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The National Science Teachers Association (NSTA) Awards Program for achievement in science teaching seeks to identify and recognize outstanding achievements in science education from preschool through college. Specifically, its purpose is to encourage the development of creative ideas, techniques, and materials that will increase the effectiveness of science education. This document identifies the recipients of the nine 1969 STAR Awards and describes their innovative, award-winning contributions to science education. (RS)

THE 1969 STAR AWARDS

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THE 1969 STAR AWARDS

Science Teaching Achievement Recognition

The STAR Awards Program, co-sponsored by NSTA and the American Gas Association, is designed to identify and recognize outstanding achievements in science education from preschool through elementary, secondary, and collegiate levels.

NATIONAL SCIENCE TEACHERS ASSOCIATION
Washington, D. C.

A Department of the NATIONAL EDUCATION ASSOCIATION

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INTRODUCTION

The NSTA STAR Awards for achievement in science teaching were reactivated in 1968 after a 7-year period of inactivity. The 1969 awards were co-sponsored and financially supported by the American Gas Association. The STAR program seeks to identify and recognize outstanding achievements in science education from preschool through college level. Specifically its purpose is to encourage the development of creative ideas, techniques, and materials that will increase the effectiveness of science education. Some goals related to this are:

1. To raise the general level of scientific literacy among the total population.
2. To influence more young people to consider careers in science, engineering, science teaching, and other related fields.
3. To assist students to develop understanding and functional control of basic concepts and principles from the scientific disciplines.
4. To provide opportunities and guidance for students to have practice and gain skill in using processes of scientific inquiry and to develop habits of creative thinking.

In addition to widely reporting these science teaching innovations through publication, the program recognizes the winners as follows:

Substantial cash awards

Bronze medallions of recognition

Personal introduction at annual convention

The STAR program is another effort of the Board of Directors to increase opportunities for participation in activities of the Association and to increase the prestige level of teachers and the profession.

Entry forms for the STAR Program can be obtained by writing to the NSTA Executive Secretary, 1201 Sixteenth Street, N.W., Washington, D.C. 20036. Forms are available in the early fall for the following year's awards.

CONTENTS

☆ FIRST GRAND AWARD ☆

The Biological Science Enrichment Course for Elementary School Children

ROBERT L. GANTERT

Nathan Hale High School
Seattle, Washington

The following report includes an incomplete summary of course content for both five four-hour classroom sessions as well as five four-hour field trips designed to teach biological science to elementary school pupils. This pilot effort represents the virgin venture of real team teaching among high school and elementary science teachers on an accelerated cyclic planned procedure. The author's great respect for the problems of the elementary teacher reached its highest peak of admiration upon the completion of the six-week study. Without the dedicated teamwork of the other three elementary teachers involved, the final outcome would not have been possible. Any recognition for this project will most certainly be shared with my elementary teacher team members.

For the past two years, the Seattle School System has been involved in a type of integrated "Continuous Progress" procedure designed to more finely delineate the basic philosophy of the elementary and the secondary science curriculum. To date this pilot experimental program has been largely confined to the physical and natural sciences because flexible scheduling in these areas permits changes of high school science personnel. Eventually, it is hoped that this integrated teaching philosophy can be expanded to embrace *all* subject matter fields. The author is currently participating in three "Continuous Progress" programs simultaneously with his regular biology teaching. However, only one of the three programs will be described in detail, namely, the Biological Science Enrichment Course for Elementary Pupils.

This year the BSE course was conducted on a 20-hour lecture-demonstration, 20-hour field-trip curriculum in two weeks of the summer school period. There were three of these two-week courses and a total of twelve elementary schools involved with Nathan Hale High School serving as the central supply center for this course. At the same time the Biological Science Enrichment Courses were in progress, a selected group of secondary science teachers were conducting similarly scheduled summer school courses in the physical sciences for elementary pupils. A type of "Kitchen Physics and Chemistry" was being taught at several elementary schools. Admittedly this type of "shotgun" approach contains many loopholes; however, even with its errors the plan has created an awakened interest among the elementary teacher and pupils of all grade levels. The tremendous enrollments this summer in these no-credit courses suggest that we are on the right track.

Before *any* scheduling for these summer science enrichment courses were organized and held, it was necessary to first enlist the support and interest of the elementary teaching personnel. This interest was stimulated through special in-service courses taught by the high school science teachers who formed the initial staff for the "Continuous Progress" programs. The author, for example, taught several twelve-hour evening courses for a limited number of elementary teachers at the local Woodland Park Zoo. The course, "How to Know Your Zoo," utilized the zoological staff as well as the living animals at the zoo in a new "Living Experience Approach." An interesting and practical lecture was given by a trained zookeeper. Without the sincere practical knowledge of these dedicated zookeepers the course would have fallen flat on its face.

The next step in preparation for the Biological Science Enrichment Program was to schedule a series of lecture-demonstrations in the elementary schools in which the rotating zoo at Nathan Hale High School could be fully introduced and made available on a loan basis to the elementary teacher. This scheduling was accomplished through free time granted the author to present "Live Teaching Programs" periodically throughout the regular school year. With 100 elementary schools in the Seattle System, the scheduled series of lecture-demonstrations had to be restricted. Since the average enrollment of elementary schools in Seattle is about 600 to 800 pupils, a tight time schedule had to be followed. In brief, three and occasionally four separate assemblies were given at each school. Kindergarten pupils were taken alone since the vocabulary must be carefully chosen and each child must be allowed to touch an animal. The other grades were grouped into units: First and second; third and fourth; and finally the fifth and sixth grades formed the audiences. The lecture-demonstrations were repeated in each of the assemblies; however, some variation occurred since each group asked increasingly varied questions.

The complete ten-day cycle of four-hour sessions included:

First day - General Orientation Session

Second day - Field trip to the Arboretum

Third day - Classroom Laboratory Work

Fourth day - Field Trip to Woodland Park Zoo

Fifth day - Classroom Laboratory Work

Sixth day - Field Trip to Pier 56

Seventh day - Classroom Laboratory Work

Eighth day - Field Trip to Nathan Hale High School

Ninth day - Classroom Laboratory Work

Tenth day - Field Trip to Lincoln Park

A detailed daily schedule for three days of the Biological Science Enrichment Course for 1968 as presented follows. The work performed on these days is representative of the activities taking place during the entire course![1]

The author will welcome any criticism or request from teacher-readers for additional data and materials, etc.

First Day – General Orientation

I. Take the class to the museum cases and carefully remove and explain each "Strange as It Seems" display.[2] Several "Strange as It Seems" cards are presented in the accompanying box to show how easy it is to compile these interesting items. Any teacher can, by browsing through a zoology text, create a myriad of little-known scientific facts and find toys to display them. The addition of an unusual toy to the typed card is an excellent interest-stimulator.

II. Upon returning to the classroom have microscopes for students to examine while you carefully go over the basic parts. At the same time, have beside each microscope a small cut section from a plastic transparent ruler that is divided both into inches and millimeters. Since the field trip the next day will be for the collecting and later examination of minute protozoa and plant life, the question of just *how* small these microscopic organisms are and *how* they are measured is important. At this point briefly explain the units of the metric system – unit of weight (gram), unit of length (meter), and unit of volume (liter). Do not spend too much time on these units since the micron will not be used for two days.

Procedure:

Have each pupil place a small section of plastic clear ruler under the low power objective until he can easily see two of the millimeter (mm) lines and the space between them. Explain that a micron is really 1/1000 of a mm or that in a micron scale there are actually 1000 tiny divisions. A paramecium, for example, might be 20 microns, bacterium 4 microns. If available use one of the micron scales that can be placed within the eyepiece. As the organism stretches along the superimposed scale under the microscope, the student can determine its length in microns. A high school may loan you an inexpensive micron scale. At the same time, it should not be too difficult for the pupils to estimate the approximate width of the low power diameter field in microns (about 1600 microns).

III. Have at least one dissecting (stereoscope) microscope available for macroscopic use. The terms transparent, translucent, and opaque as related to the use of both types of microscopes should be made clear.

IV. Introduce the six main tools of the quadrat system: the trowel, shaking screen, insect aspirator, collecting bottles, chloroform bottle, and quadrat one foot square. Explain how each is used by demonstrating with a handful of "seeded dirt" that contains some ants. As the larger particles of dirt fall on the shaking screen and the ants slip through the finer mesh, quickly aspirate them. Another method is to bring into class a dry fish bowl containing a number of ants and have pupils experiment using the aspirator by sucking up the ants into the test tube. If no ants are available, simply roll up tiny pieces of paper the size of ants and aspirate these into the test tube. In explaining the use of the standard one-foot square wooden frame quadrat, carefully explain what is meant by "random sampling" of an area to determine the population of either small plants or organisms. Also emphasize the impossibility of trying to crawl around over an acre of ground and hand count every ant and spider. The tossing of the

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[1] Numerous charts, slides, and other descriptive material accompanied the original entry but space does not permit the inclusion of them all with this publication. However, interested readers may obtain the complete daily schedule presented in Mr. Gantert's paper by writing to NSTA STAR Awards, 1201 Sixteenth St., N.W., Washington, D.C. 20036.

[2] The "Strange as It Seems in Science" idea was published in *Science World* and the *Teaching Tools Journal* in 1958. In addition, some of the toy displays are from an award-winning 1958 STAR entry by the author.

quadrat in an open field must be done randomly in order to have a good survey of the area. For plants only a surface count is necessary; for insects, the soil should be removed to a depth of about three inches for each square foot quadrat. The chloroform bottle is used to empty the insect aspirator periodically as these organisms will be counted back in the classroom.

Procedure:

When all questions have been answered, pass out mimeographed sheets in which letters in the English alphabet are used to take the place of living organisms one might find within each quadrat in the field. Pass out quadrats one inch square cut from cardboard. These quadrats are to be used the same way as the one-foot square quadrat. However, in this case, the field will be the pages of any magazine or book and the cardboard quadrat is dropped on the printed page at random a total of ten times. Students are to count all the letters that fall within the boundaries of the one-inch square. Across the top of the mimeographed sheet the numbers 1 to 10 stand for the quadrats. The letters A to Z can stand for various insects. After all the "random samples" have been taken, explain that frequency means percent and is determined not by the number but rather by how many quadrats out of the ten each letter appears. For example, if the letter C appears in six out of the ten quadrats, the frequency is 60 percent. Density, on the other hand, means the actual number of organisms found in each quadrat. The vowels will appear more often than other letters. Letters such as Q and Z may not appear in any of the quadrats. However, the letter E will be the highest density (total population count) as well as also having a 100 percent frequency.

V. Obtain a core borer. Bring to class a block of wood and demonstrate the use of the core borer in counting annual rings of a tree to determine its age. Later show how to insert the core back into the hole to save the tree.

VI. Demonstrate the use of a standard plant press in preparing a herbarium. Pupils can later catalog leaves according to their venation.

VII. During the final hour show the film "Nature's Half Acre." For the field trip next day, the pupils need only bring several small jars for collecting specimens. General laboratory equipment will be a net, chloroform bottle, metal collecting carrier, and plant press.

"Strange as It Seems"

1. Why do we wear jewelry? According to anthropologists, the custom is a carryover from our primitive ancestors who would wear amulets as a sign of wealth as well as a precaution against evil spirits. Even today, the Amish people still paint hex signs on their barns to ward off the so-called "evil spirits." (Display pieces of jewelry with this card.)
2. Science and medicine of the past: The Incas and Aztecs practiced brain surgery as early as the 13th century. As many as five openings have been found in one human skull. Animal skulls have also been found that the Incas and Aztecs had apparently used in surgical experiment. (Display any animal skull and a crude knife.)
3. A living toothpick! Despite his ferocious disposition and ill temper, the crocodile permits a tiny bird to enter his mouth, pick his sawlike teeth clean of food particles, and depart unharmed. The teeth of the crocodile slant in all directions and it is impossible for the animal to dislodge leftover meat that sticks in his teeth. However, the tiny bird has developed the ability to take flight backwards in case the crocodile or host shows a tendency to retain his feathered helper as part of his diet. This might be called a case of symbiosis or mutual assistance. (Display toothpicks with a stuffed baby alligator.)
4. What are some of the oldest living things on earth? The giant redwoods of California. Two reasons for their great age are a natural resistance to harmful insects as well as having a type of resin in the wood which helps resist destruction by fire. (Display sample of redwood.)
5. Forensic anthropology is a fast growing branch of science which involves the application of scientific laboratory methods to aid in the detection of crime. A man skilled in analysis of bones can determine the age, sex, and many other important facts from a single bone. (Display any kind of bones.)
6. What is your real value? Whenever you start thinking of your own vast importance in this world it might help you to remember this simple fact: If the body of an average 150-lb person were reduced to its simplest chemical composition the following elements would result: 100 lbs of water; 24 lbs of carbon; 7 lbs of lime; 2 lbs phosphorous; 5 ounces of nitrogen and traces of salt, magnesium, iodine, iron, sulfur. All these can be bought at your local drugstore for about $2.10. (Display gram scale and a few of these elements.)
7. The eyes have it! The common dragonfly has the distinction of having the largest number of facets to its compound eyes.....30,000 parts to each eye. This explains the almost impossible task of trying to swat a dragonfly on the wing. He sees a total of 60,000 hands at the same time! (Display a mounted dragonfly.)
8. A problem in simple arithmetic of the blood and heart: How much blood at the rate of two ounces per beat, and at the rate of 75 beats per minute, does the heart pump each full day? The answer you will find is slightly more than seven tons. (Display a model of a human heart.)
9. Is fish really a brain food? A certain amount of phosphorous is used to keep a brain healthy along with other minerals, but you could eat fish three times a day without raising your I.Q. one point. In brief, it is possible to have a healthy brain and at the same time possess an empty head. (Display fish and skull.)

Second Day – Field Trip to the Arboretum

I. A special school bus picks up the pupils from the elementary schools. Upon arriving at the general site, the teachers divide the pupils into tour groups to collect specimens; namely, leaves, planaria, pond samples, and other available life in the community.

Forms such as snail embryos, daphnia, and nematodes are in abundance in pond communities. Rocks and dead logs are examined for fungi, amphibians, and beetle larvae. The teachers have previously visited the community and have a knowledge of the forms of life to be collected. This particular field study depends entirely upon the ecology of the specific area. If time permits several students might take a sample quadrat by using the techniques discussed in the opening class session. Tree cores are also taken for later analysis. Total time for collecting is restricted to three hours to allow sufficient time for students upon returning to their school to store the specimens and prepare for the next day's laboratory classifications.

Third Day –
Classroom Laboratory Work

I. Spend the first two hours in examining and classifying the material collected on the field trip. Demonstrate various techniques for preparing slides, including methods to slow down movement of the more motile forms. Students work in pairs. Simple charts should be prepared for a brief analysis of life near the end of the second hour. Count of organisms found by entire class as well as individual teams of pupils can be analyzed.

II. The third hour includes showing a brief film entitled "Know the Protozoa" which will help students organize and recognize the organisms already discovered in their own cultures. Immediately upon conclusion of this short film, it is now time to begin preparation for the scheduled next day's field trip to the Woodland Park Zoo.

III. Bring to class several exotic unusual wild animals for handling and close observation by students. Since we have a large varied collection of wild animals in our own Nathan Hale Rotating Zoo, this is a simple procedure and one that has proven very stimulating to the pupils. We have a large six-foot boa constrictor, a sand boa from Africa, and flying squirrels. These wild animals are all conditioned and docile from previous handling and have proven to be relatively safe. However, always stress that any wild creature must always be handled with caution as its behavior is *not* predictable. Show a brief film entitled "Reptiles Are Interesting." The reptile is the most fascinating of all animals. Why? The introduction of the first land egg (amniotic egg) marked the beginning of a great era of independence among higher forms of life. The embryo inside the egg contained within itself all the ingredients required, and the egg was hatched by solarheat, which allowed the Great Reptiles of the Dinosaur Age to roam and reproduce freely over the vast surface of the earth's land mass. Have several reptile eggs such as turtle eggs or snake eggs for examination. Such harmless snakes as the gopher snake, which makes an ideal classroom pet for elementary age children, are introduced at the beginning. Later on the large six-foot boa is handled by the instructor and later by pupils who reveal a sincere interest. During the demonstration the features of snakes such as the following are explained:

1. How much of a snake is its tail? (About 1/10 the entire length.) For this question show where the abdominal scales merge to find the anal vent.
2. Snakes do not have any eyelids and their eyes are always open. How then do they sleep? (Scientists suspect that a snake does not always see and that it has certain periods in the 24-hour day when it is really in a coma.)
3. Differences between poisonous and nonpoisonous snakes. How can you differentiate? (By the scales as well as by the pupils of the eyes. In North America nonpoisonous snakes have round pupils; poisonous snakes have slit-like pupils.)

☆☆ The chance for an elementary child to actually work in a high school laboratory situation evoked much valuable comment from both student and parent. ☆☆

IV. During the final hour, show a series of animal slides. Carefully point out characteristic features that place certain animals in orders. For example, the *carnivores* by teeth arrangement, the *hoofed animals* by toes, the *birds* by types of beaks and feet, the *rodents* by teeth. (The animals shown are as closely associated as possible with those to be seen on the field trip through the Woodland Park Zoo the next day.) The final slides should show animals grouped according to the realm in which they are found in the wild state: for example, the chinchilla from South America, the orangutan from Asia, the lion from Africa, the kangaroo from Australia, the fox from North America.

Many other variations in conducted sessions during the six-week period of the Biological Science Enrichment Course were used by the other two teachers involved in this experimental venture. We all learned a great deal from the successes and the failures encountered. A few of the mistakes and criticisms are offered here so that future classes might improve upon the general content.

Criticisms of the Course and Problems Encountered

1. A four-hour class session is too long for the age group. The preparation required to maintain the sustained interest of children this age is tremendous to say the least. A three-hour session with several breaks, as well as playground facilities available for taking care of these breaks, is recommended.
2. The placing of pupils just recently from the third grade with those on the way to seventh grade is too big a gap both academically as well as otherwise to promote harmony as well as real understanding. A better selection of age groupings is needed.
3. If the course is intended to be an experience not encountered within the normal school year, it should be taught by the introduction of secondary materials and not by the use of elementary materials. In brief, holding the class sessions at either a junior or senior high school where the materials are already on hand seems the logical solution. In my own case it was necessary to transport many pieces of equipment from Nathan Hale High School to meet the needs not only of my own classes, but also to supply the needs of the other teachers involved. If the classes could be held at an equipped junior or senior high school, greater uniformity and organization as well as superior instruction and worthwhile pupil learning would probably occur.
4. It should not be too difficult to prepare a general format from the experiences gained from this pilot six weeks, a more uniform method of classroom content to be covered, as well as field trip study. This does not mean that the individual teacher must follow any stereotyped course and not be allowed to pursue any creative ideas of his own or of his students. It merely implies that if the students are to have the same advantages and experiences, a more equal distribution of both materials and teaching procedures should be followed.
5. If this type of course is intended to result in the type of specialized instruction used by the more progressive elementary school which has trained specialists teaching all the art, music, and science on a visiting schedule, the course should be designed with this goal in mind and planned so that it could be adapted to that type of schedule.

Evaluation of the Course

The students seemed to derive a great deal from the experience, both in general knowledge and a broadening of scientific scope. It presented an excellent opportunity to initiate the pupil at an early stage into the growing complexity of team teaching. The chance for an elementary child to actually work in a high school laboratory situation evoked much valuable comment from both student and parent. Many parents called me later to voice their opinions of this phase of introducing advanced material and the inspirational effect it seemed to have on their children. In this age when all education is receiving such a dramatic accelerated "boost" it is most gratifying to hear parents comment so favorably. I found the course to be a most stimulating experience and one I enjoyed thoroughly despite the problems involved.

The course was flexible to allow for individual creativity to evolve. I know in my own case that I did not teach the same procedure in exactly the same manner for the three separate sessions. In fact, the revision was made both in text and procedures in each of the three sessions as I learned which ideas were less valuable in content. The sign of good teaching centers around the ability of the teacher to either revise elementary material and concepts to challenge secondary students or by the same reasoning, to be able to take any secondary concepts and transform them into understandable elementary education needs. In this course, I had ample opportunity to try out my philosophy by using high school concepts from BSCS, as well as my own, and stepping it down to elementary aptitude.

☆ SECOND AWARD ☆

Breaking Better Bridges

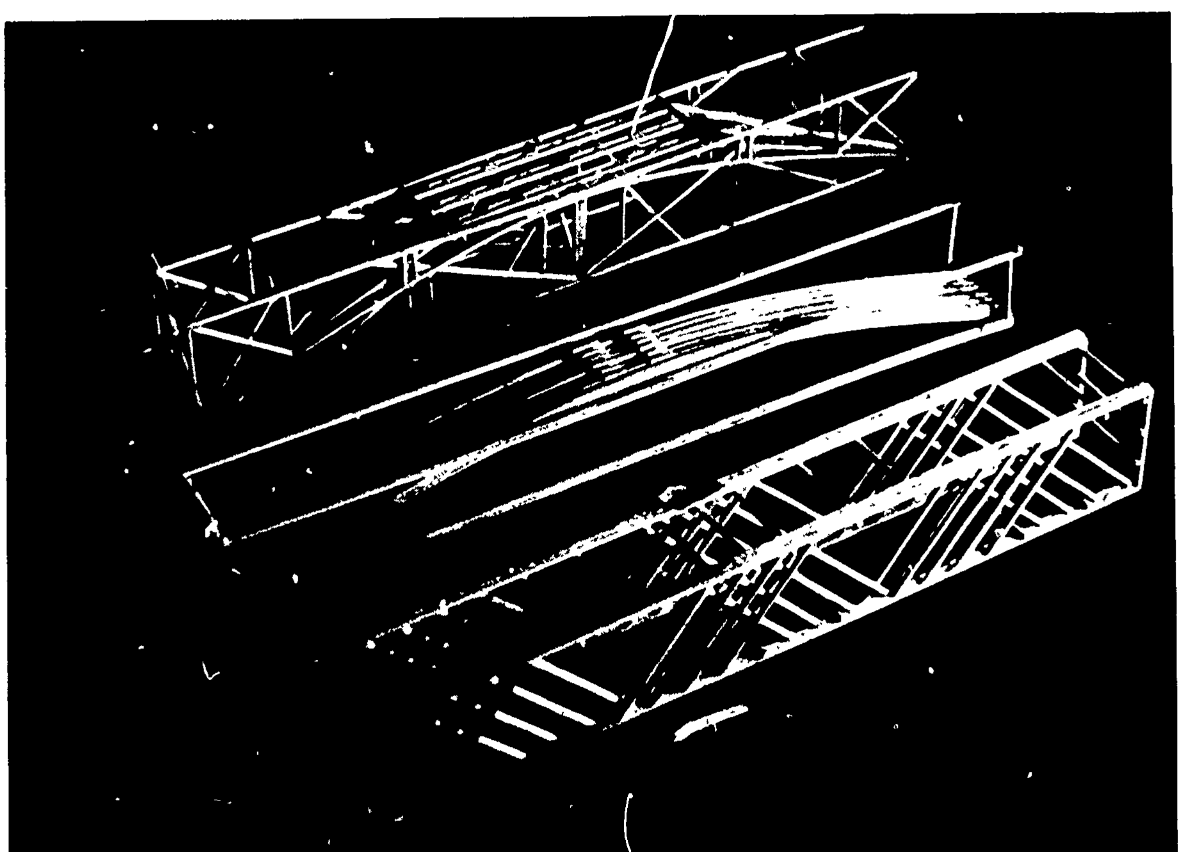
BUEL C. ROBINSON

Washington High School
Denver, Colorado

The trouble really began with the article published in the May 1965 issue of *The Science Teacher* which described a model bridge design contest held in our school as a part of the physics program. From the remains of the broken bridges the idea has spread throughout Colorado and, to our surprise, to many other states as well. It has become too large for us to manage, yet is still too much alive for us to let go.

