A COMPARISON OF THREE METHODS OF INSTRUCTION IN SCIENCE RELATIVE TO THE INTERPRETATION OF EXPERIMENTAL DATA

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PREFACE

The principal objective of this study was to discover whether the manipulation of laboratory apparatus, or the viewing of the manipulation of laboratory apparatus, had a significant effect upon the ability of elementary education majors to interpret experimental data correctly.

I am especially grateful to Dr. Kenneth E. Wiggins for the invaluable help, encouragement, and advice throughout the program of study.

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I am especially indebted to the panel of nine professors who read and validated the instrument used in the study. Thanks is also due to the students enrolled in Education 4K2 during the spring semester of 1967 for gracefully participating in this study.

I am very appreciative of the continual encouragement and assistance given to me by my friends and family. A special word of thanks is extended to my wife Connie for her help.

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CHAPTER I

INTRODUCTION

Today, science education literature is saturated with teaching designs which have been created by a number of organizations that were established for the exclusive purpose of producing new approaches to the teaching of science (19). The varying views of how best to teach science, which probably equals the number of researchers involved, are reflected in the multitude of forms that science education programs have assumed. A majority of the educators, working on new teaching approaches, endorse inquiry that centers about laboratory work (22). Superimposed on the inquiry theme are two more important themes. One theme is of special interest to the teacher in that it holds that the student at work should emulate the scientist at work (1, 211, 32, 36). The other theme is of special interest to teacher-training instituions because it assumes that students who become teachers tend to teach in the manner in which they have been taught (5, 31).

In order to so expose students and teachers to science, great emphasis has been laid upon laboratory work, especially upon the manipulation of laboratory apparatus. This emphasis upon laboratory work in the new approaches ranges as widely as do the approaches themselves; that is, from kindergarten through college (28, 7). Usually a particular modern approach will have as a part of its overall program inexpensive but quite ingenious laboratory apparatus. Much time and effort on the part of the teacher, as well as the student, is spent in mastering the manipulation of ingenious pieces of laboratory equipment.

This study addresses itself to the question of what effect the manipulation of laboratory apparatus has upon one of the processes that the student should master during his study of science. That process is the interpretation of experimental data as defined by the American Association for the Advancement of Science in its modern approach entitled Science, A Process Approach (9).

Background of the Study

The studies discussed in this section served to establish a background for this study. Completed dissertations, reports, and articles were reviewed in order to ascertain whether a study similar to this one was available for perusal. The three following dissertations were among the most closely associated works found.

One study done at Oklahoma State University by Oshima was entitled "Changes in Attitudes Toward Science and Confidence in Teaching Science of Prospective Elementary Teachers" (24). Oshima's study concerns elementary education majors who were exposed to two different teaching methods while taking a nine-week science methods course. The two methods of instruction used were lecture-demonstration and individual investigation. At the end of the study, the conclusions drawn by the investigator were that the groups did not significantly differ in (1) their attitudes toward science, (2) their scores in science achievement, and (3) their student-teaching behavior. Only their confidence toward teaching science differed significantly (.05). The individual investigation group scored higher in confidence.

In a study by Postle entitled "The Value of Laboratory Work in the Natural Sciences for Students in Programs of General Education," three groups of general education students were used (29). When tested for proficiency and reasoning ability, those people who were exposed to laboratory work did not score significantly different from those people who were not exposed to laboratory work during the course.

Another study by Oliver entitled "The Efficiency of Three Methods of Teaching High School Biology" employed three methods of teaching biology: the lecture-discussion, the lecture-discussion with demonstration, and the lecture-discussion with demonstration and laboratory exercise (23). The investigator found no significant differences among the three groups in their ability to retain factual information.

No studies involving the process of data interpretation were discovered, and as a result, this study came to be more of an exploratory rather than a definitive work. However, the teaching method treatments used in this study were based upon the method of inquiry teaching developed by Dr. J. Richard Suchman at the University of Illinois in Urbana, Illinois (42). Dr. Suchman's method of teaching by inquiry has been referred to as the "Suchman Method" and Chapter II of this study contains a rather detailed description of his work.

Specific Statement of the Problem

The principal objective of this study was to discover whether the manipulation of laboratory apparatus or the viewing of the manipulation of laboratory apparatus--a demonstration--had a significant effect upon the ability of elementary education majors to correctly interpret experimental data. Research on the principal objective of the study demanded the development of an instrument because there was no appropriate instrument available at the time of the study.

Specifically, the study attempted to ascertain significant differences as mentioned in the hypotheses. The study compared three methods of instruction in science relative to the interpretation of experimental data.

Hypotheses

The principal hypotheses tested in this study were:

1. There is no significant difference in scores concerning ability to correctly interpret experimental data made by education majors who have experienced the Suchman method of inquiry exclusively and those who have witnessed a demonstration employing laboratory apparatus, in addition to having experienced the Suchman method of inquiry.

2. There is no significant difference in scores concerning ability to correctly interpret experimental data made by elementary education majors who have experienced the Suchman method of inquiry exclusively and those who have manipulated laboratory apparatus, in addition to having experienced the Suchman method of inquiry.

3. There is no significant difference in scores concerning ability to correctly interpret experimental data made by elementary education majors who have witnessed a demonstration employing laboratory apparatus, in addition to having experienced the Suchman method of inquiry and those who have manipulated laboratory apparatus, in addition to having experienced the Suchman method of inquiry.

Need for the Study

Time, effort, and money are required to set up and maintain laboratory apparatus. Any instructional innovation that might save a little time, effort, or expense on the part of the institution training elementary teachers, which in turn could be used by the elementary teacher while on the job, would indeed be worthy of research.

Limitations of the Study

There were several limitations involved in this study that may have been influencing factors.

1. The population used for analysis was limited to only senior female, elementary education majors at Oklahoma State University. None of the students used in the analysis had previous teaching experience and their ages did not exceed twenty-five years.

2. Since the participation of the cooperating student teachers was not on a voluntary basis, there may have been some covert reluctance on their part to participate in this study with full enthusiasm.

3. The actual topics of academic study used in the instruments concerned physics and math. Few elementary education majors have had extensive experience with physics and math; therefore, there may have been some hesitation on their parts to participate in this study with a normal measure of confidence.

Assumptions of the Study

The following assumptions were made:

1. The instrument used in this study was valid in measuring ability to correctly interpret experimental data.

2. The experiments selected for application in this study were the type suitable for the exercise of data interpretation.

3. The topics selected for discussion were commensurate in difficulty with the ability of the student teachers used in this study.

Definition of Terms

1. Apparatus--An instrument, device, or piece of equipment that is essential for the proper execution of laboratory work.

2. Approach--A large organized manner or theme of teaching of an entire subject body complete with all texts, laboratory books, laboratory equipment, films, etc. It is usually set up by a committee such as: Biological Science Curriculum Study, Physical Science Study Committee, etc.

3. Data--Phenomena, observations, occurrences, and measurements used as a basis of reckoning or some facts on which an inference is based. More specifically, materials serving as a basis for discussion and further thought or action (9).

4. Demonstration--A showing emphasizing salient phenomena, and principles which always involved the apparatus that was used by the laboratory group.

5. Demonstration group--The class group that received a demonstration by the teacher of the same experiment upon which the laboratory group worked.

6. Experiment--A trial made to confirm or disprove some principle or effect.

7. Inquiry group--The class group whose entire treatment following the pretest consisted solely of the Suchman method of inquiry.

8. Interpretation--A student's explanation, conception, belief, version, judgment, or elucidation concerning experimental data.

9. Inquiry method--A teaching method in which a student follows a series of procedures very much like the procedures used by a scientist in solving a problem (22).

10. Laboratory--A space devoted to experimental study, especially a place where something is prepared or some operation is performed with some special apparatus.

11. Laboratory group--The class group that actually performs the experiment that the demonstration group saw demonstrated.

12. Lecture--A formal discourse intended for instruction

13. Pretest--The instrument administered to all groups just following the television tape viewing and just preceding the treatment.

14. Posttest--The instrument administered to all groups shortly after the treatment.

15. Process--A mental ability, skill or practice essential in the solving of scientific problems (5).

16. Manipulation--The act of treating or operating apparatus with the hands.

17. Method--A regular way or manner of teaching; a set form of procedures of instruction.

18. Retest--The instrument administered to all groups after the practice teaching experience.

19. Suchman method of inquiry--An inquiry method of teaching in which the students, after seeing the manifestation of a scientific principle, put a series of verbal questions answerable by a "yes" or a "no" to the teacher (42).

20. Topic--The subject of a discourse or any section of it.

Organization of the Study

This study is composed of five chapters. Chapter I is the introductory chapter and contains sections which relate the background of the study, the specific statement of the problem, the hypotheses to be tested, the need for the study, the limitations of the study, the assumptions of the study, and the definition of terms mentioned in the study. Chapter II is entitled "Review of the Literature." In that chapter, pertinent literature is discussed under the topic headings of: "Inquiry in Science Teaching," "Programs of Science Teaching Approaches," "Educators' Views on Science Teaching Methods," "Science--A Process Approach," "Data Interpretation," "The Suchman Method," and a "Summary." Chapter III is concerned with methodology and design. That chapter includes a description of the sample used in the study, the design of the instruments used in the study, the manner of application of the instruments used in the study, the data gathering procedure, and the statistical design of the study. Chapter IV contains the findings of the study. Topic headings of that chapter include: "Results of Hypotheses Test," "Analysis of the Chi-Square Tables," and a "Summary of the Findings." Chapter V bears the title of "Summary, Conclusions, and Recommendations."

CHAPTER II

REVIEW OF THE LITERATURE

Our advance in education is limited to the level obtained by skilled teachers working on the basis of past experience just as the technical advances of the 18th century metallurgist was limited to the experience of the artisan. This paraphrased statement was made by Conant (10) in 1947. Fortunately, today, science education is advancing and the advances being made are seldom based on past experience of the teacher. Conant went on to say that scientists developed molecular and atomic models, and subsequently with the new models, metallurgy advanced beyond the wildest dreams of the artisan. So it is today, because models of teaching method have been created that are, no doubt, quite beyond the wildest dreams of the skilled teacher who was trained a few decades ago.

Inquiry in Science Teaching

According to Schwab (35), there exist two kinds of inquiry: stable inquiry and fluid inquiry. Stable inquiry is directed toward the embellishment of what is current. When the current set of principles no longer fits the problem at hand, then fluid inquiry should be brought into action.

> Fluid inquiry then proceeds to the invention of new conceptions and tests them for adequacy and feasibility. Its immediate goal is not added knowledge of the subject matter, per se, but

> development of new principles which will redefine that subject matter and guide a new course of effective, stable inquiries.

About the time of Sputnik, science education underwent a fluid inquiry purge. Today, stable inquiry, in the form of new ways in which to teach science, is flourishing.

The common denominator of the new models in education is inquiry. Inquiry may take many forms and involve many terms, but it is ubiquitous in science education today (33). The word "inquiry" has been used so much that Joseph Schwab (30) has coined the word "enquiry" in reference to science teaching.

In order to have an inquiry curriculum there must be teachers trained in the inquiry approach. About a program of teacher education in the inquiry curriculum, Schwab (31) says:

> A teacher whose own study has been dogmatic and doctrinaire will be unprepared to teach science as inquiry. A teacher whose own training has demanded, or done little to discourage, acquiescence, dependency, and passivity will, in all likelihood, demand the same of his students. The first of these strictures bears mainly but not exclusively on the teacher's training in the subject matter. He will need to have a substantial part of that training in the form of inquiry into inquiry--enough of it to equip him with the ability to read and understand reports of inquiry. He will need to become familiar with the sorts of questions whose answers illuminate such materials. He will, himself, need to understand the ways in which invention and observation, datum and conception, interpenetrate to form the growing fabric of scientific knowledge. It is in this way, by developing the competence to participate in the movement of scientific inquiry, that the teacher of science can, in truth, be a scientist.

In other words, the teacher should be taught in the same manner that he will be expected to teach.

Textbooks in science education are bearing out the feelings of Schwab. In the preface of the textbook, Teaching Science Through Discovery, by Carin and Sund (2), the authors say:

> The concepts of teaching science as inquiry and as methods for investigation are developed and coupled with the vast accumulation

> of tested ideas and principles. Evidence points clearly toward an active program of science education utilizing problem solving techniques. Procedures for the active involvement of professional scientists, blended into cooperative planning and teaching of science with children, are given as guidelines for teachers and supervisors, who recognize the need for greater structure and continuity in the science program.

The new approaches in the teaching of science that have been developed since the advent of Sputnik do embody the features about which Schwab, Carin, and Sund wrote.

Programs of Science Teaching Approaches

Professional scientists and educators have been active in the planning of new science education programs. The fruits of their labor has taken the form of new approaches in the teaching of science. Because of the involvement of many interested and capable professionals contemporary teaching methods, especially in science education, have been the product of many minds. A glance through the Report of the International Clearinghouse on Science and Mathematics Curriculum Developments reveals that there exists a large number of organizations which have been formed for the sole purpose of creating new approaches in the teaching of science (19). There is available to the science teacher an even greater number of different approaches since a few organizations have produced more than one approach. The new approaches encompass more than new teaching techniques; they are manifestations of Conant's "new models" in education.

The first new approaches that were developed and put to widespread application in the classroom were programs that were designed expressly for secondary level curricula. After the secondary level approaches were in use, then both elementary and college level programs emerged.

Although there are now many elementary level approaches available, there is but one well known new approach that was intended for the college curriculum. The Berkeley Physics Course is that modern college level approach (28).

One early organization, circa 1959, established for the purpose of creating a new approach in the teaching of physical science, was the Physical Science Study Committee. A noted collaborator of the Physical Science Study Committee program was Jerrold R. Zacharias of the Massachusetts Institute of Technology. The Physical Science Study Committee physics program, the Chemical Bond Approach, and the Chemical Education Materials Study program were all designed for application at the secondary level (4, 3, 26). By 1963:

> Reports from PSSC, CBA, and CHEM Study teachers over the past few years have clearly indicated that an understanding of the nature of experimental physical science and some of the basic scientific skills could and should be acquired by the students before they take these courses in the senior high school. This served as the starting point to evolve a laboratory-oriented introductory physical science course which would properly equip students to meet the challenges of modern senior high school courses.

Those words were written by Uri Haber-Schaim of Educational Services Incorporated in the preface of the <u>Introductory Physical Science</u> text (25). The Introductory Physical Science approach was a product of the Physical Science Study Committee, and was designed for junior high school students.

More than once the same scientists and educators have served on committees that have designed teaching approaches. Livermore worked with programs in secondary level chemistry and then again was associated with an approach for elementary school students (4, 18). Zacharias, a pioneer in physics at the secondary level, with his work in the Physical

Science Study Committee physics approach, helped produce a program for elementary students entitled the Elementary School Study (13). It too, like its sister studies, is a complete work that includes special laboratory apparatus.

Educators' Views on Science Teaching Methods

A chain reaction, set off by the many new approaches that have come into being, produced a plethoric number of articles. In each article, the author expressed his own interpretation of the new approaches.

Heathers (16) envisioned three processes at play in elementary school science: first, the process of inquiry with use of the scientific method; second, the process of nature in the cause and effect relationship; and third, the process of applying knowledge through the use of the process of inquiry in nature. About the relationship of process, Gega (14) wrote:

> Most modern educators realize that for intelligent functioning it is at least as important to learn science thinking skills and attitudes (processes) as principles and facts of science (products).

Neal (20) has written that the laboratory school at Colorado State College is involved with a program that was designed to lead the pupils in the ways that scientists work, think, and organize material. "In the ways of the scientist," appears many times over in comments concerning the new approaches. In another article, Neal (21) stated that a major purpose of science education for children is to develop their ability to use methods of scientific inquiry that lead to critical thinking. Critical thinking or analytical thought demands the strengthening of several skills, such as recognizing and stating problems, selecting pertinent and adequate data, formulating and evaluating hypotheses, formulating conclusions, and applying conclusions and methods of scientific inquiry.

In the same vein, Hawkins (15) says that the difficulty that college students have with the intellectual process does not stem from the complexity of college work, but rather from their home background and first years of formal education. For example, a student must have a concept of relativity of motion or at least realize the simple geometric relationship of light and shadow or he cannot begin to appreciate Ptolemaic astronomy. A student must have at his disposal a structure on which to build new concepts and expand old ones.

In reference to the first years of formal education of which Hawkins mentioned, Utah State University is working on a project called "The Elementary School Science Project." Under this program, elementary pupils have been reported to be capable of mastering sophisticated information not taught to them in the past. A junior high school science curriculum was not moved down to the elementary school level in order to do this. Rather science is taught as the scientist practices it, as a process and as a product. The students not only learn some facts, but also they learn of the "structural features" of the subject (1, 44).

