apparently the second treatment, investigative module, was more effective for animal scores than for plant scores. There is a greater overall gain in animal scores. Specific factors related to these differences will be discussed as the data are examined for each hypothesis.

TABLE 8.--PERCENTAGE MEAN DIFFERENCES FOR PLANT AND ANIMAL MODULES

PREPLA-PREANI	9.2	PREPLA-INTPLA	8.3	PREANI-INTANI	9.1
INTPLA-INTANI	8.4	INTPLA-POSPLA	4.0	INTANI-POSANI	12.7
POSPLA-POSANI	- .3	PREPLA-POSPLA	12.3	PREANI-POSANI	21.8

The second hypothesis rejected was that there is no difference between the high skill level and low skill level for the plant data ($F = 3.52$, $p < .0183$) and animal data ($F = 9.05$, $p < .0001$). Differences for plant and animal data according to skill level are in Table 9. The graphs in Figure 3 represent changes that occurred by skill level and subject.

TABLE 9.--PERCENTAGE MEAN DIFFERENCES FOR PLANT AND ANIMAL MODULES BY SKILL LEVELS

Plant Data			Animal Data		
	High Skill	Low Skill		High Skill	Low Skill
PREPLA-INTPLA	15.5	1.0	PREANI-INTANI	12.7	5.5
INTPLA-POSPLA	.8	7.2	INTANI-POSANI	5.1	20.4
PREPLA-POSPLA	16.3	8.2	PREANI-POSANI	17.8	25.9

The differences in pretest scores between the high and low skill level groups shown in Figure 3 are of interest. Remember, the skill levels are based on results from a test on general information concerning the maintenance of plants and animals. This same division for skill levels can be made from pretest scores based on specific knowledge of the Daphnia. But the skill levels do not hold for pretest scores based on specific knowledge concerning the growth and maintenance of plants. The low skill level group

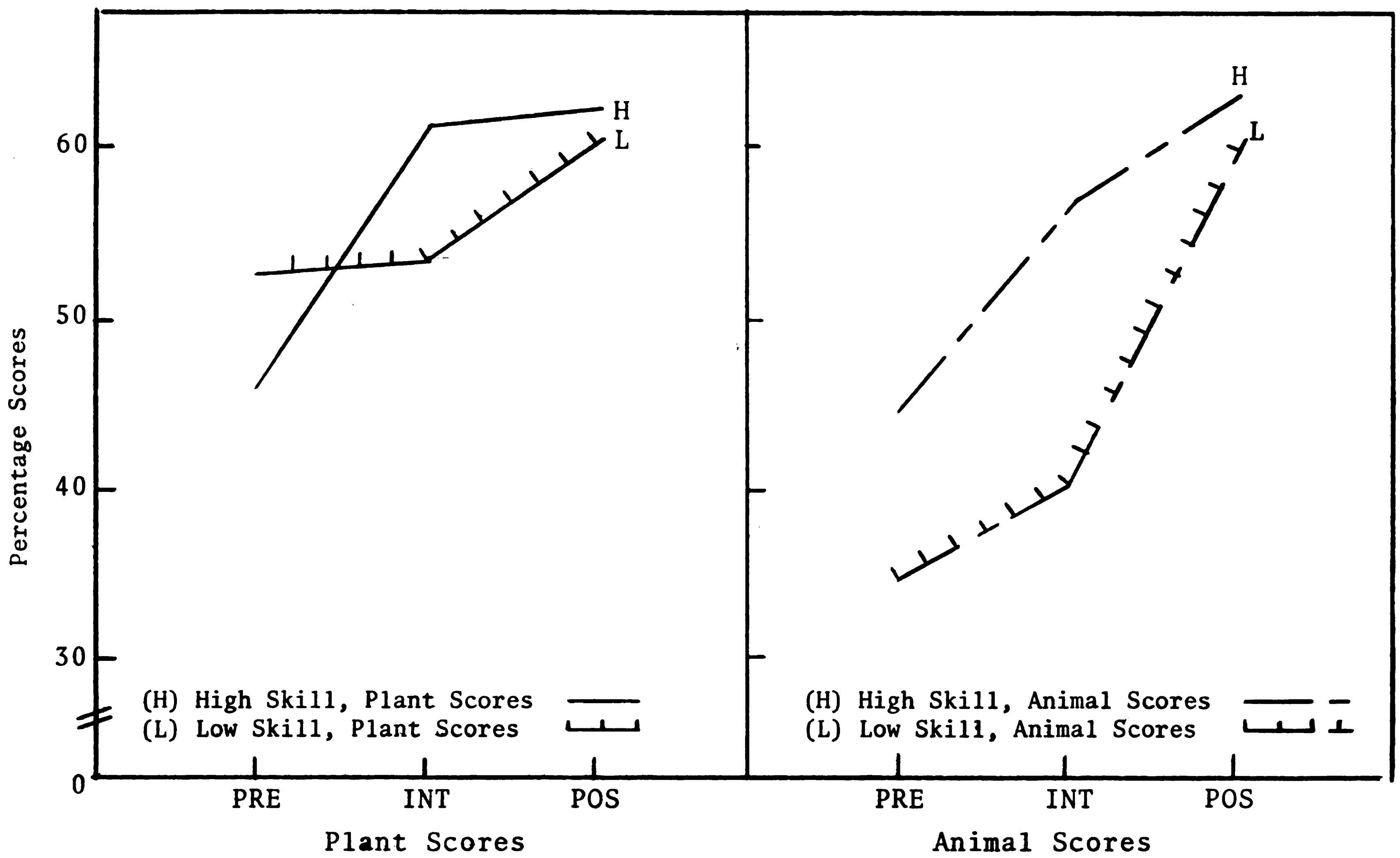


FIGURE 3.--COMPARISON OF HIGH AND LOW SKILL LEVELS FOR PLANT AND ANIMAL MODULES

performed better than the high skill level group on specifics of plant growth.

Looking at the plant results only in Figure 3, the informative module had very little effect on the low skill group (PRE-INT, L). The investigative module had a minor effect on the high skill group (INT-POS, H). Although the second treatment, the investigative modules, did cause a change for the low group (INT-POS, L), the high skill level had a greater overall gain from the plant modules.

For the animal modules in Figure 3, again the informative module was more effective for the high skill level (PRE-INT, H), and the investigative module was more effective for the low skill level (INT-POS, L). The overall gain for the animal modules was greater for the low skill group. Apparently, the investigative modules are more effective for the low skill group and the informative modules are more effective for the high skill level. The low skill level showed a greater gain on the animal modules and the high skill level experienced a greater gain on the plant modules.

The third hypothesis concerning order of module presentation was not rejected using the plant data. However, the data has been graphed in Figure 4 for comparison with animal data. A chart of differences due to order of module presentation is in Table 10.

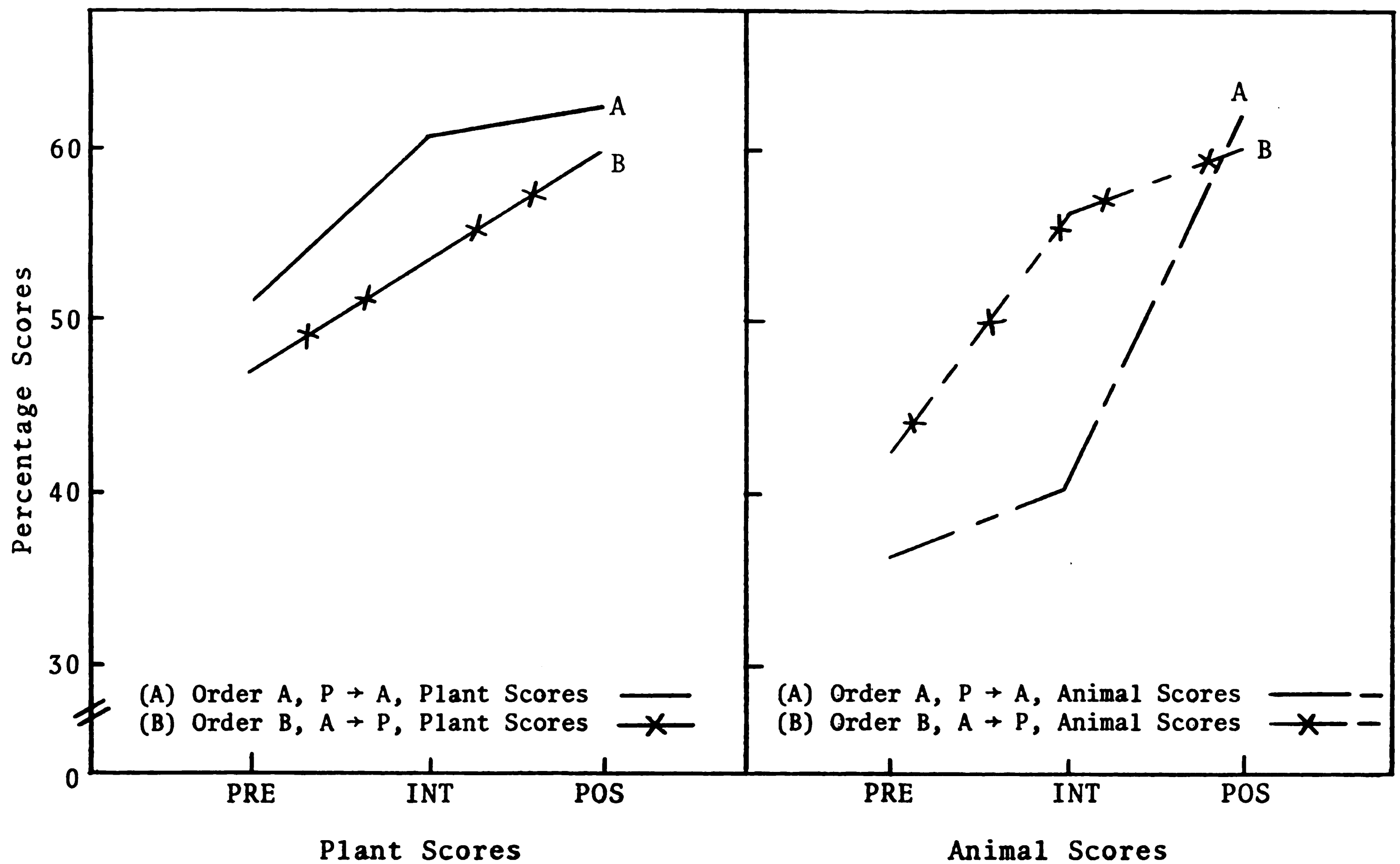


FIGURE 4.--EFFECT OF THE ORDER IN WHICH MODULES ARE PRESENTED ON PLANT AND ANIMAL SCORES

TABLE 10.--PERCENTAGE MEAN DIFFERENCES BY ORDER OF MODULE PRESENTATION

Plant Data			Animal Data		
	Order A P → A	Order B A → P		Order A P → A	Order B A → P
PREPLA-INTPLA	9.8	7.0	PREANI-INTANI	4.3	13.9
INTPLA-POSPLA	1.8	6.2	INTANI-POSANI	21.7	3.8
PREPLA-POSPLA	11.6	13.2	PREANI-POSANI	26.0	17.7

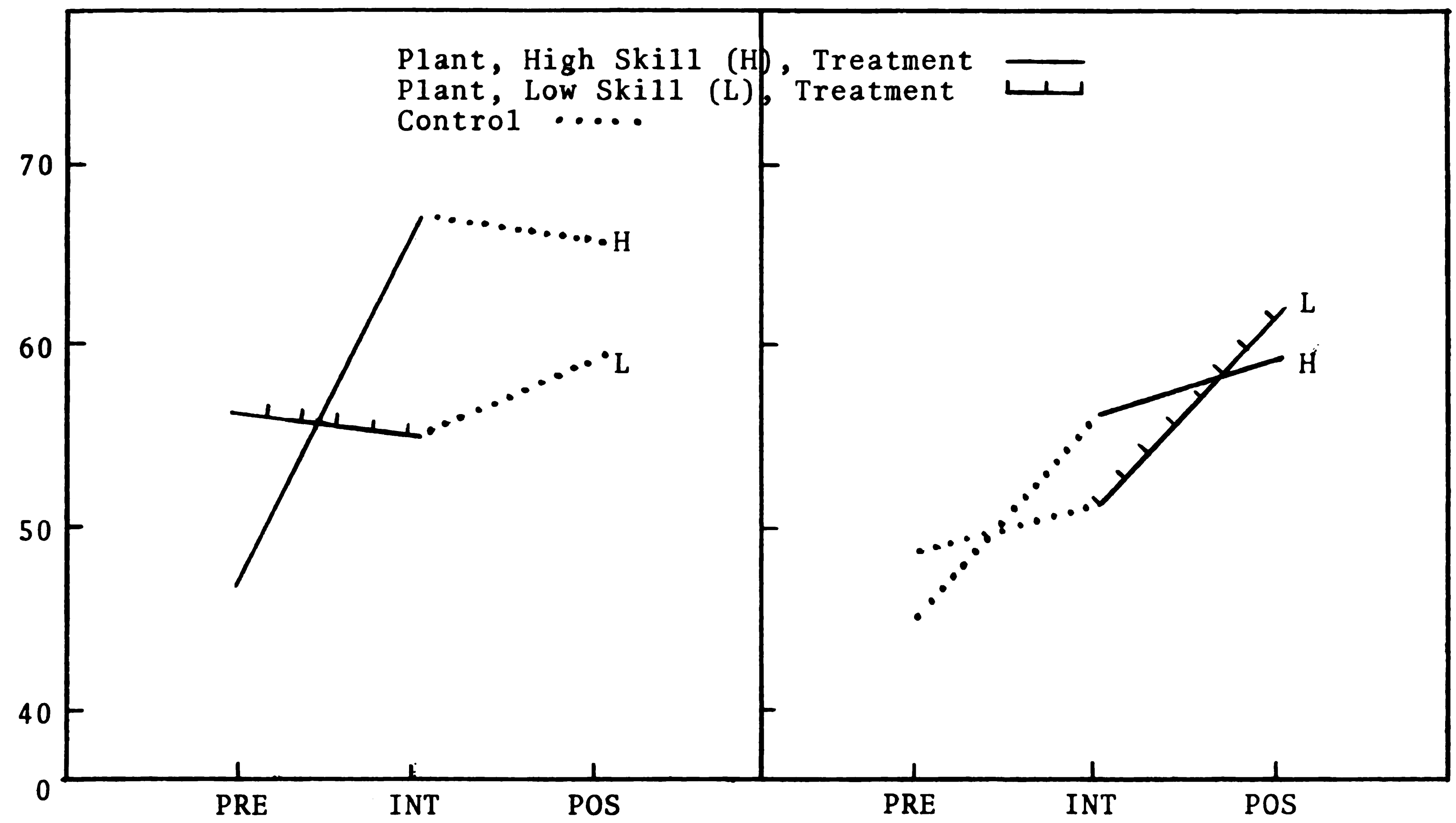
As support for failure to reject the hypothesis for the plant data the graph in Figure 4 shows that there was no significant difference between Order A and Order B for the pretest scores. There, also, was no significant difference for the posttest scores. What has happened for Order B, however, should not be ignored. The gain from pretest to intermediate test of 7.0 points for the plant scores is unexpected since these students received the informative animal module first. Since the informative module was shown previously to be more effective for the high skill level, a further examination of the data by order and skill level will be made with the next set of graphs.

The graph of animal scores in Figure 4 shows that the gain for each order was negligible when the plant modules were received: Order A, pretest to intermediate test--4.3 points; Order B, intermediate to posttest--3.8 points. When the animal modules were studied the gain was significant for both orders. However, since the gain for Order A (INT-POS, A) was greater than for Order B (PRE-INT, B) the questions raised are whether this difference is due to difference in skill level performance, the type of module used to study the animal or if the difference is caused by exposure to the plant information first?

The graphs discussed thus far indicate that there might be a relationship between the skill levels and order of module presentation that needs further examination. Therefore, in the next set of graphs the data are plotted to show the effect of treatment versus no treatment at each skill level for the plant and animal modules. In Figure 5 the relationship between treatment versus no treatment for the plant modules is graphically represented.

The informative plant module was effective only for the high skill level (Figure 5 (1), line H). The investigative plant module was more effective for the low skill level (Figure 5 (2), line L).

The unexpected occurrence is the change in mean scores for the control groups. After the low skill group completed the investigative animal module, both the animal scores and plant scores were affected. Compare the control portion of Figure 5 (1), line L, with the treatment portion



(1) Informative Plant Module
Order A

(2) Investigative Plant Module,
Order B

FIGURE 5.--TREATMENT EFFECT, PLANT MODULES

of Figure 6 (2), line L. Since the gain was so slight it is highly possible that this increase was due to chance or to maturation rather than some cross treatment effect.

A similar relationship occurred with the high skill level. After the completion of the informative animal module there was a mean gain for plant scores and animal scores. Compare the control portion of Figure 5 (2), line H, with the treatment portion of Figure 6 (1), line H. The magnitude of the difference suggests that there could be a causal relationship other than maturation.

The same strange relationship can also be observed for the animal data presented in Figure 6. From this graph, it is clear that the informative animal module was more effective for the high skill level. The investigative animal module resulted in significant changes for both skill levels but was more effective for the low skill level. Again, as with the plant modules, the low skill level that took the informative animal module first showed a greater gain in animal scores after receiving the investigative plant module. (See Figure 5 (2), line L, treatment portion, for plant test results and Figure 6 (1), line L, control portion, for animal results.) Table 11 shows the numerical differences for the treatment-no treatment groups for plant and animal data.