The contest began in the physics classes as a result of some speculation on vectors. It was decided to see what a few (30 to 40 lineal feet) sticks of fragile (3/32-inch square) balsa wood could hold if used properly. From this idea the extracurricular contest resulted that year in the crushing of eighty bridges before an interested but puzzled group of students in the school lobby. Because of the *Science Teacher* article and similar stories in the local papers and several engineering publications, and due to the TV coverage, the idea and contest have almost gotten away from us. This year, in our school alone, over three hundred bridges were crushed in the school gym to the cheers of the 3,000-member student body. Scenes like this were going on all over our state. We have just completed the Second Annual Colorado Model Bridge Design Contest in which over sixty schools in the state participated. Our school is a sponsor for the statewide contest, but we have been fortunate to secure as co-sponsors the professional engineers of the state and State Highway Department. The financial and professional help has made the contest possible on a large scale. The preliminary contests in all the participating schools are held locally, but the state finals are held under closely supervised conditions in the impressive testing laboratories of the State Highway Department and run by professional engineers. The contest rules are now written and supervised by the best engineers in the state.

Design ideas varied drastically.



They donate their valuable time to the project.

Engineering and scientific groups and teachers from all over the U.S. have contacted us for information on rules and the running of the contest, and we have received many reports of similar contests now in operation throughout the country. The United States Information Service printed an article overseas on the contest, and we have heard from schools as far away as Japan.

What Has Been Learned?

A project like this one should not be taken too seriously. We don't pretend that great contributions to scientific and technological development have been forthcoming, and we don't claim that this experience causes students inclined otherwise to decide on science and engineering as a career. In answer to a repeated question: No, we don't think the contest has uncovered any new radical structural breakthrough; but some things have been learned.

We believe that an additional spark of interest has been added to a considerable number of high schools in the country. Before the contest begins in the fall, letters and calls for information begin. Teachers, fearing that they have been left off the mailing list, contact us, and our own students, who have witnessed the contest as sophomores, beat us to the punch in their eagerness to get started.

The contest is used as a basic part of an advertising campaign to interest students in physics, and it has worked so well that our enrollment has shot up in the past few years as it has done in other local schools using the same approach. This is in opposition to the national downward trend in physics enrollment.

The contest can be a school morale builder. The school winning the state contest last year contains large numbers of students from minority groups and has had many problems and few successes of late, but the presentation of the impressive trophy by the engineering profession was hailed as a highlight of the year by that school's administrators. This year a small unheard-of school in a distant corner of the state with only eight students in the physics class took home three trophies in competition with many large but less successful schools from the cities.

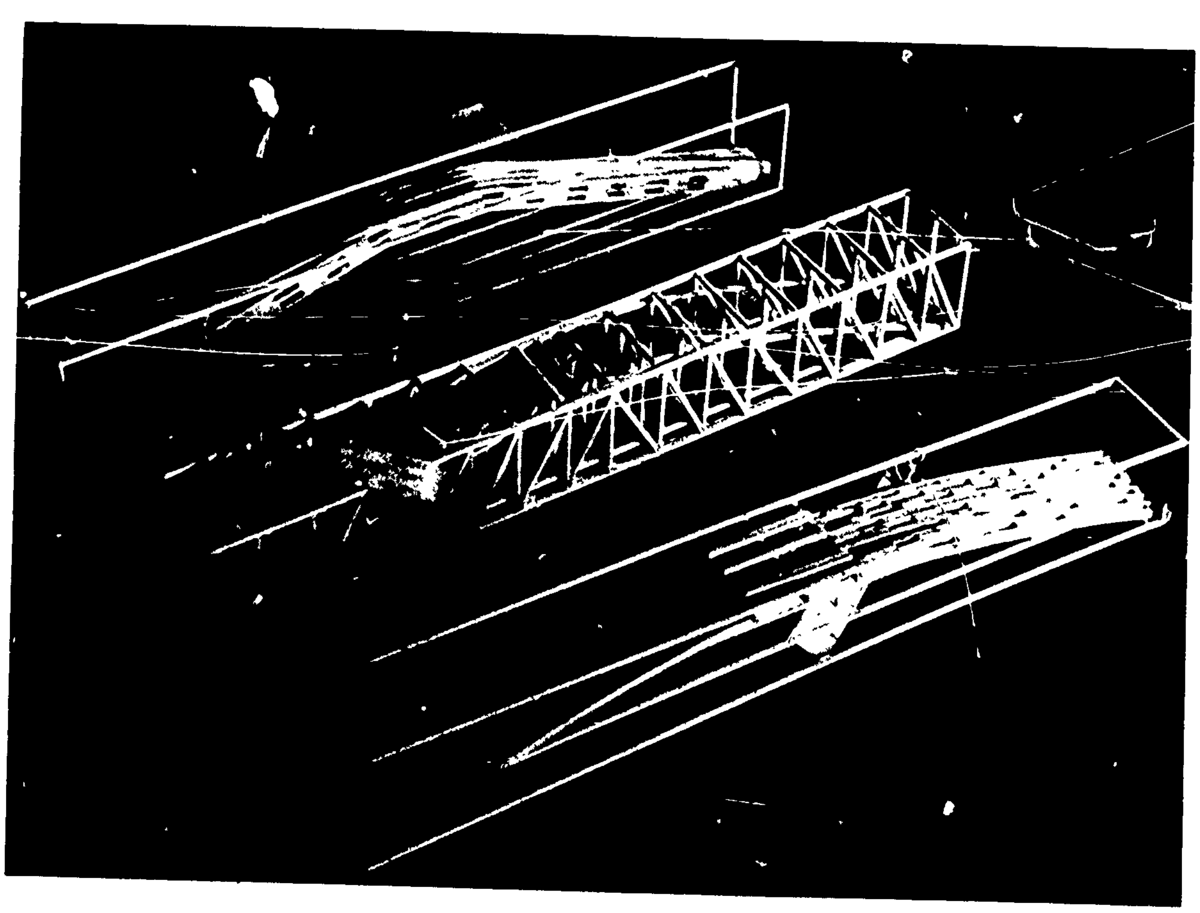
There is satisfaction in being able to interest so many students. The cost of material is less than a dollar, and the design and construction time is not burdensome to students already busy doing required school work. All students, regardless of athletic, acting, or musical ability, can participate in a program calling for thought, planning, and ingenuity. The winners receive considerable recognition from the school, and it is sweet music to hear your fellow students cheer while your bridge is being loaded with greater and greater loads.

The community has shown great interest in the program, and opportunities to cooperate with people outside our school have been many. The numerous newspaper articles and the TV coverage do nothing to hurt the image of a school system that depends on the public for its support. We have been working closely the past three years with the engineering profession in the state. The engineers have been more than generous with their time, talent, and money in support of the contest.

The project is very rewarding to the classroom teacher. There is satisfaction in watching the students become excited with and take hold of a new idea. While many students make only a perfunctory attempt, a surprising number accept the project for the challenge it is and enter into it with the true scientific spirit of inquiry. Americans have always been known as inventive and resourceful people, and this characteristic does not seem to be missing in our often maligned younger generation. No sooner are the rules distributed than sketches, drawings, and partially built models crop up everywhere. Arguments are overheard in the halls on the relative merits of one basic design over another, and a run on library books on structures, forces, and vectors takes place. A steady stream of bridges arrives for preliminary testing and they are analyzed for defects.

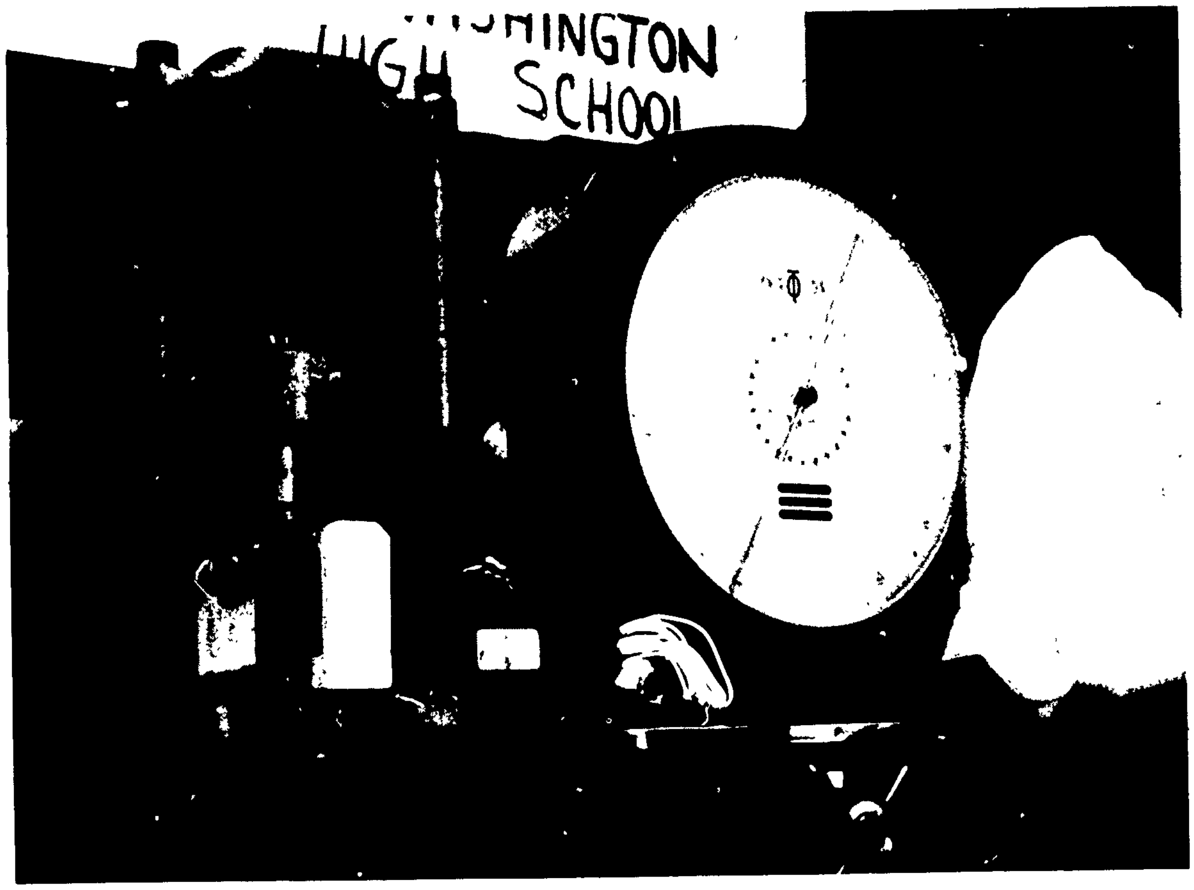
The really perceptive designers go over the rules with a fine-tooth comb looking for a clue to a major design breakthrough. The students are often so clever that they get a step ahead of the professional engineers who help formulate the rules. Students were splitting the matchstick-size balsa and then gluing it back together getting a reinforced concrete effect. This approach had not been covered in the rules. Now it is. In order to keep the students guessing, it is necessary to make drastic changes in the design rules from year to year. Some rule

The more successful designs combined several structural ideas into one bridge.



changes have been made in self-defense because individual schools lack heavy testing equipment. Two years ago the winning bridge, weighing less than one ounce, held over 1200 pounds.

Our mass-production school systems often do not provide sufficient opportunities for creativity. While art students may have such creative experiences daily, science students do not. Science fairs are helpful, but they often require months or years of preparation and considerable money for successful participation, and they are aimed at that special science-oriented student. The short but intense bridge design contest gives students who only have a few hours to spare an opportunity to be creative both with mind and hands. The variety of design ideas is very broad, and it even surprises the experienced engineers judging the contest. Imaginative design does not always win but the evidence of ingenuity and thought that went into a design is often reward enough. The students who are the most creative are not always the students who are best in the routine classroom work. There seems to be a spark in some students that needs to be nourished into a burning fire, and some of the designers have caught fire to the extent that they have built and destroyed five bridges before arriving at a final contest model. Although it was not intended that students take the contest so seriously, they are not about to be discouraged with an attitude like that.



A materials testing engineer loading a bridge in the state finals.

In the fall, as school begins again, we often ask ourselves if it is worth all the work, because it does take many hours and days of planning, writing, mailing, and supervision for both our local and the state contest. Although we often say, "Let's quit," we don't. We just wouldn't want our students and ourselves to miss all that fun.

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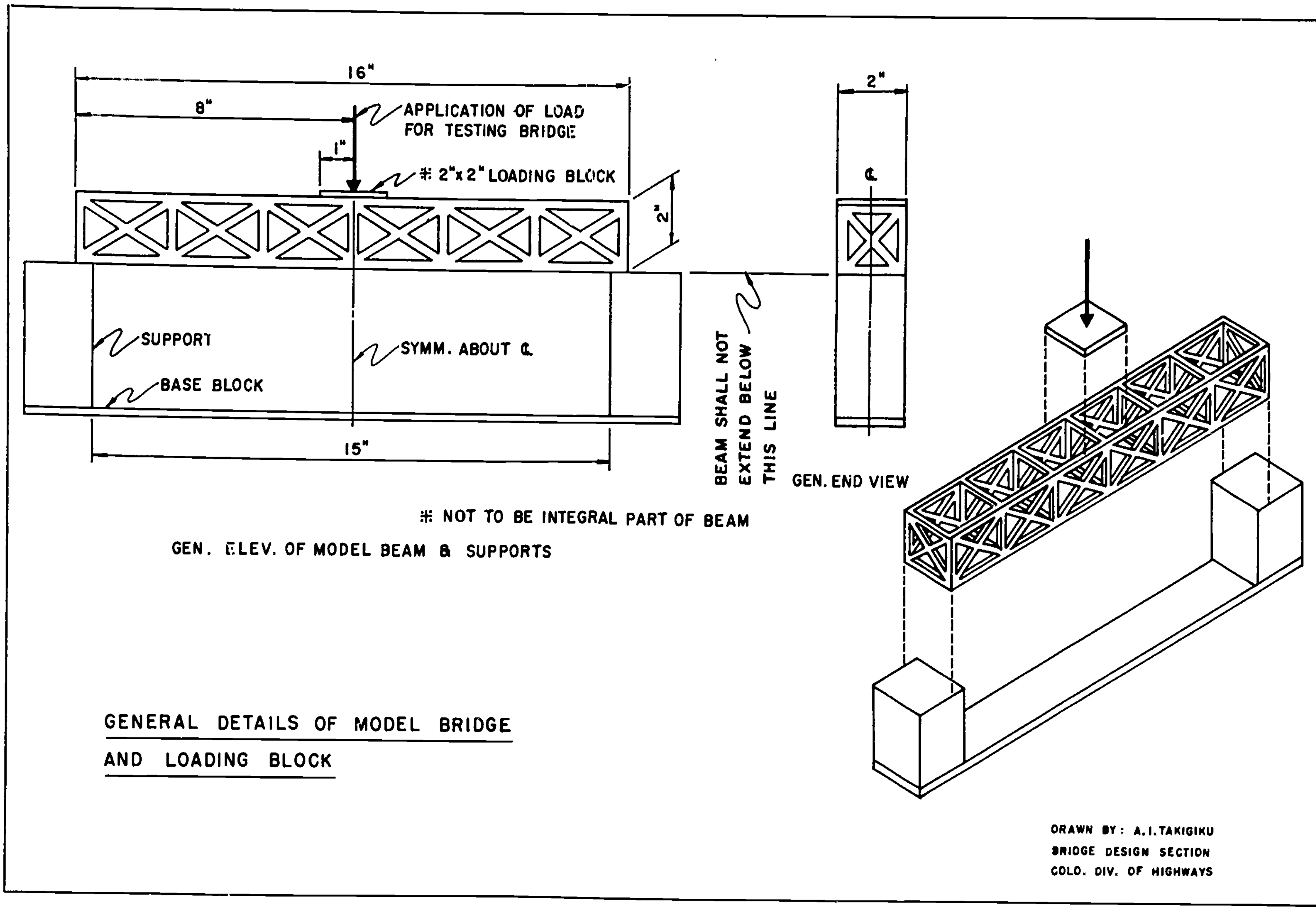
that they get a step ahead of the professional engineers

who help formulate the rules. ☆☆



OFFICIAL RULES

1. The design for the 1968 model bridge is that of a beam bridge. The outside dimensions of the beam must be two (2) inches constant width by two (2) inches constant height by sixteenth (16) inches long. The beam must be straight and shall not extend below the base blocks. Refer to the drawing above for all critical measurements.

2. The only material allowed is forty (40) lineal feet of 3/32 square balsa wood and airplane glue. No other material permitted. Cement shall be a transparent airplane glue— no resins, epoxies, or white glues will be accepted. Cements may not be used in large amounts at joints or to coat structural members. No more than four (4) sticks of wood shall be laminated together. Sticks shall not be split.

3. Contest is open only to students currently enrolled in physics or mechanical drawing classes in a participating high school. The school must be registered in the competition by your teacher who must return an official registration card to the state committee.

4. School entries in the finals must be properly tagged with the student's name and certified by the instructor that the models comply with official rules. Only three finalists will be allowed from each participating school. Certification notices must be mailed to the state committee by the teacher not later than December 2, 1968 and include the names and standing of the three school finalists.

5. Final testing will be under the supervision and direction of engineers of the Colorado Highway Department Bridge and Materials Testing Section. Models must be mailed in time to arrive at the laboratories by December 6, 1968, or, if delivered in person, must be at the Denver labs not later than 9:00 a.m. on December 7, 1968. All models will be loaded to the point of failure while positioned on the official base blocks and under the official loading block, as shown in the above drawing.

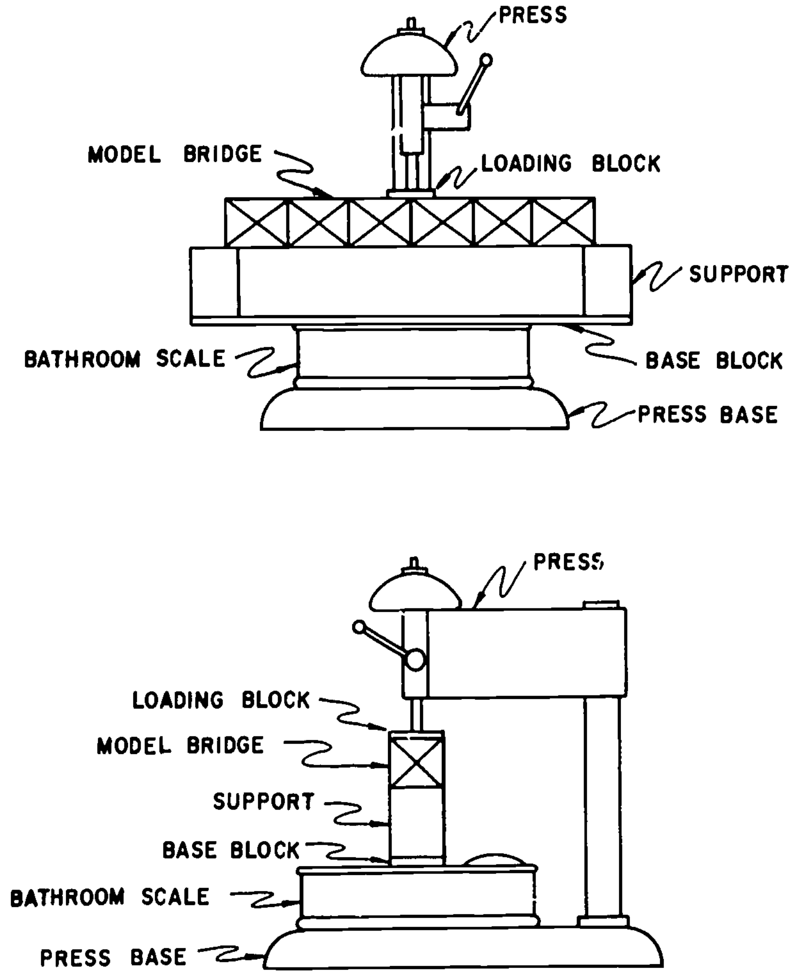
TEACHERS NOTE:
If you have not received a registration card, model tags and certification notice or if you have any question regarding any phase of the 1968 COLORADO HIGH SCHOOL MODEL BRIDGE BUILDING COMPETITION, please contact: Buel Robinson, George Washington High School, Model Bridge Building Contest, 655 S. Monaco Parkway, Denver, Colo. 80222.