Science--A Process Approach

The American Association for the Advancement of Science, Commission on Science Education promotes the philosophy that science is more than a mere body of facts; it is a way of investigating and exploring. Process, discovery, concept, and inquiry are all terms freely used in the new approaches. Science--A Process Approach, created by the

American Association for the Advancement of Science commission attempts to bring all of these terms to a meaningful fruition of experiences for the elementary child (18). The American Association for the Advancement of Science approach was written by a group of people, two-thirds of whom were astronomers, biologists, chemists, geologists, mathematicians, physicists, psychologists, and science educators, and one-third of whom were elementary teachers, and elementary school supervisors (18). This is just one example of the cooperative efforts of both scientists and teachers to build a satisfactory science teaching approach.

Science--A Process Approach contains several unique features in its design. The unique features constitute deliberate divorce from the traditional ways of teaching science or any other subject area. In the realm of student evaluation, all objectives are stated in terms of behavior and are measured with a binary scale. There is no ambiguity; either the child shows to the teacher, during individual contact, that he understands the concepts involved in the process of the exercise, or that he does not. The results are tabulated by the teacher in a "yes" or "no" form. Special guides have been constructed to aid the teacher in evaluation (5).

Before the writing of each exercise was begun, the objectives of the exercise were defined. Based on the objectives, a clear and concise set of processes, or ways of science, to be mastered by the student, were set. The basic processes according to American Association for the Advancement of Science, are observing, classifying, recognizing space/time relationship, using numbers, communicating, inferring, and predicting (6).

At the upper elementary grade level, the basic processes are integrated into formulating hypotheses, controlling variables, interpreting data, defining operationally, formulating models, and experimenting (9). These processes are steps that the scientist climbs as he does his research. The science student is thus guided to work with his challenges much like the scientist works with his.

Another feature of inquiry-oriented learning is that it is unnecessary in planning courses for elementary school teachers, to organize them according to the traditional disciplines because "it is becoming increasingly difficult to separate the various scientific disciplines and to separate the sciences from their social implications" (22). The American Association for the Advancement of Science approach adheres to this line of thought since it is process oriented rather than content oriented.

Data Interpretation

A closer look at just one of the American Association for the Advancement of Science integrated processes, that of interpreting data, reveals the character of inquiry as it related to process. Concerning interpretation, Schwab (34) writes:

> Problems are posed to which the student does not already know the 'right' solution. Goals are set which call for development by the student of plans of attack and patterns of experiment. There may also be the effort to set situations in which the student is to find and formulate a problem as well as plan procedures and carry them out. In still other cases, the student is called upon to exercise judgment and choice concerning the parameters to be chosen for study, the indicators to be used, and the interpretation to be put on the data noted.

The Science--A Process Approach Commentary for Teachers (7) has this to say about the meaning of data interpretation as an integrated process:

> The process of interpreting data is inherent in all of the other processes. It is presented as a separate process in Science--A Process Approach to stress the usefulness and often the nuances of this relationship. When a child is observing, classifying, using numbers and space/times relations, communicating, measuring, inferring, predicting or engaging in any of the other integrated processes, he is also interpreting data at many points along the way ... He deals with raw, unorganized data ... He then organizes the raw data into sets and classification of his own choosing ... He begins to learn to interpret data quantitatively. Graphing is introduced a little later as a useful means for communicating and interpreting ... He learns the purpose of classification in data collecting ...

Thus it is that the interpretation of data, as a process, is inexorably woven into the matrix of inquiry.

The Suchman Method

J. Richard Suchman (43) has developed a fascinating version of the inquiry approach. He has worked exclusively with K-6 students at the University of Illinois. The Suchman method of inquiry, strikingly unlike other inquiry methods, makes only remote use of laboratory hardware. In lieu of the student's manipulating apparatus in experimentation, Suchman has prepared a series of 16 millimeter, silent, color films. The film clips last from three to five minutes each, and are episodes that depict short physics demonstrations. The demonstrations show the action of selected cause and effect phenomena. Film segments are shown to the class and are immediately followed by a period in which the students ask questions of the teacher. The questions are so structured as to be answerable by a "yes" or "no" response. With this inquiry method format, the children themselves seek to solve the riddle of why a cartesian diver bobs up and down, or why a bimetallic strip bends the way it does. Concerning inquiry guided learning, Suchman (42) wrote:

> To these children and others who are inquiring into the causes of physical phenomena, science is the discovery of new relationships. Children sometimes discover by accident; and sometimes by a skilled teacher. Whichever way it occurs, children are typically thrilled by the sudden new insights, and the learning that results has deep roots. But if we are going to teach the child how to discover meaningful patterns independently and consistently in a highly complex environment, we must teach him how to probe aggressively, systematically, and objectively, and how to reason productively with obtained data. In other words, we must teach the skills of inquiry.

Suchman's (42) comments about the film segments are:

> In addition to their motivational function, the films pose cause-and-effect problems in very specific terms. They make available some parameters and suggest areas where important additional parameters might be sampled. In short, the films provide a portion of empirical experience which the child must then relate to his conceptual system. To the extent that these systems are not sufficiently developed to accommodate the experience, he must expand and strengthen them through inquiry until he is capable of explaining the episode.

Again from the same article, Suchman (42) gave his reasons for using the "yes" or "no" format.

> All probes are verbal, originate from the children, and must be so phrased as to be answerable by 'yes' or 'no.' Keeping the inquiry at the verbal level permits the teacher and the rest of the group to keep track of most of the information the children are obtaining. The questions must originate from the children because the selection and design of questions are as much a part of inquiry as the interpretation one makes of the answers. The questions must be answerable by 'yes' or 'no' because in this way only can the child be discouraged from transferring control of the process to the teacher. 'Yes' or 'no' questions are hypotheses. The teacher in answering merely establishes the tenability of the hypotheses. If the children are permitted to ask, 'Why did the can collapse?,' the responsibility for selecting the kind of information to be supplied next would be on the shoulders of the teacher. The children would thus be relinquishing their roles as inquirers by returning to the traditional dependent role of obedient listeners and memorizers. This would inhibit the occurrence of inquiry behavior.

In support of his method of inquiry, Suchman (42) said:

> Most of the children who receive training become more productive in their design and use of verification and experimentation. They develop a fairly consistent strategy which they can transfer to new problem situations. They make fewer untested assumptions; they formulate and test more hypotheses; and they perform more controlled vs. uncontrolled experiments in the course of their inquiry.

Suchman has apparently struck at the heart of inquiry without the aid of mechanical devices which usually play an integral role in the teaching of science. More than one science educator has been aware of this inquiry-device relationship. Schwab (31) makes reference to laboratory apparatus in terms of students sought for scientific training.

> We have sought the student who is attracted by the subject matter of our science or by its technical methods and devices: live things, telescopes, electronic devices, dissection, collecting, construction ... These criteria are useful, but they are not enough. Taken alone, they may identify stable inquirers and standard engineers. They provide little, however, by which the student of original mind and bent for frontier investigation can identify himself and be attracted.

Summary

Schwab (31) succintly summarized the characteristics of the traditional science curriculum when he wrote: "The traditional courses have been, on the whole, a literal treatment of science and rhetoric of conclusions." He went on to say that conventional courses have been prone to give full attention to the conclusion or the end product of inquiry rather than accenting the process that brought about the conclusion. Because of emphasis on a content oriented approach rather than a process oriented approach, a false image of what science really is was conveyed to the student. The new approaches are the antithesis of Schwab's opinion of the traditional way of teaching because the method of reaching a conclusion is emphasized more than the conclusion itself.

Among the modern inquiry approaches available today, two have been selected by the investigator to form the foundation on which this study is built. The Suchman method of inquiry (42) and the process of data interpretation as defined by the American Association for the Advancement of Science (9) was the bases for the methodology and design of the study which is discussed in detail in the next chapter. Chapter III also mentions the actual topics that formed the academic portion of the instruments used in the study as well as the modern approaches from which the topics were selected. Sample description, instrument design application of instruments, data gathering procedure and statistical design are all subheaded parts of Chapter III.

CHAPTER III

METHODOLOGY AND DESIGN

Description of the Sample Included in the Study

The sample included in this study consisted solely of students enrolled in three sections of Education 4K2, Science in the Elementary School Curriculum, during the spring semester of 1967 at Oklahoma State University. Education 4K2 is a science methods course designed for prospective elementary school teachers. The course deals with the purposes, selection and organization of content, teaching and learning procedures, and evaluation of outcomes in elementary school science. Education 4K2 is a senior level course meeting only during the first half of the semester. The second half of the semester is occupied with practice teaching which was done off campus. All of the students in the course had taken at least one high school laboratory science course, usually biology; at least two years of high school mathematics, usually four hours in geometry; at least eight semester hours of college science, usually four hours in bological science and four hours in physical science; and at least six semester hours of college mathematics. All participants in the study had maintained at least a 2.3 overall grade point average (4.0 = A) while enrolled in the university.

There were several restrictions that were enforced upon the sample: (1) Sampling was restricted to women students since there was but one male in the total class enrollment population. (2) Sampling was restricted to exclude any students who were over twenty-five years of age. (3) Sampling was restricted to exclude any students who had not been in attendance at all of the data gathering sessions. The total number included in the final analysis was seventy students, none of whom had taught prior to their enrollment in the class.

Design of the Instrument Used in the Study

A search for a suitable instrument with which to measure an individual's ability to interpret experimental data was unsuccessful, and the investigator was obliged to construct one for this study. The instrument consisted of pretest, posttest and retest segments. The pretest and the posttest were composed of four parts, each of which were given on different days. At the time of the administration of the tests, there were twenty questions in each part of the pretest and the posttest. Therefore, there was a total of one hundred sixty questions, eighty in the pretest and eighty in the posttest, given during the first phase of testing. During the second phase of testing, the retest was administered. A validation jury composed of nine experts selected sixty questions from the posttest which they deemed to be most valid and appropriate for the interpretation of data. These same sixty questions that were taken from the posttest were assembled to make up the retest. Each question of the instrument closely followed the form of questions found in the Physical Science Study Committee physics questions published by the Educational Testing Service (12) in that they were of the multiple choice variety, having five responses from which choices could be made. There was but one correct answer for each question.

The physical science topics from which the experimental data were drawn were deliberately selected. The intention was to select physical science topics that did not inexorably rely upon the use of laboratory apparatus for the interpretation of experimental data. Four physical science topics were chosen as vehicles for the interpretation of data. The topics were borrowed from experiments found in three modern approaches intended for elementary school, junior high school and high school work. The particular experiments involved were: (1) Molecular Layers" which was adapted from an Introductory Physical Science Experiment entitled "The Size and Mass of an Oleic Acid Molecule" (25), (2) "Inertia" was modified from a Physical Science Study Committee laboratory experiment entitled "A Variation on Galileo's Experiment" (27), (3) "Conservation of Mechanical Energy and Components of Work" was based on a Physical Science Study Committee laboratory experiment entitled "Changes in Potential Energy" (27), (4) "Levers" was adapted from an American Association for the Advancement of Science, Science--A Process Approach experiment entitled "Analysis of Levers" (8). The investigator adapted four sets of laboratory instructions for use in this study from the laboratory directions written for the corresponding modern approaches from which the physical science topics were taken. The laboratory instructions used in this study can be seen in the appendix.

Four taped television lectures, with the investigator as the lecturer, were produced for use in this study. The television sequences, lasting from sixteen to twenty-eight minutes each, were intended to serve as the sole source of factual information allowed the students since no texts, previous assignments, or advanced notices of any kind concerning the physical science topics to be taken up, were given to the students.

The television lectures were planned and written by the investigator in the television script form suggested by Draper (11) before any taping took place. One complete script and three scripts in outline can be seen in the appendix of this study. The equipment used to tape the television lectures included a Sony model CVC-100 television camera and a Sony model SV-300 one-half inch television tape recorder (40). All recording was done on campus in the science education classroom-laboratory before class meetings. The students viewed the television tapes during the class period in the classroom-laboratory on a Stechell-Carlson model 2100 twenty-one inch monitor (38).

There always exists the possibility that one lecture can be presented in as many different ways as there are teachers to give it. Then too, one teacher may present a lecture a little different each time he gives it. Therefore, the impetus for the engagement of taped television as an instructional medium coupled with the Suchman method of inquiry arose from a continued effort to eradicate the spurious factor of teacher influence upon the different groups of students used in this study. With taped television, each student group received exactly the same lecture in its most minute detail.

Manner of Application of the Instrument

During registration, the students of Education 4K2 were allowed free choice of any one of three meeting times. Assignment to groups was, therefore, considered to be random, although groups of friends may have chosen the same meeting time after consulting with each other. The investigator made no effort to control choice factors of meeting time selection. Class meeting times can be seen in Table I.

TABLE I

CLASS MEETING SCHEDULE OF THE THREE STUDY GROUPS

Group	Students in Attendance	Students in the Study	Meeting Times on Mondays and Wednesdays*
Inquiry	31	20	10:30 - 11:45 a.m.
Demonstration	27	20	12:30 - 1:45 p.m.
Lecture	40	30	2:00 - 3:15 p.m.

*All groups met Mondays, 3:30 - 3:50 p.m.

Before registration was completed for Education 4K2, the three groups to be used in the study were labeled sequentially with the inquiry group meeting first, the demonstration group second, and the laboratory group last. The decision as to which group was to meet which time was made far in advance of registration and was prompted by the availability of teaching personnel. Each group met at different times for one hour and fifteen minutes on Mondays and Wednesdays and simultaneously for twenty minutes at different locations on Monday afternoons. As it turned out, there were thirty-one students in the inquiry group which met 10:30 to 11:45 a.m., twenty-seven students in the demonstration group which met 12:30 to 1:45 p.m., and forty students in the laboratory group which met from 2:00 to 3:15 p.m. However, the actual number of students used in the statistical analysis of the study was twenty, twenty, and thirty, respectively. Since Oklahoma State University subscribes to a teaching block program, the students met classes for one-half of the semester and then did nine weeks of practice teaching before returning to the campus at the end of the semester. Mondays were chosen as days for data gathering since each of the groups met classes twice on that day. The third, fourth, sixth, and final Monday meetings were designated as data gathering sessions for the pretest and the posttest. All of the Education 4K2 students returned to the campus at the end of the semester for one day only. On that final class meeting of the semester, the retest was administered to the three groups.

Data Gathering Procedure

At the beginning of the data gathering sessions, each of the three groups was shown the prepared closed-circuit taped television lecture. The students were encouraged to take notes while viewing the television. Immediately following the completion of the television tape, the members of the group took the part of the pretest that concerned that day's physical science topic. Scratch paper, but no notes, were allowed during the pretest administration. The test periods were exactly twenty minutes long and were electrically timed. Following the collection of the pretest booklets and answer sheet, all students were encouraged to again look at their notes that they had taken during the television lecture.

Up to this point, each of the three groups' exposures were identical; i.e., television viewing, quickly followed by the pretest. The treatment of the groups following the pretest administration was supervised by the investigator in the inquiry and the demonstration group and by another teacher in the laboratory group.

The inquiry group experienced an interlude of inquiry immediately after taking the pretest. The Suchman method of inquiry (42) was the exclusive method of treatment of the inquiry group. It allowed the participants to ask questions requiring a "yes" or "no" answer of the teacher. The students were encouraged to consult their notes and to converse with their classmates. Usually, a spokesman at each table, after a conference with her table mates, asked the questions. The questioning of the teacher extended to the end of the period.

One week before the data gathering sessions began, all three groups spent one period in training for the Suchman method of questioning. The three groups saw two brief television sequences which were patterned after Suchman's own short film clips (43). The students in all three groups posed questions concerning the topics seen. The training session included a pedagogical discussion about the merits of this method of teaching. The reason why the Suchman method was chosen for this study was to further limit the spurious factor of teacher influence when answering questions of the students. The "yes" or "no" answer of the teacher supports only truths or falsehoods and has little bearing on whether the students are following a prescribed train of thought.

The demonstration group, after participating in the pretest, witnessed a demonstration of an experiment that was adapted from the appropriate modern approach based on the physical science topics seen on television that same day. The dialogue of the demonstration teacher was minimal during the demonstration. The students were encouraged to refer to their notes taken while the television lecture was in progress. Once the demonstration was over, the students were allowed to ask questions in keeping with the Suchman inquiry method; i.e., questions answerable with a "yes" or "no."

The laboratory group, following the pretest, was presented with written instructions for the day's laboratory experiment. The students worked on the experiment in squads of three or four individuals. The experiment was the same one, with the same apparatus, that was performed by the teacher in front of the demonstration group. The students were encouraged to review the notes taken during the television lecture, converse among themselves, and ask questions of the teacher in the same form that questions were asked in the other two groups.

On the same Mondays that the pretests were given, all three groups of students met simultaneously but in different rooms. Each group was given the section of the posttest based on the day's physical science topic with a twenty minute time limit again imposed. The forementioned procedures were repeated four times on four different Mondays during the first nine weeks of the semester. Finally, when the students returned from their nine week off-campus-practice teaching experience, they were then administered the retest segment of the instrument. Briefly, a summary of the data gathering procedure is as follows: each of the three groups saw the same taped television lecture and then took the same pretest; each group received a different treatment involving either inquiry, demonstration, or laboratory; each group took the same posttest; and finally, nine weeks later, each group took the same retest.