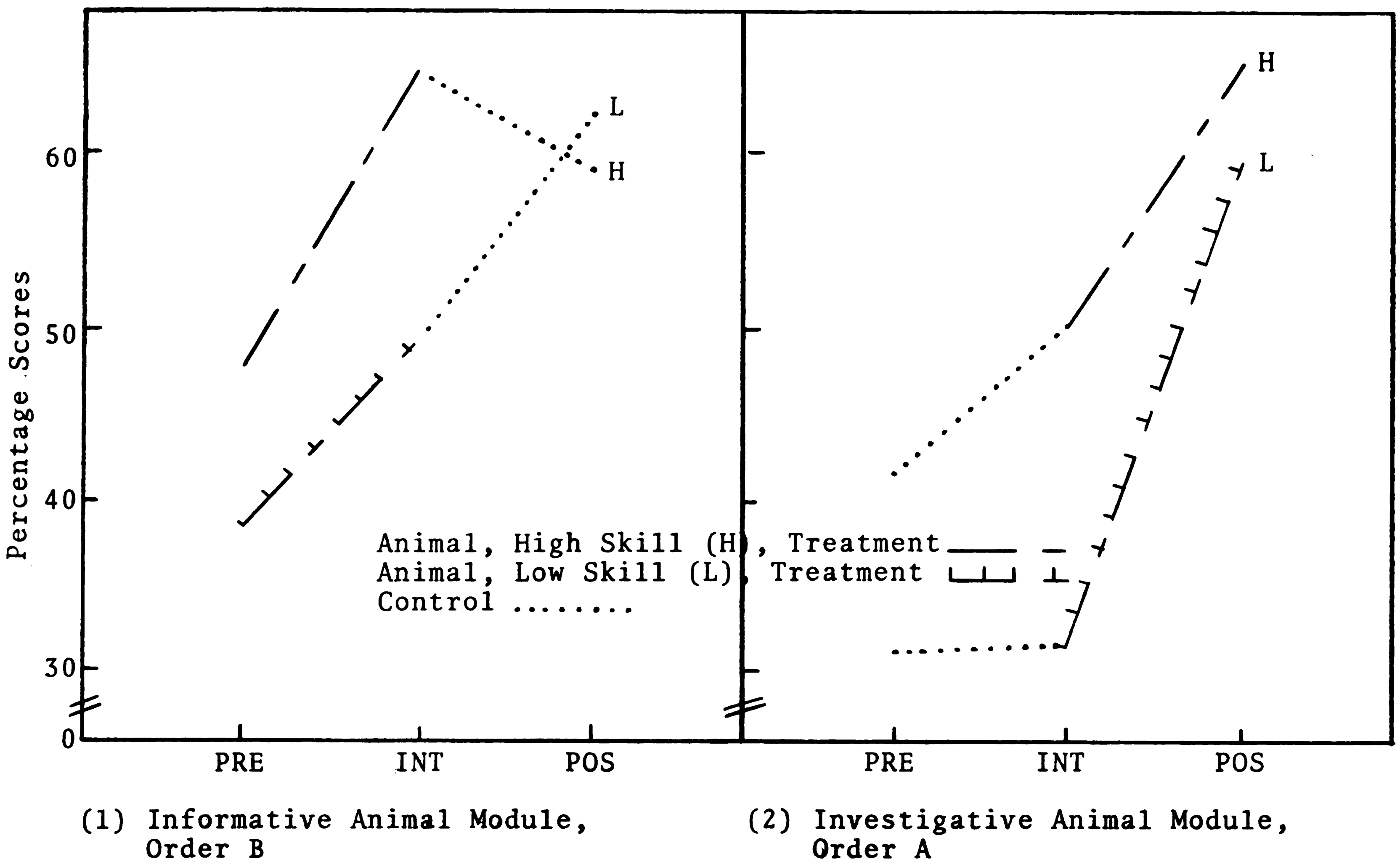


FIGURE 6.--TREATMENT EFFECT, ANIMAL MODULES

TABLE 11.--PERCENTAGE MEAN DIFFERENCES BY ORDER AND SKILL LEVELS FOR PLANT AND ANIMAL DATA

Modules	High Skill Level		Low Skill Level	
	Treat-ment	Con-trol	Treat-ment	Con-trol
Informative Plant Module	20.1	-1.5	-1.0	4.7
Investigative Plant Module	3.5	11.0	10.5	3.0
Informative Animal Module	17.0	-5.4	10.8	13.0
Investigative Animal Module	15.5	8.4	27.9	0.1

Since the control group for both plant and animal modules showed similar responses, the temptation is to conclude that the investigative module itself was effective in helping the low skill level to assimilate information that had been presented in an earlier treatment with the informative modules. With the high skill level the "carry-over" treatment effect appears to be associated with the informative modules. Obviously, more evidence is needed before a definite conclusion can be reached.

Summary

Since the hypotheses were investigated using the data in three different ways, the results can best be summarized by grouping the hypotheses according to the results from the three sets of data.

The following hypotheses were rejected using: 1) combined plant and animal data, 2) separate data from the plant tests, and 3) separate data from the animal tests:

Ho_1: There is no difference between the three repeated measures for the MLOC tests.

Ho_2: There is no difference between the high skill level and the low skill level as measured by the MLOC tests.

The following hypothesis was rejected using: 1) combined plant and animal data, and 2) separate data from the animal tests; but it was not rejected using the plant tests data:

Ho_3: There is no difference between Order A and Order B as measured by the MLOC tests.

The following hypotheses were not rejected by either of the three data pools used:

Ho_4: There is no difference between achievers and non-achievers as measured by the MLOC tests.

Ho_5: There is no interaction between skill levels and order of module presentation for the MLOC tests.

Ho_6: There is no interaction between skill levels and achiever status for the MLOC tests.

Ho_7: There is no interaction between order of module presentation and achiever status for the MLOC tests.

Ho_8: There is no interaction between skill levels, order of module presentation and achiever status for the MLOC tests.

The hypothesis of main interest was tested by comparing gain scores for plant and animal data. This hypothesis was not rejected for the plant data but was rejected for the animal data:

Ho_9: There is no difference between the informative and investigative modules as measured by the MLOC tests.

CHAPTER V

SUMMARY AND CONCLUSIONS

Elementary school science programs have been developed during the past decade to prepare students to live in a rapidly changing age dominated by science and technology. Many of the activity-centered programs emphasize the process approach and seek to develop "scientifically literate and personally concerned individuals with a high competence for rational thought and action."[1]

To meet the challenge of the "new science", colleges of education are re-structuring traditional science education courses.[2] Process skills, individualization, performance/competency-based programs and student involvement are key items for development. An area of increasing concern, therefore, is the identification and validation of skills a teacher needs to perform effectively in a modern elementary science classroom. An objective of this study was to investigate one of those skills, the maintenance of living organisms in the classroom.

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[1]Merrill, "NST A Position Statement," p. 21

[2]Systems Development Corporation, Summaries for Model Teacher Education Program, pp. 1-77

Development and Testing of Instructional Modules

A major portion of the study was the development of instructional modules to train pre-service elementary teachers to maintain organisms.

A pilot study was conducted with fifty-seven students enrolled at Michigan State University in Education 325F, Teaching Science in Elementary School. Five modules, concerned with training pre-service teachers to establish and maintain environments suitable for the survival of seven organisms, were tested. Problems of logistics and space dictated that the final test modules be limited to fewer organisms. Objections to the traditional "cookbook" method of instruction warranted the experimental study of more modern procedures.

The final modules, therefore, were limited to the study of the common plants, grass, rye and clover and one animal, the Daphnia sp. Behavioral objectives for the study of the growth and maintenance of the plants and the animal were used as the basis for the development of an informative and an investigative module for each organism studied.

The informative modules involved passive student participation, while the investigative modules required active involvement. In other words, the same objectives to be reached through experimentation in the investigative modules were carefully unfolded through dialogue and pictures in the informative modules. For the investigative modules students were to establish and maintain different environments for a particular organism, to record observed changes, and to interpret data in order to reach the desired objectives.

The Study

Students from Michigan State University enrolled in Biological Science for Elementary Teachers, winter term 1973, were subjects for testing the final modules. To begin the study, all subjects received a general skills test designed to determine general knowledge concerning the germination of seeds, the growth requirements for plants and the establishment of an environment suitable for the survival of animals.

Students were assigned to high or low skill groups based on the general skills test results. Within each skill level the students were randomly assigned to one of two groups for order of module presentation. Order A was to complete the informative plant module the first week, followed by the investigative animal module the next week. Order B was to start with the informative animal module the first week, followed by the investigative plant module the next week. All students, therefore, completed an informative module, either plant or animal, during the first week of the study, followed by an investigative module with a different organism the next week.

The effectiveness of the modules was evaluated using a specific skills test. One part of the test covered the germination of seeds and the growth requirements for the plants used in the study. The other section sought information on specific requirements for survival of the Daphnia. Each section of the test was treated separately as a different test in analyzing the data.

Equivalent forms of the test were given as a pretest, intermediate test and posttest. The pretest was administered immediately before the informative modules. One week later the intermediate test was given just before the investigative modules. The posttest was given two weeks later when the experimentation required for the investigative modules was completed.

Limitations of the Study

A major limitation of the study was the test instrument. Although equivalent forms of the test were used, the reliability decreased with each testing. The group became more homogeneous with each treatment. As the variance decreased by two-thirds from 8.08 for the pretest, to 5.93 for the posttest, the reliability also decreased by two-thirds. Perhaps the reliability of the three forms of the test should have been established using different groups of students.

Another major limitation was the setting in which the study was conducted. Students were told that the study was a required part of the biological science course work. But because there were no additional objectives added for the weeks' work, meaning this would not be an experience required for testing, many students did not take the study seriously. There was no way to evaluate how much a mild flu epidemic and another study conducted with some of the students earlier in the term, affected the results or the number of students who failed to complete the study.

Natural maturation was another factor not controlled. Although the organisms used were purposely chosen to avoid conflict with the material being covered in the biology class, it was not possible to judge just how much the increased knowledge in biology affected the results of the study.

Potential sources of bias, difficult to eliminate by experimental control, could possibly have affected test results. This would include such things as attitudes toward living organisms and laboratory work, previous experience with laboratory equipment and problem-solving situations, and efficiency in recording and interpreting data.

Differences in laboratory skills were observed as being a major factor in the amount of time required to complete an investigative module. For example, students who did not know how to properly use the pipette wasted much time in trying to capture five Daphnia. There was no way to measure the effect of this frustration on test outcomes.

Findings

The following hypotheses were tested using a multivariate repeated-measure analysis:

Ho_1: There is no difference between the three repeated measures as determined by the MLOC tests.

This hypothesis was rejected using the combined plant and animal data, the animal data alone, and the plant data alone. The difference between the three measures is related to interaction between pretest and posttest for combined data, the grand mean for the plant data and the differences between intermediate-posttest and pretest-posttest for the animal data. This hypothesis indicates that there are differences between the three repeated measures without regard to any group related differences.

Ho_2: There is no difference between the high skill level and the low skill level as measured by the MLOC tests.

The rejection of this hypothesis, using combined data, was primarily related to the difference between the plant and animal scores. While there was no overall difference between plant and animal scores there was a difference by skill level. For the plant data, the high skill group gained more than the low skill group. The low skill group showed a greater gain for the animal modules.

A most interesting kind of relationship is noted, however, when the difference in pretest scores is taken into account:

Pretest Plant Scores		Pretest Animal Scores	
High Skill	46.1	High Skill	44.9
Low Skill	52.4	Low Skill	35.0
Difference	6.3	Difference	9.9
Total Gain, High	16.3	Total Gain, Low	29.9
Difference	6.3	Difference	9.9
	10.0		16.0
Total Gain, Low	8.2	Total Gain, High	17.8
	1.8		-1.8

Although not enough evidence is available to make a conclusion about the "1.8" factor difference, it can be stated that any pretest differences between the two skill levels were all but eliminated by the end of the study. The posttest plant scores are: High Skill 62.4, Low Skill 60.9. The posttest animal scores are: High Skill 62.7, Low Skill 60.9. Note that there is a factor difference of 1.8 points between each set of scores. This similarity in posttest scores suggests that there might be a ceiling effect for the class, influenced either by the test instrument or the modules being used in the study.

Ho_3: There is no difference between Order A and Order B as measured by the MLOC tests.

Interaction between intermediate and posttests appears to be the basis for rejection of this hypothesis using combined data. A look at Table 10, Plant Data, shows that the gain scores for Order A (11.6) and Order B (13.2) are not significantly different. Therefore, the hypothesis was not rejected for the plant data.

For the animal data, the overall gain for Order A, plant module first, is higher. This gain is directly related to the differences in gain scores after the animal was studied for each order. When the animal module was studied first (Order B), the gain score was 13.9. When the plant module was studied first (Order A), followed by the animal module, the gain score was 21.7. This could be an indication that the informative animal module was not as effective as the investigative animal module or that exposure to the plant module first had a positive influence for the animal module.

Ho_4: There is no difference between Achievers and Non-Achievers as determined by the MLOC tests.

This hypothesis was not rejected for combined data, plant data or animal data. To relegate the failure to reject this hypothesis to a minor position might lead, however, to the false conclusion that it is not necessary for students to achieve the objectives set for a study.

An important factor is the criteria used for separating the achievers and non-achievers. The data sheet for each investigative module contained questions that required an interpretation of the data collected. The answers to these questions were used to help the investigator decide if the objectives for the modules had been achieved by the students. Those who answered these questions incorrectly or who omitted the answers were classed as non-achievers. It is highly possible, therefore, that many students were incorrectly classified if they chose not to answer the questions.

A look at the cell frequencies in Table 2 shows that 60% of the non-achievers are in the low skill group. Although this group's scores were not significantly different from other scores (achievers vs non-achievers) one might infer that this group kept poor records, had difficulty interpreting data or, because of difficulties with communication skills, failed to record responses to the questions and were erroneously classed as non-achievers.

Ho_9: There is no difference between the informative modules and the investigative modules as measured by the MLOC tests.

The informative plant module was effective for the high skill level but not for the low skill level. This module also seemed to cause a significant change in animal scores for the high skill level. The investigative plant module was more effective for the low skill level and seemed to have an affect on the animal test performance also. Since the difference between the two modules for the plant data, based on gain scores from the treatment effect, was not significant, the hypothesis was not rejected for the plant data.

The informative animal module, which was slightly effective for the low skill level, was more effective for the high skill level. An unexpected increase in the plant scores was noticed for the high skill level after the completion of the informative animal module. The investigative animal module, effective for both skill levels, was even more effective for the low skill group. There was also an unexplained increase in the plant scores for the low skill level after completion of the investigative animal module. This hypothesis was rejected, based on the gain scores from the animal data.

A difference in order of module presentation was not associated with the plant data. However, the students in the low skill level, who had the animal module first, gained less than those who had the plant module first.

Based on the evidence presented the following conclusions were reached concerning the investigative and informative modules: 1) informative modules were not as effective as the investigative modules, 2) investigative modules were more effective for the low skill level,

3) informative modules were more effective for the high skill level, and 4) the investigative animal module was more effective than the investigative plant module.

The other hypotheses tested (Ho_5-Ho_8) stated that there was no interaction between the three independent variables. The interactions can be summarized as, interactions between: skill levels and order of module presentation; skill levels and achiever status; order of module presentation and achiever status; skill levels and order of module presentation and achiever status. The interaction hypotheses were not rejected at the 0.05 level of significance.

Conclusions

One purpose of the study was to develop modules for teaching pre-service elementary teachers the skills needed for maintaining living organisms in the classroom. Eight different modules involving seven organisms were developed. Modules used in the pilot study were: The Aquarium, Daphnia and Chlamydomonas, Drosophila (Fruit Fly), Tenebrio Beetles (Mealworms), and the Terrarium with the Chameleon. Modules used for the experimental study were: Informative and Investigative Plant modules - concerned with the germination, growth and maintenance of grass, rye and clover; Informative and Investigative Animal modules - concerned with the establishment and maintenance of environmental conditions suitable for the survival of *Daphnia sp*. cultures. (Copies of modules developed are in Appendix C and Appendix F.

The success of the modules was determined by pre-test, posttest examinations, on-site inspections of the experimental setups and student questionnaire responses. The significant gain scores from pretest to posttest attested to the effectiveness of the modules. Inspections of the experimental setups and the data sheets indicated that over fifty percent of the students were successful in maintaining the organisms they started.

At the end of the posttest, questions were added to get the opinion of students concerning science in the elementary school and their opinion of the modules. They were asked which tapes they thought should be eliminated and what they disliked most about the tapes. Sixty-four percent of the students felt that both tapes (informative and investigative modules) should be retained. The length of time required to complete the tapes was the unfavorable factor about the modules chosen by forty-four percent of the students. Other choices were: extra work involved in checking setups, keeping data sheets and "other".

The second purpose of the study was to determine the relative effectiveness of informative and investigative modules in training pre-service elementary teachers to maintain organisms in the classroom. Tests results indicated that the investigative modules were more effective than the informative modules. The informative modules were more effective for the high skill level and the investigative modules were more effective for the low skill level. The animal modules, both informative and investigative, were more effective than the plant modules.

Implications for Education

Many of the unanswered questions and speculations about results obtained in this study were associated with the skill level divisions. In this study the high skill group showed the most improvement in test scores after completing the informative modules and the low skill group gained more from the investigative modules. Since there was no significant difference between the posttest scores of the high and low skill groups, it can be concluded that both groups learned from the modules, but the process of learning was different.

The low skill group that started cultures of Daphnia, watched their progress and observed environmental conditions showed a much greater gain score for treatment effect than their matched low skill group that listened to information about the Daphnia, its growth and required environmental conditions. Although the high skill group's treatment gain scores were better for the informative modules than for the investigative modules, the relationship was not equal for all modules. The treatment effect for the informative plant module was almost six times greater than the treatment effect for the investigative plant module. At the same time, the treatment effect for the informative animal module was only slightly higher than for the investigative animal module. The implication here is that when studying familiar material the high skill level can get the information just as well without the activity. However, when an unfamiliar subject, such as the Daphnia, is presented, then some of the high skill level students learn better through the activity.

A different analysis should be made to determine if in fact there is an intellectual difference between the high and low skill levels, other than general knowledge of plant and animal growth. If such a difference holds, a rationale can be established for using teaching techniques compatible with a student's intellectual development, even at the college level.