HOMEMADE TEST STAND

A satisfactory testing stand can be fashioned out of a bathroom scale and a drill press stand. The chuck should be removed from the drill press stem and wooden loading block and base blocks placed between the model and the press and scales. Pressure from the drill press will be transmitted via the loading block to all parts of the model and the load can be read in terms of pounds on the dial of the bathroom scale.

The design and dimensions of the loading block is given on the drawing with the official rules. This may be constructed out of wood.

Please refer to the drawing here on suggested use of a bathroom scale and drill press for testing model bridges at your school. Note that drill press stem should strike loading block in dead center.



SUGGESTED LOADING DEVICE FOR TESTING MODEL BRIDGES LOCALLY

MODEL BRIDGE BUILDING FINALS

Department of Highways, State of Colorado, Central Materials Testing Laboratory December 7, 1968

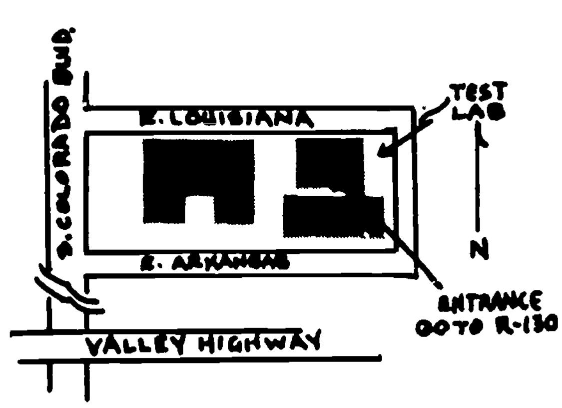
The final testing on a hydraulic press in the Central Materials Testing Laboratory of the Colorado Highway Department will be under supervision of Paul Chuvarsky, chief bridge engineer in the bridge design section, on Dec. 7, 1968. The preliminary school testing must be completed in time for the teacher to send in certification cards by Dec. 2, 1968. The certification cards notify the committee of the number of model bridges which are to be tested and are addressed to the attention of Paul Chuvarsky.

Models for the final testing should be repaired if damaged during the preliminary school testing, but cannot be altered in design. Each of the three school final models should be tagged with identification cards and certified by the teacher. At the time the certification postcard is mailed to the State Highway labs, the teacher should note on these cards the method of delivery of the models. If the models are to be mailed, they should be packed so as not to be damaged enroute and posted in time to arrive at the Highway Department not later than Dec. 6, 1968.

If some representative from your school is to bring the models to Denver in person, these models should be delivered directly to the laboratory east of the main building between 9 a.m. and 9:30 a.m., Dec. 7, 1968. The actual testing will begin at 9:30 a.m., Dec. 7, and all models will be tested to failure.

The space in the state materials testing quarters is limited so if too large a crowd shows up, some may have to wait in line to witness the testing of their models.

The mailing address is: Colorado State Highway Department, Attn: Paul Chuvarsky, 4201 E. Arkansas, Denver, Colo. 80222.



New Directions for Chemical Education in High Schools

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What is today's student in high school chemistry supposed to learn? What are students in chemistry actually learning? What in chemistry is it desirable that a student learn? Answers to these questions are urgently needed to provide the knowledge necessary to formulate and support thoughtful recommendations for improving current practices in chemical education at the high school level.

This paper is a report of our efforts since 1966-67 at Marple Newtown Senior High School to find answers to these questions. Some of the extensive subjective and objective data collected so far are included in this report. Our experience to date is shared in the hope that the information will generate deliberative responses and provide a basis for additional efforts to examine the efficacy of prevailing instructional procedures, the adequacy of existing course materials, and the merit of existing school organizational structures.

Goals and Content Today

What do the authors of existing course materials in chemistry say that students should learn in a chemistry course? Since the early sixties two well-known NSF-financed curriculum projects, CBA and CHEMS, have pioneered in reorienting chemical education in the secondary schools. The point of view expressed by the CBA writers (1) is that "through their own study and investigation of chemical systems, students should learn how experiments and ideas contribute to the understanding of chemistry." The CHEMS writers (2) stated that the "laboratory should be a place where the student makes and records careful observations, seeks 'regularities' in what he observes, and then 'wonders why'." Pode (3) in an extensive analysis of the CBA and CHEMS courses found that nine major topics: "stoichiometry, atomicity, kinetic-molecular theory, periodicity, energy, rates of reaction, equilibrium, bonding and acids and bases," were common to both courses although the presentation in each case was quite different. The influence of CBA and CHEMS on other high school chemistry texts has been considerable. Summerlin and Craig (4) found that the amount of descriptive material in chemistry texts published from 1961 through 1965 decreased from 60 percent to 5 percent and was "replaced by modern concepts of atomic structure, energy effects in chemical processes, chemical bonding, and mechanisms by which chemical reactions occur."

Although CBA and CHEMS were completely new approaches in the early sixties, it is quite apparent that in stated goals and content most chemistry texts published since are in much the same mold. The authors consider essentially the same topics, espouse general goals which emphasize the interaction of the laboratory and ideas, and wish for the student an understanding of chemistry as the chemist sees it.

Textbooks and laboratory guides do not in themselves transfer or even communicate understanding. Furthermore, although the materials are written for students, the emphasis is on the science. The student follows the particular development of a text and laboratory guide. In many cases the student is exposed to an excellent weave of the content and processes of science. What is not clear is how the student should be changed by the course. The interaction of data and ideas can only take place in our minds; only people understand; and understanding is a complex process which is difficult to evaluate in its many facets. Can those students who understand chemistry be identified? The behavioral responses of individuals who understand chemistry should be different from those who do not. It should be possible to determine and agree on observable behaviors which are indicative of specific understandings in chemistry.

Gagné (5) has said "content needs to be stated as objectives, and that these objectives mean things that the student is able to accomplish." None of the available chemistry textbooks and course descriptions available today provides a description of content in terms of what the student should be able to do after completing the course; however, it is possible to analyze a course to determine the behaviors one might expect a student to possess as a consequence of his involvement. If such an analysis of a course is made, the resulting statements of what the student should be able to do on completion of the course will represent a description of the course content that is not topical but in terms of the expected and observable changes in the student. At least, the specification of such behavioral objectives would permit value judgments to be made on the question whether or not possession of the desired behaviors is acceptable evidence that the person does have an understanding of chemistry. Furthermore, it would be possible to determine whether or not students can acquire the behaviors.

Behavioral objectives can be used to answer the question: What is today's student in high school chemistry supposed to learn? This question can be answered by describing the content of a course in terms of behaviors the students should acquire during the course. Once the behavioral objectives are defined in observable and measurable terms, the attention of the learner can be directed to the behavior he is to acquire and as Skinner (6) has said "we can then begin to teach."

Constructing Behavioral Objectives

How does one proceed to write behavioral objectives for a course in chemistry? A simple direct answer to this question cannot be given – there must be many ways to proceed. This report presents our attempt to develop behavioral objectives for our chemistry course. Mager (7) suggests that a useful objective identifies the performance expected, describes the conditions under which the learner will be expected to demonstrate his competency, and specifies the minimum quality of performance that will be acceptable. Our experience indicates that it is necessary to require an additional characteristic. The nature of the behavior should be broadly based so as to permit the description or invention of a variety of situations in which the student should be expected to demonstrate that he has acquired the behavior. In other words, the objective should specify a behavior that is not limited to a single, specific event, time, or place. The imposition of this fourth characteristic enhances the possibility that an objective has overall educational significance. Thus, four characteristics must be considered in developing a behavioral objective. Let us proceed by thinking through the development of several behavioral objectives in chemistry.

Changes in matter and chemistry are inextricably related. Any course in chemistry discusses changes in matter, and students investigate these changes in the laboratory. The student must understand what changes are if he is to study them. The student learns that a difference will be observed in a system in which a change occurs. How will he know when there is a difference? Observations are made at different times – in the initial and final states. If the observations are different, a change has occurred; if not, a change has not occurred. Now, let us ask, what should a person who understands what a change is, be able to do, which cannot be done by a person who does not understand what a change is. A person who understands what a change is should be able to say when a change has occurred. If a student can identify changes when they occur, we can infer that he knows what changes are. We have made our first decision.

Under what circumstances will the student be expected to identify changes? Will he be expected to identify changes in real systems in the real world? If so, the following objective would be acceptable. The student should be able to:

Identify (8) systems in which a change occurs, given the components of the systems in their initial states and the experimental procedures to follow.

We may decide that in addition or as a substitute the student should be able to demonstrate his competency with paper and pencil. In that event, the following objective would be acceptable. The student should be able to:

Identify systems in which a change occurs, given descriptions of the systems in both the initial and final states.

The two preceding objectives do not include a statement of the minimum acceptable standard of performance. For example, if the student is given descriptions of ten different systems in the initial and final states and asked to identify the systems in which a change occurs, how many systems must he correctly identify before his performance is acceptable as evidence that he does understand what a change is? We have found it convenient to specify a 70 percent or higher level or performance as acceptable for all objectives rather than include specific acceptable performance levels as part of each objective. Consequently, a student who correctly identifies seven or more of the ten systems is said to have achieved the behavior described in the objective.

Is it possible to describe or devise a variety of situations in which the student is to demonstrate his competency in identifying systems in which a change occurs? Obviously, the number of systems that can be described or given to a student for investigation is almost limitless. The objectives do meet the criterion of broad application.

Halliwell (9) has said, "If you want pupils to develop judgment, you must not only see that they are confronted with the opportunity and need to make a decision, but you must show them what to do to know whether they have been sound or not in their judgment." What better place is there than the laboratory to permit students to make decisions and to find out for themselves the measure of their judgment? Students should ask questions, design experiments, collect data, and interpret their findings. Students must be faced with situations in which they look to themselves for solutions if they are to develop their potential as contributors and creators. How does one present opportunities for students to use their minds in an original manner? Although students are encouraged to do so, our experience indicates that it is unrealistic to expect beginning students as a group to pose questions for which answers can be found by studying data that can be collected in school laboratories. As an alternative, topics for investigation are suggested, and the student is asked to construct appropriate questions and to design procedures for their investigation. For example, the student may be asked to:

Construct a procedure for qualitatively determining which, if any, of two substances in the initial state of a system is present in the final state, given solutions of substances which produce a precipitate when they are mixed.

The student has to decide what experimental procedure will produce data that can be used to provide an answer to his original question in terms of the specific solutions of substances he will be given. He must also explain why the particular procedure will enable him to obtain the data he needs to answer his question. He then goes to the laboratory to collect the data.

The behavior of constructing a procedure is a creative one of designing an experiment. What will you do if a student cannot construct a procedure? You may want the student to run experiments, collect and interpret his own data particularly in regard to the establishment of fundamental generalizations in chemistry even if he can't in every case construct the procedure. To accomplish this purpose an objective related to the preceding one would state that the student should be able to:

Demonstrate a procedure for qualitatively determining which, if any, of two solutions in the initial state of a system is present in the final state, given the procedure and two solutions which produce a precipitate when they are mixed.

The student would submit a report of his findings and interpretations as evidence in his competency in the objective. The behavior of demonstrating a procedure is essentially one of doing what is required in the laboratory to collect the data and of writing a report which presents and interprets the data.

In summary, our procedure for writing behavioral objectives begins with an intensive analysis of the topic of immediate concern to delineate the major ideas and processes essential to its understanding. The analysis is followed by decisions on what one would expect that only a person who understands the topic should be able to do which is observable and measurable. Having identified such a behavior, one needs only to describe the conditions, specify the performance level, and determine whether the behavior expressed in the objective can be assessed in a variety of situations. With these four characteristics present, the objective is ready for tryout with students.

Constructing Criterion Test Items

The student must make whatever effort is necessary to acquire the behavior expressed in the objective. How can the student be sure he possesses the desired competency? He takes a criterion test item designed to evaluate his performance. The criterion test item cannot be made difficult or easy; it simply fits the prescription in the objective. The student doesn't have to guess what he will have to learn or what he will have to be able to do when asked to demonstrate his achievement; he will know. He has to be able to do whatever is stated in the objective and nothing more. Knowing what he should be able to do, he can spend his time concentrating on achieving the desired behavior. The criterion test item provides a measure of whether or not the student can do whatever is stated in the objective. For any objective it should be possible to write a large number of different but equally appropriate criterion test items. If not, there is good reason to doubt the adequacy and educational significance of the objective.

Let us assume that we have agreed that students should understand and be able to use moles in thinking and working in chemistry. Students are told that they should be able to:

Apply the rule for determining the number of moles of formula units in a sample of a substance, given the formula and either (1) a sample of a substance or (2) the mass of a sample of the substance.

If the student has acquired the behavior expressed in the objective, he should be able to answer either of the following criterion test items. The first criterion test item must be done in the laboratory; the second is done with paper and pencil.

(1) You have been given a bottle which contains a sample of sodium carbonate, Na_2CO_3.

(a) What is the mass of 1 mole of Na_2CO_3?
(b) How many moles of Na_2CO_3 do you have in your sample?

(2) A bottle contains 3.70g of calcium hydroxide, $Ca(OH)_2$.

(a) What is the mass of 1 mole of $Ca(OH)_2$?
(b) How many moles of $Ca(OH)_2$ are in the bottle?
(c) Assume that you had been given a bottle containing $Ca(OH)_2$. Describe what you would do to determine the number of moles of $Ca(OH)_2$ in the bottle.

The preceding criterion test items represent only two of an almost limitless number of items that could be constructed to test whether or not the student possesses the behavior described in the objective.

The following objective states that students should be able to:

Construct a hypothesis as to the formula of the single product of a synthesis reaction, given the formulas of the reactants and the experimentally determined masses of all components in the initial and final state of a system.

Many criterion test items can be written to measure the competency expressed in this behavioral objective. As one example, if the student can do what is stated in the objective, he should be able to do what is asked in the following criterion test item.

In an investigation of the reaction of lead with sulfur, it was determined that only one product is produced. Several trials were run with different masses of lead and sulfur. Analysis of the final state provided information on (a) the mass of the product produced and (b) the mass of the reactant present, if any. The data collected are summarized in the following table.

Initial State($\pm$0.02g)

Trial	Pb	S
1	3.76	1.42
2	2.51	1.23
3	8.42	0.75

Final State($\pm$0.02g)

Pb	S	Product
—	0.84	4.33
—	0.84	2.89
3.56	—	5.60

(a) What is the combining mass ratio of Pb/S?
(b) What is the combining mole ratio of Pb/S?
(c) What is the formula of the product that is supported by the data?

The task of writing criterion test items is easy compared with that of constructing behavioral objectives. However, the possibility of writing a set of criterion test items for an inadequate objective is practically nil. The criterion test item simply describes a situation in which the learner can demonstrate that he does or does not possess the behavior. If a criterion test item is difficult to write, the problem is most likely with a poorly written objective.

What Do Students Learn?

What students in chemistry are supposed to learn can be described in terms of behavioral objectives. A set of behavioral objectives for our course in chemistry (see appendix) has been written (10). To whatever extent our chemistry course is representative of chemistry courses taught in other high schools, the set of behavioral objectives is also applicable. The assumption was made that students should and could achieve these objectives. We are now in a position to find out what our students do learn: A set of behavioral objectives has been drafted and the corresponding criterion test items have been written for our high school chemistry course. The question is: What percentage of our students do acquire the behaviors described in each of the objectives? Such a study was made in 1967-68 and is being repeated in 1968-69.

Each of the approximately 300 students in 13 college preparatory chemistry classes at Marple Newtown Senior High School was given copies of the behavioral objectives for each chapter of the basic text. The students were told that the statements described what they should be able to do when they had completed their study of the relevant topics in each chapter and the related laboratory work. The teachers planned class activities which had as their focus the achievement of the behavioral objectives. Students were also told that the examinations would be composed only of criterion test items having a one-to-one correspondence with the behavioral objectives, and nothing more would be expected of them. Students who demonstrated a behavior at a 70 percent or higher level of achievement would be credited with having acquired the objective. Essentially, then, each student knew exactly what he was supposed to learn to do. All he had to do was learn to do it.

A record was kept of the number of students who attempted to demonstrate the competency and the percentage of students who successfully demonstrated the competency for each objective. Data collected in 1967-68 for three representative objectives are presented below. The number of students tested and the percentage who scored 70 percent or higher on the criterion test item is written following the statement of each objective.

1. Identify and describe the system, initial state, and final state, given a report of an experiment performed and the observations collected. 301–92 percent

2. Apply the rule for calculating the combining mass ratio and the combining volume ratio of two gases, given their densities and either mass or volume data from an investigation of their reaction at the existing conditions of temperature and pressure. 298–53 percent

3. Construct and demonstrate a procedure for obtaining data to test the hypothesis that a given aqueous solution is homogeneous with respect to subdivision. 187–92 percent

The first objective above was achieved by 92 percent of our students. Fifty-three percent of our students

☆☆Students must be faced with situations in which they look to themselves for solutions if they are to develop their potential as contributors and creators.☆☆

demonstrated that they had acquired the second objective. One hundred and six objectives which constitute the content of our chemistry course were analyzed in this manner. The percentage of students who achieved an objective ranged from a low of 7 percent to a high of 100 percent with a median achievement of 64 percent; that is, each of 53 objectives was achieved by less than 64 percent of the students and each of 53 objectives was achieved by more than 64 percent of the students.

It should be noted that objective three of the immediately preceding three objectives is now written as two objectives. Constructing a procedure and demonstrating a procedure constitute different behaviors and must be evaluated separately. The procedure of writing two objectives related to an experiment was adopted in 1967-68 as soon as we became aware of the need to do so. The data collected in 1968-69 for this particular experiment indicate that 25 percent of 313 students were able to construct the procedure and 91 percent of 313 students were able to demonstrate the procedure. The data collected for all of the other experiments follow the same pattern. The percentage of students who are able to construct a procedure is considerably lower than the percentage of students who are able to demonstrate a procedure.

The mean percentage of students achieving the objectives for each chapter was also determined to arrive at an estimate of the average achievement of the group as the year progressed. The mean percentages in 1967-68 for each chapter have been plotted in Figure 1. The graph indicates that approximately 90 percent of the students achieved the objectives of chapter 1, about 70 percent achieved the objectives of chapter 2, and thereafter roughly 50 to 60 percent of the students were achieving the objectives of each of the succeeding chapters.

What do students learn? We are faced with the fact that 40 to 50 percent of our students did not meet the minimum standards for achieving the objectives of every chapter except chapters 2 and 3. Needless to say, we did not fail 40 to 50 percent of our students in the course; the grades were based on the standard curve (11). However, this procedure does not provide a valid assessment of each student's achievement. The evaluation of achievement is based, instead, on the student's performance relative to the performance of his peers. The student's grade is not interpretable in terms of what he has learned. Such grades do not tell you what students learn. What is needed is an indicator of the relationship between what the student has learned to do and what he was expected to learn to do.

Implications for Teachers

Students in our classes knew what they should learn to do. If we assume that the objectives are educationally significant and that students will do what is expected of them if they are able, then two questions become relevant. First, are the expectations reasonable; that is, do the objectives represent tasks that the student is able to achieve? Secondly, if an expectation is reasonable, has the student been allowed the time he needs to acquire the behavior? The possibility exists in our chemistry courses that many students are confronted with tasks they cannot accomplish, at least, at the time they are required to do so and in the time provided to do so.

How do we answer the question of whether or not the achievement of an objective is a reasonable possibility? Our data show that the achievement of objectives by our students ranged from a low of 7 percent to a high of 100 percent. These data reflect the performance of students in the typical classroom setting in which the pace is determined by the teacher for the class. One might predict that given more time more students would be able to demonstrate the desired competencies. On the other hand, some tasks may be so challenging as to require an inordinate amount of time and intellectual capacity. Criteria need to be established for selecting objectives which take

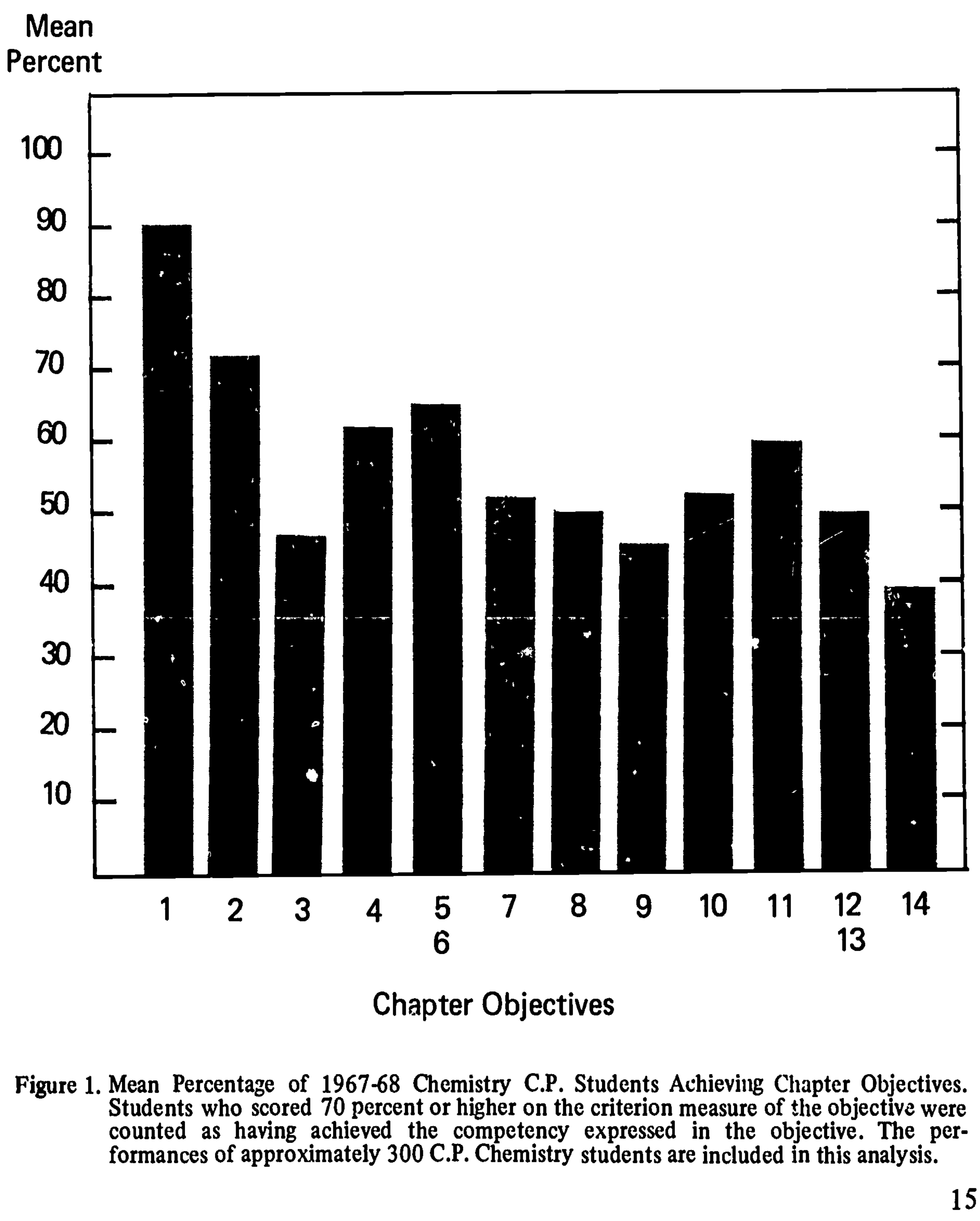

Figure 1. Mean Percentage of 1967-68 Chemistry C.P. Students Achieving Chapter Objectives. Students who scored 70 percent or higher on the criterion measure of the objective were counted as having achieved the competency expressed in the objective. The performances of approximately 300 C.P. Chemistry students are included in this analysis.

these variables into consideration. A set of minimal objectives which represent reasonable expectations for all of our students in a course needs to be developed. This would permit students to attempt tasks which they can achieve rather than be frustrated by involvement in activities in which it is unlikely or impossible for them to succeed. We are now (1968-69) in the process of collecting data on the performance of students on each of the objectives allowing whatever time the student who can achieve needs. The data will be used to establish a set of minimal objectives for our chemistry course.