Statistical Design

Even though the students who made up the population of this study were screened to meet the prerequisites that were established for student teachers at Oklahoma State University, the investigator could not be sure that the population upon which the study was performed was of normal distribution. Therefore, according to Siegel (37) non-parametric statistical tests were in order. Since the hypotheses involved only significant differences of the three groups, taken two at a time and the instrument, on final analysis, contained only sixty questions on which to base conclusions, a decision to look for central tendency rather than variance was made. Finally, the groups were independent and the data gathered was of ordinal value. In consideration of the characteristics of the study, the two tailed form of the median test was selected to test the hypotheses. Siegel (37), in reference to the median test, stated:

> The median test is a procedure for testing whether two independent groups differ in central tendencies. More precisely, the median test will give information as to whether it is likely that two independent groups (not necessarily of the same size) have been drawn from populations with the same median; the alternative hypothesis may be that the median of one population is different from that of the other (two tail test) ... The test may be used whenever the scores for the two groups are in at least an ordinal scale.

The pretest, posttest, and retest were subjected to the median test for two independent samples and "N" equal to or greater than twenty. With an "N" of equal to or greater than twenty, the final statistical analysis appears in the form of a chi-square table. The two tailed form of the median test was used since the hypotheses did not predict in which direction the final results would be.

The pretest served as a tool for detecting significant differences between the groups previous to experiencing the treatment. The posttest was used to detect any significant differences between the groups shortly after the treatment exposure. The retest was employed to detect any significant differences between the groups some-time after the treatment. A comparison of the students' ranks of the posttest and the retest made it possible to then test for reliability. All testing was done relative to the interpretation of data and the significant difference limit was set at the .05 level of confidence.

Content validation of the instrument used in this study was accomplished by submitting the pretest, posttest and retest segments of the instrument to a panel of nine experts. The validation panel included four physicists, a chemist, an astronomer, a meterologist, and two science educators. In the book, Foundations of Behavioral Research, Kerlinger (17) has written the following about content validation:

> Content validation, then, is basically judgmental. The items of a test must be studied, each item being weighed for its presumed representativeness of the universe. This means that each item must be judged for its presumed relevance to the property being measured, which is no easy task. In many cases, other 'competent' judges must also judge the content of the items. The universe of content must, if possible, be clearly defined; that is, the judges must be furnished with specific directions for making judgments, as well as with specification of what they are judging. Then, some method for pooling independent judgments must be used.

Those questions that received either a majority of comments, no matter how slight, or those questions which contained a serious defect, even if only one juror mentioned it, were cast out. Twenty-two questions were so removed from the total of one hundred sixty questions and they were not included in the statistical analysis. The posttest was thus reduced to sixty questions by the jury. Later the students were again the recipients of these same sixty questions in the form of a retest.

A posttest-retest comparison made it possible to determine a measure of reliability of the instrument. The statistical tool used for the measure of reliability was the Spearman Rank Correlation Coefficient for tied observations (37). The reliability was found to be .535.

In brief, the statistical design was as follows: the pretest was used as a tool for ascertaining whether the three groups had equal standing before the treatment. The posttest served the purpose of detecting differences among the groups following the treatments. In conjunction with the posttest, a retest was used in a test-retest situation. A panel of experts established the validity of the test questions and test reliability was measured with the Spearman Rank Correlation Coefficient statistical tool. In the next chapter of this study, Chapter IV, the results obtained from using the statistical design mentioned in this chapter is discussed.

CHAPTER IV

THE FINDINGS OF THE STUDY

A detailed discussion of the statistical results of this study constitutes the body of this chapter. Pretest, posttest, and retest segments of the instrument were utilized in gathering data from which assessments could be made of the comparative effectiveness of the teaching methods used in this study. The statistical test applied in analyzing the data was the median test (37). Since each of the three treatment groups contained twenty or more students, it was necessary to employ the chi-square form of the median test to the data gathered. The level of confidence, alpha, was set at .05 for significant differences. The raw data collected from each student included in this study appears in this chapter and the statistical procedures used on that data are appropriately indicated.

Results of Hypotheses Tested

Indicated in Table II are the raw scores made by the students on the pretest segment of the instrument used in this study. The maximum possible score on the pretest was 78, and the range of the scores attained was from 27 to 70. The laboratory group contained both the highest and the lowest scores. The median test was applied to the pretest scores for the purpose of determining whether the three groups of students were significantly different, at the .05 level of confidence, in their ability to interpret experimental data correctly before any treatment was given them. There was no significant difference between the scores on the pretest of any of the groups that was detected by the median test. For the pretest, the null hypothesis of no significant difference was accepted.

Seen in Table III are the scores made on the posttest by each of the three groups. The maximum possible score on the posttest was 60 and range in scores was from 25 to 54. Again the laboratory group contained both the highest and the lowest scores. After statistically treating the scores with the median test, no significant difference was found between the inquiry group and the demonstration group. The null hypothesis of no significant difference between the inquiry group and the demonstration group on the posttest was accepted. No significant difference was detected between the inquiry group and the laboratory group either. Therefore, the null hypothesis of no significant difference between the scores of the inquiry group and the laboratory group had to be accepted. When the raw scores of the demonstration group were compared to the laboratory group's raw scores, again no significant difference between the groups was found. The null hypothesis of no significant difference between the demonstration group and the laboratory group in relation to their scores on the posttest was accepted. Finally, in summary, there was no significant difference found between any of the groups on either the pretest or the posttest.

Nine weeks after the administration of the posttest, the same 60 test questions, in the form of a retest, were again posed to the students in each of the three groups. In Table IV are the retest scores of the three groups of students. The laboratory group no longer contained

TABLE II

PRETEST RAW SCORES FOR THREE GROUPS
(N = 70)

Inquiry Group (N = 20)	Demonstration Group (N = 20)	Laboratory Group (N = 30)
54	50	70
54	49	55
50	46	52
49	46	50
48	46	50
47	46	50
47	45	49
47	45	48
46	43	47
46	43	47
46	42	46
44	42	44
43	42	44
43	41	44
43	41	44
42	41	43
41	41	41
40	41	41
39	40	39
37	39	39
		39
		39
		39
		39
		35
		34
		34
		32
		32
		27

Median is 43.5

X^2 for Inquiry-Demonstration is .90*

X^2 for Inquiry-Laboratory is .16*

X^2 for Laboratory-Demonstration is .16*

*Not significant at .05

TABLE III

RAW SCORES OF POSTTEST FOR THREE GROUPS
(N = 70)

Inquiry Group (N = 20)	Demonstration Group (N = 20)	Laboratory Group (N = 30)
48	51	54
47	50	53
45	49	53
45	45	52
42	44	51
42	44	46
42	44	44
41	44	41
40	42	41
39	41	40
38	41	39
38	40	39
37	39	39
37	39	38
37	38	37
36	38	36
36	35	36
33	34	36
31	34	35
30	33	34
		33
		33
		33
		33
		31
		29
		28
		28
		28
		25

Median is 39

X^2 for Inquiry-Demonstration is .40*

X^2 for Inquiry-Laboratory is .29*

X^2 for Laboratory-Demonstration is 2.46*

*Not significant at .05

TABLE IV

RETEST SCORES FOR THREE GROUPS
(N = 70)

Inquiry Group (N = 20)	Demonstration Group (N = 20)	Laboratory Group (N = 30)
38	39	50
37	39	46
35	36	42
35	33	38
35	33	34
34	32	32
32	32	31
32	32	30
32	32	30
31	31	29
31	31	29
30	30	28
30	30	28
29	30	28
29	29	28
28	29	27
28	28	27
27	23	27
24	22	27
21	16	26
		26
		26
		25
		23
		21
		20
		20
		17
		17
		17

Median is 30

X^2 for Inquiry-Demonstration is .00

X^2 for Inquiry-Laboratory is 3.94*

X^2 for Laboratory-Demonstration is 3.94*

*Significant at .05

both the maximum and minimum scores. The range in scores on the retest was from 16 to 50 with the demonstration group having the lowest score and the laboratory group retaining the highest score. Even though the demonstration group was the holder of the lowest score tabulated, there was no measurable difference, with the median test employed, between the inquiry group and the demonstration group. Therefore, the null hypothesis of no significant difference between the inquiry group and the demonstration group was once again accepted. However, unlike the posttest scores, the retest scores indicated a significant difference between the inquiry group and the laboratory group. The null hypothesis of no significant difference between the inquiry group and the laboratory group based on the final testing was, therefore, rejected. Since no measurable difference appeared between the inquiry group and the demonstration group, and since the inquiry group differed at the .05 level of confidence from the laboratory group, then the demonstration group also differed significantly from the laboratory group. The null hypothesis of no significant difference between the demonstration group and the laboratory group was, therefore, also rejected.

In summary, the pretest and the posttest scores indicated no significant difference between any of the groups. The retest scores did not indicate any measurable difference between the inquiry group and the demonstration group but they did indicate significant differences at the .05 level of confidence between the inquiry group and the laboratory group, as well as between the demonstration group and the laboratory group.

Analysis of the Chi-Square Tables

Interesting characteristics of the data gathered became evident on closer inspection of the chi-square tables. The information in Tables V and VI indicate that on the posttest, nine students of the inquiry group scored above the population median and eleven students scored below, while on the retests, some nine weeks later, the situation was reversed, with eleven students scoring above and only nine students scoring below the population median. In comparison, on the posttest, the demonstration group contained twelve students that were above the median and eight students that were below the median. However, by the time that the retest was administered, the demonstration group was identical to the inquiry group in respect that it too contained eleven students above and nine students below the population median. Although the inquiry group, as a whole, did not do quite as well as the demonstration group on the posttest, it did equally as well as the demonstration group on the retest some nine weeks later.

When the inquiry group was compared to the laboratory group, a significant difference did not appear between the groups on the posttest, but did appear on the retest. The information upon which this observation was based can be seen in Tables VII and VIII. It can be seen that while the inquiry group increased its number of students above the median after nine weeks, the laboratory group failed to do the same. The laboratory group had ten students above the median and twenty below the median on the posttest and then had seven students above and twenty-three students below the median on the retest.

TABLE V

CHI-SQUARE TABLE OF THE POSTTEST FOR THE INQUIRY GROUP AND THE DEMONSTRATION GROUP (N = 40)

Median	Inquiry Group	Demonstration Group	Total
Above	9	12	21
Below	11	8	19
Total	20	20	40
α = .70	X^2 = .40*		

*Not significant

TABLE VI

CHI-SQUARE TABLE OF THE RETEST FOR THE INQUIRY GROUP AND THE DEMONSTRATION GROUP (N = 40)

Median	Inquiry Group	Demonstration Group	Total
Above	11	11	22
Below	9	9	19
Total	20	20	40
α = .00	X^2 = .00		

TABLE VII

CHI-SQUARE TABLE OF THE POSTTEST FOR THE INQUIRY GROUP AND THE LABORATORY GROUP (N = 50)

Median	Inquiry Group	Laboratory Group	Total
Above	9	10	19
Below	11	20	31
Total	20	30	50
α = .70	X^2 = .29*		

*Not significant

TABLE VIII

CHI-SQUARE TABLE OF THE RETEST FOR THE INQUIRY GROUP AND THE LABORATORY GROUP (N = 50)

Median	Inquiry Group	Laboratory Group	Total
Above	11	7	18
Below	9	23	32
Total	20	30	50
α = .05	X^2 = 3.94*		

*Significant at the .05 level of confidence

Finally, when the posttest and retest scores of the demonstration and laboratory groups were compared, the trend of greater disparity between the groups continued as can be seen in Tables IX and X. On the posttest the demonstration group had twelve students above and eight students below the population median while the laboratory group contained ten students above and twenty students below the median. The two groups were not significantly different at the .05 level of confidence and the null hypothesis was accepted for the posttest. Nine weeks later on the retest, the demonstration group had fewer students above the median than before but the laboratory group had lost students from above the median also. The demonstration group had eleven students above and nine students below the population median while the laboratory group had seven students above and twenty-three below the population median. The difference between the groups on final testing had become significant at the .05 level of confidence and the null hypothesis was rejected.

The statistical tool employed in finding the reliability of the instrument used in this study was the Spearman Rank Correlation Coefficient for tied observation (37). A correlation was determined between the posttest and the retest scores and was found to indicate a reliability coefficient, r_s, of .535.

Summary of Findings

On final testing, the retest evinced that the inquiry group and the demonstration group were identical in their ability to interpret experimental laboratory data. The null hypothesis of no significant difference between the inquiry and demonstration groups was accepted.

TABLE IX

CHI-SQUARE TABLE OF THE POSTTEST FOR THE DEMONSTRATION GROUP AND THE LABORATORY GROUP (N = 50)

Median	Demonstration Group	Laboratory Group	Total
Above	12	10	22
Below	8	20	28
Total	20	30	50
α = .20	X^2 = 2.46*		

*Not significant

TABLE X

CHI-SQUARE TABLE OF THE RETEST FOR THE DEMONSTRATION GROUP AND THE LABORATORY GROUP (N = 50)

Median	Demonstration Group	Laboratory Group	Total
Above	11	7	18
Below	9	23	32
Total	20	30	50
α = .05	X^2 = 3.94*		

*Significant at the .05 level of confidence

On final testing, it was discovered that the inquiry group scored significantly different, at the .05 level of confidence, from the laboratory group. The null hypothesis of no significant difference between the inquiry and the laboratory group was rejected.

On final testing, it was found that the demonstration group scored significantly different from the laboratory group at the .05 level of confidence. The null hypothesis of no significant difference existing between the two groups was rejected.

Lastly, on final testing it was seen that the inquiry group and the demonstration group each had more students scoring above the median than below within the group and each had a greater total number of students scoring above the median than did the laboratory group even though the laboratory group had one-third more students than either of the other two groups.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to discover whether the manipulation of apparatus, or the viewing of the manipulation of apparatus had an effect upon the student's ability to correctly interpret experimental data. The definition of the process of interpreting data was taken from Science--A Process Approach, by the American Association for the Advancement of Science (9). The interpretation of data is considered by them to be one of the integrated processes that a student should master during his elementary school study (7). In accordance with the purpose of the study, an attempt was made to detect significant differences between three groups of students. The student groups were labeled inquiry group, demonstration group, and laboratory group. Group identification was determined by the amount of laboratory apparatus manipulation in which the students engaged. (1) The inquiry group received no exposure to the manipulation of laboratory apparatus. (2) The demonstration group witnessed a demonstration that involved the manipulation of laboratory apparatus by the instructor, and (3) the laboratory group actually manipulated laboratory apparatus while engaging in laboratory experiments. The groups were tested relative to their ability to correctly interpret experimental data. The instrument used in the testing of the groups was constructed by the investigator expressly for this study.

Inquiry is the underlying theme of nearly all the modern approaches to the learning of science, and, since the Suchman method (42) of inquiry was of a type that did not rely upon the manipulation of apparatus, it was the method selected for use in this study. The Suchman method of inquiry differs from other methods of inquiry in that the students manipulate no apparatus, however, after seeing a physical phenomenon reproduced, the students then ask questions of the teacher concerning that phenomenon. Only a verbal response of "yes" or "no" is made in answer. Suchman (42), the originator of the method, has said about the "yes" or "no" format:

> The questions must originate from the children because the selection and design of the questions are as much a part of inquiry as the interpretation one makes of the answers. The questions must be answerable by 'yes' or 'no' because in this way only can the child be discouraged from transferring control of the process to the teacher. 'Yes' or 'no' questions are hypotheses. The teacher in answering merely establishes the tenability of the hypotheses.

The instrument used in this study was constructed by the investigator, reviewed by a panel of nine experts for validity, and rendered a reliability of .535. The students used in the study were females who were under twenty-five years of age and were members of the Education 4K2 class entitled, "Science in the Elementary School Curriculum," which was a class for prospective elementary school teachers. The data used in this investigation was gathered during the spring semester of 1967 at Oklahoma State University.

Basically the design of the study was:

Each group of students viewed taped television lectures adapted from experiments found in several modern approaches to the teaching of science. The approaches, from which borrowing took place, included the Physical Science Study Committee physics course, the Introductory Physical Science course, and the Science--A Process Approach course of study (26, 25, 7).

Immediately following the viewing of the television tape, each group was administered a pretest instrument. After the pretest, each group received a different treatment: (1) The inquiry group experienced an interlude of the Suchman method of inquiry. (2) The demonstration group viewed a live demonstration involving the manipulation of some laboratory apparatus. The demonstration was followed by a short Suchman inquiry interlude. (3) The laboratory group did an experiment using the apparatus which the demonstration group saw used. After reading instructions concerning the experiment, members of the laboratory group were allowed to ask Suchman-type questions while they worked on their experiment. Shortly after the treatment, each group was administered a posttest, and finally, nine weeks after the posttest, the groups were retested.

The hypotheses tested in this study were:

1. There is no significant difference in scores concerning ability to correctly interpret experimental data made by elementary education majors who have experienced the Suchman method of inquiry exclusively and those who have witnessed a demonstration employing laboratory apparatus in addition to having experienced the Suchman method of inquiry.