The implication from this study is that the high skill group, particularly when working with an unfamiliar subject, can work at what Bruner describes as the ikonic level or at the symbolic level.[3] The student working at the ikonic level is able to deal with mental images of objects without direct manipulation. At the symbolic

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[3]Lee S. Shulman, "Psychological Controversies in the Teaching of Science and Mathematics", The Science Teacher, 35, September 1968, p. 35

level he is able to manipulate symbols and no longer requires the mental images. On the other hand, the low skill group performs better at Bruner's enactive level. For these students, direct manipulation of materials is important to their success.

Implications for Future Research

Questions raised concerning differences in high and low skill groups in this study can best be answered by designing and testing an instrument to determine the intellectual level of operation for pre-service elementary teachers. Once the groups are better defined, then the study could be repeated to see if the same results are obtained. A better knowledge of the operational level of the students would help to sharpen the focus for future research.

A replication of this study is also needed to investigate other factors from the incomplete design that was used. One advantage of an incomplete design is that is allows one to explore certain areas of concern using a few subjects, and to look for trends that might need further investigating. The results of this study indicate that the investigative module might be more effective than the informative module.

Therefore, two of the other design models from Chapter III could be used as models for the replication of this study. Both designs require the division by skill level. In Design B subjects use only informative modules. In Design C all subjects use investigative modules. By carefully matching the students in Design B with those in Design C, it would be possible to better determine which module is more effective, since the confounding variables would be removed.

As stated in Chapter I, evaluation is one part of modular design that is often not well developed. In this study the evaluation instrument was a weak link. A performance instrument is needed that will accurately assess the ability of a student to maintain a life support system. A student might respond on a written exam that the soil around a plant should be damp to the touch. Yet his plant may be found always dry and its growth stunted. False conclusions then may result from an interpretation of his data.

A performance check could be maintained by the student also, and when a system failed a comparison of instruments by the instructor and student could quickly clear up the trouble. Once a rated performance instrument had been developed and validated it could be correlated with a pen and pencil process-type test. A process test, using pictures and posing problem situations for the organisms being studied, would serve as a double check on the understanding of relationships between environmental conditions needed for the survival of organisms, i.e., a higher temperature requires more water.

A first step at designing such an instrument is included in Appendix K. These performance sheets were used during the pilot study but, because of the time required to validate the instruments, the use was discontinued.

Another limitation of this study was differences in experience for the subjects. Entry level skills need to be established and a method designed to assess these skills. For example, in this study some students, already familiar with seeds and how they looked inside, were bored with the activity and should have been able to proceed to the next step without fear of losing information.

A junior high school science program, Exploring Your Environment, published by the American Book Company, uses the skill card approach to introduce a research problem. If the student is already familiar with this component he continues with the problem at hand. Similar skill cards should be developed for the maintenance of living organisms.

In an effort to design modules to better meet individual needs, it should be determined if some students learn better and are better able to follow instructions from a written script than from a tape recording. For this study, the time spent in completing an investigative module was a primary concern of many students. The time varied from twenty minutes to one hour. Much time was lost turning off the tape, pulling off earphones, relistening to an operation described on the tape, then repeating the tape manipulating procedure. What was to be a few grains (6-10) of yeast turned out to be a spoonful in translation from tape to operation and the Daphnia subsequently died from lack of oxygen in the small baby food jars.

One way to eliminate this loss of time and information could be to use written instructions with triple spacings between each step. This procedure was successfully tested with a few students during the pilot study.

Leonard Simons from Susquehana University presented a paper at the 1973 NARST convention in which he described the results from a study that compared the relative effectiveness of written scripts with an audio tape in teaching college biology. His results indicated that more research was needed to determine if the type of instruction was student-specific or if a combination of written script and audio tapes could be effective.[4]

A final question that should be answered is: If pre-service teachers are trained to maintain organisms will

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[4]Leonard Simons, "A Comparison of the Relative Effectiveness of Written Scripts and Audio Tapes in Teaching College Biology," (paper presented at the National Association for Research in Science Teaching, Detroit, Michigan, March 1973)

this make them more effective in teaching the life science portion of elementary school science? Indications as to the value of the training could be obtained from a micro-teaching situation. However, the true value of training teachers to maintain organisms can only be assessed through a longitudinal study in which the pre-service teacher is studied as an in-service teacher. After other modules using more organisms have been tested (see Appendix C) it would be possible to determine:

1) if the experience of handling organisms during pre-training, changes attitudes toward tolerating or using "crawly bugs" in the classroom.
2) if teacher confidence in using living organisms is related to pupil achievement.
3) if learning to manipulate the life support system for plants and animals better equips a teacher to handle environmental relationships necessary to create a desirable learning environment in the classroom.

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APPENDICES

APPENDIX A

RESULTS FROM SKILLS DEVELOPMENT QUESTIONNAIRE

RESULTS FROM SKILLS DEVELOPMENT QUESTIONNAIRE

Experiences and Skills in Teaching

Juanita T. Whatley

The following check list includes experiences and skills that an elementary teacher will find useful in teaching life sciences. Some of the skills might also be applicable to other subject areas.

If you are quite competent in the skill listed, check the column headed skilled. If your experience is limited and you feel you could use more training, check the column headed familiar. If you have had no encounter with the skill check the column headed unfamiliar. (A - Skilled; B- Familiar; C - Unfamiliar) Results are percentages; average number of responses 77.

		A	B	C
1.	Design and conduct a controlled experiment.	43	54	3
2.	Identify variables in an experiment.	43	50	7
3.	Construct a histogram.	13	17	70
4.	Average raw data from an experiment.	42	50	8
5.	Make a line graph.	73	26	1
6.	Read and interpret data from a graph.	70	27	3
7.	Determine optimum range from a data chart.	44	44	12
8.	Conduct inquiry type discussions.	36	54	10
9.	Use divergent and convergent questions.	16	61	23
10.	Recognize and interpret non-verbal responses.	23	67	10
11.	Design a scientific model to explain a common occurrence.	17	62	21

Experiences in Teaching	A	B	C
12. Distinguish between an inference and an observation.	44	48	8
13. Operate a compound microscope.	73	26	1
14. Determine the magnification of object viewed with a compound microscope.	73	19	8
15. Operate a dissecting microscope.	49	36	15
16. Prepare a wet mount of liquid or solid materials to view with a microscope.	77	23	0
17. Use identification keys such as Master Tree Finder.	71	26	3
18. Use indicators for the following tests:			
a. Presence of acid/base	31	60	9
b. Acid/base concentration	24	63	13
c. Carbon dioxide	20	68	12
d. Oxygen	22	64	14
19. Build a simple incubator	10	45	45
20. Collect soil animals using a Berlese funnel.	12	8	80
21. Use a triple beam balance.	19	18	63
22. Use a metric ruler.	39	47	14
23. Use a manometer to measure gas exchange.	3	31	66
24. Plan and conduct a twenty minute ecological field trip.	39	47	14
25. Collect and preserve water or soil specimen.	31	43	26
26. Determine the number of organisms in a large population without counting each one.	10	52	38
27. Prepare damp chamber for growing fungi.	15	38	47

Experiences in Teaching	A	B	C
28. Incubate eggs.	17	49	34
29. Germinate seeds.	52	47	1
30. Maintain plants indoors.	71	28	1
31. Establish and maintain a balanced aquarium.	43	49	8
32. Distinguish between male and female guppies.	13	26	61
33. Hatch frog eggs.	9	30	61
34. Maintain crayfish.	5	38	57
35. Care for warm blooded animals such as gerbils.	49	34	17
36. Establish and maintain a terrarium.	42	45	13
37. Prepare a hay infusion.	3	10	87
38. Use a hay infusion to illustrate succession.	3	14	83
39. Establish and maintain cultures of the following:			
a. Daphnia.	10	36	54
b. Drosphila. (fruit flies).	34	49	17
c. Frogs	24	46	30
d. Mealworms (beetles)	32	51	17
e. Crickets	23	44	33
f. Land snails	17	35	48
g. Isopods	1	20	79
h. Chameleons	19	43	38

APPENDIX B

USING LIVING ORGANISMS IN ELEMENTARY SCIENCE ARTICLES IN SCIENCE & CHILDREN

USING LIVING ORGANISMS IN ELEMENTARY SCIENCE ARTICLES IN SCIENCE & CHILDREN

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Long, Paul F., "Sink Full of Salamanders" 9(2), Oct. 1972, 14-15

APPENDIX C

PILOT STUDY: LIFE SCIENCE MODULES FOR ELEMENTARY PRE-SERVICE TEACHERS

PILOT STUDY: LIFE SCIENCE MODULES FOR ELEMENTARY PRE-SERVICE TEACHERS

The life science modules are designed to teach the skills needed to create a suitable environment for a living organism.

Each module is in four parts. You will complete parts one and two today.

1. A pretest. The pretest is to determine your present skill level. An answer sheet is attached to the test. Be sure to put your name and the name of the module you are doing on the answer sheet. Do not guess on the test. If you do not know an answer leave it blank. If you do not know anything about the organism you have chosen to study leave the answer sheet blank but make sure your name is one the sheet. Return the answer sheet and test when you have finished the test to your instructor. Complete the pretest first.

2. Setting up a culture. The instructions for starting each culture are provided. Follow the step by step instructions carefully. The materials for each culture have been placed together in a package arrangement. The living organisms have been placed in common stocks in the room for you to get as you need them. The animals for the terrarium will not be needed immediately. They will be in class at your next meeting. If you wish to use a chameleon you must purchase your own at a local pet store. You are to keep all the materials in your package until you return your culture in two or three weeks.

3. Observations. You are required to observe your cultures every 2-3 days and record your observations for a two-three week period depending on the progress of the organisms.

4. A posttest. A posttest will be given when you return the culture you prepared, all the materials used, and your observation sheet to this room at the end of the two-three weeks. This test is to determine if the module helped to improve your skills in maintaining a living organism. You will also be asked to comment on the effectiveness of the module as a training device.

The Fresh Water Aquarium

Objectives: Upon completion of the module the student should be able to:

1. assemble the correct materials to establish an aquarium.
2. prepare this material for use in an aquarium.
3. distinguish between a male and female guppy.
4. complete the assemblage of an aquarium.
5. recognize and be able to correct atypical conditions in the aquarium.

Materials needed: (for each student)

1 1-gallon aquarium
2 cups white sand (bagged)
2 plastic tumblers
paper towel
guppy food
label
Picture of water plants
Picture of male and female guppy
Summary Sheet
Data Sheet

Materials needed: (for the class)

Stock cultures:

Anacharis

Eel grass
pond snails
guppies

3 dip nets

Establishing an Aquarium

A small freshwater aquarium is one of the simplest habitats to establish. For that reason the aquarium is one of the earliest activities in many elementary science classes.

Check your kit to make sure you have all the materials you need before you begin. Your kit should include a 1-gallon aquarium, 2 cups of sand, 2 plastic tumblers, and paper towels. You will be directed to get the other materials you need from the stock table as you need them.

Aged water has been prepared by allowing tap water to set for 48 hours. The chlorine, which is harmful to fish, escaped. A supply should be kept on hand in your classroom and used to re-fill the aquarium as water evaporates.

First, you will clean the aquarium. Rinse it well in warm water. Do not use soap as it is most difficult to wash out and a soap residue may be fatal to fish. Complete this step now.

Put two cups of sand in the clean aquarium. Rinse the sand well in tap water to remove loose dust. Stir the sand under a stream of running water until the water is clear after it has set for a few minutes. Complete this step now at the sink.

Place a paper towel over the surface of the sand. This will keep the sand from being disturbed as you pour in the water. Fill the tank about three quarters full with aged water then remove the towel. Complete this step at the stock table.

Look at the pictures of the plants on the attached sheet. Study them so that you can recognize the plants. These are not the only kind of plants you can have in an aquarium but they are rather hardy and will help provide a natural environment for the fish. The Anacharis, commonly called Elodea is the tall plant with small leaves that appear to be wrapped around the stem. The eel grass looks much like grass while the small floating plant which propogates well and is sometimes eaten by snails is duckweed.

You are now ready to add your organisms to the aquarium. You will need from the stock table a snail, two sprigs each of Elodea and eel grass and 5-10 duckweed plants. Use the tumbler to get the organisms. Complete this step now.

Anchor the eel grass in the sand. The Anacharis can be anchored or allowed to float with the duckweed on the surface of the water. Drop in the snail. The snail will serve as a scavenger and help keep the bottom clean.

Study the pictures of the male and female guppies. The attached pictures are common guppies, not the fancy type. The female is usually a rather plain silver, greenish gray color. She will be larger than the male and the fin on the bottom near the tail, called the anal fin, will be fan shaped. The male is usually more colorful with orange or blue spots. The tail is rather large and sometimes has a long pointed end; the anal fin is thickened and more pointed than the female's. Young males may lack color so examine the anal fin carefully. Even the fancy male and female guppies can be distinguished by the differences in color, the male being the more colorful, and the thickened, pointed anal fin of the male. At the stock table you will use the dip net to transfer the fish to a tumbler. You should get at least one male and female. Go and get the fish now in your tumbler.

Transfer the guppies to the aquarium by gently lowering the tumbler into the water, then, turn it to let the fish swim out.

Get a label from the stock table to put on the tank. Record the data and your name. Plan to keep the aquarium where it can receive enough light for the plants to grow. Do not place it in direct sunlight or near a heat source where the temperature will vary greatly. A cover will prevent loss of water by evaporation. Give the fish a small amount of food at least every other day. Feed them only what they can consume in five minutes.

How you maintain the aquarium will depend on how you plan to use it in the classroom. Refer to your Teacher's Guide if you are using SCIS materials. Assume, however, that this aquarium is to illustrate a balanced situation representing the optimum conditions for growth. Then, let us examine some atypical conditions you want to avoid.

If the tank becomes cloudy or foul with excessive waste on the bottom you should clean the tank. Remove the fish, snail and plants to a container of aged water. Wash the sand again and set up the tank as you did before. The cloudiness can be caused by giving the fish too much food. What they do not eat settles to the bottom, begins to decay and clouds the water. Dead and decaying fish or plants not consumed by the snail can also foul the water. Use a baster to remove excess waste from the surface of the sand before the water gets cloudy.

If the tank becomes green when you want it to remain clear your light source is too strong. (The green color is a microscopic green alga, Chlamydomonas, which is used in some studies with the aquarium.) For the small one gallon tank it is probably best to change the water, wash the sand well and find another spot with less light. It might be possible to simply cover one side of the aquarium with an opaque sheet of paper to block the light. If you use a larger aquarium, you may wish to purchase an algae-eater from the pet store. Students will be interested in seeing it feed.

A fine, hair-like, filamentous green algae growth may also develop. This can be a nuisance and should be removed if the growth becomes too thick. It can sometimes be controlled by reducing the amount of light. It is usually not harmful but it might cause an odor in a small aquarium.

If the sides of your tank become brown with some kind of growth, the light source might be too weak. It is best to clean the tank as recommended previously and find a better light source.

The fish should be inspected periodically for fungus growth. If a white cotton-like patch of growth appears on the tail or trunk of a fish remove it immediately to another container of aged water. Go to a local pet store and buy a fungicide for freshwater fish. Put it in with the infected fish and also in the main tank. Follow the directions on the box. Do not put the infected fish back in with the others until all signs of infection have disappeared.

Observe your aquarium for the next two weeks. Correct any conditions you think threaten the survival of your organisms, both plant and animal. If a fish, plant or snail should die see if you account for the cause of death. Keep a careful record of all your observations and corrective actions done to maintain a balanced condition. Date each observation. Return the aquarium and your observation sheet to this room at the end of two weeks. If you wish to keep the aquarium longer check with your instructor.

Summary

The small aquarium can be maintained for a long period of time without any difficulty if these simple rules are followed:

a. Keep the water level constant by adding aged water.

b. Feed the fish only what can be consumed in 5 minutes.

c. Keep the tank from direct sunlight and excess heat.

d. Keep the temperature between 70° - 80° F.

e. Remove dead plants and animals not consumed by the snail in one or two days.

f. Change the water and clean the aquarium if the water becomes cloudy.

g. Correct atypical conditions when they are first noticed.

Observation Guide For Aquarium

Date of Observation	Water	Plants	Animals	Other Comments
1.				
2.				
3.				
4.				
5. Termination				

Directions for chart:

condition of water: clear, cloudy, green, other.
condition of plants: good, fair, dead or dying.
condition of animals: healthy, number dead.
other comments: list any other changes or observations.

Questions:

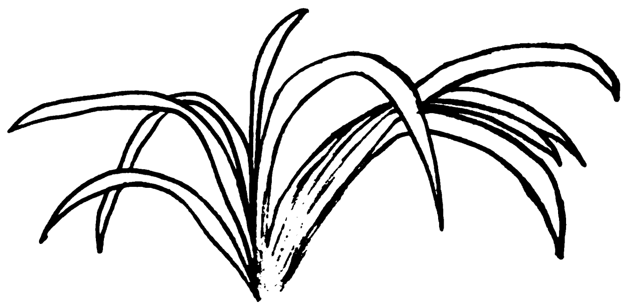
Have you ever maintained a small aquarium before?

How often did you feed the fish?

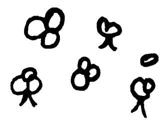
Account for the environmental conditions (light, temp., etc.) that contributed to the success or failure of your aquarium.

Aquarium Organisms

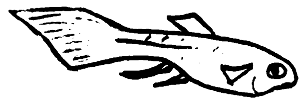
Anacharis



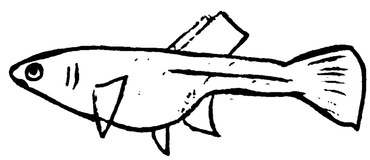
eel grass



Duckweed



Male guppy



Female guppy

Establishing a Terrarium

Objectives: Upon completion of this module the student should be able to:

1. Choose the correct container for a terrarium.
2. Select the proper materials, biotic and abiotic, to include in a woodland type terrarium.
3. Establish an environment suitable for the maintenance of terrarium organisms.
4. Recognize and be able to correct atypical conditions.