Each of us has his own capacity for learning and a unique set of interests. We ignore the uniqueness of individuals when we cluster them and treat them uniformly. A system of education which consists of one class – one pace – one course generates unhappiness and frustration. For many students the pace is too fast and for others too slow. A course defined by a single set of objectives makes no allowance for individual motivations and intellectual capacities. Ideally, each student should be able to fashion his own scheme for achieving an acceptable set of course objectives in the time he needs to do so. Perhaps this degree of individualization is unrealistic to arrange now for all of our students, but the way is clear to making a start.

The content of a course should be described by a set of behavioral objectives. The set should include many behavioral objectives with multiple ways of achieving them, and of such variety that special interests, tastes, and intellectual capacities can be satisfied and stimulated. This means that some objectives, at least, must be achievable by different routes and that some objectives may be achieved only by some students. The guiding structure must be defined in such a way that the choices the students can and should make are clear. In Figure 2, the first segment of a hierarchy chart now being constructed to guide our students in studying chemistry is shown. The hierarchy includes those objectives which we now believe all students should be expected to achieve as the minimum requirement for the course in addition to others which are considered desirable but optional. The behavioral objectives are arranged in terms of dependency relationships. Competency in the objectives preceding a specific objective in the hierarchy is considered a necessary prerequisite to its achievement. Alternate pathways and optional objectives are identified by the dashed-line arrow. This segment of our hierarchy is representative of our beginning attempt to modify our chemistry course so as to provide for variation in individual interests and capabilities.

What are the desirable behavioral objectives in chemistry for high school students? This question remains unanswered. Decisions must be made to select from the large number of behavioral objectives it is possible to write in chemistry those which have a high degree of educational significance for students. This is not a task for one person. A study needs to be made of what in chemistry students should learn to do. Such a study by competent people in chemistry and education should result in a clarification of what chemistry students should spend their time and energy achieving. The very act of trying to decide how the study of chemistry should change a student and describing these expectations in terms of behavioral objectives would be beneficial in forcing us to assess what we are now doing. The question of why teach chemistry must be answered in terms of the specific behaviors it is desirable that students achieve.

Recommendations

Although this study dealt with high school chemistry, there is no reason to believe that the observations and conclusions do not apply equally to any of the sciences. New directions are needed for the study of all of the sciences in our secondary schools.

1. The content of high school science courses should be described in terms of behavioral objectives which students can be reasonably expected to achieve.
2. Scientists and educators should identify behavioral objectives in the sciences which are most likely to be educationally significant.
3. Behavioral objectives should be arranged in a hierarchy which permits students the choice of alternate pathways and optional objectives. The multiplicity of objectives, pathways, and options should make it possible for each student to design his own course.
4. Students should receive credit for a course when they have achieved the competencies of a specified minimum set of behavioral objectives rather than when they have spent a specified time with a course.
5. Students should know when they begin a course what they will be expected to be able to do when they have completed the course.
6. Examinations should be given when the student is ready, and only on the objectives for which he is ready to demonstrate his competency.
7. Students should be evaluated in terms of their progress in a curriculum rather than in terms of their progress relative to that of their classmates.

Any attempt to implement all of the above recommendations would require a restructuring of school organizational patterns, teaching strategies, and evaluation procedures – much too much, perhaps, to make a full scale attempt practical initially. However, it is quite possible to begin, as we have done, with a small-scale program which has been described elsewhere (12).

APPENDIX

Behavioral Objectives for College Preparatory Chemistry at Marple Newtown Senior High School in 1967-68

Each of the underlined words in the objectives is one of nine action words used by the AAAS *Science - A Process Approach* project (8). Each objective is identified by the letter C which indicates that it is an objective in chemistry. The Roman numeral refers to the chapter in the basic text used by the student (10). The Arabic number identifies the objective by number within the chapter. The letter L means that the competency expressed in the objective must be demonstrated in the laboratory. The objectives are addressed to the student for his achievement.

Most of the objectives in the set have been revised several times as a result of feedback from students and teachers. Modifications, deletions, and additions continue to be made as needed (13). At the completion of his study of college

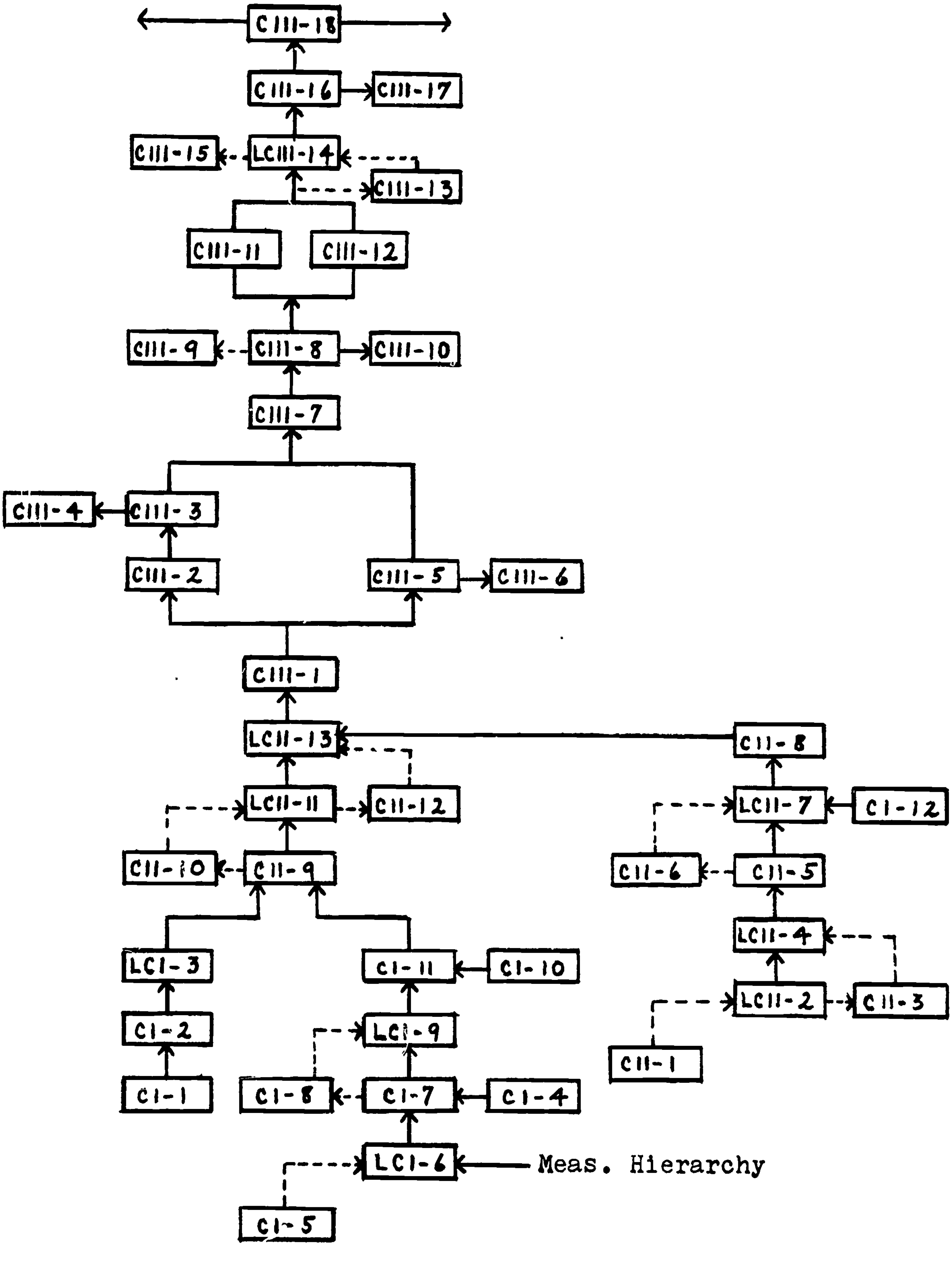

Figure 2. Chemistry CP Behavioral Objectives Hierarchy (Segment 1)

Each block represents the designated behavioral objective. The location of each objective in the hierarchy is based on a judgment of the necessary prerequisites. (This hierarchy has not been validated experimentally.) The student proceeds through the hierarchy by following the direction indicated by the arrows attached to the solid lines. Alternate pathways are indicated by the arrows attached to the dashed lines. Alternate pathways provide for flexibility, variation, individualization, and enrichment of the curriculum.

preparatory chemistry, the student should be able to:

CI-1 *Identify* and *describe* the system, initial state and final state, given a report of an experiment performed and the observations collected.

CI-2 *State* and *apply the rule* for identifying systems in which a change occurs, given the components of the systems in their initial states and the experimental procedures to follow.

LCI-3 *Demonstrate* the procedure and *apply the rule* for identifying systems in which a change occurs, given the components of the systems in their initial states and the experimental procedures to follow.

CI-4 *Distinguish* between definitions which are operational or conceptual, given a set of definitions.

CI-5 *Construct* a procedure for obtaining the data necessary to calculate the density of a substance in the solid or liquid phase.

LCI-6 *Demonstrate* the procedure and obtain the data necessary to calculate the density of a substance, given a sample in the solid or liquid phase.

CI-7 *Identify* samples of matter as mixtures, solutions, substances, elements and compounds, given observations of the properties of the samples.

CI-8 *Construct* a procedure for distinguishing between a substance and a solution which is based on at least two kinds of evidence, given a liquid which is either a substance or a solution of a solid.

LCI-9 *Demonstrate* the procedure for distinguishing between a substance and a solution which is based on at least two kinds of evidence, given the procedure and a liquid which is either a substance or a solution of a solid.

CI-10 *Construct* a line graph, given a set of paired data for two variables.

CI-11 *Identify* the smallest number of different substances represented in a set of samples, given either mass-volume and/or time-temperature data for each sample in the set.

CI-12 *Distinguish* between observations and hypotheses (theories).

CII-1 *Construct* a procedure for obtaining data to determine the solubility of a given solid substance in water.

LCII-2 *Demonstrate* a procedure for obtaining data to determine the solubility of a given solid substance in water.

CII-3 *Construct* a procedure for obtaining data to determine the effect, if any, of temperature on the solubility of a solid substance in water.

LCII-4 *Demonstrate* a given procedure for obtaining data to determine the effect, if any, of temperature on the solubility of a given solid substance in water.

CII-5 *Demonstrate* the preparation of an aqueous solution of specified volume and concentration, given a solid substance, the volume of the solution, and the concentration in grams of solute per unit of volume of solution.

CII-6 *Construct* a procedure for obtaining data which can be used to test the hypothesis that a given aqueous solution of a solid is homogeneous with respect to subdivision.

LCII-7 *Demonstrate* a procedure for obtaining data which can be used to test the hypothesis that a given aqueous solution of a solid is homogeneous with respect to subdivision.

CII-8 *State* and *apply the rule* for determining either the mass of solute, volume of solution or concentration of a solution, given values for the other two.

CII-9 *Identify* systems in which interaction between the initial components can be assumed upon mixing, given mass and volume data of the systems in their initial and final states and systems composed initially of either two solids, a solid and a liquid, or two liquids.

CII-10 *Construct* a procedure for qualitatively determining which, if any, of two substances in the initial state of a system is present in the final state, given solutions of substances which produce a precipitate when they are mixed.

LCII-11 *Demonstrate* a procedure for qualitatively determining which, if any, of two solutions in the initial state of a system is present in the final state, given the procedure and two solutions which produce a precipitate when they are mixed.

CII-12 *Construct* a procedure for obtaining data to determine the relationship (mass ratio) if any, between the mass of either of two initial components and the mass of the precipitate produced after mixing, given solutions of the initial components and their concentration in grams of solute per unit volume of solution.

LCII-13 *Demonstrate* a procedure for obtaining data to determine the relationship (mass ratio) if any, between the mass of either of two initial components and the mass of the precipitate produced after mixing, given the procedure and solutions of the initial components and their concentration in grams of solute per unit volume of solution.

CIII-1 *State* and *apply the rule* for calculating the combining mass ratio and the combining volume ratio of two gases, given their densities and either mass or volume data from an investigation of their reaction at the existing conditions of temperature and pressure.

CIII-2 *Apply the rule* for calculating the molecular mass ratio of two gases, given the combining mass ratio and the combining volume ratio of the gases at standard temperature and pressure and Avogadro's hypothesis.

CIII-3 *Construct* a hypothesis concerning the simplest atom ratio of elements (formula) in molecules of specified gaseous components of a chemical system in the initial or final state, given (a) the experimentally obtained volumes of each of the gaseous components, (b) the name of the elements in each substance and (c) Avogadro's hypothesis.

CIII-4 *Name* substances, given formulas of binary compounds and diatomic elements.

CIII-5 *Apply the rule* for calculating the atom mass ratio of two gaseous elements, given the combining mass ratio and the combining volume ratio of the elements at the same temperature and pressure, their formulas, and the Avogadro's hypothesis.

CIII-6 *Construct* a table of atom mass ratios, given the atom mass ratios of all possible pairs of elements within a set of four elements and a numerical value for an element in the set specified as the standard.

CIII-7 *Apply the rule* for determining the formula mass of a substance, given the formula and the table of atomic mass units.

CIII-8 *Apply the rule* for determining the number of moles of formula (structural) units in a sample of a substance, given the formula and either (1) a sample of a substance or (2) the mass of a sample of the substance.

CIII-9 *Apply the rule* for calculating the mass and/or apparent volume of the formula unit of a substance, given its (empirical or molecular) formula, its density, the Avogadro number, and the table of atomic masses.

CIII-10 *Apply the rule* for determining the number of formula (structural) units and/or specified atoms in a sample of a substance, given the formula and the number of moles of the substance in the sample.

CIII-11 *Apply the rule* for converting the concentration of a solution expressed as mass of solute/volume of solution to a molar concentration (moles of solute/volume of solution), or if expressed as a molar concentration to mass of solute/volume of solution.

CIII-12 *Apply the rules* for determining either the volume of a solution, moles of solute, or molar concentration of a specified solution, given values for the other two.

CIII-13 *Construct* a procedure for obtaining data to determine the mole ratios between the reactants and between each of the reactants and a product, given a system in which mixing two reactants, each in aqueous solution, produces a precipitate as a product; the molar concentrations of the solutions; and the formula of each reactant and the precipitate.

LCIII-14 *Demonstrate* a procedure for obtaining data to determine the mole ratios between the reactants and between each of the reactants and a product, given (a) the procedure; (b) a system in which mixing two reactants, each in aqueous solution, produces a precipitate as a product; (c) the molar concentrations of the solutions; and (d) the formula of each of the reactants and the precipitate.

CIII-15 *Construct* a hypothesis as to the formula of the single product of a synthesis reaction, given the formulas of the reactants, the experimentally determined masses of all components in the initial and final state of a system and the table of atomic masses.

CIII-16 *Construct* an equation for a change in a chemical system, given the formulas, the experimentally determined masses of all components in the initial and final state, and the table of atomic mass units.

CIII-17 *State* and *apply the rules* for writing equations to represent changes in chemical systems, given the formula and phase of each of the reactants and products of a chemical system.

CIII-18 *Apply the rule* for calculating the quantity in moles or mass units of a reactant or a product of a chemical change, given the equation for the reaction and the quantity in moles or mass units of one of the other reactants or products.

CIV-1 *Apply the rule* for calculating either the thermal energy transferred to or from a substance, its mass, heat capacity, or temperature change, given values for the other three.

CIV-2 *Construct* a procedure for obtaining data to determine whether or not there is a unique thermal energy change per mole of reactant, given a finely divided metallic element, an aqueous solution of a substance of specific molarity with which it reacts and the equation for the reaction.

LCIV-3 *Demonstrate* a procedure for obtaining data to determine whether or not there is a unique thermal energy change per mole of reactant, given the procedure, a finely divided metallic element, an aqueous solution of a substance with which it reacts and the equation for the reaction.

CIV-4 *Identify* (a) the polarity of the electrodes of an electrochemical cell, (b) the potential difference between any two points in a circuit, (c) direction and magnitude of current in a circuit, (d) quantity of charge which passes a point in a circuit in a given time, and (e) solutions which contain ions, given either the necessary equipment or a description of a procedure and the observations recorded.

CIV-5 *Demonstrate* and/or *describe* a procedure for obtaining electricity from chemical systems, given a system composed of strips of two dissimilar metallic elements and an aqueous solution of a compound of each of the metals.

CIV-6 *Construct* a procedure for obtaining data to determine the relationship, if any, between quantity of charge and quantity of products produced at the electrodes of an electrolytic cell during electrolysis, given the components of a system in the initial state and the equation for the reaction.

LCIV-7 *Demonstrate* a procedure for obtaining data to determine the relationship, if any, between quantity of charge and quantity of each product produced at the electrodes of an electrolytic cell during electrolysis, given the procedure, the components of a system in the initial state and the equation for the reaction.

CIV-8 *Apply the rule* for determining either the quantity of charge, the mass, or the charge to mass ratio of an element produced during electrolysis, given the values for the other two.

CIV-9 *Construct* a hypothesis as to the number of electrons transferred per atom or ion of either of two elements in a system which has undergone electrolysis, given the electrons transferred per atom or ion of one of the elements, the mass of each element produced at each of the electrodes, and the hypothesis that charge is conserved.

CV-1 *Demonstrate* and/or *describe* procedures for determining the type of charge, if any, on (a) an object, (b) an electroscope, and (c) the terminals of a battery.

CV-2 *Construct* or *describe* a hypothesis which explains the behavior of charged bodies, given an observation of the interaction of two charged bodies.

CV-3 *State* and *apply the rule* for determining whether or not the force between two charged bodies is increased or decreased and by what amount when either the magnitude of the charges, distance between the charges, or the medium (given the dielectric constant) between the charges is changed.

CV-4 *State* and *apply the rule* for determining whether or not the potential energy of a system of two like or unlike charges is increased or decreased when the charge separation, magnitude of the charges, or the medium (given the dielectric constant) is changed.

CVI-1 *Identify* the type of charge and its direction of flow in (a) high vacuum discharge, (b) thermionic and (c) photoelectric tubes, given either the necessary equipment or a description of an experiment and the observations recorded.

CVI-2 *Apply the rules* for determining the atomic number and mass number of an isotope of an element, given the number of electrons, protons, and neutrons in an atom of the isotope; or given the atomic number and mass number, determine the number of electrons, protons, and neutrons.

CVI-3 *Identify* isotopes of an element, given a set of elements described only by their atomic number and mass number.

CVI-4 *Describe* the structure and composition of atoms of an isotope of an element in terms of the hypothesis of the atom devised by Rutherford, Chadwick and others, given the atomic number and mass number of the isotope.

CVII-1 *Describe* or *identify* a property of matter which is explained by or supports a given assumption of the charge cloud hypothesis of the atom; and/or *name* an assumption of the charge cloud hypothesis of the atom which explains a given property of matter.

CVII-2 *Construct* charge cloud diagrams and/or three-dimension models of atoms of elements with atomic numbers 1 through 20.

CVII-3 *Construct* charge cloud diagrams and/or three-dimensional models of substances composed of elements with atomic numbers 1 through 20, given their formulas.

CVII-4 *Identify* the type of bonding between designated atoms, given a charge cloud diagram and/or three-dimensional model of a substance.

CVII-5 *Describe* the geometric shape and bond angles of the arrangement of nuclei and of electron clouds, given a charge cloud model of a substance.

CVII-6 *Construct* both Lewis and Couper structures of a substance given either the formula or the charge cloud model of the substance.

CVII-7 *Construct* a procedure for obtaining data which can be used to test the hypothesis that the reaction of $NH_{3(aq)}$ and $HCl_{(aq)}$ is a proton transfer reaction.

LCVII-8 *Demonstrate* a procedure for obtaining data which can be used to test the hypothesis that the reaction of $NH_{3(aq)}$ and $HCl_{(aq)}$ is a proton transfer reaction.

CVII-9 *Identify* equations of proton transfer reactions and *name* the acid and the base of each system in its initial state.