2. There is no significant difference in scores concerning ability to correctly interpret experimental data made by elementary education majors who have experienced the Suchman method of inquiry exclusively

and those who have manipulated laboratory apparatus in addition to having experienced the Suchman method of inquiry.

3. There is no significant difference in scores concerning ability to correctly interpret experimental data made by elementary education majors who have witnessed a demonstration employing laboratory apparatus in addition to having experienced the Suchman method of inquiry and those who have manipulated laboratory apparatus in addition to having experienced the Suchman method of inquiry.

Conclusions

A non-parametric test was applied to the raw data gathered from the tests' scores. The instrument consisted of three segments which were administered during different phases of the study. The segments were pretest, posttest, and retest.

The pretest was administered before the three groups received different treatments. Since statistical analysis of the pretest scores supported the null hypothesis of no significant difference, it was then assumed that the three groups were at the same ability levels concerning that topic at the beginning of each data gathering session. The null hypothesis was thus accepted for the pretest.

The posttest, administered after the three groups had received different treatments, failed to uncover any significant differences among the groups. The null hypothesis was again accepted and once more the assumption was made that after different treatments, the groups remained at the same level of ability with regard to the interpretation of data.

The retest, given nine weeks later, did, however, reveal some significant differences. It was found that the inquiry group and the demonstration group both had more students scoring above the median than they had below. It was subsequently found that no differences existed between these two groups for the retest, and the null hypothesis of no significant difference was then accepted. It was also discovered that, although the inquiry group did not score significantly different from the demonstration group, it did score significantly higher than the laboratory group. The demonstration group also scored significantly higher than the laboratory group. In summary, the inquiry group and the demonstration group remained the same, but both of these groups differed significantly from the laboratory group.

Based on these results, it could be inferred that ability to interpret experimental data correctly may relate inversely to the amount of manipulation of the laboratory apparatus in which the groups were engaged. Nine weeks after the posttest, the inquiry group and the demonstration group exhibited equal ability with regard to data interpretation; i.e., the group which saw a demonstration of the experiment by the instructor scored no higher when tested than did the group which did not. Both groups had seen television tapes that dwelt upon the principles behind the experiments and both were allowed to ask questions which could be answered with a "yes" or "no."

Both of these groups, when compared with the laboratory group, did better than the group which performed its own experiments. It would appear that even though this latter group did the experiments, nine weeks later the laboratory group apparently did not remember as much about the principles as did the other two groups who did not actually do the experiments themselves.

A very weakly supported inference might be that the group which received the least help in the form of acquaintance with laboratory apparatus relied more heavily on their own resources than did the other two groups. It might be more reasonable to infer that the students in the laboratory group had their attention and efforts focused upon the accomplishment of the laboratory experiment and the manipulation of the apparatus set before them rather than upon the principles and mathematical entanglements found in the exercise. It is the feeling of the investigator that both of these factors had an influence on the results of this study.

Recommendations

As a preface to the recommendations, it should be noted that although this study used some concepts in physics as a vehicle for content, the objective of the study should, in no way, be construed to be that of teaching physics in a science method course.

There are several recommendations concerning further study that have stemmed from this investigation. The following recommendations are intended to strengthen, as well as broaden the scope of this study, should future investigations of this type be contemplated.

Recommendations for strengthening the study are:

1. In this investigation the taped television lectures were of varying lengths. The lectures ranged from sixteen minutes to twenty-eight minute segments. In the future, the television segments should not exceed twenty minutes duration in consideration of student attention span and the most efficient utilization of seventy-five minute class period.

2. The instrument designed for this study was validated by a majority of nine experts in physical science. In consideration of comments from the validation panel, the instrument could be strengthened with an increased emphasis on graph and table founded data interpretation. Perhaps even photographs, like those used in the Science--A Process Approach, might be incorporated into future instruments (9).

Recommendations for broadening the study are:

1. The instrument of this study involved content belonging exclusively to one area of physical science, that of physics. In order to broaden any future study that might have associated objectives, other areas of both the physical and the life science should be considered as content vehicles.

2. Carefully selected pre-service elementary school teachers were the only students included in this investigation, however, in possible future studies, other students with different backgrounds and ages might be encouraged to participate.

3. Science--A Process Approach described eight basic science processes and six integrated science processes in its program. Only the integrated process of data interpretation was drafted into this study. Future studies might include other processes as well.

Finally, there are two recommendations, based on the results of this study that might be incorporated into the teaching of a science methods course. They are:

1. When the sole objective of a particular exercise is to interpret experimental data correctly, laboratory work should be dispensed with, and the outcome of that exercise will not be altered appreciably, provided: (a) that the exercise being done is of the type suitable to

the interpretation of data, (b) that well organized instruction concerning the topic involved is provided, and (c) that sufficient time is allotted for the posing of questions by the students.

2. Laboratory exercises used in the teaching of a science methods course should emphasize the techniques of the approach and the processes involved. The content of the exercise on the other hand should not be emphasized at that time, but rather discussed at some time other than when the students are involved in the manipulation of laboratory apparatus, unless there has been sufficient preparation made on the part of the students for the exercise prior to performing the exercise in class.

Since no other closely associated studies were found, this study became an exploratory rather than a definitive piece of research.

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APPENDIX A

"MOLECULAR LAYERS"
(Television Script)

VIDEO	AUDIO
Open with a tight closeup shot of a carton of milk being spilled across a kitchen table.	Would you believe that there is a connection between the spilled milk accident that you have just witnessed and the method by which scientists might compute the dimensions of an invisible building block of nature? I hope that you do believe me, because this is the case; and the invisible building block to which I refer is the tiny molecule.
Long shot of speaker	Let me help you construct a mental picture of how the measurement of an object invisible to all but the electron microscope might be approximated with neither the aid of sophisticated devices nor sophisticated personnel to operate highly sensitive apparatus. I hope that you will take down a few notes, mental or otherwise, as we

VIDEO	AUDIO
	discuss this topic for the next 15 minutes.
Medium closeup of speaker	Let's imagine that you have a job that requires you to hammer and pound on a chunk of metal until the metal forms into a thin sheet. Imagine not any metal, but rather, some particular metal like lead or, better yet, gold. We have to be concerned about our selection of a metal because some metals are brittle and will crumble when struck, while others have that property of malleability that we are seeking. Gold can be hammered so thin that it will allow the passage of light through a thin sheet. The light that comes through the gold sheet has a greenish cast. Very thin sheets of gold, called gold foil, will stick to clean glass panes and that's why we can have real gold letters on glass doors and windows. A craftsman can "float"

VIDEO	AUDIO
	these letters on a clean, smooth surface.
Tight closeup of speaker	Now, I wouldn't try to convince you that the gold foil that is used for making letters is only one molecule thick. However, can you think of a substance that just might be thinner in terms of the numbers of layers of molecules, assuming that molecules form in layers, of course; or, in other words, what material might contain fewer strata or layers of molecules when stretched out very thinly? Well, it is always easier to suggest what might not be, rather than what might be.
Medium shot of aluminized mylar	The shiny surface on this piece of plastic is aluminum. The aluminum was fixed on the mylar plastic sheet by a special process. We are not concerned with the mechanics of the process, but rather with the fact that the aluminum layer is nearly one molecule

VIDEO	AUDIO
	thick. The thickness of this piece of plastic including the aluminum layer is less than five ten thousandths of one inch thick.
Write number on the chalkboard	That is about 0.0005" or 5×10^{-5} inches. That is a dimension about 1/3 the thickness on one hair on your head! The plastic sheet is many, many times thicker than is the aluminum layer. This is all grand, but in order to secure such a thin molecular layer on the surface of a plastic sheet, we must employ sophisticated personnel and equipment. Earlier, we implied that we could approximate molecular dimensions with simple materials and techniques. Perhaps a liquid would be more satisfactory for our purposes. Milk certainly is not very thin. Water is really no candidate either, mainly because of its ability to stick together so well as to form droplets. What about this?

VIDEO	AUDIO
Long shot of can of Conoco motor oil	This is a can of motor oil. The hottest brand going. You have, I am sure, seen oil slicks on water. An oil slick causes that beautiful iridescent blue-green-purple-gold color on a sunlit water surface. Since oil has a lesser density than water, oil will float on the water surface. An extremely small volume of oil will quickly cover a large surface area on water.
Tight closeup of speaker	There is a liquid that will spread out over water even thinner than does oil. The liquid that will give us an exceedingly thin film
Tight closeup of oleic acid bottle so labeled	is oleic acid. Oleic acid will spread itself out on a water surface until it is just one molecule thick. I expect that you are now thinking, "How does he know that the layer of oleic acid is only one molecule thick?" Please don't expect an air-tight proof. Proofs in science are usually very intricate.

VIDEO	AUDIO
	However, in order to support my contention that the layer is one molecule thick, let me pose an analogy. We will have to do a little figuring first. Next, we need to find the thickness of a diameter of a single bee bee.
Closeup on a graduated cylinder	Now, let's see. There are 116 cm^3 of bee bees in the graduated cylinder.
Wide shot of speaker at laboratory table	Now, let's pour the bee bees into the pie tin.
Speaker pours bee bees from graduated cylinder into pie tin and smiles	Isn't that amazing? They just fit. Only one bee bee thick layer covers the entire bottom surface of the pan. See what a little preparation before class time will do for you!! Next we need to find the thickness or diameter of a single bee bee. How can we do that?
Pause--speaker then picks up ruler	Do you get the hint?
Speaker measures diameter of circle of bee bees in the pie tin	The diameter of our circle of bee bees measures to be just about 20

VIDEO	AUDIO
	centimeters.
Write on chalkboard	Volume is equal to length times width times depth or thickness. We also know that area equals l times w. Now, how can we find the area of a circle? A_c equals Πr^2. We also know that r equals the radius of a circle and that the diameter of the same circle is two times the radius. The radius is one-half the diameter, also. So, let's measure the diameter of our bee-bee circle.
Tight closeup of figures on screen	D equals 20 cm and the radius is just 1/2 that or r equals 10 cm. Let's record our data on the chalkboard. Next, we know that Π is 3.14 or 22/7. Let's use 3.14; I always have problems with fractions. A_c equals Πr^2 which equals 3.14 times $(10 \text{ cm})^2$ or 314 cm^2. V equals l times w times d and A equals l times w; therefore, V equals A times d. All we need to find now is the depth of

VIDEO	AUDIO
	thickness. We divide both sides by A; V equals A times d; V/A equals (A times d); V/A equals d; d equals V/A. Filling in data we get d equals 116 cm^3/314 cm^3. Let's divide the data out. There is the result .37 cm. O.K., just for the fun of it, I am going to check the results mechanically.
Tight closeup shot to measure diameter of a single bee bee	That's not a bad approximation! .37 cm calculated to .47 cm measured. It is only .1 cm off. Of course, we can't use a micrometer to measure the dimension of a molecule; but, I hope that with this little analogy, you will agree that we don't really need to. If we were to use only half our former volume of bee bees, then what could you expect the results to be concerning the area, providing that the thickness of the layer did not change?
Long shot of speaker	While you ponder that question, and before we leave the topic,

VIDEO	AUDIO
	there are a couple of points worth mentioning. One is that we have pictured the oleic acid molecule as being spherical in shape, sort of like a bee bee. In reality, the oleic acid molecule has a length that is about ten times its diameter. It is long and thin. We considered the bee bee to be spherical, but we calculated its volume as if it were a cube. The volume of a sphere is $4/3\ \Pi\ r^3$. We know that the volume of a cube is a single side times a single side times a single side or a side length cubed.
Medium closeup of speaker	Actually, the oleic acid molecule stands almost upright on the water surface and is neither spherical nor cubical. So these are the main reasons that I was so careful to say "approximate the dimensions of a molecule." Still, calculations by way of our analogy are only about 100 times greater than results obtained by highly

VIDEO	AUDIO
	sophisticated methods. Our results are only two orders of magnitude off. This may at first seem like a large error, but without our experiment, we would have known nothing of the size of the oleic acid molecule except that it was too small to see. Scientists often must approximate, just as we have, in doing their work. Our data is still quite valid and useful, providing that we realize its discrepancies.
	And finally, if you were to actually carry out this experiment using oleic acid instead of bee bees, you would very soon discover that just one full drop of oleic acid would cover an entire swimming pool. So it might be desirable to dilute the oleic acid in alcohol. After a drop of the diluted mixture hits the water, the alcohol soon evaporates and leaves only the oleic acid in a small circle on the surface of the water.

VIDEO	AUDIO
	A good ratio of mixture would be one part oleic acid to 499 parts of alcohol. Ratios can be adjusted to the size of swimming pools or pie plates used. Knowing the ratio of mixtures would help with the actual counting of the number of molecules in the drop. Also it is difficult to see oleic acid on the water so if some chalk dust or powder is sprinkled on the water surface before the oleic acid is placed on the water, then the results are quite visible.
Tight closeup of a printout of the summary	Now let's quickly recap what we have seen during the past few minutes. (1) Some substances can be spread so thin that they are but one molecule thick. (2) If we know the volume of the substance to begin with, and (3) the area that the volume requires when one molecule thick,

VIDEO	AUDIO
	(4) then we can calculate the thickness of a single molecule by: Volume/Area equals depth,
	(5) and, finally the thickness of the layers approximate the dimensions of the molecules of the substance used.
Long shot of speaker with table and chalkboard	Now we are going to give you some data to work with and a selection of several different interpretations of that data in the form of multiple choice items. Would you try your hand at approximating molecular dimensions?
Fade out	

SUMMARIZED OUTLINES OF THE TELEVISION SCRIPTS

Inertia

The opening shot is of a low friction puck gliding across a table top. The accompanying dialogue in the scene is in reference to perpetual motion according to the Webster dictionary definition. The next shot is of line drawings of several types of wheel-like devices which were unsuccessful attempts to make perpetual motion machines. The drawings are followed by a closeup of a real radiometer which is set in motion by a bright light being focused upon it. Simultaneously, the dialogue is presented concerning the workings of the radiometer. The picture then changes to the lecturer pushing a chalk eraser across the top of a laboratory demonstration desk. The lecturer very briefly mentions some of the history concerning the laws of motion up to the time of Galileo, and leads into Galileo's famous mental experiment about the ball on a slope. This is the same experiment described in the Physical Science Study Committee physics text book. The next few minutes of the tape is devoted to the operation, by the lecturer, of an apparatus consisting of a ball bearing and a slope similar to the one sketched in the Physical Science Study Committee physics text book. While using the slope apparatus, the lecturer defines velocity and force. Questions are put to the audience concerning the performance of the ball bearing on the slope. However, the answers are not given by the lecturer, since the questions are intended to point out key properties of inertia. Finally, in conclusion, a six point summary is printed out on the screen as the lecturer reads them aloud. The tape ends with the question, "Do you believe that perpetual motion is possible?"

Conservation of Mechanical Energy

The scene opens showing a room with a pendulum suspended from the ceiling. A man enters and sets the pendulum in motion, allowing it to swing for a few oscillations. Standing with the back of his head touching the wall, he pulls the bob up to the tip of his nose and lets it swing free. The camera pans to follow the bob. An instant before the bob reaches his nose on the return swing, a voice says, "Let's stop it right there!" The picture snaps to the lecturer who asks the audience whether they think that the man suffered a broken nose. A lecture about motion and energy follows in which work, potential energy, and kinetic energy are defined and discussed. Some props such as a slinky spring and sling shot are used, but the major portion of the tape is taken up with very tight shots of a pad of paper on which the lecturer sketches diagrams, puts down new terms, and writes out equations such as: Work = force x distance, $mgh + \frac{1}{2}mv^2$ = Total energy and mg = weight. Energy due to the gravitational field of the earth is compared to a spring pulling objects back to earth, and the definition of a newton is stated in simple terms. A printout of the summary of the points mentioned in the tape is put on the screen and is read out loud by the lecturer. Finally, the audience is asked again whether the man at the beginning of the tape was struck with the pendulum bob. The opening scene is then rerun with its ending, and the audience sees that the pendulum could rise no higher than it started, and could not possibly have struck the man's nose.

Analysis of Levers

At the opening of the tape, the lecturer stands behind a laboratory demonstration desk and says, "The great philosopher, Archimedes once said, 'Give me a place to stand and I will move the earth,' and in making this boast, Archimedes was undoubtedly referring to the lever." The lecturer proceeds to discuss the three classes of levers and uses a meter stick and a world globe to illustrate a lever in action. He shows where the fulcrum, point of effort or force and the resulting lift positions are located on the lever. Diagrams of levers found in human body such as the jaw with its hinge points are discussed. A beam balance and a seesaw help in introducing mechanical advantage, however, mechanical advantage per se is not mentioned. Although several equations involving force applied and lever arm distance are written out and discussed, the "law of the lever" is never stated. Recognition and application of a formula for lever analysis is left to the students. A printout of the summary of the salient points mentioned during the lecture is shown and is narrated by the lecturer. The tape closes with the lecturer stating that the class will be given an opportunity to test their skill at working with data concerning levers and weights.