Materials for each student:

- 1 2-gallon terrarium/cover
- 5 cups soil
- seeds:
  - 5-10 peas
  - 5-10 beans
  - 20-40 clover
  - 20-40 grass
  - 20-40 mustard
- water sprinkler
- thermometer
- lables
- 3 snails
- 3 crickets
- 6 isopods
- 6 beetles
- 1 chameleon
- 1 petri dish top or bottom (for dry spots)

Establishing a Terrarium

In this module you will establish a woodland type terrarium. This type is suitable for maintaining animals normally found in grassy or forest areas. The terrarium will be set up in two stages. First, the seeds will be planted and the plants allowed to grow. Then the animals will be added when the plants are large enough to support the animal population. Keep in mind that this is not the only way to start a terrarium but this particular type is best if you are going to do population studies with your class.

Check the materials in your kit to make sure you have everything you need. You should have: a 2-gallon terrarium, about 5 cups of soil, packages of pea, bean, clover, mustard and grass seeds, a water sprinkler, a thermometer, and labels. The animals you will need later will be on the stock table.

Put about 1" - 1 1/2" soil in the terrarium. Put the soil in loosely, do not pack it in place. A gallon jar or a clear plastic shoe box would make good containers for terraria. We will use the standard terrarium used by many schools for turtles.

Make 5-10 holes about one-half inch deep for the peas and beans. Drop one seed in each hole and cover them with soil.

Sprinkle about 20-40 each of clover, mustard and grass seeds throughout the terrarium. Cover them lightly with a thin layer of soil.

Sprinkle the soil with water using the water sprinkler. Do not oversoak the soil as mold might result. Put the terrarium cover in place.

The terrarium should be put in a warm preferably dark place for two or three days until the plants start to sprout. Be sure to keep the soil damp to the touch. Check about every two days.

When the plants in the terrarium begin to sprout, the terrarium should be moved to a source of light. Use an artificial source of light if the natural light is poor. Fluorescent lights are best to use but a 100-watt incandescent bulb can be used if it is turned off at night. The regular light bulb gives off heat that often dries out the terrarium.

At this point you should decide whether you want to add a chameleon or the other smaller organisms.

If you choose to study the chameleon refer to the instruction sheets for the chameleon when your plants in the terrarium are about an inch high.

If you choose to study the small animals on the stock table follow the instructions below after the plants are an inch high.

You should add 2-3 crickets, 2-3 snails, 4-6 beetles and 4-6 isopods.

You may wish to look for other organisms in the woods to see if they can survive in your terrarium. Look under stones, old logs, tree limbs and in the forest litter for other animals such as salamanders or frogs.

The crickets in the terrarium need a dry spot to perch. Find a rock to add or make a platform from an old jar top or a petri dish cover or bottom. Elevate the jar top or petri dish cover above the plants.

Observe the terrarium with the animals for 7-10 days. If you wish to maintain it for more than two weeks you might need to add new plants. You may gather moss, fern or small seedlings from the forest or plant more seeds.

I have not mentioned food for the animals. See if you can determine why from the observations you make.

Keep a careful record of changes that occur in the terrarium in both the plant and animal population. Record any additions you make. Date each observation. Be sure to keep the soil damp to the touch and that the plants receive enough light. Return the terrarium set up along with your observation sheet in two or three weeks to this room.

The Chameleon

Now that the plants are growing well in your terrarium you are ready to add the chameleon.

On the stock table you will find a petri dish bottom. Place the petri dish in the terrarium pressing a few plants aside to make it level. Food for the chameleon will be put in this dish.

Add a twig or a potted plant so the chameleon will have a place to perch. If you decide to keep the terrarium for an extended length of time you should add moss, fern or other woodland plants more suitable than the peas and beans. Bark and rocks may be added to give the chameleon a hiding place.

Make sure everything is in place, then gently place the chameleon in your terrarium. Secure the cover in place with the tape or you might find your pet missing.

A chameleon will eat insects such as houseflies, fruit flies, small grasshoppers, crickets, and mealworms. He may even be enticed to eat a piece of raw meat if it is jiggled in front of him. Mealworms are available in the classroom for you to use. You may try some of the other foods if they are in season! Put two or three mealworms in the petri dish. They may stay there long enough to attract the chameleon. As time goes on you may be able to get your chameleon to take the mealworm from your hand.

The chameleon should be fed about every two or three days. He might go as long as two weeks without food. Do not be concerned if he is still active and seems content. If, however, he appears sluggish and will not respond to attention then you should force feed him a mealworm. To do this hold the chameleon at the neck where the hinge of the mouth is located. Force the mouth open with an instrument like a blunt case knife. Put in the mealworm using a pair of tweezers to hold it in place. Get a friend to help you the first time.

Water is much more critical to the survival of the chameleon than food. Sprinkle the plants with water to simulate dew each day. You may also sprinkle the chameleon but he will rarely drink from a dish. You might try putting water in the petri dish to see how he responds. He might just splash around in it.

Chameleons are subtropical animals and prefer warm temperatures. Maintain temperature of 75° - 80° F. Use a light on the terrarium and leave it on all the time if the room temperature is not high enough or if it is likely to get below 65° F at night. At low temperatures the chameleon will be very sluggish and will refuse to eat.

You should keep a record of all observations made of your terrarium. Record feeding habits and any unusual or interesting behavior of your organisms. Date each observation. Return the terrarium and observation sheet to this room in 2-3 weeks. Let us review the factors critical to the survival of the chameleon:

a. Keep the environment warm, 75° - 80° F.
b. Give a generous supply of water.
c. Vary the diet of insects.
d. Supply foliage or twigs for climbing comfort.

Culturing Drosophila (Fruit Flies)

Objectives: Upon completion of this module a student will be able to:

1. choose the correct media for fruit flies.
2. maintain the correct environment for the growth of fruit flies.
3. perform a simple transfer of fruit flies from one culture to another.
4. distinguish between male and female fruit flies.
5. recognize the stages in the development of fruit flies.

Materials: (For each student)

Drosophila media
14 dram vial/cap and fruit fly media
squirt bottle with water
tape, absorbent
dry baker's yeast
2 magnifiers
fruit fly culture
1 label
1 wood stirrer

Culturing Drosophila (Fruit Fly)

Drosophila or fruit fly cultures can be started by putting a piece of banana in a jar and leaving it exposed for a few days during spring or summer. Fruit flies will be attracted and will lay eggs in the soft decaying fruit.

However, since the fruit has a tendency to mold and get too mushy it is best to use another media that makes it easier to control moisture and spoilage. Instant Drosophila Media can be purchased from a biological supply house or you may use an instant mashed potato mix. Both will have a mold inhibitor.

Since most elementary teachers will purchase fruit flies and use them to study life cycles or populations we will go through the simplest procedures for handling fruit flies.

Your assignment is to start a new culture and observe each stage of the life cycle.

You have in your kit a vial with fruit fly media. Remove the cap and sprinkle a few (10-20) grains of dry yeast on the surface of the media. Use the squirt bottle to add water to the media. Add the water slowly, allowing time in between squirts for the water to soak into the media. Continue adding water until the media is about the consistency of thick mashed potatoes. If necessary use the stirrer to mix the media.

Place the cap on the vial. To test the media turn the vial upside down and tap gently. If part of the media falls it is too dry, if it starts to flow en masse down the sides of the vial the media is too wet. Add more water if too dry or a few flakes of media if too wet. Stop and test your media now.

Remove the tape from the cap of the vial you are preparing. Lightly press the tape on the side of the vial somewhere near the top. This leaves the hole in the cap open and the tape in a position to be put over the opening quickly when the transfer of flies is completed. We will refer to this as the transfer vial and the vial with the flies as the culture vial.

The next steps involve the transfer of flies from one vial to the other and must be done quickly to avoid the escape of flies. Read the complete instructions for the transfer then go back and do each step.

Take the culture vial of fruit flies in your left hand. Tap the top of the vial with a finger of your right hand to force the flies toward the bottom of the vial. Remove the tape from the cap of the culture vial and place it on the side of the vial near the top. Place your thumb over the opening.

Hold the transfer vial upside down with your right hand. Now quickly remove your thumb from the culture vial and replace it with the transfer vial being sure to match the holes in the caps.

Hold the vials together with the thumb and forefinger of your left hand. Wrap the other fingers and the other hand around the culture vial to put the flies in the dark. They will be attracted to the light in the transfer vial. It may be necessary to tap the bottom of the culture vial on the table to force out flies.

After 5-10 flies have entered the transfer vial put the two vials on the table still in piggy back position. Remove the tape from the side of the vials. Tap the vials to force flies near the bottoms toward the media. Quickly separate the vials leaving the transfer vial upside down while you put the tape over the openings in each cap.

The transfer is now complete.

In order to study the life cycle of the fruit flies you must be sure that you have at least one male in the new culture. Use the magnifying glass to help you examine the culture.

Study the pictures of the male and female Drosphila. Some of the more obvious characteristics you can pick out using the magnifier. For a more detailed study you will have to etherize the flies and study them using a steroscopic disecting microscope. We will not go into that procedure in this lesson.

Compare the size of the flies. The female is larger overall and will have a larger abdomen. The male has only two dark bands on its abdomen while there may be as many as four on the female. The abdomen of the male is blunt and has a large, dark, pigmented area on the end. The female has a pointed abdomen and does not have as much black on the end. Examine your culture carefully.

If you find a male in the vial, your culture is satisfactory. If no male is present make another transfer. Put the data and your initials or identifying mark on the tape and place the vial away from bright light. The culture will develop at room temperature, 70° to 77°F.

Use the culture vial to complete your study of the life cycle. If you combine two hand lenses you may be able to see the eggs. They appear as specks on the side of the vial. Two filaments are on one end. Use the pictures to help you identify the stages.

The larvae can be seen crawling around on the surface of the media or down in the media. The black mouth-parts can be seen moving in the media. Larvae should be found in your culture in 2-4 days after the transfer.

The mature larvae will climb up on the sides of the vials to pupate. The larval covering forms the case of the pupa. The pupal case is a hard shiny light brown color. It becomes darker and harder as the larvae changes shape. Empty pupal cases can be seen after adults emerge. Examine each of these stages. The complete cycle takes from 10-15 days depending primarily on the temperature.

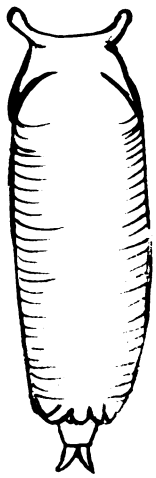
Observe your culture every 2-3 days. Keep a careful record of your observations. Be sure to date each observation. At the end of two weeks return the cultures and your observation sheet to this room.

Can you answer these questions?

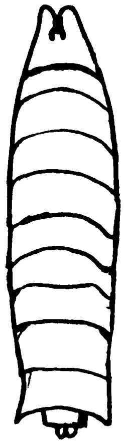
a. What is suitable media for <u>Drosophila</u>?
b. What conditions are necessary for growth?
c. What condition do you want to avoid in the media?
d. What are the obvious differences between a male and female fruit fly?
e. Can you recognize the stages in the development of fruit flies?
f. Can you start a new culture of <u>Drosophila</u> from an old culture?

Life Cycle of the Fruit Fly

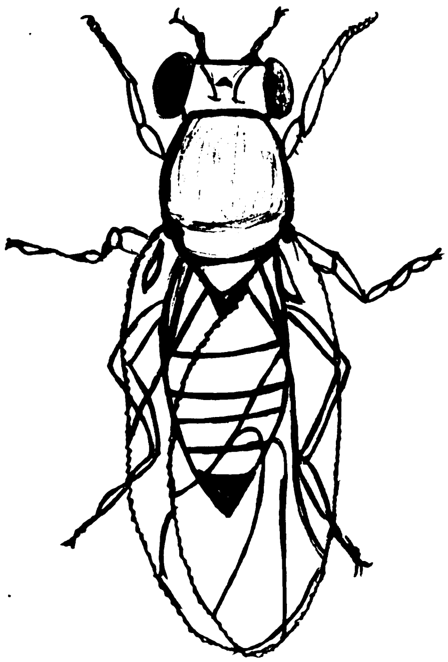
egg



Pupa

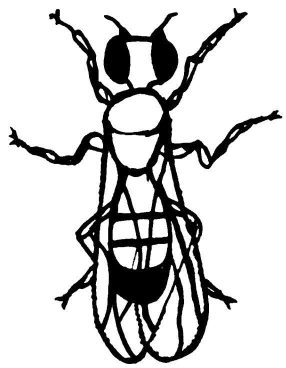


Larva

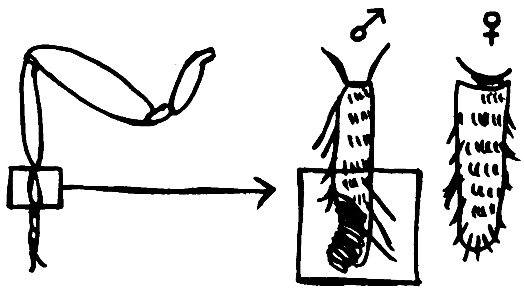


Adult Female Fly

Sex Characteristics of the Fruit Fly

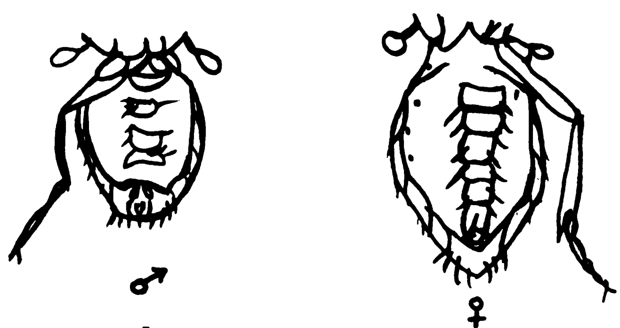


Adult Male



Male left foreleg

Enlargement of sex comb



male

female

Culturing Tenebrio Beetles (Mealworms)

Objectives: Upon completion of this module students will be able to:

1. recognize the stages in the development of *Tenebrio*.
2. to choose the correct media for the beetle culture.
3. maintain the proper environment for the growth of *Tenebrio*.

Material: (for each student)

Plastic shoe box and cover
Bran - 1 bag - labeled
Carrot
Packing material or grade B cotton
Mealworm culture, 25 for each student
Magnifier
Petri dish bottom
1 label

Culturing Tenebrio Beetles (Mealworms)
(Tape Script)

Tenebrio is a rather common beetle raised primarily for its larvae which are used as food for many classroom animals. They are also used in life cycle studies.

The larval stage, called a mealworm, is encased in a yellow to brown shiny shell-like covering and it resembles a wireworm. The time spent in the larval stage ranges from 2-4 months depending on the temperature. When the larva is about an inch long it will pupate. The adult will emerge from the pupa some 2-3 weeks later. The female will begin to lay eggs in 7-10 days. These eggs will hatch about 14 days later. The complete life cycle may take from 4-6 months depending on the temperature of the culture. Study the pictures showing the stages in the life cycle of the mealworm.

You will use a class culture to study the stages in the life cycle. Sift through the bran in your kit and find each stage. Stop the tape and find each stage, then place these in a petri dish bottom. Examine each stage with a magnifier. Note the movement in the pupa's tail end if you tickle the abdomen. When you finish put the organisms back in the culture. Stop the tape and complete your examination.

A variety of containers can be used to house a mealworm culture if it is at least 5 inches deep. You may choose a quart or gallon jar, a gallon aquarium, an old 3 lb coffee can or a plastic shoe box. Either of these will support a culture large enough for normal classroom use.

Mealworms can be grown in uncooked wheat bran, bran flakes, oatmeal or cornmeal. Cornmeal is messy as the meal sticks to the larval stage.

To begin your culture put about 3 inches of bran in the contained in your kit. Add 20-25 larvae taken from the stock culture. You may also add a few adults to see if there is a change in the rate of reproduction. Turn off the tape and find the larvae you need.

Place a piece of carrot on the surface of the bran to provide moisture and additional food. Half an apple or potato, stale peanuts or bread may also be used. When foods are added check often for mold since the mold can be poisonous to the larvae.

Cover the culture with a layer of packing material at least 1/4 inch thick. The mealworms will find this a good "nesting" place and you will find this a good spot to collect larvae and pupae. You may also use crushed or shredded paper toweling, Grade B cotton batting, sheets of newspaper with bran between, or heavy muslin instead of packing material on top of the culture. Sprinkle the top lightly with water about once a week. You need enough water to raise the humidity slightly but not enough to cause mold. It is best to cover the container with a perforated cover to keep out intruders and to keep the adults from escaping. For our study rather than perforate the tops simply put the covers on lightly to allow air to get inside.

Your culture is now complete. Label and place it in a warm, dark place. Room temperature is satisfactory but optimum temperature for development is 85° F. Lower temperatures increase the time required for the beetle to complete its life cycle. Stop the tape and find a suitable spot for your cultures. Be sure to put your name on the label.

Add about one inch of bran each month. When the bran becomes fine and flour-like it has no more food value. However, it is best not to destroy this used bran as it will contain many eggs and small larvae. You may either sift it through a fine screen to catch the eggs or just add new bran on top of the old. A completely new culture should be started every three months.

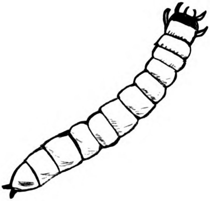
The culture requires little care. Remember the important conditions:

a. Warm temperature - optimum 85° F.
b. Moisture supplied by carrot or other foods. Sprinkle surface once a week with water.
c. Bran as main source of food.
d. Avoid mold conditions - excess moisture and temperature.
e. Leave one culture undisturbed for breeding.

Check your culture every three days. Record any changes you observe. Date each observation and give an estimate of the temperature. Return the culture and your observation sheet to this room in four-five weeks.