CVIII-1 *Apply the rules* that relate the Kelvin and Celsius temperature scale units to convert a temperature reading on one scale to the corresponding temperature on the other.

CVIII-2 (Optional) *Construct* the procedure for determining the constant which relates the pressure, volume, temperature and quantity (expressed in moles) of any gas sample.

LCVIII-3 (Optional) *Demonstrate* the procedure for determining the constant which relates the pressure, volume, temperature and quantity (expressed in moles) of any gas sample.

CVIII-4 *Apply the rule* for calculating either the volume, pressure or temperature of any fixed mass of gas, given values of each of the properties in the initial state and the values of two of the three properties in the final state.

CVIII-5 *Demonstrate* the procedure for obtaining the volume, pressure, and temperature of a gas sample collected in a calibrated container by liquid displacement, given a gas supply, barometer, thermometer, and data on the vapor pressure and density of the displaced liquid at various temperatures.

CVIII-6 *Construct* a procedure for obtaining data to indicate the relationship between the number of moles of gas produced at standard temperature and pressure and the number of moles of each of the reactants, given a system in the initial state composed of either $NaHCO_{3(aq)}$ and $HCl_{(aq)}$ or $Mg_{(s)}$ and $HCl_{(aq)}$

LCVIII-7 *Demonstrate* a procedure for obtaining data to indicate the relationship between the number of moles of gas produced at standard temperature and pressure and the number of moles of each of the reactants, given the procedure and a system in the initial state composed of either $NaHCO_{3(aq)}$ and $HCl_{(aq)}$ or $Mg_{(s)}$ and $HCl_{(aq)}$

CVIII-8 *Apply the rule* for calculating the volume of gas in the final state of a system, given the quantity of one of the other components in the system in the initial or final state, the equation for the reaction and the pressure and temperature of the system in the final state.

CVIII-9 *Apply the rule* for calculating either the molecular mass or density of a substance in the gas phase, given one of the values.

CVIII-10 *Describe* the relationship between the Kelvin temperature and the kinetic and potential energy of the molecules of a substance in the solid, liquid, and gas phases.

CVIII-11 *Order* a set of gases on the basis of increasing heat capacity given the formula.

CVIII-12 *Apply the rule* of electrical symmetry to predict and/or interpret differences in the melting point, boiling point, or magnetic properties, given charge cloud diagrams and/or three-dimensional models of any two substances composed of elements with atomic number 1 through 20.

CVIII-13 *Identify* and *describe* the basis for van der Waals attraction in a given substance composed of either atoms or molecules.

CVIII-14 *Order* a set of gases in terms of increasing diffusion rates given their molecular masses.

CVIII-15 *Describe* or *identify* a property of matter which is explained by or supports a given assumption of the kinetic-molecular theory of matter; and/or *name* an assumption of the kinetic-molecular theory of matter which explains a given property of matter.

CIX-1 *Apply the rules* for calculating enthalpies of reaction and writing thermochemical equations for chemical changes, given (a) the formulas of each component of a system in its initial and final state and (b) the quantity of heat transferred for a given quantity of one of the components.

CIX-2 *Construct* a procedure for obtaining data and calculating the enthalpy of reaction of a system composed of an acid and a base in its initial state.

LCIX-3 *Demonstrate* a procedure for obtaining data and calculating the enthalpy of reaction of a system composed of an acid and a base in its initial state, given the procedure, an acid and a base.

CIX-4 *Construct* a procedure for obtaining data and calculating the enthalpy of solution of a solid substance in water.

LCIX-5 *Demonstrate* a procedure for obtaining data and calculating the enthalpy of solution of a solid substance in water, given the procedure and a substance.

CIX-6 *Apply the rule* for calculating the quantity of heat transferred for a given quantity of reactant or product of a chemical change, given the thermochemical equation for the reaction.

CIX-7 *Apply the rule* known as Hess's law to write the thermochemical equation for a change, given either the enthalpy of formation or the enthalpy of dissociation for each component in the initial and final state of the system.

CIX-8 *Construct* a thermochemical equation for the enthalpy of formation of a substance, given its formula and enthalpy of formation and a list of all elements in their standard state (25°C and 1 atm.).

CIX-9 *Apply the rule* known as Hess's law to calculate the enthalpy of dissociation and bond energies for specified components in the initial or final state of a system, given the thermochemical equation for the change, the *National Bureau of Standards Circular 500-Part I*, the *Handbook of Chemistry and Physics* or tables of data abstracted from them.

CIX-10 *Demonstrate* the ability to obtain heat capacities and enthalpies of formation, vaporization, and fusion from the *National Bureau of Standards Circular 500-Part I* and the *Handbook of Chemistry and Physics* or from tables of data abstracted from them.

CIX-11 *Describe* the relationship between the enthalpy change for a system and the energies associated with the bonds broken and the bonds formed, given the thermochemical equation for the change.

CIX-12 *Identify* and *distinguish* among enthalpies of reaction, vaporization, fusion, combustion, formation, dissociation, solution, and dilution given thermochemical equations for the changes.

CIX-13 (Optional) *Demonstrate* the calculation of the enthalpy of reaction for a change, given the equation for the reaction and the *National Bureau of Standards Circular 500-Part I* and/or the *Handbook of Chemistry and Physics.*

CIX-14 *Apply the rule* known as Hess's law to calculate the apparent change in enthalpy for the change in a system which cannot or has not been carried out experimentally or for which the change in enthalpy is otherwise unavailable, given the equation for the change and tables of thermochemical equations from which to select those required for the calculation.

CX-1 *Identify* and *distinguish* among continuous, line and absorption spectra.

CX-2 *Order* photons of light as to increasing energy, given either the color or the wavelength of the photons.

CX-3 *Describe* the relationship between the experimentally observed line spectra and ionization data for an element and the inference of either (a) the orbits of the Bohr model or (b) the standing electron waves of the wave mechanics model of the atom.

CX-4 *Identify* and *distinguish* among s, p, sp, sp 2 and sp 3 orbitals as to shape and orientation.

CX-5 *Apply the rules* for assigning electron waves to orbitals to write the electronic configuration of atoms or ions of an element, given its atomic number.

CX-6 *Describe* or *identify* a property of matter which is explained by or supports a given assumption of the atomic orbital model; and/or *name* an assumption of the atomic orbital model which explains a given property of matter.

CX-7 *Construct* diagrams and/or three-dimensional representations of the orbitals in the outer energy level of atoms within a molecule in terms of both the charge cloud and atomic orbital model given the formula; and *identify* the number of single, double and triple bonds, bond angles and the geometric shape of the molecule.

CX-8 *Identify* the s, p, sp, sp 2 and sp 3 atomic orbitals used to form the bonds of a substance, given the structural formula (Couper structure).

CX-9 *Identify* the sigma and pi bonds in a diagram or three-dimensional representation of the atomic orbital model of a substance.

CX-10 *Construct* a procedure for obtaining data to indicate the trend, if any, in the enthalpy changes for reactions of the Group IIA oxides of magnesium, calcium, strontium and barium with an acid.

CX-11 *Demonstrate* a procedure for obtaining data to indicate the trend, if any, in the enthalpy changes for reactions of the Group IIA oxides of magnesium, calcium, strontium and barium with an acid, given the procedure, the Group IIA oxides and an acid.

CXI &XII-1 *Identify* samples of substances as metallic, covalent or ionic, given (1) a sample of a substance, (2) a sample of a substance and one or more of its properties or (3) observations of the properties of a substance; and *name* the criteria used to make the identification.

LCXI &XII-2 *Identify, name* and *construct* diagrams and/or three-dimensional representations of both aggregates and unit cells of hexagonal closest packed (hcc), face-centered cubic packed (fcc) and body-centered cubic packed (bcc) metal crystal structures.

CXI &XII-3 (Optional) *Apply the rule* for determining the packing efficiency of hcc, fcc and bcc metal crystal structures, given three-dimensional representations or diagrams of the unit cells.

CXI &XII-4 *Apply the rule* for determining the atomic radius of a metallic element, given the unit cell structure and either a sample of the metal or its density.

CXI &XII-5 *Identify, describe* and *construct* diagrams and/or three-dimensional representations of both aggregates and unit cells of sodium chloride lattice and cesium chloride lattice ionic crystal structures.

CXI &XII-6 *Describe, name* and *identify* properties of substances which are explained by or support one or more of the hypotheses that (a) bonding electrons in metals are delocalized among nuclei, (b) bonding electrons in covalent substances are localized between nuclei, (c) bonding electrons in ionic substances are localized around individual nuclei.

CXI &XII-7 *Identify* and *describe* atomic, covalent, van der Waals and ionic radii, given diagrams of aggregates of the structural units of substances.

CXI &CXII-8 (Optional) *Apply the rule* known as Hess's law to calculate the crystal energy of an ionic crystal, given the formula of the substance and the *National Bureau of Standards Circular 500-Part 1* and/or *The Handbook of Chemistry and Physics.*

CXI &XII-9 *Construct* equations for the reaction of any element in Groups IA, IIA, or IIIA with any element of Groups VI or VII of the periodic table.

CXI &XII-10 *Apply the rule* for classifying bonds as ionic, polar covalent or nonpolar covalent, given the electro-negativity of each element in the substance and its formula.

CXIII-1 *Construct* net ionic equations for reactions in which precipitates are formed when aqueous solutions are mixed, given systems in the initial state composed of pairs of aqueous solutions selected from ammonium, alkali metal, nitrate, perchlorate, halide, sulfate, sulfide, hydroxide, carbonate or phosphate compounds.

CXIII-2 *Construct* a procedure for obtaining data to test the generalization that the change in a system resulting from the interaction of ions in solution is independent of the presence of non-interacting ions in the solution.

LCXIII-3 *Demonstrate* a procedure for obtaining data to test the generalization that the change in a system resulting from the interaction of ions in solution is independent of the presence of non-interacting ions in the solution, given the procedure and three solutions of substances, two of which contain interacting ions.

CXIII-4 *Construct* a procedure for identifying each solution in a set of six to ten unlabeled aqueous solutions, given the names of the solutions in the set but no other reagents.

LCXIII-5 *Demonstrate* a procedure for identifying each solution in a set of six to ten unlabeled aqueous solutions, given a set of unlabeled solutions and the names of the solutions in the set but no other reagents.

CXIII-6 (Optional) *Apply the rule* known as Hess's law to calculate the hydration energy of an ionic substance, given the crystal energy and enthalpy of the substance.

CXIII-7 *Apply the rule* for calculating the oxidation number of each constituent element of a substance given its formula or name.

CXIII-8 *Name* the formula given either the classical or stock name of an inorganic compound, and *name* both the classical and stock name given the formula of an inorganic compound.

CXIII-9 *Identify* oxidation-reduction reactions, given equations for the reactions.

CXIII-10 *Identify* the oxidizing and reducing agents and the elements oxidized and reduced, if any, in a system in which a change occurs, given the equation for the changes.

CXIII-11 *Construct* a procedure for ordering in decreasing strength the reducing agents and the oxidizing agents in a set of eight substances which contains four elements each in two oxidation states, given the substances, or solutions of the substances, but no other reagents.

LCXIII-12 *Demonstrate* a procedure for ordering in decreasing strength the reducing agents and the oxidizing agents in a set of eight substances which contains four elements each in two oxidation states, given the procedure and the substances, or solutions of the substances, but no other reagents.

CXIII-13 *Construct* equations for oxidation-reduction reactions given formulas of the reactants and products and net ionic equations for oxidation-reduction reactions in acidic, basic and neutral aqueous solutions given formulas and all of the reactants and products, except H_2O, H^+ and OH^-

CXIV-1 *Construct* a procedure for obtaining data on the value and sign of the maximum electrode potential of each of four unlabeled metal-metal ion half cells, one of which is designated the standard electrode.

LCXIV-2 *Demonstrate* a given procedure for obtaining data on the value and sign of the maximum electrode potential of each of four unlabeled metal-metal ion half cells, one of which is designated the standard electrode.

CXIV-3 *Construct* a procedure for obtaining data of the effect, if any, of changing the concentration of the metal ion on the maximum electrode potential of a metal-metal ion half cell.

LCXIV-4 *Demonstrate* a given procedure for obtaining data of the effect, if any, of changing the concentration of the metal ion on the maximum electrode potential of a metal-metal ion half cell.

CXIV-5 *Order* the reducing agents in a given set of half reactions in decreasing strength, given a table of standard electrode potentials E^o.

CXIV-6 *Construct* net ionic equations for spontaneous reactions, if any, given pairs of standard half reactions and a table of standard electrode potentials E^o.

CXIV-7 *Apply the rule* for calculating the maximum potential difference of an electrochemical cell, given a description of the standard half cells and a table of standard electrode potentials E^o.

CXIV-8 (Optional) *Construct* a procedure for obtaining data to determine the effect of (a) quantity of charge ($I\Delta t$) and (b) the potential difference (ΔV) on the energy transferred from an electric circuit as heat.

LCXIV-9 (Optional) *Demonstrate* a given procedure for obtaining data to determine the effect of (a) quantity of charge ($I\Delta t$) and (b) the potential difference (ΔV) on the energy transferred from an electric circuit as heat.

CXIV-10 (Optional) *Demonstrate* a procedure for determining the relationship between the energy transferred from an electric circuit as thermal energy and the product of potential difference(ΔV), current (I) and the time (t), given a report of an experiment and the data collected.

CXIV-11 *Apply the rule* for calculating the free energy change produced by an electrochemical cell (assuming constant E^o), given a description of the standard half cells, the potentials difference and either (a) the current and time of operation or (b) the change in quantity of a component of the system.

CXIV-12 *Apply the rules* for calculating either (a) the change in quantity of a component or (b) the change in free energy, ΔG produced by an electrochemical cell, given the value of one of the changes, a description of the standard half cells and a table of standard free energies.

CXIV-13 *Construct* net ionic equations for spontaneous reactions, if any, given pairs of standard half reactions and a table of standard free energy changes ΔG^o.

CXV-1 *Identify* complete and incomplete changes in aqueous chemical systems, given the volumes and concentrations of each of the reactants and either the solubility or mass of each of the products.

CXV-2 *Describe* the effect on a given chemical system in the equilibrium state of (a) increasing or decreasing the concentration of one or more of the components, (b) increasing or decreasing the pressure on one or more of the gaseous components, and (c) transferring thermal energy into or out of the system.

CXV-3 *Construct* a procedure for obtaining data and calculating the equilibrium constant, $K_{eq.}$, for an (a) acid-water system or (b) partially soluble solid-water system in equilibrium.

LCXV-4 *Demonstrate* a procedure for obtaining data and calculating the equilibrium constant, $K_{eq.}$, for a system in the equilibrium state, given the procedure and an (a) acid-water system or (b) partially soluble solid-water system.

CXV-5 *Apply the rule* for determining the equilibrium constant, given the equation and the concentrations of each of the components of the system at equilibrium.

CXV-6 *Apply the rule* for determining the solubility product of a substance, given its solubility.

CXV-7 *Apply the rule* for determining the concentration of a component of a system in the equilibrium state, given the equation, the value of the equilibrium constant and the concentration of all of the other components of the system.

CXV-8 (Optional) *Demonstrate* the validity of the relationship $\Delta H^o = \Delta G^o + T\Delta S$ for a reaction, given the equation and either *NBS Circular 500 - Part 1* or ΔH^of, ΔG^of, and S^o values for all components of the system in the initial and final state.

CXVI-1 *Identify* substances which are acids or bases given (a) aqueous solutions of substances and/or (b) descriptions of the properties of their solutions.

CXVI-2 *Identify* the Lewis, Brønsted-Lowry and Arrhenius acid-base reactions in a given set of equations written with either empirical or structural formulas.

CXVI-3 *Name* the conjugate acid-base pairs, given equations representing Brønsted-Lowry acid-base reactions.

CXVI-4 *Construct* a procedure for ordering acids in decreasing strength, given aqueous solutions of four acids.

LCXVI-5 *Demonstrate* a procedure for ordering acids in decreasing strength, given the procedure and aqueous solutions of four acids.

CXVI-6 *Order* substances which are acids and/or bases in aqueous solutions as to decreasing acid and/or base strength, given equations for spontaneous reactions which occur when each of the substances is mixed with each of the other substances in the set.

CXVI-7 *Apply the rule* for calculating either the $[H_3O^+]$ or the $[OH^-]$ in an aqueous system, given the concentration of the other.

CXVI-8 *Apply the rule* for calculating the $[H_3O^+]$ and/or the $[OH^-]$ in an acid-water system at equilibrium, given the concentration of the acid in the initial state and its ionization constant.

CXVI-9 *Construct* a procedure for obtaining data to determine the concentration of acidic and/or basic aqueous solutions, given an acidic solution, a basic solution and the concentration of one of the solutions.

LCXVI-10 *Demonstrate* a procedure for obtaining data to determine the concentration of either an acidic or a basic aqueous solution, given the procedure, an acidic solution, a basic solution and the concentration of one of the solutions.

CXVI-11 *Apply the rule* for calculating either the concentration or the volume of either the acid or the base, given data obtained from the titration of the acid with the base.

CXVI-12 *Construct* a hypothesis which explains differences in the strengths of a set of acids given the structural formulas, ionization constants and the electro-negativity of each element in the acids.

CXVII-1 *Describe* how the rate of a reaction might be changed, given the equation and the enthalpy change.

CXVII-2 *Construct* a procedure for determining the effect of changes in either the temperature and/or concentration of a reactant on the reaction rate of a chemical system.

LCXVII-3 *Demonstrate* a procedure for determining the effect of changes in either the temperature and/or concentration of a reactant on the reaction rate of a chemical system, given the procedure and the equation for the reaction.

CXVII-4 *Name* the variable and *describe* its effect on the reaction rate of a specific change, given a description of a rate experiment and the data collected.

CXVII-5 *Identify* the activation energy, enthalpy change, the reactants and the products of a chemical system, given the potential energy diagram for the reaction.

CXVII-6 *Construct* a potential energy diagram for the change in a chemical system, given the reaction mechanism, the activation energy for each step and the enthalpy change for the net reaction.

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7. Mager, R.F. *Preparing Instructional Objectives.* Fearon Publishers, San Francisco, California. 1962.

8. In writing behavioral objectives I have used only those action words (underlined) used by the *AAAS - A Process Approach* Project. For additional information you are referred to the AAAS Miscellaneous Publication 67-9, *Science - A Process Approach - A Guide for Inservice Instruction*, 1967.

9. American Chemical Society. *International Chemical Education: The High School Years.* Washington, D.C. 1968.

10. Each student is provided with a copy of the text, *Chemical Systems*, developed by the Chemical Bond Approach Project and published by the Webster Division of the McGraw - Hill Book Company, Manchester, Missouri, in 1964. Since students are asked to construct their own questions and rationales for laboratory investigations, the accompanying laboratory guide *Investigating Chemical Systems* is not distributed; however, both publications have been used extensively as resources in writing behavioral objectives for the course.

11. The means obtained from the large-scale national application of standardized tests used to evaluate student achievement in the courses of the NSF-financed curriculum projects represent successful responses to approximately 50 percent of the items on each of the examinations. Students, on the average, answer 50 percent of the questions correctly. If the questions are assumed to be representative measures of the implied objectives of the courses, there is a striking correlation between these norms and those based on our data. Apparently only 50 percent of the students in these courses nationwide are achieving the objectives implicit in the materials.

12. DeRose, J.V. "The Independent Study Science Program at Marple Newtown Senior High School." *The Science Teacher* 35: 48; May 1968.

13. The author acknowledges with appreciation the invaluable assistance of his students and fellow chemistry teachers Paul Billett, Stanley Cochran, Tom Fourman, John Metka, Eugene Nalence, and Donald Sloat, who have through critical use of the objectives provided many suggestions and insights for their improvement.

Field Biology—
Forest, Field, Stream, and Evolution

A Modified Individual Study Approach to Field Biology

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Madison, Wisconsin

The advantage that this approach to field biology has is that a school system with a different biotic community than that of the Madison area could easily add additional exercises so that a field biology course suited to a specific locality could rapidly evolve.

Each student is given a packet of materials (the text - *"Field Biology" - Madison Public Schools - Forest, Field, Stream . . . and Evolution*, unbound, unpublished form), a portion of which includes the behavioral objectives, flexible trip schedule, experiments (potential) that might be done in each area, bibliography and weekly prepared (student) experiment signup sheets. Each student can select from 200+ listed experiments the one(s) they want to use or they are free to add their own with the instructor's consent. Not all experiments that are listed together near the end of the text are useful in a particular study area but, each potential class study area has been listed and lab references have been indicated. This approach puts a burden on the students to select their lab exercises but, if one or more have a particular interest, they can pursue this in studying a variety of biotic communities.

Finally, the instructor must not only have access to a large library, but must have a broad overview of the literature being used by the students. An instructor can offer first or second choices in order to give guidance in studying an area, but the students must make the final choice wherever possible.

Originally it was hoped that this approach would work in the first year field course, but it appears, after the 1968 Summer Session, that it would be far more useful as a second year field course where students have two or more years of high school biology (one year is presently required in Madison), one of these an inquiry approach (e.g. Biological Science Curriculum Study or BSCS – *Green Version*), the other a research approach (e.g. BSCS – *Interaction of Experiments and Ideas*).

1. Table of contents
2. Introduction
3. Behavioral Objectives
4. Field Biology Field Trip Schedule
5. Numbered Experiment Sheets
6. Experiment Reference Sheets
7. Bibliography
8. Reference books (supplemental) not referred to in the Numbered Experiment Sheets.
9. Supplemental Book List (Student fill-in sheet)
10. Field Biology Planning Sheet (6 copies)
11. Note Paper
12. Supplemental Field Exercises (A several–day exercise *may* be included to eliminate handling it (them) out in the field.)
13. A Classification of Organisms*

Note: This booklet cannot be copied without the author's permission in written form. This is a local curriculum project. My sincere thanks to Walter H. Jaeschke, Professor of Pathology and chairman of the Surgical Pathology Department who proofread the text. Also, my thanks to Florence Kreutzmann,

* Each locality, where this course approach is used, should develop a modified local classification.

Memorial Junior High's secretary, who did the typing; and to Ann Walden, teacher, and Richard Meister, principal, for their technical assistance.