APPENDIX B

MOLECULAR LAYERS

Molecules and atoms are so small that we cannot see them to measure their size. By using an indirect method, however, we can get an indication of the order of magnitude of the dimensions of some molecules.

A small quantity of oil placed on the surface of water will spread out to form an exceedingly thin film. The thickness of this film is at least equal to the thickness of one oil molecule. Hence if we can find the thickness of the layer of oil, we can conclude that the thickness of the oil molecule is at most no greater than the thickness of the film.

Oleic acid is a good example of an easily available material that will form a thin film. One drop of pure oleic acid dropped into a small swimming pool will cover its entire surface. Of course, if the whole surface of the pool is covered, you are not sure the film could not be thinner. To get the thinnest possible film in a small container, we shall use a drop of a dilute solution of oleic acid in alcohol.

Measure 5 cm^3 of oleic acid and 95 cm^3 of alcohol into a graduated cylinder and place the solution in a clean bottle. Shake the mixture well. Then measure off 5 cm^3 of this solution and mix with 45 cm^3 of alcohol. Calculate the concentration of this solution.

Fill a large, clean, shallow tray with water to a depth of about one centimeter. Dusting the surface of the water lightly with chalk or lycopodium powder will make the film visible. (Chalk rubbed on sandpaper will produce clean chalk dust.)

To make sure the film is caused by the oleic acid and not by the alcohol, first drop one or two drops of alcohol in the tank with the eyedropper. What do you observe?

Now use the eyedropper to apply a drop of oleic acid solution. Measure the average diameter of the film and calculate its area. Do two drops form twice the area of one drop? How about three drops? What conclusions do you draw from your answers?

Find out how many drops of this size there are in a cubic centimeter and, using the volume of the drop and the area of the layer, calculate the thickness of the layer. Estimate the accuracy of this calculation, considering the error introduced in each step.

If the thickness of the layer were magnified to 1 cm, how tall would you be on the same scale?

If the layer is considered to be one molecule thick and the molecules are assumed to be essentially cubes, how many molecules would fill one cubic centimeter?

The density of oleic acid is 0.89 gm/cm^3. What is the mass of one molecule?

A VARIATION ON GALILEO'S EXPERIMENT

Galileo argued that an object moving horizontally would continue to move horizontally forever at constant speed. He supported this argument with his observation that an object accelerates when it moves down an incline and decelerates when it moves up, reaching nearly the same height it had when it started. We can perform a similar experiment with a pendulum, observing the fall of the pendulum bob on one side of its swing and its rise on the other.

Suspend a pendulum at least 3 m long from the ceiling or a suitable stand. Clamp the pendulum thread 40 or 50 cm above the bob so it swings from this point and not from where it is suspended (Figure 1). Bring the bob sideways until it is a measured distance d above the lowest level of its swing. Let it go. Compare the distances the bob travels on either side of the lowest point. How does the highest level reached after release compare with the height from which the bob was released?

Now, instead of letting the pendulum swing through a normal arc, interpose a barrier so that, when released, the pendulum swings from the barrier (Figure 2). What do you predict about (a) the horizontal distance the bob will travel upon release, (b) the level to which it will rise? Try it.

Next, with the barrier in the same place and the clamp at various positions ranging from the initial one to the point of suspension, let the bob go from a measured height above the lowest level of its swing. Determine how high it rises at the end of its swing and roughly measure the distance from the center point. Give each pendulum length several trials. Be sure to let the bob go from the same position each time.

From your data, can you make a conjecture about the height and the horizontal distance the bob should reach from the same point of release if the pendulum could be made 10, 50, or thousands of meters long?

What do your results suggest would happen to a ball moving on a perfectly smooth, horizontal surface?

Do you think perpetual motion is possible?

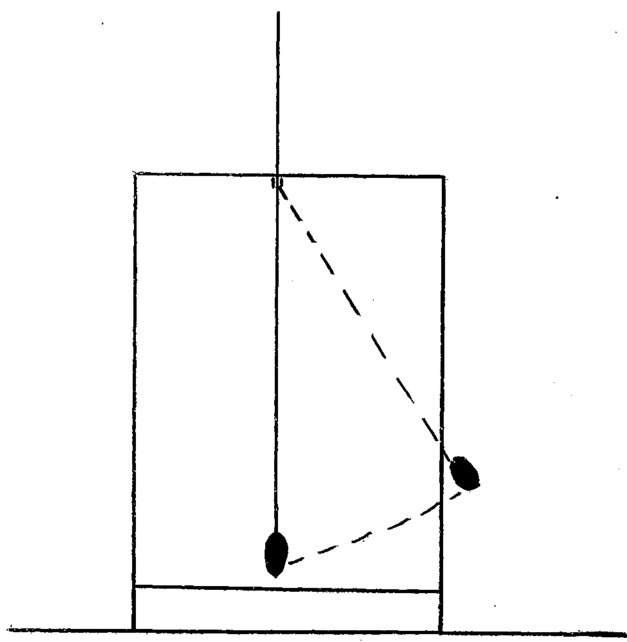

Figure 1

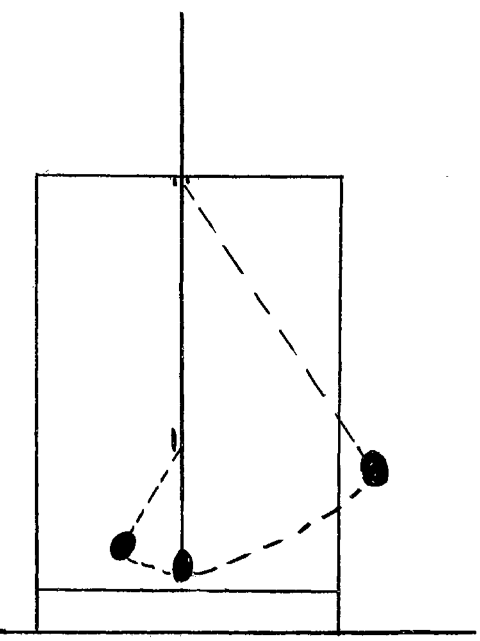

Figure 2

CHANGES IN POTENTIAL ENERGY

Hang a spring from a stand and attach a mass to it. Lift the mass a few centimeters above its rest position and let it fall. At the top and bottom of its motion it is at rest. When the mass is at the bottom of its motion, its energy is stored in the spring. At the top of its motion its energy is stored in the gravitational field. Compare the change in gravitational energy with the change in potential energy stored in the spring.

You can find the change in potential energy of the spring when it is stretched a distance Δx from x_1 to x_2 by calculating the work done in stretching it from x_1 to x_2. The change in gravitational potential energy when the mass falls this same distance Δx can be found by calculating the work done in lifting the mass through the distance Δx. You can then compare the graviational energy lost as the mass falls from rest to its lowest point with the spring energy gained as the spring stretches.

To find the potential energy of the spring, we first find how the extension x of the spring is related to the force that stretches it. Hang known masses on the end of the spring and find the extension x in meters and note the corresponding force F. Plot a graph of x as it corresponds to F. Is F proportional to x for this spring in the range of your measurements?

If your graph is a straight line, find the spring constant $k = \frac{F}{x}$ from the slope and write down the potential energy ratio of the spring, that is, the equation for the energy stored in the spring as it corresponds to the extension of the spring.

Now hang a mass on the spring and support it with your hand so the spring extends about 10 cm more than its natural length when hanging without the mass. Mark the lower end of the unloaded spring position and the point from which you drop the mass. Release the mass and note how far it falls. Mark the lowest point of the fall. (Use wire inserts in the peg board for marking the spring extensions.) Release the mass several times until you have accurately located the lowest point of the vibrations.

Calculate the loss in gravitational potential energy and the gain in potential energy of the spring when the mass falls. How do they compare? Repeat the above experiment, releasing the mass from a point about 15 cm from the lower end of the unloaded spring. Repeat the experiment with a lesser mass and calculate the change in gravitational potential energy and spring potential energy when the mass falls from a point about 5 cm below the end of the unloaded spring.

Is energy conserved in these interactions between the masses and the spring? Are they elastic interactions?

What is the sum of the two potential energies when the mass has reached the halfway mark in its fall? How does this compare with the initial energy of the mass? How do you explain this? How could you check your explanation?

ANALYSIS OF LEVERS

First hold on to the 50 cm - 100 cm end of meter stick with one hand. Then, at random, loop two washers over the meter stick somewhere between 10 cm and 30 cm mark. Note that the meter stick fulcrum is at 50 cm. Next loop three washers over the 50 cm - 100 cm end of the meter stick at a position where the two weights just balance. This may require some adjusting. Once you have secured a balance, record the cm mark of each weight in a table similar to the ones on Form A of the TV test.

Repeat several trials with different weight positions while using two and three washer weights. Record these trials.

Could you write an equation that would represent the relation of weights to distances of a lever? If you can, write it out and test the data that you have gathered from the trials in your equation. Is it consistent for all data?

Next, repeat and record the data of the trials that you did above; only this time record the distance of the weights in centimeters from the fulcrum rather than simply reading the centimeter mark on the meter stick.

Now can you write an equation that would represent the relation of weights to distances of a lever? If you can, write it out and test the data that you have gathered from the trials in your equation. Is it consistent for all data?

Make a new table with your data but this time entitle it "Distance in centimeters of sets of washers from the balance point of the lever multiplied by the number of washers." In other words, make a table that has in one column the distance that the two washer weight is from the fulcrum. Then multiply that distance by 2 because the weight is two washers. Place that product in a column headed "two washers." Do the same for the "three washers" column.

Do you see a relation between the distances multiplied by two and the distances multiplied by three? Can you now write an equation showing the relation between weight and distance with a lever? If you can, plug in the data that you have gathered. Is the equation reliable?

Finally, instead of two washers and three washers, make trials for four washers and five washers; and five washers and six washers. Plug this new data into your equation. Does it still work?

Write a universal equation (use letters instead of numbers) that can be used with all levers.

If you have time, separate the two washer group and hang two single washers a few centimeters apart on an end of the meter stick. On the opposite end separate the three washers group until each of the three washers are a few centimeters apart. Attain a balance. Write an equation that would satisfy this new condition.

APPENDIX C

TELEVISION LECTURE SERIES DATA INTERPRETATION*

DIRECTIONS:

Please do not mark in the question booklet.

Please do however,

1. Choose only ONE best answer for each question.
2. Place the letter corresponding to your choice with the number of the question on the answer sheet provided.
3. Use scratch paper and pencil.
4. Answer the easy questions first and then return to the more difficult.
5. Make reasonably intelligent guesses.

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*Pretest segment given in four parts

Form A
Title: "Molecular Layers"

TEST NUMBER ONE

1. The best reason why oleic acid can be used in an experiment which is designed to acquire data that will allow the approximation of the size of an oleic acid molecule is:

   a. It is colorless.

   b. It is heavier than water.

   c. It can be purchased only from chemical supply houses.

   d. It spreads to a one molecule thick layer.

   e. It causes light to reflect blue and gold colors.

2. In order to measure approximately the size of a molecule (by the method shown in the TV lecture) which of the following data assemblages must be known?

   a. Volume and weight of the material used

   b. Volume and color of the material used

   c. Volume and area of the material used

   d. Volume and price of the material used

   e. Volume and chemical composition of material used.

3. In order to properly calculate the area of a circle of a thin film or layer, which one of the following data groups would be absolutely essential?

   a. Circumference = 16 cm

   b. The thickness of the layer equals 2×10^{-10}cm

   c. $\Pi = 3.14$ and density = 2×10 cm^2

d. Density = 2×10^{-1} grams/2×10^{-1}cm

e. Π = 3.14 and the diameter of the circle = 8 cm.

4. In order to properly calculate the volume of a sample material, one would need which one of the following data groups?

   a. 60¢ per liter and green in color

   b. 3.3 grams and very brittle

   c. 3.3 grams per cm^3 and is packaged in a cylindrical container

   d. Length = 6 cm, width = 5 cm, and thickness = .00001 cm

   e. Length = 6 cm, width = 5 cm, and weight = .00001 grams.

5. With the data: Area = $10^6 cm^2$ and volume = 10^{-4} liters, one could calculate which of the following?

   a. Density of the sample

   b. Distance between the molecules of the sample

   c. Thickness of the sample

   d. Weight of the sample

   e. Value in cents of the sample.

6. With the data: Volume = 10^{-3} liters and number of molecules = 10^6 one could calculate which of the following?

   a. Approximate volume occupied by each molecule

   b. Approximate weight of each molecule

   c. Thickness of sample

   d. Density of sample

   e. Color of sample.

7. All aspects of a hypothetical experiment designed to measure the size of a gold molecule by the single layer method were fool proof <u>except one</u>. Within the list of aspects below is the single aspect

that is suspect of causing the greatest error in the experiment. Which one is it?

a. The color of the gold is not bright yellow.

b. The weight of the gold sample is 19.3 grams.

c. The sheet of gold to be used is not absolutely smooth on one surface.

d. The gold is very old.

e. The volume of the gold sample is 1 cm^3.

8. Which one of the data groups below supplies the best information which would make it possible to approximate the diameter of a molecule found in a thin layer that is only one molecule thick?

a. Volume = $6.81 \times 10^{-3} cm^3$ and in column two of the periodic chart.

b. Area = 4.2×10^{-18} cm^2 and blue-gold color.

c. Density = 1 $gram/cm^3$.

d. Volume = 1 cm^3 and Area = $10^7 cm^2$.

e. Price = $4.01/KG and non-toxic.

9. Which one of the assumptions listed below would cause the greatest possible error in calculating the volume actually occupied by ONE oleic acid molecule?

a. That all of the oleic acid molecules are of equal weight

b. That all of the oleic acid molecules are of equal volume

c. That all of the oleic acid molecules are of the same color

d. That all of the oleic acid molecules are of different colors

e. That all of the oleic acid molecules are perfect cubes.

10. Picture a cigar box with the lid open and filled with water. There is a device that will capture and measure all water forced from the

box. The object is to force water out of the box, using one of the types of objects listed below. The only two rules are that there can be no items protruding above the top of the box and the items must be placed in the box in a position that will drive the most water out of the box. Which one of the types of items listed below would most satisfactorily accomplish this task?

a. Stacked pennies (cylinders)

b. Marbles (spheres)

c. Bee bees (spheres)

d. Football charms from charm bracelets

e. Dice (cubes).

11. Data: Volume is 5×10^{-2} cm^3, thickness 1×10^{-5}cm. A piece of gold having the volume stated above was hammered into a thin sheet with a final thickness also stated above. What is the area of the sheet?

a. $2 \times 10^{-7} cm^2$

b. $2 \times 10^{-3} cm^2$

c. $5 \times 10^{3} cm^2$

d. $5 \times 10^{5} cm^2$

e. $5 \times 10^{7} cm^2$.

12. If the same volume of gold is stated in problem No. 11 were hammered until it was 1/2 the thickness stated in No. 11, its new area would be:

a. $4 \times 10^{-7} cm^2$

b. $1 \times 10^{-7} cm^2$

c. $2.5 \times 10^{3} cm^2$

d. $1 \times 10^{4} cm^2$

e. $5 \times 10^{7} cm^2$.

13. A single layer of equal sized bee bees completely covers the bottom of a square pan that is 20 cm on a side. When the bee bees are poured into a graduate cylinder, they fill it to the 40 cm^3 mark. The diameter of one of the bee bees is about:

a. 0.01 cm

b. 0.1 cm

c. 0.5 cm

d. 1 cm

e. 2 cm.

14. A single layer of marbles completely covers the bottom of a round layer cake pan. The radius of the pan is 50 cm. The area of the pan is most nearly:

a. 5,000 cm^2

b. 5,000 cubic centimeters

c. 600 cm^2

d. 8,000 cm^2

e. 1,000 cm^2.

15. A quantity of ball bearings 1 cm in diameter are purchased by volume. The volume purchased was 1.5 liters. Approximately how many ball bearings were bought?

a. 15

b. 150

c. 1.5

d. 750

e. 1,500.

16. A quantity of confectioner's sugar fills a box 16 cm x 8.0 cm x 5.0 cm. How many packages can be placed in a freight car 22 meters x 2.4 meters x 2.4 meters?

a. 6×10^4 boxes

b. 2×10^5 boxes

c. 1,000 boxes

d. 10 boxes

e. 400 boxes

17. Fifty cubic centimeters of spherical seeds are to be laboriously counted out one by one. However, it is found that each seed has a radius of about .05 cm. One could then say that in the volume mentioned above, there should be a quantity of seeds closest to:

a. 100

b. 200

c. 10

d. 50

e. 500

18. A single human nerve cell may extend 100 cm from the spinal column to the foot and be as much as 10^{-4} cm in average diameter. If we assume that each of the constituent atoms of this structure occupies a volume of 3×10^{-23} cm^3, what total number of atoms is required to build it?

a. 1×10^{-15} atoms

b. 3×10^{16} atoms

c. 8×10^4 atoms

d. 6×10^{10} atoms

e. 2×10^{-4} atoms.