Life Cycle of Tenebrio Beetle (Mealworm)

Adult



Larva

Pupa

APPENDIX D

INSTRUMENTATION: GENERAL SKILLS TEST, PRETEST, INTERMEDIATE TEST, POSTTEST

General Skills Test

Maintaining Living Organisms in the Classroom

There are certain skills required in order to maintain living organisms in a classroom. These skills range from keeping the proper environment to designing experiments to correct threatening conditions in the environment. This exercise is designed to establish a skill level for you and to isolate those skills you already possess. The results will in no way affect your grade.

Directions: Mark the answer of your choice on the answer sheet. Read the questions carefully and do not guess. Leave the question unanswered if you are uncertain of the answer. Be sure to put your name and your SAS section on the answer sheet.

You may begin now. Give your test and answer sheet to the instructor when you have completed the test.

Maintaining Living Organisms in the Classroom

1. The time required for a seed to germinate is determined by:

    1) the size of the seed.
    2) the amount of moisture in the soil.
    3) the temperature of the soil and air.
    4) all of the above.

2. Which factor about a seed usually determines the depth at which it is planted?

    1) The amount of moisture required for growth.
    2) The size of the seed.
    3) The number of cotyledons.
    4) None of the above.

3. Plants maintained indoors will tend to be tall and spindly if:

    1) there is too much water added.
    2) the temperature is too high.
    3) they are kept under a fluorescent light.
    4) they do not receive enough light.

4. A seed will germinate on a wet paper towel since the main requirement for seed germination is:

    1) moisture.
    2) correct temperature.
    3) stored food.
    4) a soft seed coat.

5. A teacher keeps her plants on a window sill that receives the morning light and even though she keeps them well watered the leaves still show signs of drying. What could be the cause of the trouble?

    1) too much water.
    2) not enough light.
    3) too much light.
    4) too much heat.

6. A pet chameleon escaped from its chamber in the class. Which factor will be most critical for his survival for the first week?

   1) food
   2) water
   3) shelter
   4) all of the above

Questions 7 - 10 are based on the following situation:

A cricket and a land snail are put in a grassy, woodland terrarium. The cricket dies in a few days and mold grows on his body. A small lizard is added after the cricket died and it lives happily darting in and out from beneath a small twig.

7. What is the probable cause of the cricket's death?

   1) not enough food
   2) too much moisture
   3) the land snail
   4) the mold

8. What evidence helped you determine your answer?

   1) the presence of the snail
   2) the grass in the terrarium
   3) the time it took for the cricket to die
   4) the growth of mold on the dead cricket

9. What does this situation described suggest to you about the survival of animals in a terrarium?

   1) Not all animals can live in harmony.
   2) Survival of animals in a terrarium is largely a matter of chance.
   3) This terrarium environment is not suited for all animals.
   4) All of the above.

10. What is the purpose of the plants in the terrarium?

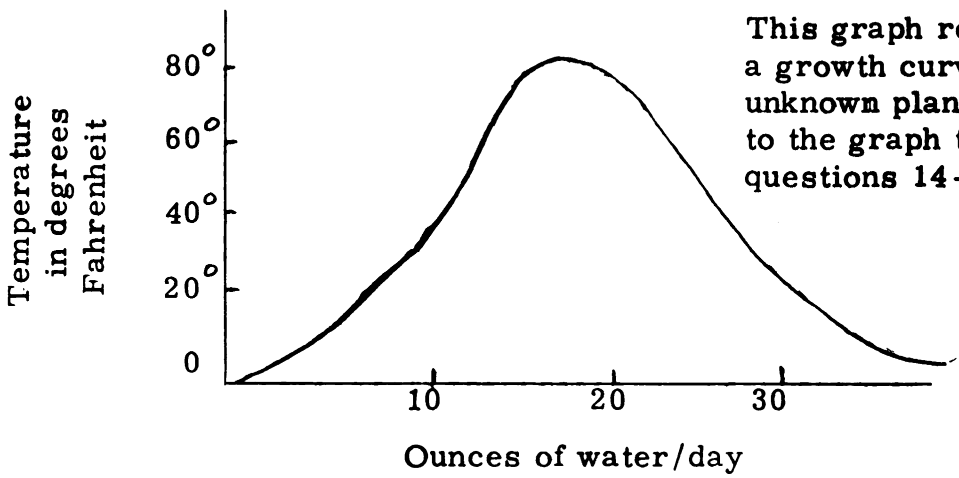
    1) provide food
    2) provide oxygen
    3) provide a natural habitat
    4) all of the above

11. What would you consider the optimum survival range for most organisms maintained in a classroom?

    1) 70° F
    2) 50° F
    3) 50° - 60° F
    4) 60° - 75° F

12. A plant that usually does well with a half cup of water added every two days requires more water when the heat is turned on in the room. What does this infer about the requirements for plant growth?

    1) Plants need water to grow.
    2) Heat makes it harder for a plant to survive.
    3) The amount of water needed is closely related to temperature.
    4) The plant requires more water as it grows taller.



This graph represents a growth curve for an unknown plant. Refer to the graph to answer questions 14-16.

13. Are you skilled in reading and interpreting graphs?

    1) yes   2) no

14. At 40° F how many ounces of water were used by the plant?

    1) 7
    2) 10
    3) 13
    4) 30

15. The optimum survival factor for this plant as indicated on the graph is:

    1) a temperature of 80^{o} F
    2) 15 ounces of water/day
    3) both 1 and 2
    4) not enough evidence

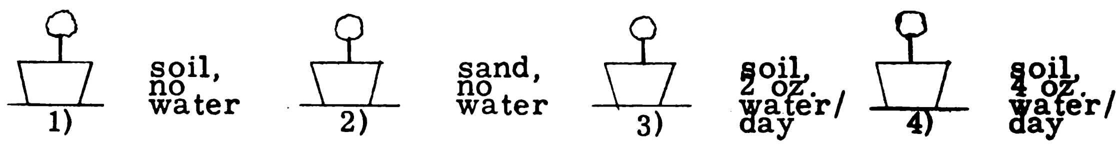
16. What information about the growth of this mystery plant does this graph convey?

    1) The plant will not grow at 20^{o} F.
    2) The plant will not grow with 30 oz. of water/day.
    3) Maximum growth of the plant is obtained at 80^{o} F.
    4) Growth of the plant depends on temperature and water.

Questions 17-22 are based on the following experiment, results and conclusions.

A class is given several geranium plants. After a few days the leaves start to turn brown around the edges. The teacher suspects the amount of water being put on the plants might be causing the change.

The following experiment is designed by the class to find the cause of the change:



These results were obtained:

1) plants 1 and 2 died.
2) plant 3 developed brown around the edge of the leaves.
3) plant 4 was the same as plant 3.

These conclusions were reached by the class:

1) The 4 ounces of water is better than the 2 ounces.
2) The plants need water to survive.
3) More than 4 oz. of water is probably needed by the plant.

17. Which pot represents the control?

18. Which pot is not a necessary part of the experiment?

19. What is (are) the variable(s) in the experiment?

    1) sand
    2) soil
    3) water
    4) all of the above

20. Which conclusion is not correct based on the evidence given?

21. Which conclusion is based on result number 1?

22. Which conclusion is based on result number 3?

PRETEST

Maintaining Living Organisms in the Classroom

Directions: This pretest is designed to determine your command of information concerning the raising of plants, Daphnia, and a green algae. Choose the answer that best completes each statement or answers the question asked.

Mark your answer on the answer sheet with a scoring pencil or a soft lead pencil. Be sure to put your name and SAS section number on the answer sheet. Before you start the tape return the test and answer sheet to the desk attendant.

1. Which of the following methods is feasible to use in preparing a seed for germination?

   1) Soak the seed overnight in water.
   2) Remove the seed coat.
   3) Heat the seed slowly in a warm oven.
   4) All of the above.

2. If you were directed to plant pea or bean seeds, how deep would you plant them?

   1) Place them on the surface of damp soil.
   2) Barely cover with soil.
   3) 1/4 inch.
   4) 1/2 - 1 inch.

3. The amount of water a plant needs depends on:

   1) The kind of plant.
   2) The kind of soil.
   3) The temperature of the room.
   4) All of the above.

4. What is a good rule of thumb to follow in watering plants kept in a classroom?

   1) Add a tablespoon of water each day.
   2) Add 1/4 cup of water each day.
   3) Add water if the surface soil feels dry.
   4) Keep the plant in a tray of water.

5. Radish seeds are placed on damp blotters in two petri dishes and covered with paper towels. Dish 1 is placed in the refrigerator and Dish 2 on a lighted window sill. The seeds in Dish 1 did not germinate while those in Dish 2 did. What is the probable reason for the difference in results?

   1) Dish 1 did not receive light.
   2) Dish 1 did not receive enough heat.
   3) Both reasons 1 and 2.
   4) Not enough evidence presented.

6. A small plastic swimming pool is put on a lawn. In two weeks when the pool is moved the grass has turned yellow and appears to be dying. Which is the most reasonable explanation for the change?

   1) The grass did not receive enough light.
   2) The weight of the water in the pool crushed the grass.
   3) The plastic trapped too much heat.
   4) Too much air was taken away from the grass.

7. Two teachers, one in Kentucky and the other in Michigan, were using the same teacher's guide to help them grow plants for the classroom. All conditions seemed the same including the amount of water used and the type of soil. The plants of both were placed in a window with a northern exposure. Both teachers grew strong healthy plants until October when the Michigan teacher noticed her plants were not doing well. What would be a reasonable guess about the nature of her problem?

   1) The difference in water in the two states.
   2) The difference in temperature.
   3) The difference in exposure.
   4) Not enough evidence given.

8. If corn, wheat, radish and bean seeds were planted at the same time under the same conditions, which would you expect to germinate first?

   1) corn
   2) wheat
   3) radish
   4) bean

9. For most of the common garden variety of seeds which factor would you consider the least important for germination?

   1) water
   2) light
   3) warm temperature
   4) all factors are important

10. A plant that is left in the dark after it germinates:

    1) will not grow at all.
    2) will grow normally but will be colorless.
    3) will grow tall and spindly with relatively small leaves.
    4) none of the above.

11. Pond water or aged tap water is recommended for fresh water organisms since it:

    1) is not polluted.
    2) has no chlorine.
    3) contains minerals.
    4) contains no minerals.

12. Tap water is considered aged water when it is allowed to set a minimum of:

    1) 8 hours.
    2) 24-48 hours.
    3) 1 week.
    4) 10-14 days.

13. Stirring a culture of Daphnia or Algae is necessary in order to:

    1) aerate the water.
    2) aid reproduction of algae.
    3) keep food for the Daphnia suspended.
    4) either 2 or 3.

14. Daphnia cannot be kept in the dark since:

    1) they require light to feed and reproduce.
    2) the algae they eat needs the light.
    3) light is needed to maintain a constant temperature.
    4) no correct answer is given.

15. A culture of Daphnia may be kept in:

    1) fresh tap water
    2) deoxygenated water
    3) salt water
    4) pond or aged tap water

16. The diet of the Daphnia includes:

    1) green algae
    2) bacteria
    3) both green algae and bacteria
    4) small fish

17. The best temperature range for a Daphnia culture is:

    1) 70° F
    2) 50° - 60° F
    3) 65° - 70° F
    4) 75° - 79° F

18. The green algae, Chlamydomonas, commonly called green water:

    1) grows best in salt water.
    2) can be found in ponds.
    3) both 2 and 1.
    4) feeds on fish.

19. Daphnia and Chlamydomonas survive best in:

    1) separate containers.
    2) full sunlight.
    3) subdued light.
    4) no light.

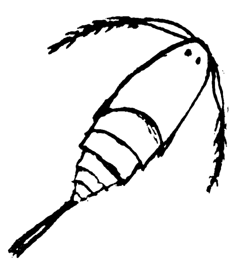
20. Chlamydomonas survive best at:

1) 50° F
2) 60° F
3) 70° F
4) 80° F

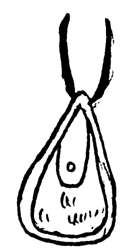
21. If optimum factors of temperature, light and heat are maintained and a culture of Chlamydomonas still fails, a probable cause of the failure is:

1) low mineral supply.
2) too much oxygen.
3) a stray fish in the container.
4) any of the above.

22. Which of the organisms pictured below is a Daphnia?


1.


2.


3.

23. How deep would you plant clover or grass seeds?

1) lay on the surface of damp soil.
2) barely cover with soil.
3) 1/4 inch.
4) 1/2 - 1 inch.

INTERMEDIATE TEST

Maintaining Living Organisms in the Classroom

Directions: Mark your answer on the answer sheet with a scoring pencil or a soft lead pencil. Be sure to put your name and SAS section number on the answer sheet. Before you start the tape return the test and answer sheet to the desk attendant.

1. A teacher purchased a jar of Daphnia from a pet store. They were put in a container of tap water that had been allowed to set for eight hours. Within a few hours the Daphnia were all dead. What was the probable cause of death?

   1) lack of oxygen
   2) lack of food
   3) the chlorine in the water
   4) not enough evidence

Questions 2-7 refer to the following situation:

A group of students experimenting with growth requirements for Daphnia planned the following set ups:

Group I - Kept in the light, kept warm, changed water every other day.
Group II - Same as Group I but added yeast every other day.
Group III - Kept in the dark, kept warm, added green algae every other day.

2. Which group probably would have the least success in keeping their culture going.

   1) Group I
   2) Group II
   3) Group III
   4) all groups should be successful

3. The "warm" temperature for each group should be:

   1) 60° F
   2) 70° F
   3) 65° - 70° F
   4) 75° - 79° F

4. Which group(s) provided food for the Daphnia?

   1) Group I
   2) Group I and II
   3) Group II and III
   4) all groups provided food

5. If the culture for Group III did not survive the probable cause of failure could be:

   1) no light was provided
   2) the culture was too warm
   3) the algae was disagreeable
   4) not enough evidence given

6. The food supply in these experiments was:

   1) no food was provided
   2) dissolved minerals, yeast, algae
   3) yeast, algae
   4) algae

7. The green algae was added to the cultures in Group III because:

   1) no minerals would be present to help the algae grow
   2) no light was provided for the algae
   3) the algae requires cold water to grow
   4) not enough evidence given

8. A Daphnia can be recognized by its:

   1) transparent, segmented body
   2) the ventral brood pouch of eggs
   3) peculiar oval shape and jerky movement
   4) none of the above

9. Which of the following is essential for algae growth but not Daphnia growth?

   1) warm water
   2) subdued light
   3) food supply
   4) oxygen

10. If Daphnia and the green algae, Chlamydomonas, are to be in the same container which temperature range would satisfy them both?

   1) 75°- 79° F
   2) 72° - 74° F
   3) 70° F
   4) 65° - 70° F

For questions 11-13 select your answer from the choices below:

1) radish 2) bean 3) sunflower 4) pumpkin

11. Which seed would you plant just beneath the surface of the soil?

12. Which seed would probably germinate first if all were planted at the same time?

13. Which seed would you plant deeper, the pumpkin or sunflower?

14. Which condition is necessary for plant growth but not essential for germination?

   1) water
   2) light
   3) air
   4) warm temperature

15. A first grade student anxious to grow his first plant kept the seeds inundated with water. What essential element was being denied the seed?

   1) water
   2) light
   3) air
   4) warm temperature

16. A small aquarium is being kept on the teacher's desk. The students notice that some of the leaves on the plants are turning brown and although the plants are growing faster, the new leaves are not as large as before. What might be the reason for changes in the plants?

    1) the plant is not suited for water
    2) the aquarium water is too warm
    3) the fish are eating the plants
    4) the aquarium is not getting enough light

17. Bean seeds are often soaked before they are planted. Of what value is the soaking?

    1) it softens the seed coat
    2) it softens the cotyledons
    3) it helps to decrease germination time
    4) all of the above

18. Clover and squash seeds are planted in the same flower pot. The clover seeds germinate and grow nicely while all the squash molds. What is a probable cause for this failure?

    1) clover requires less water and time to germinate
    2) the squash seeds were already infected with mold
    3) clover seeds are less susceptible to mold
    4) all of the above are reasonable

19. Two flats are planted with grass. Flat A is kept in the dark while Flat B is kept in the light. Which statement below is not a reasonable hypothesis about the plants based on requirements for seed growth and germination.

    1) Flat A will have tall grass
    2) Flat B will have more grass to germinate
    3) the grass in Flat A will be colorless
    4) the grass in Flat B will be green

20. A plant that is given the right amount of light and water might still grow smaller than normal if:

    1) the water used is too warm
    2) it is the wrong season for it to grow
    3) the soil is lacking minerals
    4) the plant is turned daily

POSTTEST

Maintaining Living Organism in the Classroom

Directions: Mark your answer on the answer sheet with a scoring pencil or a soft lead pencil. Be sure to put your name and SAS section on the answer sheet.

For questions 1-3 refer to these seeds:

1. lima bean   2. corn   3. marigold

1. Which seed would you plant closest to the surface of the soil?

2. The seed coat of the lima bean and the corn are relatively thin and the cotyledon(s) of both are relatively dry. What might be a reason for the corn germinating before the bean if they both are in the same planter?

   1) corn requires less light for germination.
   2) corn requires less heat.
   3) corn is smaller than the lima bean.
   4) no correct answer given.

3. Which seed would probably germinate first?

****

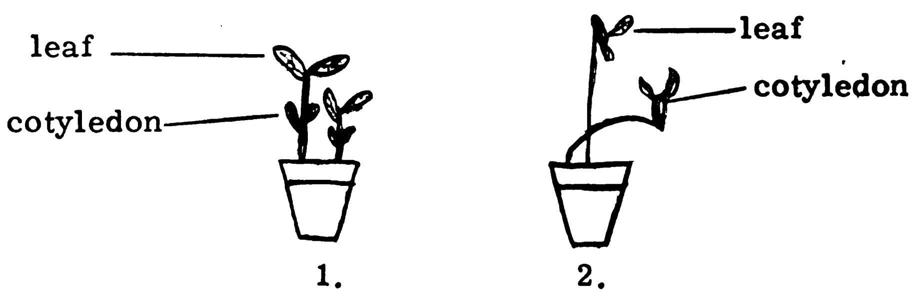
4. Grass and marigolds are planted in damp soil and placed on a window ledge where the temperature ranges from 65° to 70° F. If, after seven days the seeds have not germinated, what might be the reason?