Introduction

This course, offered this year as part of the enrichment program, is intended to give you an appreciation of the problems that biologists encounter when they attempt to "catagorize" the environment. Recommended laboratory exercises will be given in the context under the headings "First Choice" or "Must Be Done". However, supplemental exercises that you can do besides the required ones will also be listed. In some cases where materials can be obtained you may, after obtaining my O.K., substitute an Individual Study (I.S.) or a supplemental exercise for the required one. *

NOTES:

A. Some I.S. is listed separately at the end of this course booklet.
B. The ability of a person to communicate with his friends is important. In recording data obtained in the laboratory or field, do so immediately with a pencil of hardness 3 or with an indelible ink pen. This data may include numerical measurement, observation, which may be recorded as neat line drawings (no shading in), and observation, which is in word (phrase) form. Always use a bound data book and certainly never use a loose sheet of paper which can be lost.
C. The final reports are to be in the following form:

    1. Title
    2. Purpose of the exercise: the hypothesis.
    3. Materials and equipment.
    4. Data: this includes graphs, charts, and answers to any questions you, your instructor or the author of a particular laboratory raised.
    5. Conclusion: This is a summary statement which ties together and interprets the data and relates it to previous work or relates it to new questions which might be posed.
    6. References: This is to be in the form – Author (underlined), Title (in quotes), Publisher, date of publication, page reference (if needed).

D. Your report must be clearly stated so that others can understand what you did and gained from the exercise.
E. Absences – Board of Education Policy is followed as pertains to summer school attendance. However, special arrangements for experiments which might be done elsewhere (outside of the Madison area), by yourself, can be made. *
F. Clothing – shorts are acceptable and swimming suits and tennis shoes will be needed on some outings. Shoes MUST be worn at all times except in a Lifeguard-protected swimming area. Everyone participates (dependent on swimming ability) in all labs. Health problems of a special nature should be cleared through the summer school office.
G. On Friday each team of 4 persons (as assigned) shall turn in a schedule (schedule sheets stapled on at the end of this booklet) of laboratory exercises to be carried out the following week (note inserted forms for this purpose) and these are to coincide with the trip schedule which follows.
H. One half credit can be granted for this course at the discretion of the school principal by presenting to him evidence of satisfactory completion of the course.
I. The various publications mentioned in this guide are either in the Science-Math Reading Materials Center (RMC) or in my own collection during the year, and are available in the field biology room.
J. This course is 6 weeks long, 5 days a week and a minimum of 4 hours a day. Most final writeups will have to be done at home.
K. Please read the behavioral objectives on the following page to better understand the goals of this course.
L. A "classification of organisms" (5 pages) can be found preceding the Bibliography.
M. If you find new books you think would be worthy additions to the course, list them on the supplementary book list (end of booklet).

No final exam will be given unless I feel one is necessary. You are graded on your class participation (ability to follow instructions or submit practical suggestions), your laboratory notebook and final writeups which you will turn in one day before the end of summer school. Unless I request the right to retain one or more of them, the manuals plus your final grade will be given to you on the last day.

BEHAVIORAL OBJECTIVES FOR FIELD BIOLOGY

The student should be able to
1. observe and sample some of the many ecological habitats that exist in Wisconsin, including forest, transition zone, lake and quarry (fossil record of prior habitat).
2. become acquainted with local plants and animals of the southern Wisconsin area, both fossil and present forms.
3. become acquainted with practical natural history concepts of the flora and fauna, particularly the interdependence of the two (e.g. food chains).
4. observe, demonstrate and appreciate sound conservation practices in the field.
5. be a better informed citizen when it comes to understanding and/or supporting pending legislation which may allow man to live on earth a few more years.
6. Develop an understanding of the techniques useful in field biology for preserving, collecting, mounting, identifying and classifying zoological and botanical specimens.
7. become familiar with the geography of southern Wisconsin, its wildlife refuges, arboretums, parks and institutions of higher learning.

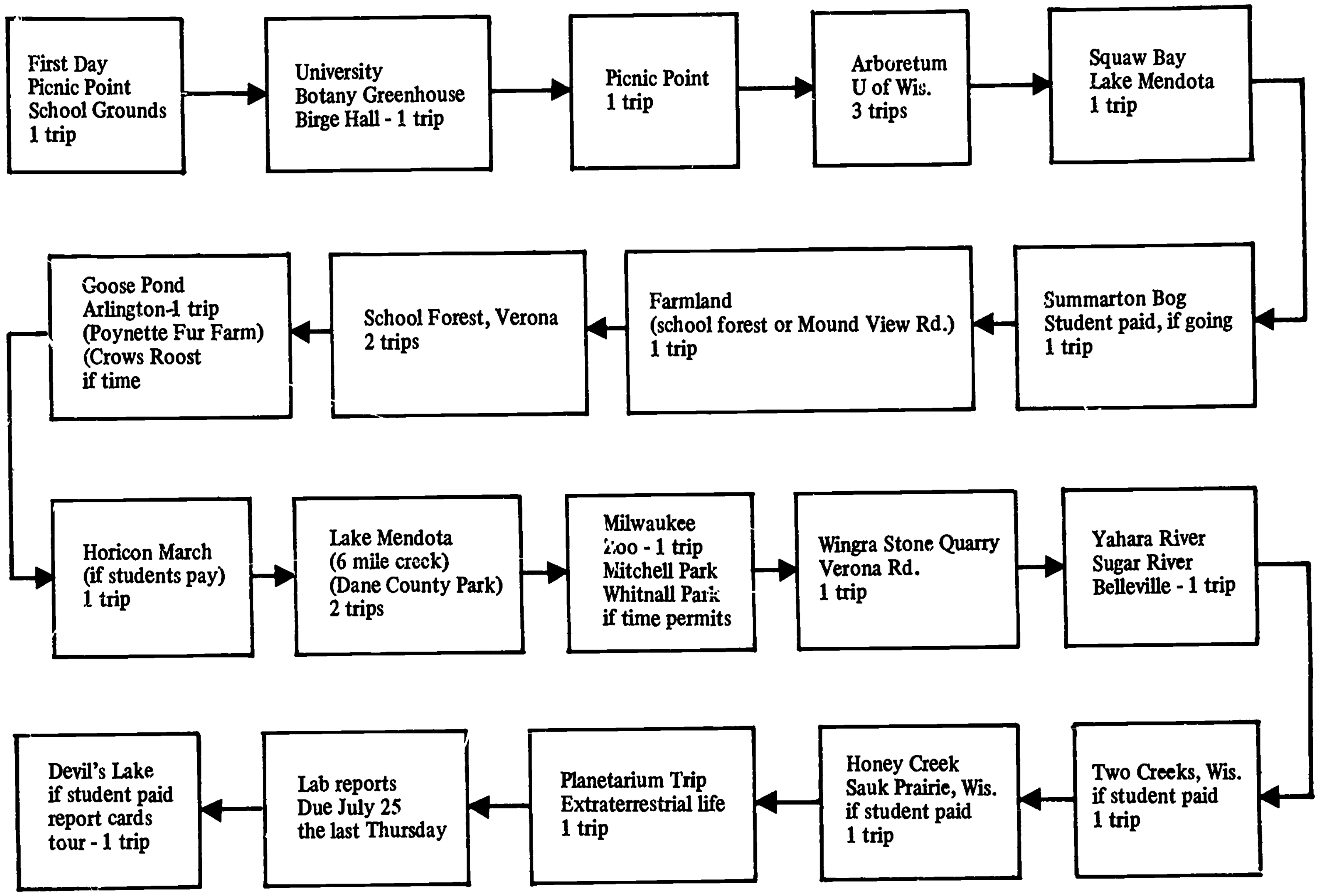
* Enough "First Choice" items exist to constitute one summer school course. A second summer's work, based on an I.S. approach, is possible.

* At a cottage or trip site.

FIELD BIOLOGY – FIELD TRIPS

Minimum Number of Trips- 17
Maximum Number of Trips - 22
Total Class Days - 29

Tentative Schedule
Dates to be decided upon
each week for the next
week – firm commitments



Introduction

Note: The numbers correspond to numbered references at the end of the booklet. Please fill in after each number the material from the reference section. If you do this, do so neatly and please print. This will serve as an outline of labs, so that you won't have to refer, continuously, to the experimental reference sheets.

13
196
186
179
204
197
176
175
174
178
184
191

169
170
165
191
193
202

First Day–Suggested reference if specimens brought back to lab–"*How to know living things*" by Jacques

Use at Picnic Point or anywhere–1st choice

50
54
61
62
92
149
duVair-1 (150)-1st
duVair-2 (150)-1st
duVair-3 (150)-1st

151
152

Picnic Point

1
3
6 - Page 38
6 - 3 Faces
6 - Why Woods
6 - Page 42
6 - Page 40
8
6 - Page 45
6 - Page 47
6 - Guess Wood Uses
17
30
45
49
50
51
54
56

67
68
69
72
80
81
82
91
94
98
114
116
95
97
100
120
123
126
129
132
155
163
200
205
232
238
251

University of Wisconsin Botany Greenhouse - Birge Hall

209 - 1st choice
217

Arboretum, University of Wisconsin -
Quik-key to Wildflowers by Archbald - 1st choice in references.
2 - 1st choice
Wildflowers of the Arboretum by Zimmerman - 1st choice in references.
8
6 - Page 38
Quik-Key to Birds by Emlen - 1st choice in references.
6 - 3 Faces
6 - Why Woods
6 - Page 42
6 - Page 40
6 - Page 45
6 - Page 47
6 - Relative
24
27
28
42
45
46
49
51
56
57
59
60
64
67
72
79
80
81
82
3 - 1st choice
91
94
95
96
97
98
100
114
117
116
120
123
126
129
132
duVair 4 (150) - 2nd choice
duVair 26 (150) - 2nd choice
155 - 2nd
173
179
201
204
205
206
207
208
221
227
230
232
234
235
238
240
251

Farm Field

94
95
100 - 1st choice
70
76
79
88
91
121
123
139
234

School Forest

Ornithology (Bird Study)
Quik-Key to Birds by Emlen - 1st
104
Quik-Key to Wild Flowers by Archbald - 1st choice in references.
198
203
107
159
189
Other Labs
8
17
22
27
28
30
36
39
40
41
43
45
49
50
51
53
54
56
57
3 - 1st
65 (collect)
66
67
72
94
95
97
98
99
112
117
120
125
126
129
132
135
148
141
duVair 5 (150) - 2nd
151
155 - 1st
154
185
200
205
207
208
221
225
226
238

246
248
251

Summarton Bog

142
19
84
87
93
183
233
238

Transition Zones (Goose Pond, Squaw Bay, Horicon March)

Some of these labs (36-94) may also be used with a study of a farmer's field

104
107
45
50
55 - 1st
91 - 2nd
94
36
97
100 - 1st
115
duVair 24 (150) - 2nd
duVair 7 (150) - 1st
duVair 8 (150) - 1st
7
21
17
26
30
54
duVair 9a (150) - 1st
161
169
180
181 - 1st
195
199 - 2nd
223
224
240
251

Lake Mendota and Feeder Stream Analysis plus Effluent Openings

1j
27
30
47
50
56
60
61 (could be a first day lab)
62
73
77
83
94
97
99
109
112
115
126
133
148
160
7
9
10
11
18
20
22
34
48
54
duVair 6 (150) - 2nd
duVair 7 (150) - 2nd
duVair 8 (150) - 2nd
duVair 9a (150) - 2nd
duVair 11 (150) - 2nd
duVair 14 (150) - 2nd
duVair 16 (150) - 2nd
duVair 17 (150) - 2nd
duVair 22 (stream) (150) - 1st
duVair 23 (lake) (150) - 1st
195
160
169
180
181
182
218 - 1st
219
220
223
224
241
244

River Analysis - Yahara River Pollution

7
9
10
11
17
18
20
30
34
45
50
53
54
78
94
97
126
duVair 27 (150) - 1st
169
219
220
244

River Analysis - Sugar River - Pollution

7
9
10
11
18
20
50
78
94
97
126
27
12
duVair 27 (150)
244

Street Lab Exercise (Community Exercises)

162 - 1st
187 - 1st
208
243
251

Evolution and Paleontology - Wingra Stone Quarry

45
duVair 30 (150) - 1st choice
166 - 2nd
216 - 2nd

Honey Creek, Sauk Prairie, Wis.

185
251
252

Evolution (Recent) – Milwaukee Zoo

50
53
duVair 29 (150) - 1st Choice
duVair 28 (150) - 1st
166
90 - 1st (Bus Route)

Mitchell Park (a tour)

Whitnall Park (take a nature trail trip if time permits)

Devil's Lake (Report cards given out, a tour, picnic)

duVair 11 (150)
31 - 2nd
86
90 - 1st

Devil's Lake Tour - 4 (East Bluff) - 1st

219
226
227
238
239
248

Individual Study (I.S.)

14
23
25
29
32
33
35
37
52
63
74
75
71
85 (Could do on the Wisconsin River)
87 (Could be done at Door County with a stopoff at the Ridges Wildflower Sanctuary and Upper Peninsula State Park)
101
102
103
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106
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112
113
118
119
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124
127
128
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131
134
137
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143
145
146
147

duVair (150)
10
15
19
20
21
25
28
160
165
167
171
172
173
174
186
188
190
191
193
210
213
214 (Laboratory Work - pages 37, 39)
215
222
229
231
233
236
237
241
243
244
245
247
250

Rainy Day Ideas in addition to regular lab writeups

194
152
156
157
159
161
228
242
253
254
255
256

EXPERIMENT REFERENCE SHEET

Note: Refer to the bibliography following this section for complete data.

1. Seed germination experiment (refer to the Green Version Laboratory Manual - any type of seeds may be used)
2. *Arboretum Tour Guide* by Dr. James Zimmerman and John Jaeschke
3. *School Forest Ecology Laboratory* by John Jaeschke and Ken Schroeder
4. *Devil's Lake Tour* by John Jaeschke and Dr. James Zimmerman
5. Territorial behavior of birds (work done by Dr. and Mrs. Hammerstrom, Plainfield, Wisconsin, on the Prairie Chicken.)
6. Forest Products Laboratory, *Classroom Demonstrations of Wood Properties* by A. N. Foulger.
   A. "Not All Oaks Are Alike" - p 38
   B. "How Water Moves in Plants" - p 18
      You might use plastic containers to store water and field test the samples right away.
   C. "The Three Faces of Wood" - p 25
   D. "Why Woods Have Different Properties" - p 27
   E. "What is Specific Gravity" - p 42
   F. "What Happens When Wood Gets Wet" - p 40
      Dry blocks of wood from swamp trees versus upland forest types and compare (twigs "might" be substituted).
   G. "How Specific Gravity Affects Expansion" - p 45
   H. "How Strong is a Single Fiber?" - p 47
   I. "Relative Strength of Woods" - Field Test - You need a set of weights and must select young, new growth of equal circumference from a number of different trees of different habitats. Then, attempt to guess or discover what uses the woods might be put to.
7. Water Analysis (refer to the testing kit directions and determine what basic tests you are going to repeatedly conduct in various areas)
8. Soil Analysis (refer to the booklet in the kits and the publication *How Good is Your Land* by I. Hembre, University of Wisconsin – the kit is the Soil Test Kit)
9. "Fish Stomach Analysis" (Refer to *Field Biology* by Paul duVair)
10. Bottom seine-pressure studies (Refer to above reference)

11. Plankton Net (Refer to above reference)
12. Mendota stream analysis (Refer to above reference)
13. Introduction, p 388, *The American Biology Teacher*, "Summation of a Field Biology Course" by Richard C. Powell, May 1966
14. Nature photography (see Mr. Jaeschke)
15. Twin Creeks Forest Trip (Glacially-crushed trees), Nature Conservancy, Lake Michigan
16. Horicon Marsh Trip, Roland Zielsdorf, Guide, Horicon, Wisconsin
17. Radioactivity in grass, water, etc., using specimens placed in planchets following the determination of the counting chambers background count.
18. DDT uptake in aquarium - held lake fish noting any unusual behavior of the fish such as in respiration, feeding, reaction to various stimuli followed by dissection of the fish noting any microscopic changes in the stomach contents as well as in other structure. Line aquariums with plastic.
19. A Trip to a Bog - p 367 (refer to number 13) (see also number 183)
20. Aquatic Ecology - p 364 (as above) (see also number 182)
21. Biology of a Pond - p 351 (as above) (see also number 180)
22. "Chromatography" - p 51, *Science Projects Handbook of Experimental Biology*
23. Herbarium collection (refer to mounting techniques suggested by the University of Wisconsin Herbarium)
24. Ant Nest Observation - suggested area - University of Wisconsin Arboretum with permission of the Arboretum Staff.
25. Embryology - Frog Egg Development (refer to the *BSCS Green Version* Study Manual)
26. *Science Experiments* - "Does the Community of a Pond Change?" - p 3
27. "Analyzing Soil for Biological and Chemical Activity" - *Science Experiments*
28. "What Organisms Live in the Soil?" - p 18, *Science Experiments*
29. "Studying Live Parasites" - p 30, *Science Experiments*
30. Lightmeter studies in various environments relating this to a specific plant and its growth pattern. Selective light absorption studies might also be run on various plants using colored filters.
31. The Study of a Microclimate - p 50, *Science Projects Handbook*. Devil's Lake, the East Bluff, might be used, as might the Arboretum's pine stand.
32. Plastic embedding of biological material using plastic materials from the Hanover House Gift catalog or Faust Scientific Co., Madison, Wisconsin.
33. Taxidermy using polyethylene glycol from the Crane Creek Gunstock Company, Waseka, Minnesota. (see Mr. Jaeschke's folder on Taxidermy*)
34. Rice Water Paper Prints (refer to above)
35. "Plant Grafting" in *Propagation*, Brooklyn Botanic Garden Handbook, Brooklyn Botanic Garden, 1000 Washington Ave., Brooklyn, New York 11225, $1.00 - may also be available at Mitchell Park Conservatory in Milwaukee.)
36. Effects of mineral deficiencies (*Handbook of the Biological Sciences* or laboratory notes of the Plant Physiology Course of the University of Wisconsin)
37. *Skeleton Preparation* (see the notes of the Beloit College Embryology Department)
38. Study of young, nonphotosynthetic growth of green plants versus photosynthetic growth using chromatography and/or colorimeter analysis of pigment concentrations and various wave lengths of light.
39. Tracing of water conduction pathways in Jewelweed or Solomon's Seal using eosin or some other water soluble dye.
40. Finding the Root of the Problem - p 50, *Experimental Biology*
41. "Measurement of Root Pressure" - see above
42. "Transpiration - Respiration Chamber" - see above pp 87-97
43. "Detecting Transpiration by Manometry" - see above
44. "Stethmanometer in Measuring Breathing Rate and Heart Rate" - see above
45. Thistle Collecting and the difference in species distribution depending on the area. Refer to Dr. James Zimmerman's notes for the Reading the Landscape Course, *Diversity of our Environment*

*Referred to in number key.