Form A
Title: Inertia

TEST NUMBER TWO

Items 1 - 8 are concerned with matching different types of data with an appropriate type of motion. Each item mentions an object and its condition as to motion. Please select the type of motion that the object will exhibit.

Type of motion (same set for 1 - 8, use only one selection per item).

a. Speeds up until it hits something or reaches bottom
b. Goes around at about a constant speed
c. Slows down and stops
d. All of the above
e. None of the above.

1. Automobile (out of gas and without brakes)
2. Book which has been pushed so that it slides on desk
3. Chalk which is dropped
4. Ball rolling downhill
5. Moon revolving around earth
6. Earth rotating on its axis
7. A molecule of water which has just passed over the upper edge of a waterfall
8. Astronauts in orbit.

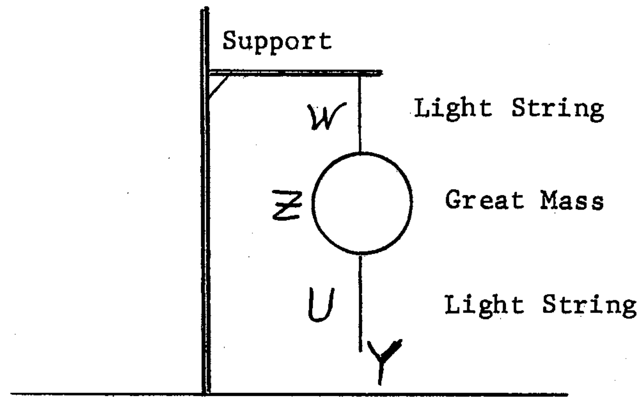

Figure 1

9. Refer to Figure 1 above:

A powerful and swift downward directed force applied at Y would most likely result in:

a. the string breaking at W

b. the great mass breaking at Z

c. the string breaking at U

d. nothing happening

e. There is no scientific evidence available in order to predict what most likely would result.

10. Refer to Figure 1 above. A powerful and slow steady downward directed force applied at Y would most likely result in:

a. the string breaking at W

b. the great mass breaking at Z

c. the string breaking at U

d. nothing happening

e. There is no scientific evidence available in order to predict what most likely would result.

11. A ball bearing is released from rest on the right-hand incline of the TV lecture slope apparatus from a height of 20 cm above the lowest point of its path. If there were no friction, what is the highest possible vertical rise of the ball bearing on the left-hand slope?

    a. Impossible to tell because the problem fails to state if both inclines are equally sloped

    b. 10 cm

    c. 15 cm

    d. 20 cm

    e. None of the above.

12. A ball bearing is released from rest on the left-hand incline of the TV lecture slope apparatus at a height of 15 cm above the lowest point. If there is no friction, what is the vertical maximum to which the ball bearing could rise on the right-hand incline?

    a. Impossible to tell because the problem fails to state if both inclines are equally sloped

    b. 10 cm

    c. 15 cm

    d. 20 cm

    e. None of the above.

13. A ball bearing is released from rest on the right-hand incline of the TV lecture slope apparatus at a height of 10 cm above the lowest point. If there is no friction and if the left-hand incline rises vertically 1 cm for every 10 cm of horizontal distance, how far will the ball bearing travel in horizontal distance?

    a. 100 cm

b. 200 cm

c. 50 cm

d. 1 kilometer

e. 10^3 cm.

14. A ball bearing is released from rest on the left-hand incline of the TV lecture slope apparatus at a height of 10 cm above the lowest point. If there is no friction and if the right-hand incline rises only 1/2 cm for every 10 cm of horizontal distance, how far will the ball bearing go in horizontal distance?

a. 100 cm

b. 200 cm

c. 50 cm

d. $\sqrt{2} \times 10^3$ cm

e. 1 kilometer.

15. A car is traveling at 60 m.p.h. on a level road. If the sum of all the forces acting on the car is zero, the car will:

a. slow down, but never come to rest

b. slow down and come to rest

c. go faster until it hits something

d. accelerate at a constant rate

e. continue at 60 m.p.h.

16. A body will move with a constant velocity if:

a. there is one constant force acting on it

b. there is a constantly changing force acting on it

c. there are no forces acting on it

d. there are unequal but opposite forces acting on it

e. there are two parallel and constant forces acting on it.

17. Suppose we have a pendulum as sketched in Figure 2. The support of the pendulum is 100 meters long. The pendulum weight or bob is pulled up to a height of 1 meter on the right side and released. What do you estimate the highest point of rise of the bob on the left side to be?

a. 2 meters

b. .1 meter

c. 1 meter

d. 1/2 the height of the highest rise of the left side

e. Not enough data available for a good estimate.

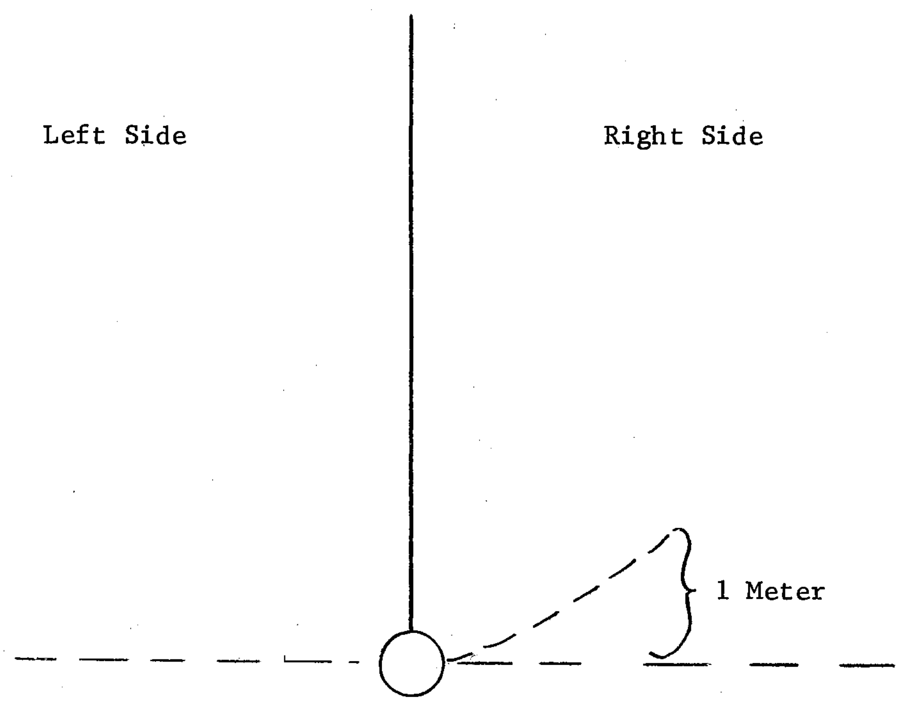

Figure 2

18. Suppose we use again Figure 2, but this time picture the bob to be pulled up on the left side to a height of 1 meter and then released. Now what do you estimate the highest point of rise of the bob on the right side to be?

a. 2 meters

b. .1 meter

c. 1 meter

d. 1/2 the height of the highest rise of the left side

e. Not enough data available for a good estimate.

19. Consider the sketch in Figure 3. It is identical to the sketch in Figure 2 except that a barrier at X has been so placed so as to force the bob to swing on the left side about a point not 100 meters above the bob as on the right side but rather only 5 meters above the bob. (Please read the foregoing statement once again and look at Figure 3.) If the bob were pulled up to a maximum height of .5 meters on the right side and released then what would be the maximum rise of the bob on the left side?

a. 1.5 meters

b. .5 meters

c. There is not enough information furnished to make an estimation.

d. 1 meter

e. 3 meters.

20. Again consider Figure 3. However, this time the bob is pulled to a maximum height of 3 meters on the left side and released. The barrier at X is unchanged. What should the maximum rise of the bob be on the right side?

a. 1.5 meters

b. .5 meters

c. There is not enough information furnished to make an estimation.

d. 1 meter

e. 3 meters.

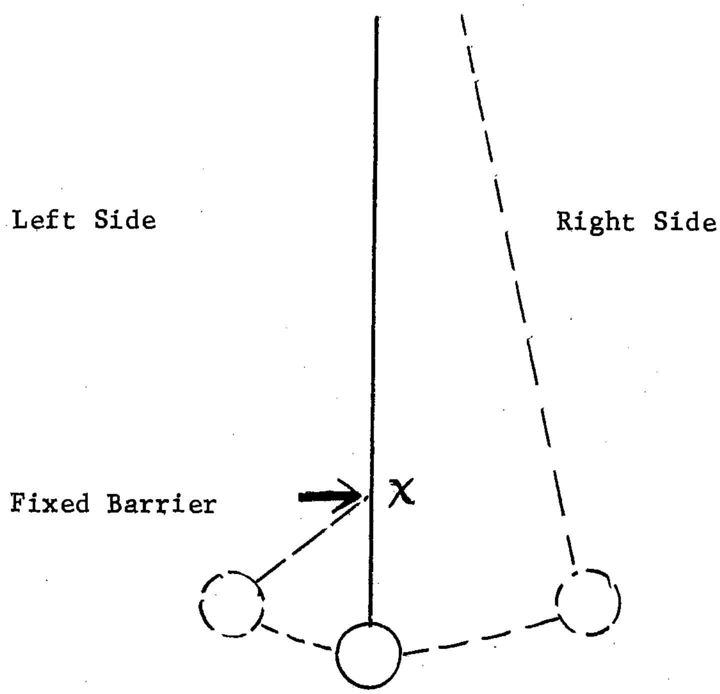

Figure 3

Form A
Title: Conservation of Mechanical Energy

TEST NUMBER THREE

Items 1 - 6 are concerned with matching different types of data with the appropriate energy relations. Each item mentions an energy conversion situation. Please select the type of energy conversion that the system will exhibit.

Types of energy relations (same set items 1 - 6, use only one selection per item).

a. Potential to kinetic energy
b. Kinetic to potential energy
c. 50% KE and 50% PE
d. 25% KE and 75% PE
e. 75% KE and 25% PE.

1. Rain falling from a rain cloud
2. A ball being carried to the top of a tower
3. The dropping of a ball from a tower
4. The ball after being dropped is 1/2 of the way to the ground.
5. The ball after being dropped is 3/4 of the way to the ground.
6. The raising of the flag in the morning.
7. In determining the <u>potential</u> energy of a system, which one of the following data groups would be most useful?
   a. Velocity = 20 meters/second, north and weight (mg) = 4.5 newtons.
   b. Velocity = 20 kilometers/hour, south and height = 100 meters.
   c. Mass = 1 kilogram, acceleration due to gravity (g) = 9.8 meters/second^2.

d. Mass = 1 kilogram, acceleration due to gravity (g) = 9.8 meters/second^2 and height = 100 meters.

e. Mass = 1 kilogram and velocity = 20 meters per second, north.

8. In determining the <u>kinetic</u> energy of a system, which one of the following data groups would be most useful?

a. Velocity = 20 meters/second, north and weight (mg) = 4.5 newtons.

b. Velocity = 20 kilometers/hour, south and height = 100 meters.

c. Mass = 1 kilogram, acceleration due to gravity (g) = 9.8 meters/second^2.

d. Mass = 1 kilogram, acceleration due to gravity (g) = 9.8 meters/second^2 and height = 100 meters.

e. Mass = 1 kilogram and velocity = 20 meters per second, north.

Refer to Figure 1 for questions 9 - 14.

a. α

b. β

c. Δ

d. Ω

e. Figure 1 does not supply sufficient data with which to make an interpretation.

9. Consider the data shown in the work graph. Work was accomplished most quickly in which system?

10. Consider the data shown in the work graph. Work was accomplished most slowly in which system?

11. Consider the data shown in the work graph. The most work was done in which system?

Work = Force x Distance

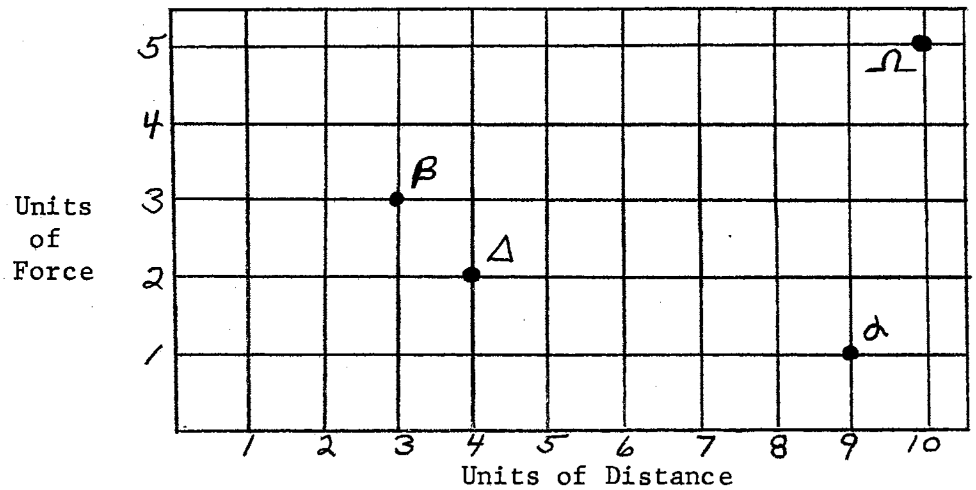

Figure 1

12. Consider the data shown in the work graph. The least work was done in which system?

13. The system that exhibits 8 units of work is:

14. Refer again to the graph of Figure 1. The two systems that have accomplished the same quantity of work are:

    a. α and β

    b. β and Δ

    c. β and Ω

    d. Ω and Δ

    e. β and α

Refer to Figure 2 for questions 15 - 18.

Force Applied Vs. Spring Displacement

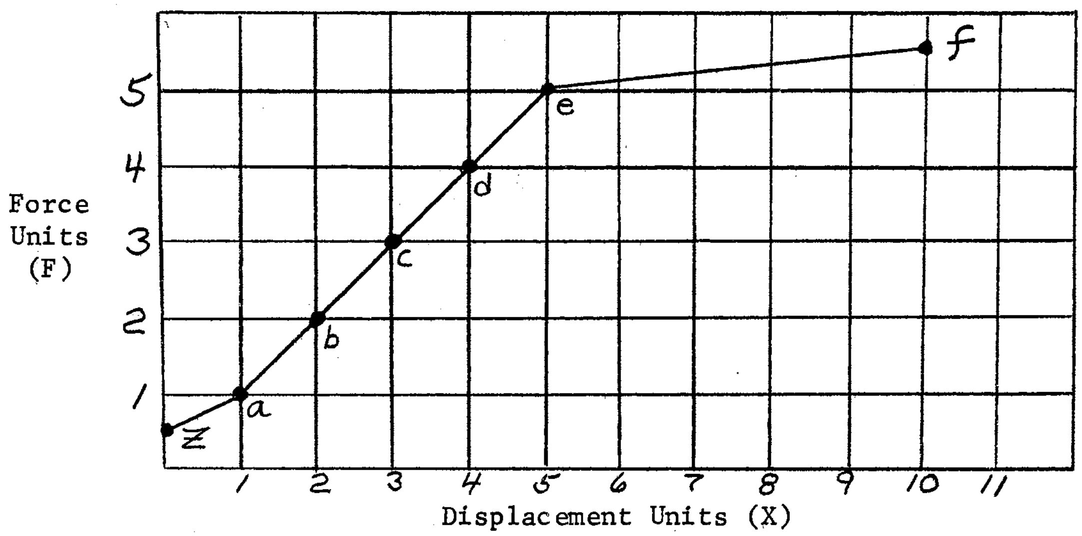

Figure 2

15. A certain spring's behavior in terms of stretch (displacement) and pull applied (force) is plotted on the graph above. Which one of the choices listed below would be the best interpretation of the data between points "a" and "e"?

a. Two units of displacement are brought about by the application of four units of force on the spring.

b. Two units of force applied to the spring result in four units of spring displacement.

c. Force is directly proportional to displacement in this spring.

d. There is no relation between force and displacement in this spring.

e. Each additional force unit results in two more units of displacement over and above the previously applied unit of force.

16. Which one of the choices listed previously would be the best interpretation of the data between points "d" and "f"?

    a. Force applied is directly proportional to resultant displacement in this spring.

    b. Each additional force unit results in two more units of displacement over and above the previously applied unit of force.

    c. The spring has been "sprung" and will no longer behave as it did between points "a" and "e".

    d. The spring will require increasing force for it to be displaced.

    e. The situation shown between points "d" and "f" is identical with the situation shown between points "z" and "b".

17. Consider data between points "a" and "e" only: If force units are called F and displacements are called X and if there is a constant ratio between these two values, it is most nearly:

    a. F/X = 5

    b. F/X = 1

    c. F/X = 2

    d. F/X = 3

    e. There is no constant ratio.

18. If there is a constant ratio of F and X, then it can be most easily read from the graph, between points "a" and "e", by noting:

    a. the number of data points on the line

    b. the area under the curve

    c. the slope of the line

    d. the length of the line

    e. It is not possible to determine from the data available.