   1) water is not provided.
   2) there is too much light in the window.
   3) the temperature is not high enough.
   4) all of the above.

5. A teacher preparing for a lesson on germination gives her second grade students the following instructions: Place a paper towel in the bottom of an aluminum pie pan. Put three bean, pea and corn seeds one inch apart. Cover the seeds with another paper towel. Stack the pans in groups of three and place them in the box at the front of the room. None of the seeds germinated. What did the teacher overlook?

    1) Seeds will not germinate in aluminum.
    2) No air could get to the seeds.
    3) The light could not get in the box.
    4) No moisture was provided.

Refer to the picture to answer questions 6-8.



6. Which plant probably grew in the dark?

7. What evidence best supports your decision?

    1) height of plant.
    2) color of plant.
    3) size of leaves.
    4) all of the above.

8. Which plant probably has greener leaves?

****

A group of students in your third grade class want to grow a variety of garden seeds just to see how the plants look as they grow. From 9-11 choose a container, the growing material and the best light.

9. Choose a container.

    1) a cut down cardboard box.
    2) a plastic egg carton.
    3) a cut down plastic milk container.

10. What would be the best growing material?

    1) sand.
    2) garden soil.
    3) vermiculite (packing material).

11. Where would be the best place to put the plants.

    1) in a window that gets bright sun all day.
    2) under an incandescent light source.
    3) in a window with sun in the morning.

****

In late spring your class collected some small fresh water animals from a pond and wish to keep them alive. The pond was semi-shaded, the water slightly green and contained large healthy Daphnia along with the other animals. Answer questions 12-16 about the pond?

12. A source of food in the pond for some of the animals is probably

    1) bacteria.
    2) algae.
    3) yeast.
    4) either 1 or 2.

13. The temperature range of the water is probably

    1) 70° F.
    2) 50° to 70° F.
    3) 60° F.
    4) 65° to 75° F.

14. The Daphnia would be larger than the other animals since

    1) they prefer the semi-shaded pond.
    2) they eat the smaller animals.
    3) they are better scavengers.
    4) no correct answer given.

15. If all the animals collected from the pond lived would you need to add minerals to keep the water green?

    1) yes.
    2) no.

16. The animals pictured below are found in pond water. Which is a Daphnia?

1. 2. 3.

****

17. In what way is aged tap water like pond water?

1) it is polluted.
2) it has no chlorine.
3) it contains minerals.
4) all of the above.

18. Daphnia maintained in a small container with yeast might have a low survival rate if:

1) the container is too small.
2) the oxygen supply is low.
3) the temperature is 75° F.
4) the above factors are combined.

19. When green algae in a Daphnia culture settles to the bottom but the water remains green, this probably means that:

1) the Daphnia are not feeding.
2) the algae is reproducing.
3) the culture needs stirring.
4) none of the above.

20. How can you tell if a Daphnia has been feeding on green algae?

1) compare the sizes of all Daphnia in the culture.
2) look at the color of the shell.
3) examine the long tube that runs the length of the body.
4) both 2 and 3.

21. You can predict to some extent the reproductive possibility of a Daphnia culture if you:

    1) compare the sizes of the Daphnia.
    2) examine the dorsal brood pouch.
    3) look for color changes in the shell.
    4) keep a record of the food consumed.

22. Do you feel that your background in biology is adequate for you to teach life science in grades 1-6?

    1) yes.
    2) no.

23. Do you believe you should be well versed in a subject before you attempt to teach it?

    1) yes.
    2) no.

24. Which do you consider more important to your learning in science?

    1) learning process skills.
    2) learning content.

25. I believe science should not be stressed in elementary school.

    1) yes.
    2) no.

26. For the plant and animal study tapes included in weeks 6 and 7, I:

    1) completed week 6.
    2) completed both weeks.
    3) started week 7 but did not gather data.
    4) did neither tape.

27. In the plant and animal study for weeks 6 and 7 which tape(s) do you feel should be eliminated.

    1) the ones that give the information only.
    2) the ones that require activity,
    3) neither type tape was helpful.
    4) keep both types,

28. What I disliked most about the tapes was:

1) the length of time they required.
2) the extra work involved in checking the set ups.
3) keeping the data sheets.
4) other (write your comments on reverse side of answer sheet).

29. I believe research is necessary to give instructors a basis for improving a course.

1) yes.
2) no.

30. I resent being used to try out new ideas for changing a course.

1) yes.
2) no.

APPENDIX E

ITEM ANALYSIS PRETEST, INTERMEDIATE TEST, POSTTEST

TABLE 12.--PRETEST RAW SCORE DISTRIBUTIONS

Raw Score	Frequency	Cumulative Frequency	Percentile Rank	Standard Score
17	2	2	99	74.7
15	3	5	97	67.7
14	6	11	94	64.2
13	8	19	88	60.7
12	24	43	77	57.1
11	22	65	60	53.6
10	15	80	46	50.1
9	22	102	33	46.6
8	13	115	20	43.0
7	3	118	14	39.5
6	6	124	11	36.0
5	6	130	6	32.5
4	3	133	3	29.0
3	1	134	1	25.4
2	2	136	0	21.9

Mean 9.96
Standard Deviation 2.84
Variance 08.08
Standard score has mean of 50 and standard deviation of 10

TABLE 13. --PRETEST SUMMARY DATA

Distribution of Item Difficulty Indices		
	Number of Items	Percentage
91 - 100		0
81 - 90	4	17
71 - 80	4	17
61 - 70	3	13
51 - 60	5	22
41 - 50	1	4
31 - 40	3	13
21 - 30		0
11 - 20	2	9
00 - 10	1	4

Distribution of Discrimination Indices		
	Number of Items	Percentage
91 - 100		0
81 - 90		0
71 - 80		0
61 - 70	1	4
51 - 60	1	4
41 - 50	1	4
31 - 40	8	35
21 - 30	6	26
11 - 20	6	26
00 - 10		0
Less than 00		0

Mean item difficulty	57
Mean item discrimination	29
Kuder Richardson reliability #20	.4803
Standard error of measurement	2.0472

TABLE 14. --INTERMEDIATE TEST RAW SCORE DISTRIBUTIONS

Raw Score	Frequency	Cumulative Frequency	Percentile Rank	Standard Score
16	1	1	99	70.5
15	2	3	98	66.7
14	10	13	92	62.9
13	16	29	80	59.0
12	16	45	65	55.2
11	15	60	50	51.4
10	13	73	37	47.5
9	12	85	25	43.7
8	6	91	16	39.9
7	7	98	10	36.0
6	3	101	6	32.2
5	3	104	3	28.4
4	2	106	0	24.5

Mean 10.63
Standard Deviation 2.61
Variance 06.86
Standard score has mean of 50 and standard deviation of 10

TABLE 15. --INTERMEDIATE TEST SUMMARY DATA

Distribution of Item Difficulty Indices

	Number of Items	Percentage
91 - 100	1	5
81 - 90	1	5
71 - 80		0
61 - 70	5	25
51 - 60	2	10
41 - 50	3	15
31 - 40	1	5
21 - 30	5	25
11 - 20	2	10
00 - 10		0

Distribution of Discrimination Indices

	Number of Items	Percentage
91 - 100		0
81 - 90		0
71 - 80		0
61 - 70		0
51 - 60		0
41 - 50	6	30
31 - 40	6	30
21 - 30	4	20
11 - 20	3	15
00 - 10	1	5
Less than 00		0

Mean item difficulty	47
Mean item discrimination	32
Kuder Richardson reliability #20	.4490
Standard error of measurement	1.9372

TABLE 16. --POSTTEST RAW SCORE DISTRIBUTIONS

Raw Score	Frequency	Cumulative Frequency	Percentile Rank	Standard Score
17	3	3	98	71.6
16	7	10	95	67.4
15	12	22	88	63.3
14	13	35	79	59.2
13	16	51	69	55.1
12	23	74	55	51.0
11	17	91	40	46.9
10	23	114	26	42.7
9	13	127	13	38.6
8	7	134	6	34.5
7	5	139	1	30.4

Mean 11.75
Standard Deviation 2.43
Variance 05.93
Standard score has mean of 50 and standard deviation of 10

TABLE 17. --POSTTEST SUMMARY DATA

Distribution of Item Difficulty Indices		
	Number of Items	Percentages
91 - 100		0
81 - 90	2	10
71 - 80	1	5
61 - 70	2	10
51 - 60	1	5
41 - 50	4	19
31 - 40	6	29
21 - 30	3	14
11 - 20	1	5
00 - 10	1	5
Distribution of Discrimination Indices		
91 - 100		0
81 - 90		0
71 - 80		0
61 - 71		0
51 - 60	2	10
41 - 50	2	10
31 - 40	7	33
21 - 30	2	10
11 - 20	6	29
00 - 10	2	10
Less than 00		0

Mean item difficulty	44
Mean item discrimination	28
Kuder Richardson reliability #20	.2857
Standard error of measurement	2.0536

APPENDIX F

MODULAR RESEARCH MATERIALS FOR MAINTAINING LIVING ORGANISMS IN THE CLASSROOM

MODULAR RESEARCH MATERIAL

Culturing Daphnia

Objectives: Upon completion of this module the student should be able to:

1. recognize a *Daphnia*.
2. establish and maintain a *Daphnia* culture for at least 14 days.
3. state the proper environmental conditions necessary for *Daphnia* growth.
4. determine the proper diet for *Daphnia*.
5. culture an algae that can serve as food for the *Daphnia*.

Materials: (for each student)

- 6 baby food jars/cover
- 6 labels
- 1 tumbler
- 1 medicine dropper
    - toilet tissue, 3-4 sheets
    - yeast, 1 tbsp.
    - stirring stick
- Magnifier

Printed materials:

- Introduction to unit
- Picture of *Daphnia*
- Summary sheet for *Daphnia* care
- Data Sheet

Materials: (for the class)

- Gallon jars of green water
  1 gal/4 students
- Gallon jars of aged water
  1 gal/4 students
- *Daphnia* stock culture
  50/student
- 3 large basters
- Extra stir sticks
- Extra green water stock
  for maintaining setups
- Extra yeast/tumbler
- Empty gallon jars for
  return of cultures
- Pan for dirty jars

Plant Study

Objectives: Upon completion of this module a student should be able to:

1. hypothesize how deep to plant seeds if given size, thickness and texture of seed coat and cotyledon.

2. state that light is not necessarily needed for certain seeds to germinate.

3. infer that water and a suitable temperature are required for seeds to germinate.

4. demonstrate a suitable method for seed germination.

5. infer that water, a suitable temperature, and adequate light are necessary for plant growth.

Material: (for each student)

plastic cup cover
magnifier
razor blade

6 planter cups/drainers
6 cups of soil (bagged)
6 labels

10 bean seeds
15 clover seeds
100 grass seeds

Specimen set of seeds

Printed Material

Introduction to unit
Picture of seeds
Summary sheet for plant care
Data Sheets

Material: (for class)

small watering bottle
watering can on shelf
3 rulers

Box for return of cups/plants

Seeds for Specimen Sets

Beans
Sunflower
Pumpkin
Squash
Wheat
Radish
Rye grass

Script for Informative Module

Plant Study

A survey of elementary science textbooks and curriculum programs indicates that seeds and plants are used extensively in the classroom to develop many concepts of growth, reproduction and environmental relationships. The study of plants is also used to help develop skills in making predictions, forming and testing hypotheses, collecting, compiling and interpreting data.

The purpose of this module is to inform you of the skills you need to successfully germinate seeds and grow plants. This knowledge should, in turn, increase your confidence in teaching the subject of plant growth to your students.

In this module there will be a discussion of factors that affect the germination of seeds and the growth of plants. Upon completion of the module you should be able to answer the following questions:

1. What are some of the factors that determine how deep a seed should be planted?

2. Is light necessary for seeds to germinate?

3. What is the effect of light on germination and the growth of plants?

Some of the more common seeds used in studying plants include: bean, sunflower, radish, clover, squash or pumpkin and rye grass. Use the pictures you received with the tape to help you recognize the seeds as they are discussed.

A careful examination of the seeds reveals some rather interesting differences. The most obvious difference is in size and color. The sizes range from the small radish to the larger pumpkin or sunflower seed. The colors vary from eggshell to brown to black. While most of the seed coats appear smooth, waterproof and rather shiny, they differ in toughness. The sunflower's seed coat appears to afford the most protection as it forms a jacket or hull-like covering. Perhaps you have seen someone pry open a roasted sunflower seed and pop the softer inner part into his mouth. The bean, squash and pumpkin seeds are equally well protected although the bean's coat is tougher and more skin-like than the pumpkin or squash. Their seed coats can be penetrated with a fingernail or snapped open easily. The inside meat of the bean correctly called the cotyledon is dry and hard, while pumpkin and squash cotyledons are soft and leave an oily spot when mashed on paper. Radish, mustard and clover seeds are all relatively small and round, the seed coats are paper-thin and easily penetrated with a razor blade if you can steady the pin-head size seed of the clover long enough to cut it. The cotyledon or stored food is much like the nut-like meat found in squash and pumpkin seeds. Wheat seeds may be placed between the squash and radish in characteristics. Rye grass seed is like the tip of a blade of dried grass. The seed coat is thin but tough with very little stored food inside.

The characteristics of seeds just discussed - size, texture of seed coat and texture of cotyledons - are important factors to consider when trying to determine the proper conditions for seed germination.

The major environmental factors of concern in germination are: air, moisture, light and temperature. For the seeds already discussed: air, moisture and a moderate temperature between 70^{o} - 75^{o} F are required. Perhaps you have germinated seeds at some time during your school career on a damp paper towel. Refer to the reference sheet again for some of the possible set ups for seed germination studies.

Care must be taken to use the correct amount of water on a germinating seed. Too much might cause mold to grow or the seed to rot. For this reason, it is sometimes difficult to germinate seeds such as beans and radish with varied physical characteristics in the same dish because the bean will require more water than the radish.

Light generally has no effect on seed germination. Most seeds will germinate equally as well in the light as in the dark if other conditions are favorable. There are always exceptions to these rules, however.

If seeds are planted in soil another question to consider is how deep to plant the seeds. As a general rule, seeds like clover and grass that are small and have a thin seed coat should be barely covered with soil. The larger seeds like beans with a hard seed coat should be planted about 1" beneath the surface of the soil. An important point to remember is that the moisture must have time to soften the seed coat so that the young plant can break through. There is enough food inside the seed coat of the larger seeds to sustain the new plant until it reaches the surface and can start producing its own food. Keep in mind that if you consider the size, seed coat and cotyledon characteristics of thickness, toughness and dryness you should be able to generalize on how deep to plant at least the seeds that have been discussed on this tape. Think for a minute--how deep would you plant a seed that is small, like grass but tough and dry, like the sunflower? How could you possibly speed up the germination process for seeds with tough seed coats and dry cotyledons?

Once seeds have been successfully germinated attention must be turned to providing conditions necessary for proper growth and development of the plant. The same environmental factors that are important for seed germination are also essential for plant growth. These major factors are air, moisture, moderate temperature and light. Seeds that are germinated in the dark must be moved to the light for the plant to continue to develop. The plant will grow for a while in the dark but the leaves will be small and colorless and the stems tall but weak. Without light the plant cannot reach maturity.

Even plants placed on a window sill or under a lamp might grow tall, spindly and generally weak. Such conditions indicate the plant is not getting the right light. A fluorescent light combined with an incandescent light is recommended when sunlight is not available. An expensive but perfect light to use is the special Gro-Lux tube.

Care should be taken to guard plants against excess heat such as you get from a radiator, direct sun rays or a strong incandescent bulb. Excess heat also means you have to water more often.

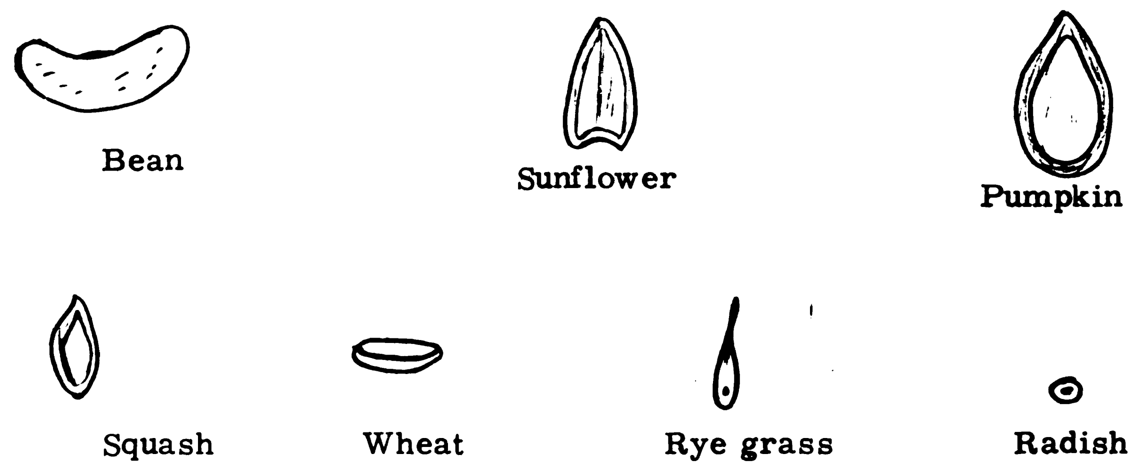
You should be careful not to over water a plant. It is not a good idea to soak a plant with water to cut down on the number of times you need to water. Water logged soil has no air and the roots will start to rot. No definite amount of water can be recommended since classroom conditions of humidity and temperature must be considered. As long as the soil is damp to touch no more water is usually needed.