46. Plant Lab – Use Dr. Zimmerman's Arboretum Guide to plants and the "Understanding of Evolution" part in *Pamphlet No. 45*
47. Test for contamination of water near major outlets of city and industry using the water test kit and coliform bacteria test. Use as a reference, "Lets Look at Our Water Resources"
48. Fish ammonia release as part of the excretory system (experiment in which a piece of rubber is put around the middle of the fish) – check Chapter 14, *BSCS Green Version* text.
49. "Conifer Forest Questions", *Ecological Organization of Forest Type*, Dr. James Zimmerman's Reading the Landscape course. Soil test conifer, deciduous and prairie vegetation areas.
50. *The Breeding Birds of the Madison Area* - Habitat Study, Reading the Landscape course, publication 3
51. *Projects on the Deciduous Forest*, Reading the Landscape course
52. *Backyard Biota*, Reading the Landscape course
53. *Energy Flow Chart*, Reading the Landscape course
54. Adaptive Radiation of Birds (possible research project)
55. Flying – an indirect movement – BSCS Laboratory Block on *The Complementarity of Structure and Function*, pp 41-47
56. "The Soil", *Life in the Soil* BSCS Laboratory Block, pp 1-6
57. *School Forest Guided Tour Booklet*, 8 pp
58. "Soil Organisms", refer to above No. 56, pp 18-22
59. "Protozoa", as above, pp 23-26
60. "Buried Slide Soil Technique" - pp 46-48 (set up 6 days prior to readout of slides)
61. Test of City Water vs. Well Water vs. Lake Water vs. Pond Water using the water test kit plus doing a slide analysis using "Algae in Water Supplies" by the United States Dept. of Health, Education and Welfare (use the 6 pages of color algae representations as reference while at the same time keeping an accurate result of your observation)
62. "Building a Microprojector", page 35, refer to above No. 60
63. Supplemental I.S. using the *Animal Behavior* BSCS Lab Block for
    A. Stickleback, pp 29-30
    B. Bees, pp 30-31
    C. Your Habits, pp 33-34

D. Daphnia, pp 40-50
E. Planaria, pp 11-20
F. Human, pp 20-24, 28-29
G. Frog, pp 27-28

64. "Seed Germination", evergreens versus deciduous trees, pp 1-4, 7-14 (seed structure, p 5), *Plant Growth and Development* BSCS Lab Block
65. A Study of Responses of Isopods (eq. sowbugs are easy to get) to Humidity, Light and Combinations of Humidity and Light, BSCS Laboratory Block *Physiological Adaptations*, Investigation 3.
66. Other exercises from the Lab Block book above
    A. "Extended Inquiry – Statistical Results", pp 85-87
    B. "Isopod Identification", pp 95-97
    C. "Isopod Trap", p 98
    D. "Kymograph smoking techniques", p 99
67. "Some Properties of Soil - Density, Porosity, Soil Texture, Soil Water, Absorption", *Plant Physiology* by Kurtz and Miller (Library Number 581, K 96p)
68. "Radioactivity - Pesticide, Herbicide", p 32, pp 37-40 (refer to number 76)
69. "Translocation", pp 31 - 35 (as above)
70. "Ashing and Mineral Nutrition Following General Field Mineral Symptoms Determinations", pp 23-25 (as above)
71. "Culture of Mineral Deficient Plants", pp 10-11 (as above)
72. "Visible Radiation - Light", Exercise 2.2, *Field and Laboratory Guide for Ecology* by Paul C. Lemon (Library Number 574.4, 154f, Memorial High RMC)
73. "Heat and Light in Aquatic Environments", Ex. 2.3 (as above)
74. "Patterns of Rainfall and Water Ecology", Ex. 3.1 (as above), I.S.
75. "Adaptations Related to Radiation and Water Ecology" (as above), I.S.
76. "Range or Pasture Grazing", pp 46-49 (as above)
77. "Aquatic Ecosystems - Freshwater (Ponds and Lakes)", Ex. 5.1, pp 59-64 (as above)
78. "Streams and Rivers", pp 65-76 (as above)
79. "Grassland Biome", pp 80-82 (as above)
80. "Coniferous Forest Biome", pp 87-91 (as above)
81. "Conifer-Hardwood Forest Biome", Ex. 6.5, pp 95-97 (as above)
82. "Deciduous Forest Biome", pp 98-100 (as above)
83. "Primary Successions", Ex. 7.1 Hydroseres (as above)
84. "Bog Succession", Ex. 7.1 pp 106 - 108 (as above)
85. "Primary Successions" - Flood Plain. Ex. 7.3 (as above)
86. "Xerosere – On Rock", Ex. 7.4 (as above)
87. "Xerosere – On Sand", Ex. 7.6. *Field and Laboratory Guide for Ecology* by Paul G. Lemon
88. "Secondary Succession - Agricultural", Ex. 8.1 (as above)
89. "Secondary Succession - Logging or Fire", Ex. 8.2 (as above)
90. "Dunes and Glacial Land Forms", Ex. 9.1 (as above)
91. "Soil Conditions Affecting Communities", Ex. 9.2 (as above)
92. "Dendrochronology - Tree Growth Analysis", Ex. 9.4 (as above)
93. "Polynology - Peat Pollen Studies", Ex. 9.3 (as above)
94. "Community Investigations", Ex. 10.1 (as above)
95. "Point and Line Intercept Techniques", Ex. 10.2 (as above)
96. "Ecological Use of Aerial Photographs" (use the Arboretum photographs), Ex. 10.2 (as above)
97. "Animal and Plant Indicators" - Bioassay, Ex. 11.2 (as above)
98. "Life Forms of Plants and Animals", Ex. 4.3 (as above)
99. "Ecological Uses of Radioisotopes", Ex. 11.3 (a fine exercise) (as above)
100. Wildlife Habitat Score Cards, *How Good is Your Land*, by I. Hembre, Wis. State Soil Conservation Committee
101. "Frog Flukes", *The Living Laboratory*, pp 41-44
102. "Social Life in an Ant Colony", pp 56-61 (as above)
103. "Terraria for Amphibians and Reptiles", pp 76-81 (as above)
104. "Identifying Birds", pp 82-87 (as above)
105. "Effect of Flooding on Seedlings", *BSCS Research Problems*, Booklet 1, p 67
106. "Can Aphids Find Their Host Plants", p 155 (as above)
107. "Analysis of Bird Territory", p 161 (as above)
108. "The Effect of Light and Other Factors on the Germination of Seeds", p 165 (as above)
109. "The Influence of Light and Temperature on Fish", p 1, *BSCS Research Problems*, Booklet 2.
110. "The Role of Light and Temperature on the Seasonal Distribution of Microflora", (as above)
111. "Variation in the Size of Pollen Cells" p 21 (as above)
112. "The Time of Most Active Cell Division in Root Tips of Plants" p 29 (as in number 109)
113. "The Influence of Temperature on the Behavior and Physiology of Amphibians and Reptiles" (as above)
114. "Antagonistic Effects of 2-4-Dinitrophenol on Growth Abnormalities Induced by 2-4-D" (as above)
115. "The Rate of Heartbeat in Nymphs of Dragonflies", p 47 (as above)
116. "Insect Reaction to Light, Color and Intensity", p 67 (as above)
117. "Secondary Succession", p 113 (as above)
118. "Factors Influencing Plant Tumor Growth", p 135 (as above)
119. "The Modification of Juvenile and Adult Leaf Forms with Plant Growth Regulators", p 155 (as above)
120. "Spider's Web Building as an Example of Innate Behavior Response", p 209 (as above)
121. "Breaking Dormancy in Seeds", p 1, *BSCS Research Problems.*
122. "The Influence of Light on Sporulation of Fungi", p 11 (as above)
123. "A Study of the Fauna in the Soil", p 23 (as above)
124. "Variation in Mouthparts of Tadpoles", p 40 (as above)
125. "The Influence of Humidity on the Behavior of Peristome Teeth in Some Species of Mosses", p 88 (as above)
126. "The Role of Competition in Determining the Intensity of Natural Selection", p 108 (as above)
127. "The Effect of Chemicals on the Rate of Regeneration in Hydras", p 116 (as above)
128. "A Study of Some Changes in Crustacea During Intermolt Cycle", p 120 (as above)
129. "Spread of an Insect Population", p 131 (as above)
130. "The Study of Biological Clocks in Plants", p 145 (as above)
131. "Measurement of Radioactivity in Plant Leaf Ash" (as above)
132. "The Influence of Orientation on the Growth Rate of Tree Stems" (as above)
133. "Variations in the Respiratory Organs of Aquatic Insects" p 71 (as in number 121)
134. "Relative Sensitivity of Fungus Spores and Mycelium to Toxic

Agents" p 31, *BSCS Research Problems*, Booklet 4

135. "The Physiological Ecology of Mosses" p 49 (as above)
136. "Effects of Cigarette Smoke on Molluscan Gill Cilia" p 57 (as above)
137. "Antimicrobial Substances From Seeds", p 63 (as above)
138. "Water Relations of Tree Seedlings", p 81 (as above)
139. "Local Floras" p 89 (as above)
140. "Maturation and Death of Plants" p 115 (as above)
141. "The Occurrence, Structure and Frequency of Root Hairs on Forest Trees" (as above)
142. "The Role of Nitrogen in the Nutrition of Insectivorous Plants", p 144 (as above)
143. "Studies on Foraging and Learning in Ants", p 152 (as above)
144. "The Use of Hard Parts of Fishes for Growth Determination", p 160 (as above)
145. "Movement Homing and Home Ranges in Frogs and Toads", p 192 (as above)
146. "Structural Effects of Low Temperature on a Ciliate Protozoan", p 196 (as above)
147. "Experiments in Mammalian Hibernation", p 200 (as above)
148. *DDT Analysis* (Student Report, 1968, Madison Memorial High)
149. "Pollination Laboratory", Mr. Jaeschke, 1966, University of Wisconsin Zoology - Botany Department Greenhouse, Birge Hall
150. *Field Biology* by Paul duVair, Exercises (as recommended under individual project areas) 1,2,3,4,5,6,7,8,9,9a,11,12,13,14,16, 17,18,22,23,24,26,27, 29,30.
151. "Bird Nest Identification List" (Found originally in the *Girl Scout Manual*). Reading the Landscape course by Dr. Jim Zimmerman. *Key to Bird Nests* by Dr. Arthur A. Allen.
152. Snake Identification (Rainy Day Project) using the jar of reptiles donated by Nasco to Memorial High.
153. Test on the Zoo, "How Good is Your Eyesight" pp 232-233, *Nature Recreation* by Vinol.
154. "Fifty Questions on the Maple-Sugar Industry" (as above)
155. "Stump Scouting" (tree stump analysis - cutting methods and animal and plant identification) – 33 questions, (as above)
156. Rainy Day Activity - Bird I.D. cards or slides or call records
157. Twig-leaf matching game - rainy day activity
158. Tree silhouettes - rainy day activity
159. Bird nest dissecting with a chart to prepare on types of building materials depending on the type of bird plus a sketch or photograph of the nest.
160. Owl Pellet dissecting – Individual Study
161. Identification of Animal Tracks
162. "City Nature Study" pp 180-188, (as in number 153)
163. "Judging Heights and Approximating Measures" p 171-172 (as above)
164. "Instructions for the Exercise in Trapping and Collecting of Small Mammal Specimens", Zoology 525-2 pp
165. "How to Build Cages", pp 226-229 (as in number 153)
166. Turtox Leaflet Number 46 - *Fossil Specimens*
167. Turtox Leaflet Number 9 - *How to Make Skeletons*
168. Turtox Leaflet Number 18 - *Insectivorous Plants*
169. *Freshwater Biology* by Needham and Needham
170. *Taxonomic Keys* (spiral bound book)
171. Turtox Leaflet Number 51 - *Hydroponics*
172. Turtox Leaflet Number 48 - *Aquarium Troubles*
173. Turtox Leaflet Number 35 - *Ant Observation*
174. Turtox Leaflet Number 24 - *Herbarium Collection*
175. Turtox Leaflet Number 22 - *Laboratory Drawings*
176. Turtox Leaflet Number 14 - *Selected Book List*
177. Turtox Leaflet Number 3 - *Preserving Botanical Specimens*
178. Turtox Leaflet Number 2 - *Preserving Zoological Specimens*
179. Turtox Leaflet Number 1 - *How to Make an Insect Collection*
180. "Biology of a Pond" by Nutting, p 351, *American Biology Teacher*, May 1966
181. "Biology Students Map a Lake", p 361 (as above), by Stopp
182. "Aquatic Ecology Studies in High School Biology" by Dindal, p 364 (as above)
183. "A Trip to a Bog" by Ramond Evans, p 367 (as above)
184. Field biology data sheets, p 389 (as above), by Powell
185. "Some Areas for Botanical Investigation" by Wagner, p 397 (as above) - References made to clones, liverwort, equisetum and fern spores.
186. Film - 16mm color - Ektachrome type B ASA 125 (indoor) available for use - needs to be mounted in 100 foot lots and processing (retail) is about $2.05/50 feet.
187. Write your own laboratory exercises and turn in for Individual Study.
188. "Dissection of Aves" - *Internal Anatomy* - Aves 11, Zoology 138, lab notes (bird dissection)
189. Aves 1, "Skeleton and Body Form" (as above)
190. "Taxonomy of North American Amphibia" (refer to 188)
191. *Laboratory Manual of Biology*, Department of Biology, College of Liberal Arts, Boston University. To be used for additional zoological and botanical phylum dissections.
193. *Reading the Landscape* by May Theilgaard Watts. This is a good, easy reading approach to ecology.
194. "How Much Dust is in the Air", p 15, *Nature and Science* April 1, 1968.
195. "A Week of Fresh-water Biology for Teenagers" by Gary F. Kelly, *American Biology Teacher*, March 1968, pp 181-185. A data form and survey of animal life "chart" is included.
196. *They Called the Land "Ouisconsin"*, by Fenton Kelsey, 1957, Americana Press (available at the State Historical Society)
197. *Pauls Alphabetical Check List of "Loon" State Birds*, Pauls Hearing Center, Anoka, Minnesota (Fine for Wisconsin birds and can be obtained free upon request)
198. *Solving Your Bird Problems* by Paul H. Fluck (Pamphlet)
199. "The Amazing Summer Pond" by Catherine M. Pessino, *Nature and Science*, p 4, July 1964
200. "Life in a Rotting Log" by Rod Cochran, *Nature and Science*, p 12, Oct. 5, 1964
201. "How Pollen Gets Around", *Nature and Science*, p 8, May 17, 1965
202. "How Ice Changed the Land", *Nature and Science*, p 8, Dec. 19, 1966
203. "On the Wing", *Nature and Science*, p 8, February 13, 1967
204. "Ways to Catch an Insect", *Nature and Science*, October 3, 1966

205. "Webs Spun to Order", *Nature and Science*, p 7, Teachers Copy, October 3, 1968
206. "A Gallery of Galls", *Nature and Science* February 5, 1968
207. "The Secret Life of Wasps and Bees", *Nature and Science*, p 13, April 24, 1967
208. "Specialized Stems", *Workbook in Fundamentals of Plant Science* by George B. Cummins, *et al.* p 80
209. Insectivorous Plants and How They Work. Take a trip to the University of Wisconsin Greenhouse (may be done in conjunction with the Pollination Laboratory Exercise described earlier)
210. Bird skin and small mammal skin preparation (see Mr. Jaeschke)
211. Microscope slide preparation for permanent collection - botanical and zoological (see Mr. Jaeschke)
212. Ask the instructor for further general reading (*The Sand Country Almanac* by Aldo Leopold or the *Life of John Muir*)
213. *Scientific Experiments in Environmental Pollution* by W.C. Weaver, 48 pages, Holt, Rinehart and Winston, New York, 1968.
214. *Laboratory Experiments in Radiation Biology* by Edward I. Shaw, suggested pages 37 and 39. Review "Contents"*
215. *Biology Experiments* (American Cancer Society), G. Congdon Wood, Editor. Exercise 24, "Experimental Production of Plant Tumors with Crown Gall Bacteria" by Edwin B. Matzke and A.C. Hildebrandt
216. *Biology* (Laboratory Manual) by Stanley Weinberg. Exercise 16 "Fossils" (Chalk)
217. *Biology Investigations* by James H. Otto, et al., 1969. Exercise 6-2, "Photosynthesis"
218. *Ibid.*, 14-1. "A Study of Classification" (Fish)
219. *Ibid.*, 16-8, "Bacteriological Analysis"
220. *Ibid.*, 18-1, "Unicellular Organization - The Protozoans"
221. *Ibid.*, 19-3, "The Mushroom"
222. *Ibid.*, 19-5, "Study of a Slime Mold" - Use if slime mold is found in the field

*Refer to "Radioisotope Experiments in High School Biology" (An annotated bibliography), U. S. Atomic Energy Commission, Division of Technical Information, Oak Ridge, Tennessee.

223. *Ibid.*, 20-1, "The Algae" (familiarization lab)
224. *Ibid.*, 20-2, "Diversity of Algae"
225. *Ibid.*, 20-3, "Lichens as Examples of the Symbiotic Relationship"
226. *Ibid.*, 21-1, "The Mosses"
227. *Ibid.*, 21-2, "The Ferns"
228. *Ibid.*, 25-1, "Absorption of Water by a Root"
229. *Ibid.*, 25-2, "Mineral Requirements of Plants"
230. *Ibid.*, 25-3, "Conduction in Stems"
231. *Ibid.*, 26-2, "Phototropism and Geotropism in Plants"
232. *Ibid.*, 27-1, "The Flower-Specialized Reproductive Structure"
233. *Ibid.*, 27-2, "Structure and Germination of Pollen Grains"
234. *Ibid.*, 27-3, "The Fruit – A Mature Ovary"
235. *Ibid.*, 49-1, "The Water Cycle"
236. *Ibid.*, 49-2, "The Carbon-Oxygen Cycle"
237. *Ibid.*, 50-1, "Nutritional Relationships"
238. *Ibid.*, 50-2, "Ecological Analysis of Two Habitats"
239. *Ibid.*, 50-4, "Life in Soil Communities"
240. *Ibid.*, 51-1, "Succession"
241. *Ibid.*, 53-1, "Soil and Water Conservation"
242. *Ibid.*, 54-1, "Forest and Wildlife Conservation"
243. *Ibid.*, 16-3R, "Effect of Weather Conditions on the Bacterial Count of the Atmosphere"
244. *Ibid.*, 16-8R, "Stream Analysis" (Bacterial)
245. *Ibid.*, 21-1 R(1) "Growing Moss Protonema"
246. *Ibid.*, 21-1 R(2) "Field Study of Bryophytes"
247. *Ibid.*, 21-2 R (1) "Growing Fern Prothalli"
248. *Ibid.*, 21-2 R (2) "Field Study of Ferns"
249. *Ibid.*, 25-1 R, "Effect of Environment on Color Changes in Fish"
250. *Ibid.*, 50-1 R, "Study of Frog Parasites"
251. *Ibid.*, 38-1 R, "Field Study of Birds"
252. Observe Marchantia's (Liverwort) Life Cycle (understand evolution) *BSCS Green Version* textbook
253. *Grassland Biomes* by Lou Woughter, Syntex Modular Program--Programmed Learning
254. *Freshwater Biomes* by Lou Woughter (as above)
255. *Forest Biomes* by Lou Woughter (as above)
256. *Marine Biomes* by Lou Woughter (as above)
257.
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263.

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Field Book of Ponds and Streams. Ann Haven Morgan. G.P. Putnam's Sons, New York. 1930.

Field Book of Insects. Frank E. Lutz. G.P. Putnam's Sons, New York. 1948.

Field Guide to Trees and Shrubs. George A. Petrides. Houghton Mifflin Company, Boston, Massachusetts. 1958.

Forest Flora of Canada. G.C. Cunningham. R45-121, Queen's Printer, Ottawa, Canada.

Grasses of Wisconsin. Norman

Fassett. University of Wisconsin. Press, Madison. 1951.

Handbook of Snakes. Volumes 1 and 2. Albert H. Wright and Anna A. Wright. Comstock Publishing Association, Ithaca, New York. 1957.

Handbook of Wisconsin Fishes. Wm. E. Dickinson. Milwaukee Public Museum, Milwaukee, Wisconsin. 1960. (alternate book - *Fishes of the Great Lakes Region.* Carl L. Hubbs and Karl F. Lagler. The University of Michigan Press, Ann Arbor, Michigan. 1958. (Price - $6.95)

How to Know the Birds. Roger Tory Peterson. Houghton Mifflin Company, Boston, Massachusetts. 1957.

How to Know the Fresh Water Algae. G.W. Prescott. Wm. Brown Company, Dubuque, Iowa. 1964.

How to Know the Spring Flowers. Mabel Jacques Cuthbert. Wm. C. Brown Company, Dubuque, Iowa. 1949. (Revised)

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Note: An excellent aid is *Sourcebook for the Biological Sciences.* Evelyn Morholt, Paul F. Brandwein, and Alexander Joseph. Harcourt, Brace and World, New York. 1958. Extremely helpful in teacher preparations.

Note: A good reference such as the *Van Nostrand Science Encyclopedia* and *Stedman's Medical Dictionary* can be of great help.

Note: One may select any college Zoology book such as *Life* and any Botany text such as *Botany* by Robbins, Weier and Stocking, 2nd Edition, published by John Wiley & Sons, Inc., to serve as basic references.

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SUPPLEMENTAL BOOK LIST

If you find any good works or articles on subjects pertaining to the biology area or specifically to field biology (personal accounts, for instance, such as those by Aldo Leopold) that you've looked over, you may include a short report in your writeups. However, I hope that you'll list them as well below.

Book Title

Author

Publisher

Date

Magazine

Article

Date

Publisher

Pages

FIELD BIOLOGY PLANNING SHEET
Make in Duplicate –
Turn one in to the teacher

Team Members

Week of

Monday *

Hour 1

Hour 2

Hour 3

Hour 4

Tuesday *

Hour 1

Hour 2

Hour 3

Hour 4

Wednesday *

Hour 1

Hour 2

Hour 3

Hour 4

Thursday *

Hour 1

Hour 2

Hour 3

Hour 4

Friday *

Hour 1

Hour 2

Hour 3

Hour 4

Extra contemplated Individual Study

*List the field trip, if any.

An Improved, Versatile, Inexpensive Astronomical and Chemical Spectrophotometer

R. M. KALRA

Mission Secondary School
Mission, British Columbia, Canada

The spectroscope was invented by Sir Isaac Newton in 1664 when he passed a beam of white light through a prism. To his surprise the prism dispersed the white beam into the colors of the rainbow. Sunlight, he deduced, was a mixture of all the colors of the spectrum, red, orange, yellow, green, blue, and violet. However, using a spectroscope with improved optics, William Herschel discovered infrared light rays by testing the region below the red with thermometers. Likewise, Ritter discovered ultraviolet light rays when he placed silver salts in the region beyond the violet. Fraunhofer introduced a further improvement of the spectroscope. He replaced the prism with a glass slide upon which he had etched thousands of lines. This was the diffraction grating, a device far more accurate than the prism. Simms, another spectroscopist, added a series of lenses and gave the spectroscope its modern form.

However, the optical spectroscope has two main disadvantages. First, the naked eye is neither sensitive nor accurate enough to permit the study of dim objects like stars. Second, time exposure spectrophotography was expensive, time consuming, and not always practical. To overcome these difficulties the eye or film plate can be replaced with a sensitive photocell and graph recorder. This is the principle of the spectrophotometer.

The theory behind the spectrophotometer is simple. An objective lens focuses the light under study on a slit, and it passes through a collimator lens that parallels the light rays. The rays are then dispersed into the various wavelengths by a diffraction grating. The spectra are reflected off a mirror and through two more lenses to focus the spectra. These focused spectra then shine on the photocell housing at the far end of the tube. In the center of the housing is another slit, just wide enough to allow one narrow wavelength through. This one band strikes the photocell and induces a current that varies with the intensity of the band. The current readings can be noted on an ammeter or graph recorder. To allow each band to pass through the slit, the photocell is mounted on a rotor which is attached to a slow, controlled motor. As the photocell passes across the spectrum the various intensities of the bands cause differentiating fluctuations on the ammeter. By noting these fluctuations and comparing them to fluctuations of known substances the presence of various elements can be determined.

The chemical photo-analyzer can be made by adding a small section of tubing in front of the objective. Inside is a continuous-spectrum light source and a glass cuvette. Various frequencies of light will be absorbed when they pass through the solution in the cuvette. Knowing that substances absorb the same frequencies that they will emit, comparison to other emission graphs will eventually lead to identification of the substances in solution.

The four-inch objective lens is a magnifying glass which can detect stars to 12.1 magnitude and will separate to 1.50 inches of arc. However, the instrument can spectrophotometrically examine celestial bodies to the fifth magnitude. It is mounted in a lens cell attached to a 48-inch aluminum tube. An adjustable slit is set at about .002 inch wide. Behind this is a rectangular collimating lens mounted with some steel plate strips. The diffraction grating has 15,000 lines per inch and is mounted in a way similar to that of the collimating lens. Because the spectra are refracted away from the optical axis, a mirror on the side of the tube reflects the spectra towards the telescope assembly. This is a tube with two short-focal-length lenses. By experiment these lenses can disperse and focus the spectra on the photocell housing. The housing is a small rectangular aluminum box with a hole drilled in the middle. Over this is a slit .003 inch wide which will allow the one wavelength being studied through. Inside an amphenol socket forms the bottom of the housing. The whole box is completely insulated with rubber. The photocell housing is bolted to a small steel rod. The rod is welded to the shaft of a small 1/15 rpm synchronous motor. The motor is mounted on the side of the telescope tube. Attached to the outside is a 60-mm astrograph for photography. It doubles as a finder scope by simple turning on the lighted reticles.