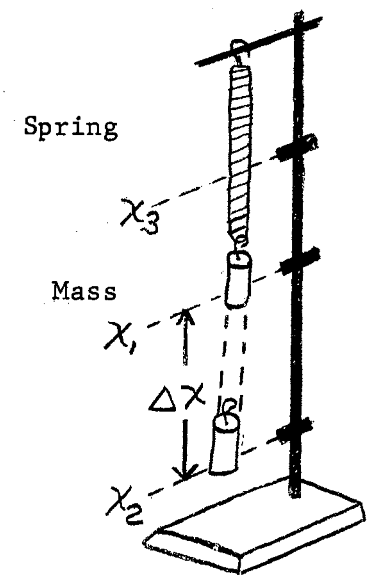

Figure 3

Consider Figure 3. It is a sketch of the apparatus used to gather the data found in the graph of Figure 2. The apparatus is designed to detect changes in potential energy. At the top and bottom of its motion, the mass is at rest. When the mass is at the bottom of its motion, its energy is stored in the spring. At the top of its motion, its energy is stored in the gravitational field or its energy is due to its higher position. Compare the change in gravitational energy with the change in potential energy stored in the spring.

19. If there is a constant ratio of F and X, let it be called K. Now which relation below best states that the potential energy stored in the spring corresponds to the extension or displacement (X) of the spring?

    a. $K = F/X$

    b. $MGH = 1/2\ KX^2$

c. $MGH = 1/2\ MV^2$

d. E total = PE + KE

e. There is no constant ratio of F and X.

20. Refer to Figure 3. Imagine yourself holding the weight at X_1. At X_1 the spring is just half way between being stretched to the maximum for the weight attached (X_2) and the position immediately before the spring stretches (X_3) because of the weight attached. In other words, X_3 roughly corresponds to point "a" on the graph of Figure 2; X_2 roughly corresponds to point "e" on the graph, and X_1 corresponds to a point about 1/2 way between "a" and "e." Now you drop the weight from X_1, and the weight bobs up and down. Which statement below best presents the energy relationship of this system? (Consult both Figures 2 and 3.)

a. The farther the weight falls, the faster it bobs back up.

b. The sum of the potential energies when the weight is halfway down (X_1) is less than the potential energy at the start (X_3), and finish (X_2) of the fall. The difference equals the kinetic energy of the falling weight.

c. The spring can store more energy than can gravity.

d. There is a continual change in the potential energy of the system.

e. There is no energy relationship in this system.

Form A
Title: Levers

TEST NUMBER FOUR

A meter stick has a hole drilled through its center at the 50 centimeter mark. A nail is slid through the hole and driven into a mount. The stick can rotate freely with the nail at the axis. Rings of equal weight are placed by means of wire loops at different centimeter marks on the stick. In the following tables are data gleaned from a series of trials in balancing with the apparatus described above. Please carefully read the table titles before attempting to select the missing data from the choices available. Select the best answer for each blank of each table.

TABLE 1. Questions 1 - 8.

Distance in Centimeters of sets of rings from the balance point (50 cm) of the lever multiplied by the number of rings.

Trial	Two Rings	Three Rings
1	70.2	-----------
2	55.1	-----------
3	---------	62.3
4	---------	38.4
5	63.4	-----------
6	92.1	-----------
7	98.2	-----------
8	---------	47.1

For Table I, select the best data from the data groups below:

Trial	A	B	C	D	E
1	20.2	27.8	29.8	70.3	79.3
2	61.3	55.1	5.1	44.9	18.1
3	37.7	12.3	62.2	78.1	1.1
4	8.5	11.5	38.5	11.6	61.6
5	28.3	63.5	36.6	13.4	10.0
6	8.0	92.2	7.8	42.2	16.0
7	22.2	1.2	50.0	48.8	98.1
8	18.8	2.9	52.9	98.3	47.2

TABLE II. Questions 9 - 12.

Distance in centimeters of sets of rings from the center of the meter stick when the lever is in balance.

Trial	Two Rings	Three Rings
9	33.2	-----------
10	---------	16.4
11	---------	6.9
12	40.3	-----------

For Table II. Select the best data from the data groups below:

Trial	A	B	C	D	E
9	18.1	66.8	22.1	26.8	33.3
10	26.2	24.6	83.6	33.6	16.4
11	93.1	43.1	6.9	10.2	21.1
12	59.7	9.7	40.3	72.2	26.9

TABLE III. Questions 13 - 16.

Position, in centimeters from zero, of sets of rings on a meter stick when the lever is in balance.

Trial	Two Rings	Three Rings
13	16.8	-----------
14	---------	66.3
15	---------	56.9
16	9.7	-----------

For Table III. Select the best data from the data groups below:

Trial	A	B	C	D	E
13	83.2	33.2	72.1	16.8	48.3
14	43.1	25.4	16.2	37.8	66.2
15	43.1	39.8	6.9	28.1	56.9
16	43.1	40.3	9.7	90.3	76.9

TABLE IV. Questions 17 and 18.

Position, in centimeters from zero, of sets of rings on a meter stick when the lever is in balance.

Trial	Four Rings	Five Rings
17	20	----------
18	----------	71.0

For Table IV. Select the most suitable data from the data groups below:

Trial	A	B	C	D	E
17	88.3	20	74.2	80.0	30.0
18	24.0	76	71.0	29.0	21.0

19. The relation of weight to distance in the operation of a lever is best shown in which of the data groups below? (Nts = Newtons)

a. 3 nts + 3 cm = 4 nts + 4 cm.

b. 3 nts + 2 cm = 2 nts + 3 cm.

c. 3 nts/2 cm = 2 nts/3 cm.

d. 3 nts x 2 cm = 2 nts x 3 cm.

e. None of the above indicate the relationship of weight to distance of the lever.

20. which one of the data groups below best illustrates, mathematically, the balancing of a lever?

a. 16 nts x 2 meters = 4 meters/8 nts.

b. 16 nts + 2 meters = 2 meters + 16 nts.

c. 16 nts + 2 meters = 16 meters + 2 nts.

d. 16 nts x 2 meters = 8 nts x 4 meters.

e. None of the above illustrates the balancing of a lever.

ANSWER SHEET TEST NO. ONE	ANSWER SHEET TEST NO. TWO	ANSWER SHEET TEST NO. THREE	ANSWER SHEET TEST NO. FOUR
Name Key	Name Key	Name Key	Name Key
1. d	1. c	1. a	1. d
2. c	2. c	2. b	2. b
3. a or e	3. a	3. a	3. c
4. d	4. a	4. c	4. c
5. c	5. b	5. e	5. b
6. a	6. b	6. b	6. b
7. c	7. a	7. d	7. e
8. d	8. b	8. e	8. e
9. e	9. c	9. e	9. c
10. e	10. a	10. e	10. b
11. c	11. d	11. d	11. d
12. d	12. c	12. c	12. e
13. b	13. a	13. c	13. c
14. d	14. b	14. a or e	14. b
15. e	15. e	15. c	15. b
16. b	16. c	16. c	16. e
17. e	17. c	17. b	17. c
18. b	18. c	18. c	18. a
	19. b	19. b	19. d
	20. e	20. b	20. d

TELEVISION LECTURE SERIES DATA INTERPRETATION*

DIRECTIONS:

Please do not mark in the question booklet.

Please do however,

1. Choose only ONE best answer for each question.
2. Place the letter corresponding to your choice with the number of the question on the answer sheet provided.
3. Use scratch paper and pencil.
4. Answer the easy questions first and then return to the more difficult.
5. Make reasonably intelligent guesses.

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*Retest segment given in one part

TEST NUMBER FIVE

1. In consideration of the method of approximating the dimensions of a molecule used during the TV lecture, which of the following data assemblages would be most useful?

   a. Volume and chemical composition of material used

   b. Volume and color of the material used

   c. Volume and price of the material used

   d. Volume and area of the material used

   e. Volume and weight of the material used.

2. The characteristic of oleic acid that allows it to be used successfully in an experiment like that mentioned in the TV lecture is its ability to:

   a. appear colorless

   b. appear heavier than water

   c. appear to reflect light especially blue and gold

   d. appear to form a thin film or layer

   e. appear to be easily available.

3. A volume calculation data would most likely be drawn from which of the groups listed below?

   a. 616 grams and very brittle

   b. 6 grams per cubic centimeter and blue in color

   c. 50¢ per pound and maleable

   d. Thickness of .00002 cm, length of 6 cm, and width of 4 cm

   e. Weight of .00002 grams, length of 6 cm, and width of 4 cm.

4. Which one of the data groups listed below could be used to find the surface area of a thin film or layer?

   a. Circumference = 20 cm

   b. The thickness of the layer equals 4 x 10^{-10}cm

   c. Density is 1 gram/cubic centimeter

   d. Density = 1 gram/cubic centimeter and the value of Π is 3 and 1/7.

   e. Diameter = 8 cm and Π = 3.14.

5. With the data: Volume = 10^{-3} liters and thickness = 10^{-4}cm, one could calculate which one of the following?

   a. Value in cents of the sample

   b. Weight of the sample

   c. Distance between molecules in the sample

   d. Surface area of the sample

   e. Density of the sample.

6. With the data: Volume = $10^{-4}cm^3$ and volume occupied by one unit = 10^{-16}, one could calculate which of the following?

   a. Approximate weight of each unit

   b. Approximate color of each unit

   c. Approximate density of each unit

   d. Approximate number of single units

   e. Approximate shape of single units.

7. Which one of the data groups below furnish the most valuable data from which it would be possible to approximate the radius of a single molecule found in a thin layer of material that is only one molecule thick?

   a. Price = 63¢/gram and non-toxic

b. Density = 1 gram/cm

c. Volume = 1 cm^3 and the area = $10^5 cm^2$

d. Area = 2 x $10^{-5} cm^2$ and bright green color

e. Volume = 1 liter and in column three of the periodic chart.

8. Which one of the assumptions listed below would cause the greatest possible error in calculating the volume actually occupied by one oleic acid molecule?

a. That all of the oleic acid molecules are perfect spheres

b. That all of the oleic acid molecules are of equal volume

c. That all of the oleic acid molecules are the same color

d. That all of the oleic acid molecules are different colors

e. That all of the oleic acid molecules are of equal weight.

9. A chunk of lead having a volume of 6 x $10^{-2} cm^3$ is forced into a thin sheet having a thickness of 2 x 10^{-5}cm. What is the area of the sheet?

a. 5 x $10^7 cm^2$

b. 6 x 10^7 $meters^2$

c. 5 x 10^3cm

d. 63 kg

e. 3 x $10^3 cm^2$.

10. If the same volume of lead as mentioned in problem No. 9 were pressed until it was just 1/2 the thickness of the sheet mentioned in problem No. 9, then its area would be changed to:

a. 6 x $10^3 cm^2$

b. 12 x $10^3 cm^2$

c. 24 x $10^3 cm^2$

d. $1.5 \times 10^3 cm^2$

e. $1 \times 10^3 cm^2$.

11. A single layer of equal-sized spheres entirely cover a square. The square measures 30 cm on each side. When the total of these spheres are placed in a volume-measuring device, a volume of 60 cm^3 is observed. The diameter of each sphere is most nearly:

a. $1 \times 10^{-2} cm$

b. $3 \times 10^{-2} cm$

c. $5 \times 10^{-2} cm$

d. $7 \times 10^{-2} cm$

e. $9 \times 10^{-2} cm$.

12. A single layer of equally-sized spheres entirely cover a circle. The radius of the circle is 5 cm. The area of the circle is most nearly:

a. 68 cm^2

b. 78 cm^2

c. 88 cm^2

d. $3 \times 10^3 cm^2$

e. $4 \times 10^3 cm^2$

13. A layer cake pan with a bottom area of $4 \times 10^2 cm^2$ is completely filled with one single layer of spheres that are all the same size. The total of each sphere is about:

a. $1.5 \times 10^1 cm$

b. $.5 \times 10^{\circ}$ cm

c. $5.5 \times 10^{10} cm$

d. $55 \times 10^3 cm$

e. $55 \times 10^{-5} cm$.

14. A quantity of ball bearings 1 cm in diameter are purchased by volume. The volume purchased was about 3 liters. Approximately how many ball bearings were purchased?

a. 15

b. 150

c. 3,000

d. 6,000

e. 1,500.

15. If it were found that 500 cm^3 of spheres weighed about 500 gms, and there were about 500 spheres in that volume, then the density of each sphere would most nearly be:

a. 5 gm/cm^3

b. 2 gm/cm^3

c. 1 gm/cm^3

d. 4.8×10^3 gm/cm^3

e. 28 ounces.

Types of motion (same set for 16-19, use only one selection per item).

a. Speeds up until it hits something or reaches bottom.

b. Goes around at about a constant speed.

c. Slows down and stops

d. All of the above

e. None of the above.

16. Eraser which has been pushed so that it slides on desk.

17. Pencil which is dropped.

18. Beach ball rolling down a sand dune.

19. A molecule of lava which has just oozed over the rim of a volcanic cone.

20. Refer to Figure 1. A swift and powerful force to the right is applied at γ. The most likely result of this action would be:

 a. The thread breaking at β

 b. The puck breaking at Δ

 c. The thread breaking at ∂

 d. Nothing happening

 e. There is no scientific evidence available with which to make a prediction as to what will result.

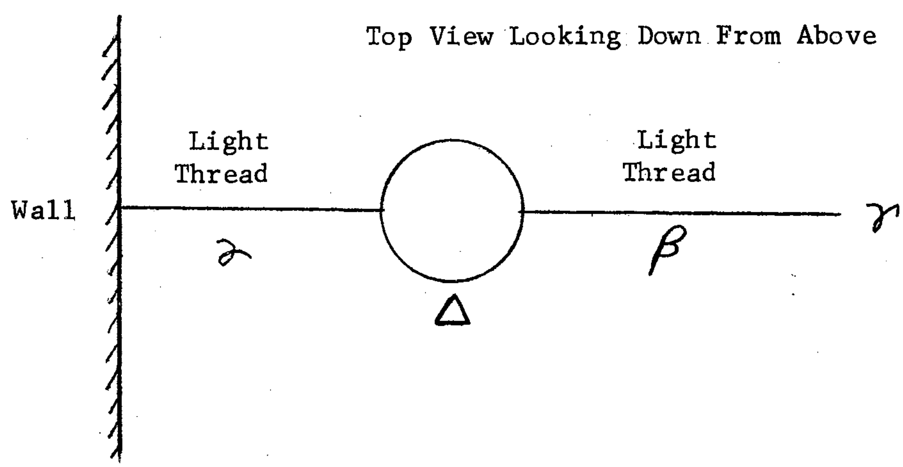

Figure 1

21. A marble is released from rest on the left-hand incline of the TV lecture slope apparatus from a height of 30 cm above the lowest point of its path. If there were no friction, what is the highest possible vertical rise of the marble on the right-hand slope?

    a. Impossible to tell because the problem fails to state if both inclines are equally sloped

    b. 30 cm

    c. 60 cm

    d. 45 cm

    e. None of the above.

22. A marble is released from rest on the right-hand incline of the TV lecture slope apparatus at a height of 45 cm above the lowest point. If there is no friction, what is the vertical maximum to which the marble could rise on the left-hand incline?

    a. Impossible to tell because the problem fails to state if both inclines are equally sloped

    b. 30 cm

    c. 60 cm

    d. 45 cm

    e. None of the above.

23. A marble is released from rest on the left-hand incline of the TV lecture slope apparatus at a height of 5 cm above the lowest point. If there is no friction and if the right-hand incline rises vertically 1 cm for every 10 cm of horizontal distance, how far will the marble travel in horizontal distance?

    a. 100 cm

    b. 200 cm

c. 50 cm

d. 1 kilometer

e. 10^3 cm.

24. A marble is released from rest on the right-hand incline of the TV lecture slope apparatus at a height of 5 cm above the lowest point. If there is no friction and if the left-hand incline rises only 1/2 cm for every 10 cm of horizontal distance, how far will the marble go in horizontal distance?

a. 100 cm

b. 200 cm

c. 50 cm

d. $\sqrt{2} \times 10^3$ cm

e. 1 kilometer.

25. An airplane is traveling at 600 m.p.h. in level flight. If the sum of all the forces acting on the airplane is zero, the airplane will:

a. slow down, but never come to rest

b. slow down and come to rest

c. go faster until it hits something

d. accelerate at a constant rate in level flight

e. continue at 600 m.p.h. in level flight.

26. An object will move with a constant velocity if:

a. there is a constantly changing force acting on it

b. there are two parallel and constant forces acting on it

c. there is one constant force acting on it

d. there are unequal but opposite forces acting on it

e. there are no forces acting on it.

27. Suppose we have a pendulum as sketched in Figure 2. The support of the pendulum is 100 meters long. The pendulum weight or bob is pulled up to a height of 2 meters on the right side and released. What do you estimate the highest point of rise of the bob on the left side to be?

a. Equally as high as the initial release point

b. Twice as high as the initial release point

c. Half as high as the initial release point

d. Three times as high as the initial release point

e. Not enough data available for a good estimate.