From this module you should have two skills well in mind--germinating seeds and growing plants. The information given refers only to the more common plants used for classroom experimentation. Other plants such as cacti, African violets, ferns, etc. require specific temperatures, moisture and sometimes special treatment. The important thing to remember is that you have to control water, light and temperature. The right combination of these factors will help to insure successful growth.

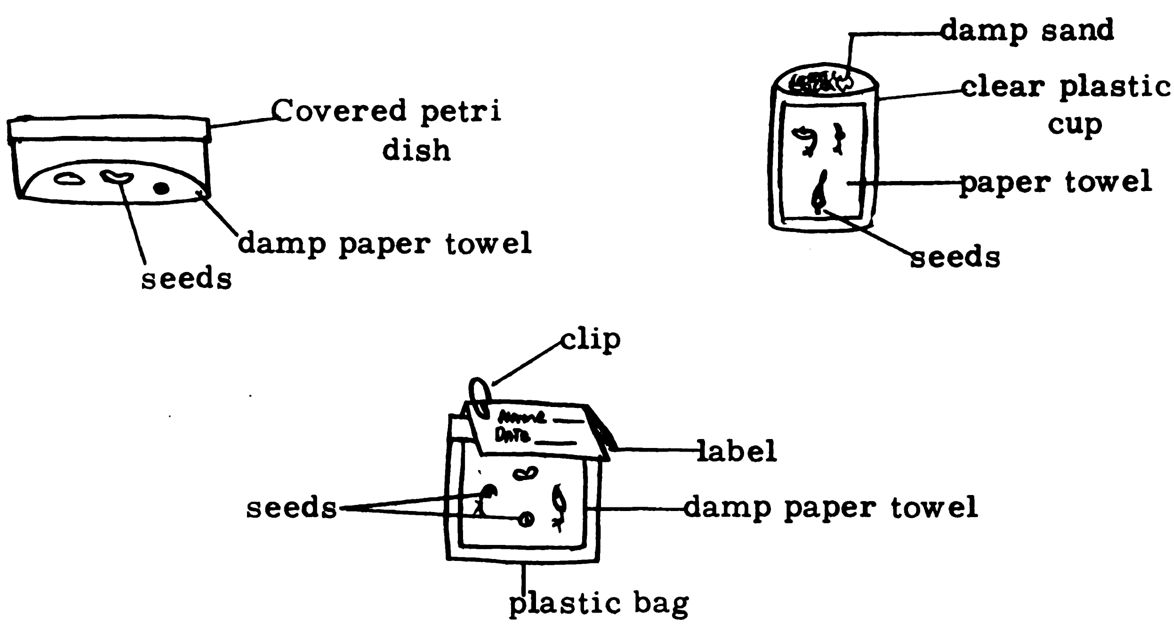
You should now be able to design many simple experiments suitable for elementary students involving plants.

Picture for Informative and Investigative Plant Modules

Seeds Commonly Used in Germination Experiments



Methods to Study Seed Germination



Script for Informative Module

Culturing Daphnia

The purpose of this module is to introduce you to the Daphnia, commonly called the water flea. At the end of the module you should have enough information to help you establish a Daphnia and algae culture. You should know the correct environmental conditions to maintain and what food you need to supply.

The tiny Daphnia can be raised in the classroom without too much difficulty. Its use in the classroom ranges from a point of interest for very young children to more sophisticated studies in developing food chains and food webs, pollution control and population studies with older children. With a little effort you could probably devise many interesting lessons involving the Daphnia once you learn how to keep them alive.

Starting in the spring of the year Daphnia can be collected from fresh water ponds or they may be purchased at any time from a biological supply house. The water where Daphnia is found is often green since Chlamydomonas, the green algae that gives the water its color, is a good source of food for them.

Daphnia can be easily recognized by its peculiar oval shape, its transparent shell and the jerky movements caused by the rapidly moving feet and antennae. Study the picture of the Daphnia you received with the tape to become familiar with the general structure while I talk about some of its features.

A close inspection of a living Daphnia reveals a tiny dorsal heart close to the surface of the skin just above the intestine. This long tube-like intestine runs the length of the body and might appear green if the animal has been feeding. If you are lucky you can even see the eggs that will hatch from the brood pouch in the area posterior to the heart. The fascinating story of how these little animals reproduce can be found in any text on freshwater invertebrates. See if you can pick out the structures just described on your picture of the Daphnia. Look for: the heart, intestine, brood pouch with eggs.

In a classroom a stock culture of Daphnia might be kept in an aquarium (without fish) in a gallon jar filled with green water. A separate container of Chlamydomonas or green water should also be maintained to resupply the Daphnia culture with food. The culture of algae should be stirred often to promote reproduction of the algae. The water will stay green if the culture is kept at a temperature of about 70° F, supplied with minerals and exposed to light at least part of the day. The minerals can be supplied by keeping a gold fish or guppies in the green water or by adding plant food. If you keep an aquarium in the room and it receives light most of the day, its water may turn green from algae growth, thus giving you another source of food for the Daphnia. You can reward your fish occasionally by giving them a few Daphnia to eat. They are a favorite food of guppies. During warm weather children will enjoy bringing water from a local green pond.

In addition to algae Daphnia also feed on bacteria and yeast. It is a good idea to vary the diet occasionally. Toilet tissue, the white unscented kind, can be added to the Daphnia culture to foster bacteria growth. The tissue decays nicely and the decay bacteria is used for food by the Daphnia. A few grains of yeast, just enough to barely cloud the water, can also be added. The water will appear slightly milky for a few days until the yeast is eaten or settles to the bottom. Be very careful not to add too much yeast as it will produce more carbon dioxide than the Daphnia can safely tolerate.

The Daphnia culture should be stirred often to keep the food particles suspended in water and aid the reproduction of the algae, bacteria or yeast. Maintain a temperature of 75° - 79° F. for the Daphnia. They seem able to withstand the lower temperatures better than the higher levels.

Provision should be made to keep the Daphnia near a light source to maintain a constant temperature and to facilitate the growth of the algae. The light is not essential if yeast or bacteria is the main source of food as long as the temperature is controlled.

In the algae and Daphnia cultures the water level will tend to vary due to evaporation but it can be kept constant by adding aged water. Aged water is prepared by allowing tap water to set for 24-48 hours thus allowing the harmful chlorine to escape.

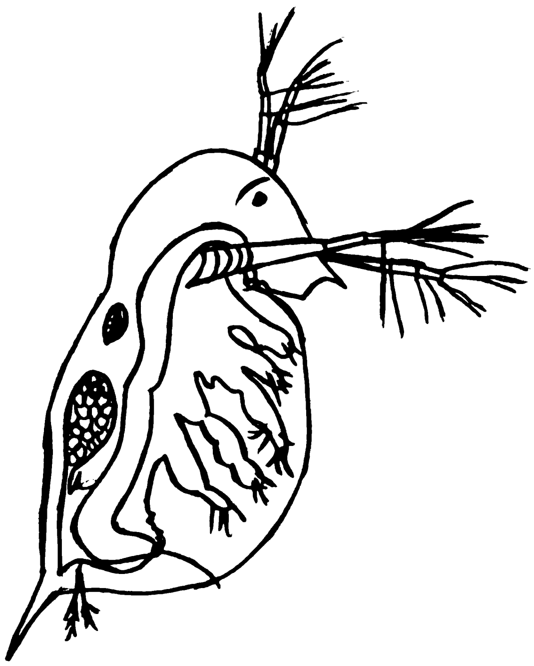
Daphnia maintained longer than a three week period follow an almost predictable growth curve. The population continues to increase steadily then for no apparent reason the population appears to be almost wiped out. Then in a week or so it recovers and starts to increase again. Children can speculate for months on why this happens and how the crash can be prevented.

Cultures of Daphnia and Chlamydomonas should do well if you follow these simple guidelines;

a. Keep the temperature constant. Optimum - 70°F for algae, 77° F for Daphnia.
b. Maintain good lighting but not direct sunlight for the algae.
c. Keep a good supply of algae and/or bacteria for the Daphnia.
d. If you keep a separate algae culture be sure to supply minerals by keeping a fish in the culture or add plant food.
e. Start new subcultures of Daphnia and algae often if you use these organisms regularly in a classroom to avoid population wipeouts.

Daphnia are often overlooked as an animal to use in elementary classrooms. Even though they can at times be tempermental they require little space and care. They work magic with young children and teachers who are reluctant to handle bugs and other creepy crawlers. Don't forget the Daphnia when you begin teaching.

Picture for Informative and Investigative Modules



Daphnia

Maintaining Living Organisms in the Classroom

During the next two weeks a study is being conducted as a part of the organism survey to determine a suitable way to introduce material that will be of practical value when you begin your teaching career. The study is a part of the regular required work but does not require or add any additional responsibility. The class objectives will remain the same. If changes are made they will be posted.

The tests that are a part of the study will not affect your grade. They are necessary to determine the effectiveness of the study. Therefore, it is most essential that the tests be completed by everyone.

For week 6 the tape will give information on how to raise a plant or an animal for classroom use. The week 7 tapes will require you to maintain either an animal or plant. If the information you receive this week is on plants, next week your work will be on a small freshwater animal and vice versa.

Keep the attached picture but return the test and answer sheet to the desk.

(Green sheet used for plant module; pink sheet used for animal module)

Maintaining Living Organisms in the Classroom - Week 7

This week you will conclude the tapes for the two-part study designed to introduce material that will, hopefully, be of value to you during your teaching career.

The test you take this week is to see if your skill level improved as a result of last week's tape. A third and final evaluation will be given at some time during week 9 when your experiments are concluded and the data sheets you will keep for the next two weeks are returned.

If the tape you did last week was on plants be sure the one you get this week covers the animal study and vice versa. For this week's tape you should receive:

1. A handout with data sheets; pink for animal study; green for plant study.

2. A kit of materials to use.

Refer any questions you might have to the special lab assistant on duty. If she is not present you will find a number at the main desk where she can be reached at all times.

Plant Study - Care of Plants

Check your containers every 2-3 days to make sure the soil is still damp to your touch. Add water as needed. Do not over water as mold might result or the seeds will rot. A watering container will be left with the plants for you to use.

Record the date the seeds germinate in cups 1 and 2 on Data Sheet II. Consider that a seed has germinated when it first breaks through the soil. When all the seeds have germinated you may terminate this part of the experiment if you wish and return cups 1 and 2 to the pan provided in the Preparation Room. When this part of the experiment is completed, fill in the last column of Data Sheet I and turn it in to the Desk Attendant.

Observe cups 3-6 closely. Record the date that at least half the seeds planted in each cup have germinated. When most of the germinated seeds in cup 4 are approximately 1/2 inch high, remove it from the box and put it on the shelf beside the box. When the plants in cup 5 are about 1/2 inch high, remove it from the shelf and place it in the box. Cups 3 and 6 remain where they were placed in the beginning.

Make note of the rate of growth of all plants in cups 1-6. Measure the plants from the rim of the cup to the tip of the plant. Record the heights to the nearest tenth of a centimeter. A ruler will be provided on the shelf for you to use. Record other conditions of the plants. Include such things as color and size of leaves and stem, strength and general appearance of plants.

Terminate the experiment after 14 days during week 9 and return all cups to the designated place in the preparation room. Also return all Data Sheets to the Desk Attendant. Your data will be added to the class data for a summary of the results. Be sure to put your name on all Data Sheets.

Script for Investigative Module

Plant Study

A survey of elementary science textbooks and curriculum programs indicates that seeds and plants are used extensively in the classroom to develop many concepts of growth, reproduction and environmental relationships. The study of plants is also used to develop skills in making predictions, forming and testing hypotheses, collecting, compiling and interpreting data.

The purpose of this module is to help develop skills in germinating seeds and growing plants. This knowledge should in turn, increase your confidence in teaching the subject of plant growth to your students.

In this module you will examine factors that affect the germination of seeds and the growth of plants. From the data you collect you should be able to answer the following:

1. What are some of the factors that determine how deep a seed should be planted?

2. Is light necessary for seeds to germinate?

3. What is the effect of light on germination and the growth of plants?

Whenever you hear this sound *** you should stop the tape and carry out the instructions given before starting the tape again.

Remove the material in the box you received and arrange it so that you can identify each item listed on the cover. *** Empty the specimen seed set into the plastic cover in the kit. *** Use the picture of seeds you received with the handouts to help you with identification. The set consists of bean, sunflower, pumpkin, squash, wheat, radish and rye grass seeds. Compare size, thickness and toughness of seed coats along with hardness and relative dryness of the material inside the seed coat. Use the razor blade to help you cut the seed coat. The magnifier will help in the examination of the material inside the seed. Use Data Sheet 1 to record your observations but do not complete the last column until you fill in Data Sheet II. Examine your seeds now and record your observations on Data Sheet I. *** You will plant only a few kinds of these seeds today. From the data you collect, however, you should be able to predict how to plant the other seeds.

There are two kinds of cups in your kit: a 9 oz. planter cup with holes in the bottom and a 7 oz. cup to serve as a drain cup. Put labels on each of the planter cups up near the rim. Number them 1-6, add today's date and your name. ***

Fill each cup to within one inch of the top with soil. One of the drain cups can be used as a scoop for the soil. There is a plastic container of extra soil on the floor near the entrance, if you need more than is in your kit. Fill your cups now. ***

Use your pencil to make eight holes about 1 inch deep in the soil of cup #1. Drop a bean seed in each of three holes and one or two clover seeds in each of the five remaining holes. *** Fill in the holes with soil. ***

In cup #2 place 3 bean and 5-10 clover seeds on the surface of the soil. Lightly cover all the seeds with about 1/8 inch of soil. ***

In cups 3-6 scatter 10-20 grass seeds over the surface of the soil. Cover the seeds with about 1/8 inch of soil. ***

Set each planter cup into a smaller 7 oz. drain cup. *** Use the water sprinkler in the carrel to slowly add water to all planter cups. The sprinkler can be refilled at the sink if it does not have enough water. The water you add to the soil will stand on the surface for awhile but will eventually soak through and drain into the smaller cup. Pour this drained water back through the planter cup at least once to insure that the soil is soaked. You can tell if the soil is soaked by looking at it through the plastic cup. Complete the watering now. ***

Put your cups in the top of the materials box you received. You will use the top as a tray to carry your plants to room 106C where they will be kept under lights. Use the front entrance if there is a class in progress. Cups 1, 2, 5 and 6 are to be placed on the tables behind the partition on the right side of room 106C.

Cups 3 and 4 are to be placed in either drawer 1, 2 or 5 of the display case behind the partition. The drawers are labeled - Dark for Plants. Take your plants to room 106 now. ***

Turn to the sheet in your handouts labeled - Plant Study - Care of Plants. This sheet gives instructions on how to care for your plants. Corrections for paragraph 3 are posted in the carrel. If you have questions ask the special lab assistant at the desk for help.

Return any material you did not use to the Desk when you return the tape. Use the inventory on top of the box to help you re-assemble the materials. This is the end of this tape.

Data Sheet I - Examination of Seeds

Seeds	Relative Size[1]	Seed Coat Thickness[2]	Seed Coat Toughness[3]	Texture of cotyledon[4]	Other Comments	How deep to plant[5]
Sunflower						
Bean						
Pumpkin						
Squash						
Wheat						
Radish						
RYE grass						

[1]You may draw for size; [2]Skin-like, paper thin, hull-like, etc,; [3]Scratch with fingernail, soft, etc.; [4]Dry, hard, powdery, oily, etc.; [5]Do not complete this column until Data Sheet II is finished.

NAME ________________ Section No. ____

Data Sheet II - Plant Study

	Cup #1 - Seeds 1" Deep		Cup #2 - Seeds 1/8" Deep	
Seeds	Date of Germination	Plant Growth Observation	Date of Germination	Plant Growth Observation
Beans 1		Date_______		Date_______
2				
3				
Clover 1				
2				
3				
4				
5				

Which seeds, beans or clover, germinated best when planted 1" deep?____________

Which seeds, bean or clover, germinated best when planted 1/8" deep? __________________

Based on the germination record for cups 1 and 2 and the examination of the seeds before they were planted what would you consider when determining how deep to plant a seed?

What factors have we controlled in this experiment?____________

Can you infer that these factors are necessary for germination?

____

How would you set up an experiment to prove that these factors are necessary?

NAME________________Section No. __

Data Sheet III - Seed Germination and Plant Growth

	Germination+	Plant Growth	Observation Date Each
Cup 3* Grm dark/ Grw dark			
Cup 4 Grm dark/ Grw light			
Cup 5 Grm light/ Grw dark			
Cup 6 Grm light/ Grw light			

*Grm - germinate; Grw - grow; +Date when 1/2 seeds in cup had germinated.

Compare the proportion of seeds that germinated in cups 3 and 4 with the proportion to germinate in cups 5 and 6.

Is light necessary for seeds to germinate under the conditions you had established?

Compare the plants in cup 3 with those in cup 4 after 5 days of growth.

Compare the plants in cup 5 with those in cup 6 after 5 days of growth.

How did the plants in cups 4 and 6 compare with those in 3 and 5?

Compare the plants in cup 4 with those in cup 6?

Does the fact that a seed was germinated in the light or dark affect the growth of the plant in the light or dark? ___________

What conclusion can you draw about the effect of light on plant growth?

What environmental conditions have been controlled to insure the growth of plants in cups 3 - 6?

NAME_______________________

Section Number______________

Script for Investigative Module

Culturing Daphnia

The purpose of this module is to introduce you to the Daphnia, commonly called the water flea. At the end of the module you should have enough information to help you establish a Daphnia and an algae culture. You should know the correct environmental conditions to maintain and what food you need to supply. The tiny Daphnia can be raised in the classroom without too much difficulty. Its use in the classroom ranges from a point of interest for young children to more sophisticated studies in developing food chains and food webs, pollution control and population studies. With a little effort you could probably devise many interesting lessons involving the Daphnia.