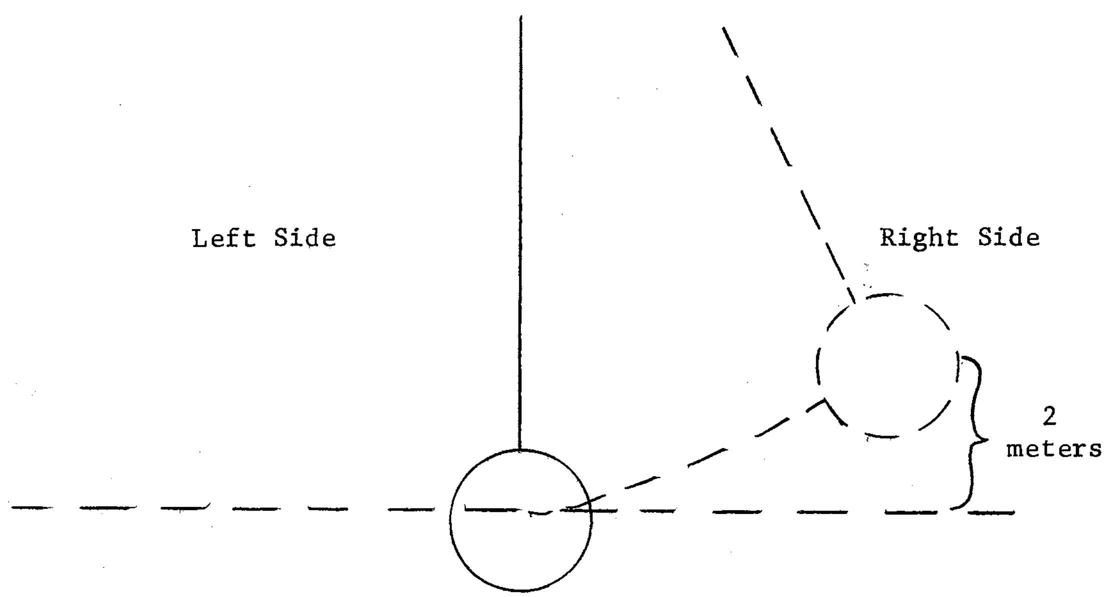

Figure 2

28. Suppose we use again Figure 2, but this time picture the bob to be pulled up on the left side to a height of 2 meters and then released. Now, what do you estimate the highest point of rise of the bob on the right side to be?

a. Equally as high as the initial release point

b. Twice as high as the initial release point

c. Half as high as the initial release point

d. Three times as high as the initial release point

e. Not enough data available for a good estimate.

29. Consider the sketch in Figure 3. It is identical to the sketch in Figure 2 except that a barrier at the arrow tip has been so placed as to force the bob to swing on the left side about a point not 100 meters above the bob as on the right side but rather only 7 meters above the bob. If the bob were pulled up to a maximum height of 1.5 meters on the right side and released, then what would be the maximum rise of the bob on the left side?

a. 1.5 meters

b. 5 meters

c. .5 meters

d. 3 meters

e. There is not enough information furnished to make an estimate.

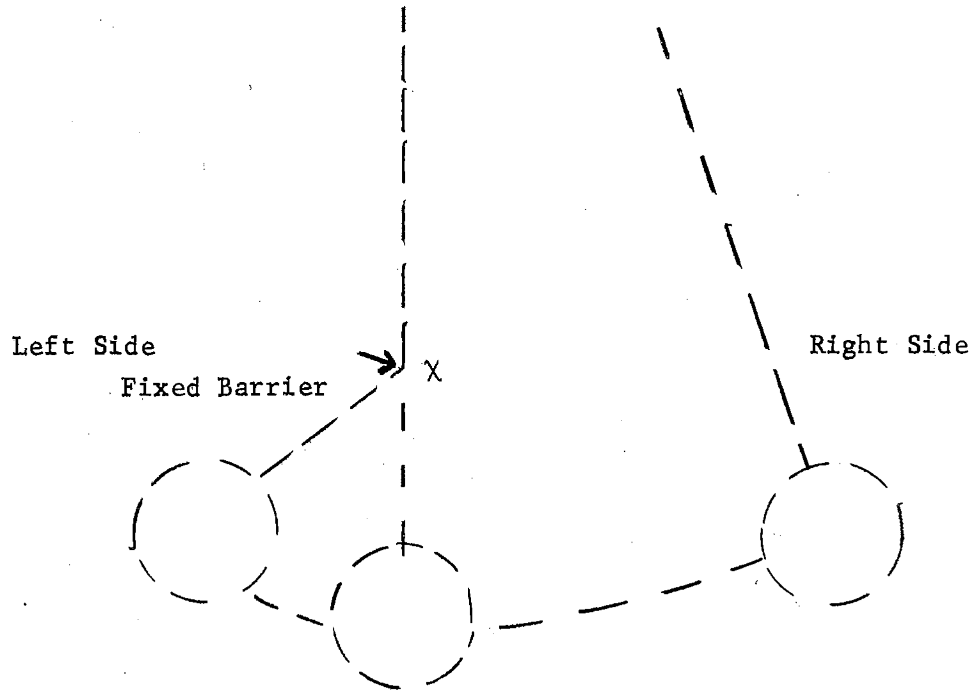

Figure 3

30. Again consider Figure 3. However, this time the bob is pulled to a maximum height of 5 meters on the left side and released. The barrier at X is unchanged. What should the maximum rise of the bob be on the right side?

a. 1.5 meters

b. 3 meters

c. .5 meters

d. 5 meters

e. There is not enough information furnished to make an estimate.

Items 31-33 are concerned with matching different types of data with appropriate energy relations. Each item mentions an energy conversion situation. Please select the type of energy conversion that the system will exhibit.

Types of energy relations (same set items 31-33 use only one selection per item.)

a. Potential to kinetic energy

b. Kinetic to potential energy

c. 50% KE and 50% PE

d. 25% KE and 75% PE

e. 75% KE and 25% PE.

31. An elevator is 1/4 of the way from the top to the ground.

32. A skydiver after stepping out of an airplane high in the sky.

33. The flag being lowered at sunset.

34. In one of the data collections below is sufficient information to calculate the kinetic energy of a system. Which one is it?

   a. 50 meters/second due north, 10 kilograms

   b. 50 meters/second due north, 10 kilograms and 100 meters

   c. 20 meters/second due south and 100 meters

   d. 1 kilogram, 10 meters, and 9.8 meters/second^2

   e. 1 kilogram, 10 meters.

35. In one of the data collections below is sufficient information to calculate the potential energy of a system. Which one is it?

   a. 50 meters/second due north, 10 kilograms

   b. 50 meters/second due north, 10 kilograms and 100 meters

   c. 20 meters/second due south and 100 meters

   d. 1 kilogram, 10 meters, and 9.8 meters/second^2

   e. 1 kilogram, 10 meters.

Refer to Figure 1 for questions 36-40.

a. 

b. 

c. 

d.

e. Figure 1 does not supply enough data with which to make an interpretation.

Work = Force x Distance

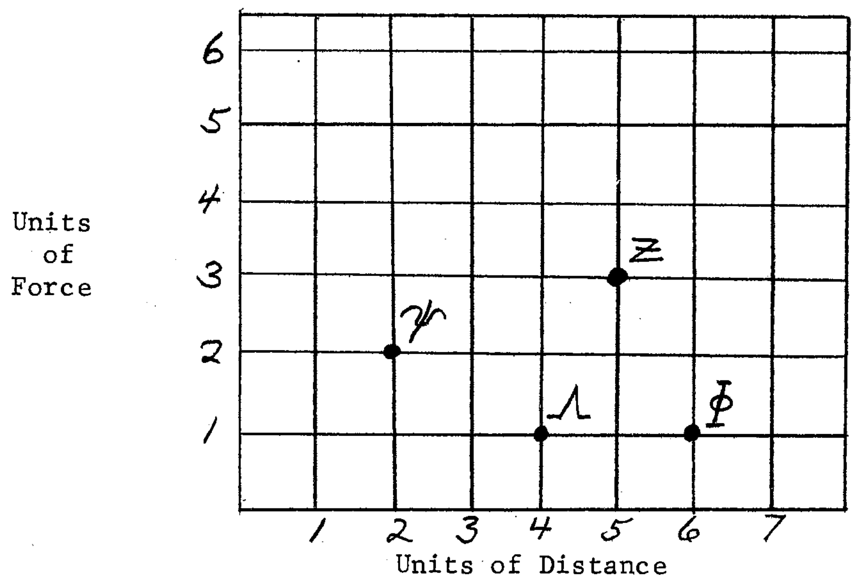

Figure 1

36. After carefully reading the work graph of Figure 1, decide which system required the longest time period to complete the work.

37. After carefully reading the work graph of Figure 1, decide which system required the shortest time period to complete the work.

38. Which system accomplished the most work?

39. The system that indicates 15 units of work is:

40. Two systems indicate equal work. Which are they?

a.  and 

b.  and 

c.  and 

d.  and 

e.  and 

Refer to Figure 2 for questions 41-44.

Spring Displacement Vs. Force Applied

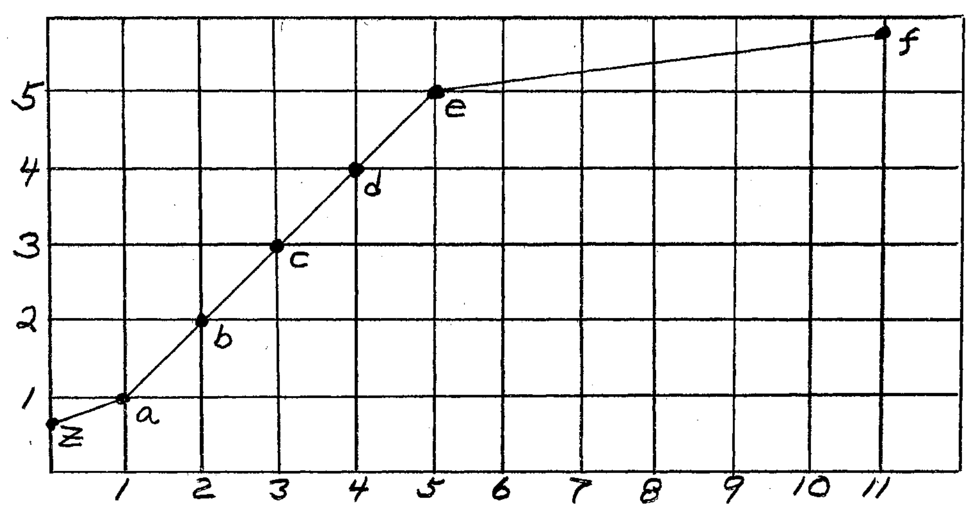

Figure 2

41. The elasticity characteristic of a large rubber band is plotted in the graph of Figure 2. Which statement below best described what occurs between points "b" and "d"?

a. Two units of displacement is brought about by the application of four units of force on the spring.

b. Two units of force applied to the spring results in four units of spring displacement.

c. Force is directly proportional to displacement in this spring.

d. There is no relation between force and displacement in this spring.

42. Which one of the choices listed below would be the best interpretation of the data between points "z" and "a"?

a. Force applied is directly proportional to resultant displacement in the spring.

b. The spring will not begin to stretch until at least 1/2 of a force unit is applied.

c. The spring has been "sprung" and will no longer behave as it did between points "a" and "e."

d. The situation shown between points "z" and "a" is identical to the situation shown between points "a" and "e."

e. The situation shown between points "d" and "f" is identical to the situation shown between points "z" and "a."

43. Consider data between points "b" and "d" only. If force units are called F and displacement units are called X, and if there is a constant ratio between these two values, it is most nearly:

a. F/X = 5

b. F/X = 1

c. F/X = 2

d. F/X = 3

e. There is no constant ratio.

44. If there is a constant ratio of F and X, then it can be most easily read from the graph, between points "b" and "d," by noting:

a. The number of data points on the line

b. The length of the line

c. The area under the curve

d. The slope of the line

e. It is not possible to determine from the data available.

Consider Figure 3. It is a sketch of the apparatus used to gather the data found in the graph of Figure 2. The apparatus is designed to detect changes in potential energy. At the top and bottom of its motion, the mass is at rest. When the mass is at the bottom of its motion, its energy is stored in the spring. At the top of its motion, its energy is stored in the gravitational field or its energy is due to its higher position. Compare the change in gravitational energy with the change in potential energy stored in the spring.

45. Force (F) and displacement (X) are in ratio. If that ratio is constant, name it C. Which statement below best indicates the relation between the potential energy of the spring and the displacement of the spring?

a. $1/2\ MV^2 - mgh$

b. C = F/X

c. E total = PE + KE

d. $mgh = 1/2\ CX^2$

e. There is no constant ratio of F and X.

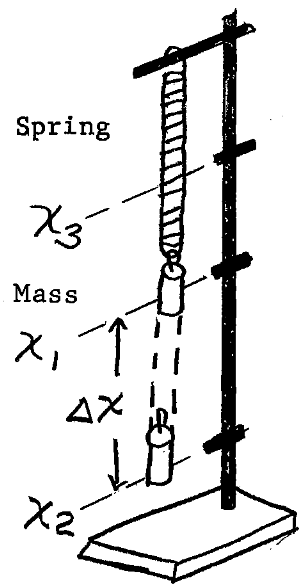

Figure 3

A meter stick has a hole drilled through its center at the 50 centimeter mark. A nail is slid through the hole and driven into a mount. The stick can rotate freely with the nail at the axis. Equal weights, of one newton each, are placed at different centimeter marks on the stick.

In the following tables are data gleaned from a series of trials in balancing with the apparatus described above.

<u>Please carefully read the table titles before attempting to select the missing data from the choices available</u>. Select the best answer for each blank of each table.

TABLE I. Questions 46-49

Distance (in centimeters of sets of weights from the balance point (50 cm) of the lever) multiplied by the number of weights.

Trial	2 Newtons	3 Newtons
46	---------	19.8
47	---------	13.7
48	63.3	---------
49	---------	66.8

For Table I. Select the best data from the data groups below:

Trial	A	B	C	D	E
46	14.1	80.2	99.0	30.2	19.8
47	50.0	86.2	21.4	13.8	36.2
48	75.5	63.3	13.3	28.0	36.7
49	2.5	33.2	66.8	15.1	16.8

TABLE II. Questions 50-53

Distance in centimeters of sets of weights from the fulcrum of the lever when the meter stick is in balance.

Trial	2 Newtons	3 Newtons
50	37.8	---------
51	---------	12.3
52	40.5	---------
53	---------	25.0

For Table II. Select the best data from the data groups below:

Trial	A	B	C	D	E
50	25.2	62.8	37.8	13.0	12.8
51	26.3	12.3	57.7	87.7	18.4
52	10.5	39.5	40.5	27.0	34.5
53	48.1	6.2	37.5	75.0	25.0

TABLE III. Questions 54-57

Position, in centimeters from zero, of sets of weights on a meter stick when the lever is in balance.

Trial	2 Newtons	3 Newtons
54	12.2	---------
55	---------	62.3
56	35.0	---------
57	---------	75.0

For Table III. Select the best data from the groups below:

Trial	A	B	C	D	E
54	57.8	75.2	32.1	87.8	12.2
53	72.1	12.3	62.3	52.0	31.6
56	75.0	45.0	60.0	15.0	65.0
57	12.5	25.0	75.0	24.5	84.5

TABLE IV. Questions 58-59

Position, in centimeters from zero, of sets of weights on a meter stick when the lever is in balance.

Trial	4 Newtons	5 Newtons
58	30.0	---------
59	---------	80.0

For Table IV.

Trial	A	B	C	D	E
58	70.0	26.0	0.0	66.0	90.0
59	20.0	12.5	70.5	40.5	30.0

60. Which one of the equations below would allow a lever to be in balance?

    a. 3 newtons + 12 meters = 12 meters + 3 newtons

    b. (3 meters) (12 newtons) = (36 meters) (36 newtons)

    c. (12 newtons) (3 meters) = (4 newtons) (9 meters)

    d. 3 newtons/12 meters = 12 newtons/3 meters

    e. None of the above would allow a lever to be in balance.

ANSWER SHEET
TEST NO. FIVE

Name Key

1.	d	21.	b	41.	c
2.	d	22.	d	42.	b
3.	d	23.	c	43.	b
4.	a or e	24.	a	44.	d
5.	d	25.	e	45.	d
6.	d	26.	e	46.	e
7.	d	27.	a	47.	d
8.	a	28.	a	48.	b
9.	e	29.	a	49.	c
10.	a	30.	d	50.	a
11.	d	31.	d	51.	e
12.	b	32.	a	52.	d
13.	b	33.	a	53.	c
14.	c	34.	a	54.	b
15.	c	35.	d	55.	e
16.	c	36.	e	56.	c
17.	a	37.	e	57.	a
18.	a	38.	d	58.	d
19.	a	39.	d	59.	b
20.	a	40.	b	60.	c

VITA

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Doctor of Education

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