Starting in the spring of the year Daphniacan be collected from fresh water ponds or they may be purchased at any time from a biological supply house. In a classroom a stock culture of Daphnia might be kept in an aquarium, (without the fish) or a gallon jar of green water.

The pond water where Daphnia is found is often green since Chlamydomonas, the green algae that gives the water its color, is a good source of food for the Daphnia. In the class if you are going to raise Daphnia a separate container of Chlamydomonas or green water should be maintained for food. Stir the algae culture weekly to promote reproduction of the algae. The water will stay green if the culture is kept at a temperature of about 70° F, is supplied with minerals and exposed to light at least part of the day. The minerals can be supplied by keeping a gold fish or guppies in the green water or by adding plant food. During warm weather children will enjoy bringing water from a local green pond. In the algae and Daphnia cultures the water level will tend to vary due to evaporation but it can be kept constant by adding aged water. Aged water is prepared by allowing tap water to set from 24-48 hours thus allowing the harmful chlorine to escape.

The stock culture of Daphnia you will use for this study is on the window ledge near the entrance. The green water you will need is in the sinks between the carrels and the aged water is on the shelf above the carrels in white plastic containers.

Remember when you hear this sound *** you should carry out the instructions given before continuing the tape.

The kit you received with the tape contains all the other materials you need. Open the box and sort the materials it contains. ***

Rinse the glass jars in your kit at the nearest sink to remove any dust or cleaning solution. *** Put a label on each glass container and a small label on each cover. Number the containers 1-6. Put your name on the label on the jar and leave space to record the number of Daphnia you will add later. Put only your name or identifying symbol on the label placed on the cover. ***

Fill jars 1-4 about 2/3 full of green water from the gallon jar in the sink near you. Use the baster to get the green water. ***

Fill containers 5-6 about 2/3 full of aged water. ***

Take the tumbler from your kit and fill it 1/2 full with aged water. *** Take the tumbler of water to the stock Daphnia culture near the entrance. Use the large baster next to the culture to transfer about forty Daphnia to the tumbler. If you do not get enough you may return for more. Do not waste time counting them now. Return to the carrel to complete the next steps. ***

The Daphnia should be swimming happily in the tumbler. They can be easily recognized by the peculiar almost oval shape, the transparent shell and the jerky movements caused by the rapidly moving feet and antennae. Catch one Daphnia in the medicine dropper so that you can see it better while I guide your examination. *** Use the magnifier to help with the examination. Try to locate the tiny dorsal heart close to the surface of the shell just above the intestine. The long tube-like intestine runs the length of the body, and might appear green if the animal has been feeding. If you are lucky you can even see the eggs that will hatch from the brood pouch in the area posterior to the heart. The fascinating story of how these little animals reproduce can be found in any text on freshwater invertebrates. Now see if you can pick out the structures just described on the picture of the Daphnia you received with the handouts. ***

Use the medicine dropper in the kit to transfer 5-7 Daphnia to each of the six previously prepared containers. Get more Daphnia from the stock culture if you need them. The Daphnia are easily counted while they are in the dropper. ***

In the exercise you will be testing the effectiveness of light and three sources of food for the Daphnia: algae, algae plus bacteria and yeast.

Jars 1 and 2 will have only the green water or algae added. To jars 3 and 4 add 2 sheets of toilet tissue from the kit after you have torn it into smaller pieces. *** The tissue should decay and the decay bacteria will serve as food for the Daphnia. Now add enough green water to jars 1-4 to fill them just below the rim of the jar. ***

Put about 10 grains of yeast into the tumbler you used before. Slowly add aged water, stirring as you add, until the tumbler is 1/2 full. The water will be only slightly milkly. This yeast solution should be added to jars 5 and 6. Add more aged water if this solution did not completely fill the jars. ***

Place the covers on the jars loosely to help prevent evaporation but not too tightly to keep out air in those containers where it is needed. ***

Daphnia survive best at a temperature range of 75° - 79° F. The Daphnia seems able to withstand the lower temperature better than the higher levels.

Put your jars in the top of the materials box. This will be used as a tray to carry your cultures to room 106 C where they will be maintained. Use the front entrance to room 106 if a class is in progress. Place jars 1, 3, 5 on the shelves set up behind the partition in room 106 on the right side of the room. The shelves are labeled - Daphnia Cultures. If the shelves are filled place your cultures under the hood in room 106 where the mice are generally kept. Place jars 2, 4, 6 in either drawer 6 or 7 of the display case behind the partition. The drawers are labeled - Dark for Daphnia.

Instructions for caring for the cultures have been given to you along with the Daphnia picture and Data Sheet. Follow these directions carefully until you terminate the experiment. An inventory is on the top of the box to help you re-assemble the materials that should be in the box. Return the box to the desk attendant when you return the tape.

This is the end of this tape.

Daphnia Data Sheet

	Condition of Water				Number of Daphnia	Other Comments
	Clear	Green	Cloudy	Other		
Jar 1 Algae/light Observation 1 2 3 4						
Jar 2 Algae/dark Observation 1 2 3 4						
Jar 3 Algae/ bacteria/light Observation 1 2 3 4						
Jar 4 Algae/ bacterial/dark Observation 1 2 3 4						
Jar 5 Yeast/light Observation 1 2 3 4						
Jar 6 Yeast/dark Observation 1 2 3 4						

Daphnia Data Sheet (Continued)

Compare the change in the number of Daphnia in Jars 1, 3, 5.

Compare the change in Jars 2, 4, 6.

Based on your observations which food produced the greatest increase in Daphnia?

Compare: Jar 1 and 2.
Jar 3 and 4.
Jar 5 and 6.

Did the change in light affect the reproduction of the Daphnia with any of the three foods?

What is the relationship between the type of food and light as far as Daphnia reproduction is concerned?

What environmental conditions were controlled for you in this experiment?

What conditions would you conclude are important for the growth of Daphnia?

If your cultures did poorly while others placed in the same area as yours appeared to be doing well, can you account for what might have been the causes or contributing factors to your lack of success?

NAME ______________ Sec. No. ____

Care of Daphnia

You should check your cultures about every three days. Stir the material found settled in the bottom of the jars. The stirring helps the reproduction of the algae and yeast by providing a greater surface area. Add more green water to Jars 1 and 2 if the color fades and to Jars 3 and 4 if the paper seems not to be decaying. Add more yeast if Jars 5 and 6 become clear. The extra material you need will be available with the cultures you have set up.

Keep a record of changes that occur in each culture on the Data Sheet provided. Date each observation. You need not get an accurate count of the *Daphnia*, a good estimate will be satisfactory for our purposes. (i.e., 10-20)

Terminate the experiment after 14 days during week 9. Pour all cultures into the gallon jars provided next to the original stock culture. Put the empty jars and covers in the container provided. Return your completed Data Sheet upon termination of the experiment to the Desk Attendant. Be sure to put your name on the Data Sheet to assure that you receive proper credit.

APPENDIX G

MULTIVARIATE AND UNIVARIATE ANALYSIS COMBINED PLANT AND ANIMAL DATA

TABLE 18.--MULTIVARIATE AND UNIVARIATE ANALYSIS: COMBINED PLANT AND ANIMAL DATA

Hypothesis 1

F-Ratio for multivariate test of equality of mean vectors = 717.4810

D.F. = 6 and 85 p less than .0001

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step Down F	p less than
GRANDM	18185.2041	4059.9316	.0001	4059.9316	.0001
PREPOS	104.7628	30.6546	.0001	2.0403	.1567
INTPOS	105.1250	46.0893	.0001	.0454	.8318
PLAANI	40.3333	15.4708	.0002	.1055	.7462
INTPXP	3.1641	1.6941	.1964	4.6575	.0338
INTIXP	.5740	.2848	.5949	3.1364	.0802

Legend:

GRANDM - Grand mean

PREPOS - Pretest - Posttest

INTPOS - Intermediate - Posttest

PLAANI - Plant - Animal

INTPXP - Interaction, Pretest and Posttest

INTIXP - Interaction, Intermediate and Posttest

TABLE 19.--MULTIVARIATE AND UNIVARIATE ANALYSIS: COMBINED PLANT AND ANIMAL DATA

Hypothesis 2

F-Ratio for multivariate test of equality of mean vectors = 6.4401

D.F. = 6 and 85 p less than .0001

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step Down F	p less than
GRANDM	77.8844	17.3880	.0001	17.3880	.0001
PREPOS	2.5723	.7527	.3880	1.0859	.3003
INTPOS	18.4311	8.0806	.0056	8.3902	.0048
PLAANI	15.0272	5.7640	.0185	4.3556	.0399
INTPXP	8.6743	4.6442	.0339	3.9274	.0507
INTIXP	1.5944	.7911	.3762	.1178	.7323

Legend:

GRANDM - Grand mean

PREPOS - Pretest - Posttest

INTPOS - Intermediate - Posttest

PLANNI - Plant - Animal

INTPXP - Interaction, Pretest and Posttest

INTIXP - Interaction, Intermediate and Posttest

TABLE 20.--MULTIVARIATE AND UNIVARIATE ANALYSIS: COMBINED PLANT AND ANIMAL DATA

Hypothesis 3

F-Ratio for multivariate test of equality of mean vectors = 5.2236

D.F. = 6 and 85   p less than .0002

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step Down F	p less than
GRANDM	.3024	.0675	.7956	.0675	.7956
PREPOS	1.3749	.4023	.5276	.3780	.5403
INTPOS	12.7644	5.5962	.0202	5.4818	.0215
PLAANI	44.6037	17.1088	.0001	13.2318	.0005
INTPXP	.6975	.3734	.5427	.0381	.8457
INTIXP	35.8693	17.7978	.0001	9.5463	.0028

Legend:

GRANDM - Grand mean

PREPOS - Pretest - Posttest

INTPOS - Intermediate - Posttest

PLAANI - Plant - Animal

INTPXP - Interaction, Pretest and Posttest

INTIXP - Interaction, Intermediate and Posttest

APPENDIX H

MULTIVARIATE AND UNIVARIATE ANALYSIS PLANT DATA

TABLE 21.--MULTIVARIATE AND UNIVARIATE ANALYSIS: PLANT DATA

Hypothesis 1

F-Ratio for multivariate test of equality of mean vectors = 860.5165

D.F. = 3 and 88 p less than .0001

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step Down F	p less than
GRANDM	9969.1973	2623.0537	.0001	2623.0537	.0001
PREPOS	72.1701	30.5829	.0001	.5448	.4625
PREINT	45.0816	23.9546	.0001	.0181	.8934

Legend: GRANDM - Grand mean
PREPOS - Pretest - Posttest
PREINT - Intermediate - Posttest

TABLE 22.--MULTIVARIATE AND UNIVARIATE ANALYSIS: PLANT DATA

Hypothesis 2

F-Ratio for multivariate test of equality of mean vectors = 3.5228

D.F. = 3 and 88 p less than .0183

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step Down F	p less than
GRANDM	12.2449	3.2218	.0761	3.2218	.0761
PREPOS	10.3469	4.3846	.0391	3.0628	.0836
PREINT	4.5918	2.4399	.1218	3.9960	.0487

Legend: GRANDM - Grand mean

PREPOS - Pretest - Posttest

PREINT - Intermediate - Posttest

TABLE 23.--MULTIVARIATE AND UNIVARIATE ANALYSIS: PLANT DATA

Hypothesis 3

F-Ratio for multivariate test of equality of mean vectors = 2.5607

D.F. = 3 and 88 p less than .0601

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step down F	p less than
GRANDM	18.7803	4.9414	.0288	4.9414	.0288
PREPOS	2.0154	.8540	.3579	.2529	.6163
PREINT	2.9194	1.5513	.2162	2.4451	.1215

Legend:

GRANDM - Grand mean

PREPOS - Pretest - Posttest

PREINT - Intermediate - Posttest

APPENDIX I

MULTIVARIATE AND UNIVARIATE ANALSIS
ANIMAL DATA

TABLE 24.--MULTIVARIATE AND UNIVARIATE ANALYSIS: ANIMAL DATA

Hypothesis 1

F-Ratio for multivariate test of equality of mean vectors = 950.1536

D.F. = 3 and 88 p less than .0001

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step down F	p less than
GRANDM	8256.3401	2512.8522	.0001	2512.8522	.0001
PREPOS	35.7568	12.2226	.0008	4.8695	.0300
PREINT	60.6173	25.1074	.0001	8.3383	.0049

Legend:
GRANDM - Grand mean
PREPOS - Pretest - Posttest
PREINT - Intermediate - Posttest

TABLE 25.--MULTIVARIATE AND UNIVARIATE ANALYSIS: ANIMAL DATA

Hypothesis 2

F-Ratio for multivariate test of equality of mean vectors = 9.0603

D.F. = 3 and 88 p less than .0001

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step down F	p less than
GRANDM	80.6667	24.5512	.0001	24.5512	.0001
PREPOS	.8997	.3075	.5806	.0554	.8146
PREINT	15.4337	6.3926	.0133	2.4385	.1220

Legend: GRANDM - Grand mean

PREPOS - Pretest - Posttest

PREINT - Intermediate - Posttest

TABLE 26.--MULTIVARIATE AND UNIVARIATE ANALYSIS: ANIMAL DATA

Hypothesis 3

F-Ratio for the multivariate test of equality of mean vectors = 7.8561

D.F. = 3 and 88 p less than .0002

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step Down F	p less than
GRANDM	26.1257	7.9515	.0060	7.9515	.0060
PREPOS	.0569	.0195	.8894	.0992	.7535
PREINT	45.7144	18.9347	.0001	14.3972	.0003

Legend: GRANDM - Grand mean

PREPOS - Pretest - Posttest

PREINT - Intermediate - Posttest

APPENDIX J

MULTIVARIATE AND UNIVARIATE ANALYSIS
PLANT DATA AND ANIMAL DATA

TABLE 27.--MULTIVARIATE AND UNIVARIATE ANALYSIS: PLANT DATA

Hypothesis 1

F-Ratio for multivariate test of equality of mean vectors = 23.5837

D.F. = 2 and 93 p less than .0001

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step Down F	p less than
COMGAN	114.7959	46.2094	.0001	46.2094	.0001
DIFGAM	7.3673	1.4857	.2260	.9719	.3268

Legend: COMGAN - common gain

DIFGAM - difference in mean gain

TABLE 28.--MULTIVARIATE AND UNIVARIATE ANALYSIS: PLANT DATA

Hypothesis 2

F-Ratio for multivariate test of equality of mean vectors = 4.1802

D.F. 2 and 93 p less than .0183

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step down F	p less than
COMGAN	2.9388	1.1830	.2796	1.1830	.2796
DIFGAM	36.0000	7.2599	.0084	7.1006	.0091

Legend: COMGAN - common gain

DIFGAM - difference in mean gain

TABLE 29.--MULTIVARIATE AND UNIVARIATE ANALYSIS: PLANT DATA

Hypothesis 3

F-Ratio for multivariate test of equality of mean vectors = 1.4633

D.F. = 2 and 93 p less than .2368

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step down F	p less than
COMGAN	.1407	.0566	.8124	.0566	.8124
DIFGAM	14.3822	2.9004	.0919	2.8688	.0937

Legend: COMGAN - common gain

DIFGAM - difference in mean gain

TABLE 30.--MULTIVARIATE AND UNIVARIATE ANALYSIS: ANIMAL DATA

Hypothesis 1

F-Ratio for multivariate test of equality of mean vectors = 23.0037

D.F. = 2 and 93 p less than .0001

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step Down F	p less than
COMGAN	82.2908	36.2645	.0001	36.2645	.0001
DIFGAM	42.2500	4.7351	.0321	7.3089	.0082

Legend: COMGAN - common gain

DIFGAM - difference in mean gain

TABLE 31.--MULTIVARIATE AND UNIVARIATE ANALYSIS: ANIMAL DATA

Hypothesis 2

F-Ratio for multivariate test of equality of mean vectors = 3.7223

D.F. = 2 and 93 p less than .0279

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step down F	p less than
COMGAN	7.7602	3.4198	.0676	3.4198	.0676
DIFGAM	25.7194	2.8825	.0929	3.9186	.0508

Legend: COMGAN - common gain

DIFGAM - difference in mean gain

TABLE 32. MULTIVARIATE AND UNIVARIATE ANALYSIS: ANIMAL DATA

Hypothesis 3

F-Ratio for multivariate test of equality of mean vectors = 9.8145

D.F. = 2 and 93 p less than .0002

Variable	Hypothesis Mean Sq	Univariate F	p less than	Step down F	p less than
COMGAN	12.8683	5.6709	.0193	5.6709	.0193
DIFGAM	98.7090	11.0627	.0013	13.2209	.0005

Legend: COMGAN - common gain

DIFGAM - difference in mean gain

APPENDIX K

PERFORMANCE SHEET FOR ORGANISM STUDY

PERFORMANCE SHEET FOR ORGANISM STUDY

Terrarium Checklist

Condition of plants:

	no growth	dead	stunted	spindly	healthy
peas					
beans					
clover					
mustard					
grass					

Soil: dry________ damp________ wet_______ moldy_____

Conditions of animals:

	number	healthy	dead	not added
crickets				
snails				
beetles				
isopods				
chameleon				

Other materials added____________________________________

Observation sheet yes _____ no______
Date started______________

Name of trainee ________________________

PERFORMANCE SHEET FOR ORGANISM STUDY

Fruit Fly Check List

Medium: moist ______ dry _____ soupy ______ moldy _____

Stages present: larva ______ pupa ______ adult ______

Did reproduction take place? yes _____ no _____

Condition: Only adult stage alive ____ Other stages present but dead _________ Other stages alive but adults dead __________

Data started: _______________ Observation sheet ____________

Name of trainee _____________________

Mealworm Culture Check List

Amount of bran: Less than three inches _______
More than three inches ______

Source of moisture used ___________ Other food source ______

Stages of beetle present: adult ____ mealworm ____ pupa ____

Dead organisms present ________ Stage __________

Observation sheet: yes ___ no __ Age of culture _____________

Name of trainee __________________________