The whole assembly is mounted on a sturdy equatorial mount supported by a 30-inch pier. The mount is designed to allow for apparent motion of stars and is equipped with clock drive for long periods of examination.

The leads from the photocell and clock drive are connected by plugs and jacks on the tube to a hand-control unit. From the unit other leads from the graph recorder, power unit, and a lock switch offer complete control of all functions from one complete unit. All leads are retractable cords for ease of movement. Each function of the unit is indicated by a pilot light so that the operator knows at a glance what sections are functioning.

The power unit is contained in a separate cabinet from the graph recorder. The power unit consists of a simple hybrid circuit with one tube and six transistors. This assembly is mounted on Verobord for ease of construction and maintenance.

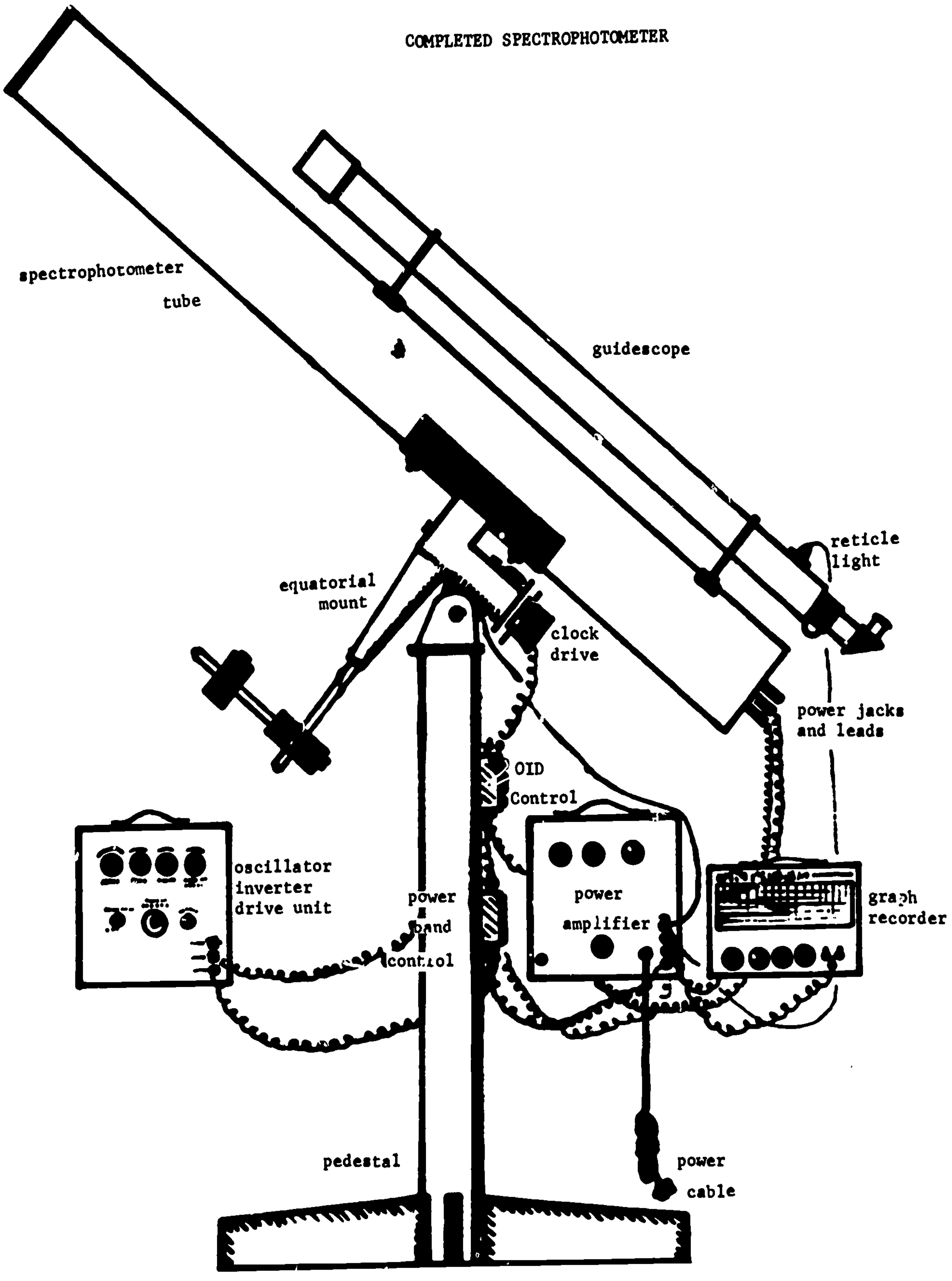
This spectrophotometer is based on a design by R.C. Dennison. However, it is improved:

(a) It is now versatile; it doubles as an astronomical spectrophotometer and a chemical spectro-analyzer.

(b) It is more convenient, self-contained, and much more accurate and sensitive than was the original.

(c) It is extremely low priced. The model can be constructed for $400 ($100 Canadian duty) and is equivalent in performance to models about three times as costly.

COMPLETED SPECTROPHOTOMETER



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2. Dennison, R.C. "The Amateur Scientist." *Scientific American* 218: 140-144; May 1968.

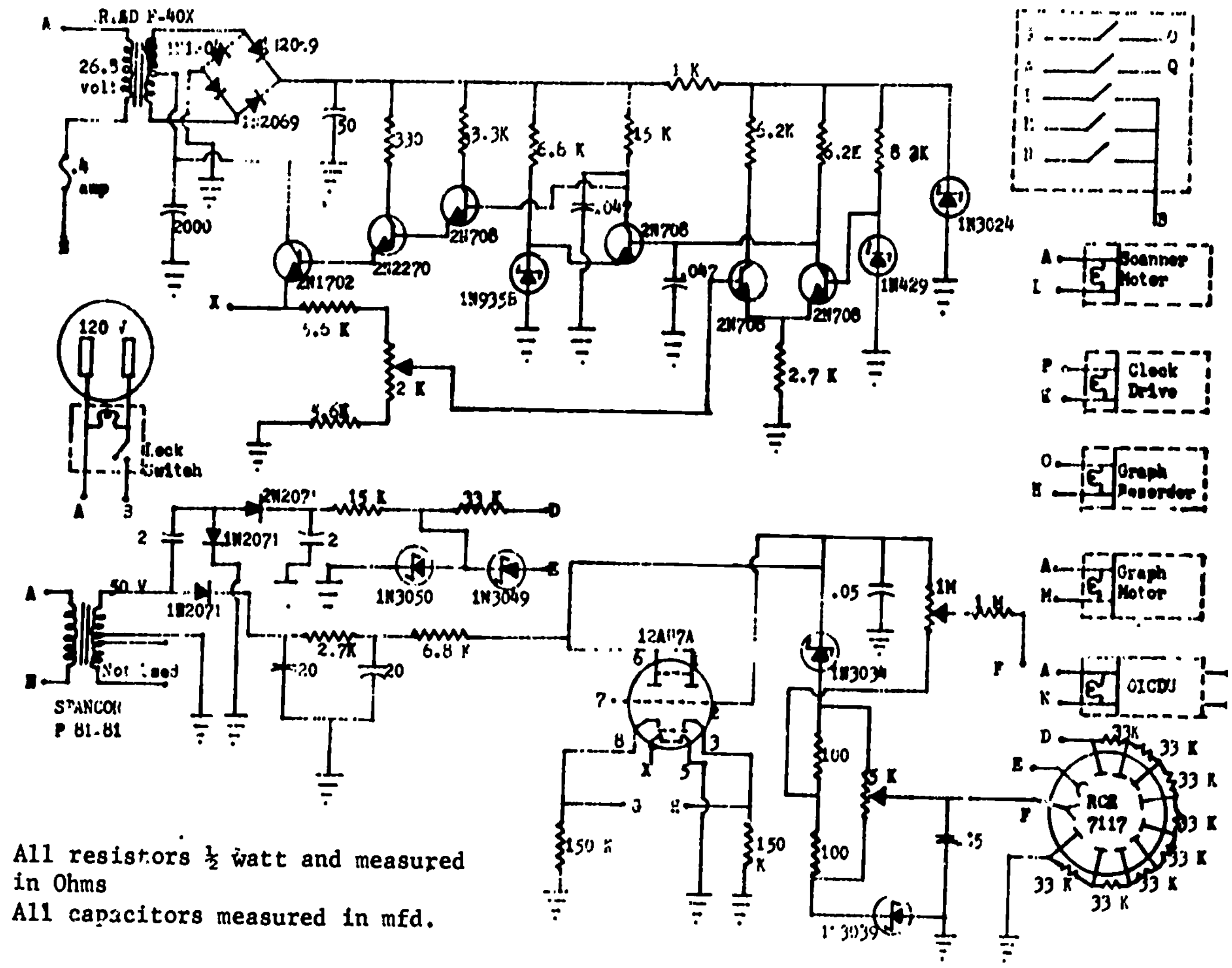
3. *Encyclopaedia Britannica.* Chapters 22-23. (1) Properties of Light and (2) The Quantum Theory. Encyclopaedia Britannica, Inc., Chicago, Illinois.

4. Holton, Gerald. *Introduction to Concepts and Theories in Physical Science.* Chapters 22-23. Addison-Wesley Publishing Company, Inc., Menlo Park, California.

5. *The Merck Index.* Merck & Company, Rahway, New Jersey.

6. *Practical Organic Chemistry,* Part I. University of British Columbia, Vancouver, Canada.

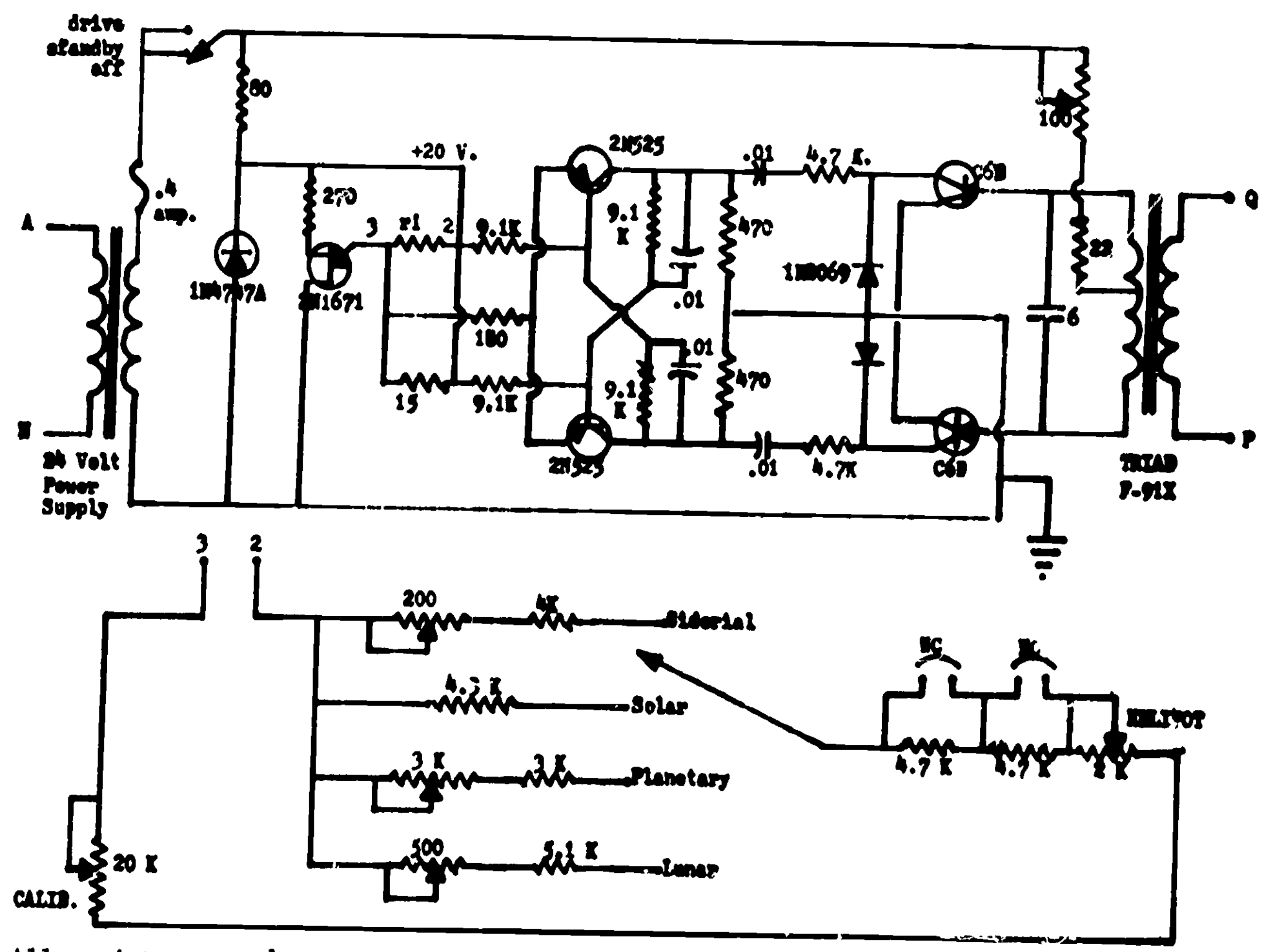
SPECTROPHOTOMETER POWER AMPLIFIER SCHEMATIC DIAGRAM



All resistors ½ watt and measured in Ohms

All capacitors measured in mfd.

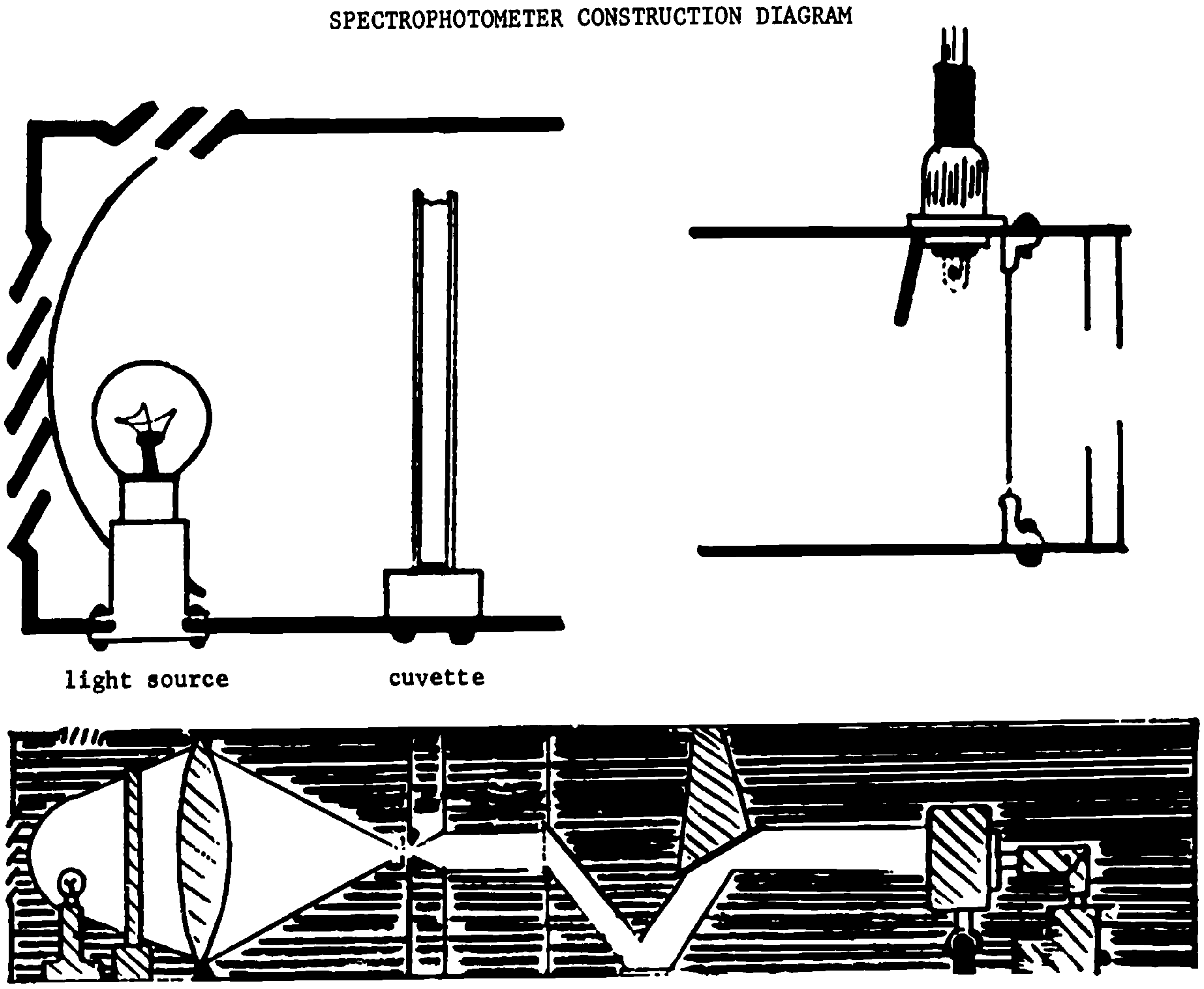
OSCILLATOR-INVERTER DRIVE SCHEMATIC DIAGRAM



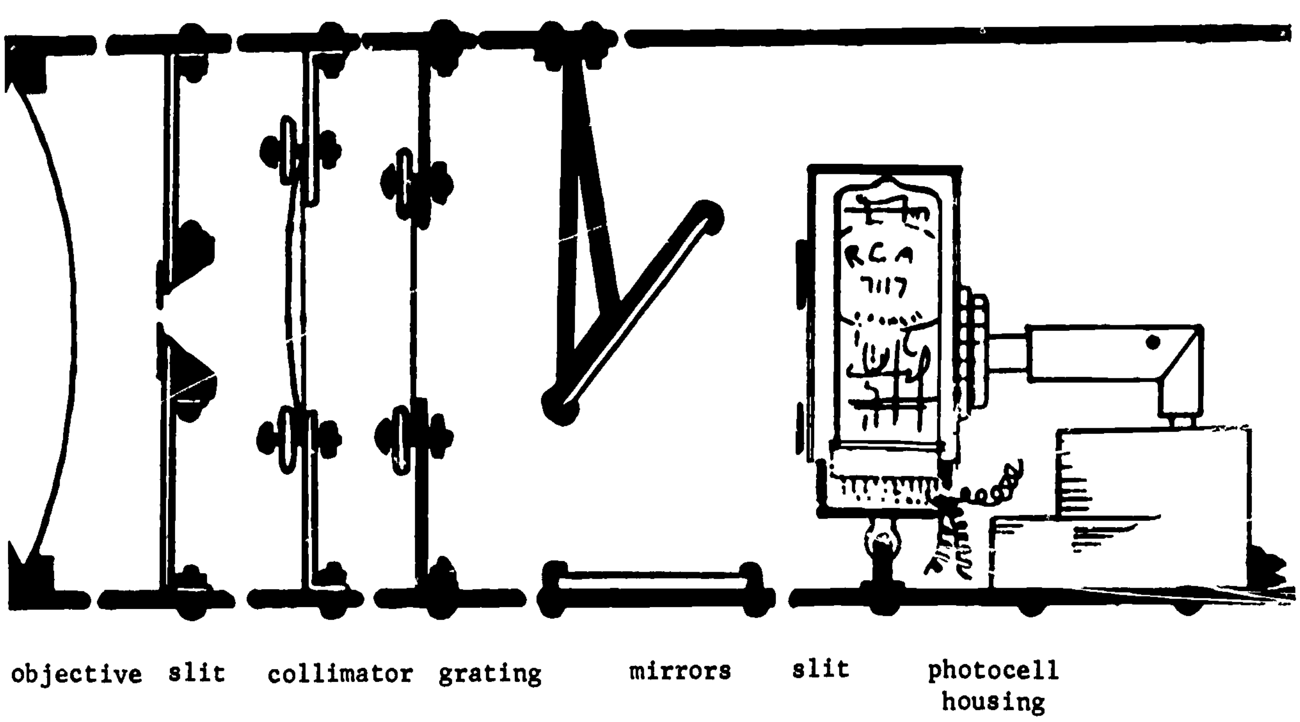
All resistors are ½ watt-measured in Ohms

All capacitors measured in mfd.

SPECTROPHOTOMETER CONSTRUCTION DIAGRAM



SPECTROPHOTOMETER CONSTRUCTION DIAGRAM



A Scientific Research Course for High School Students

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An earth science research course that enables students to pursue work at their individual levels and interests is presently offered to eleventh- and twelfth-graders at the Garden City Senior High School, Garden City, New York. The course has led to published articles by students, to research grants received by students, to receipt of a NASA – NSTA award, and to our school becoming an air pollution monitoring station for the Nassau County Department of Health.

The youngsters work singly or in groups on projects which they select themselves and make periodic progress reports at monthly seminar sessions. Advice, questions, and criticism by all the participants are considered afterward. Final reports (oral and/or written) are made by each group at the conclusion of its work.

As the teacher, I counsel with the students in th selection of projec's and help them plan their research procedures. I also guide them in selecting and operating whatever equipment might be necessary in obtaining published and unpublished references to previous work that was done in their area, in gathering and interpreting data, and in preparing reports which may lead to formal publication. I usually suggest more than one line of attack so that they can have the joy and valuable experience of making decisions themselves. Occasionally, I work along with them, and that particular project then becomes a joint student-teacher venture.

In addition to learning a great deal about earth science and its socioeconomic applications, the students keep abreast of current research problems and procedures through perusal of a variety of periodicals such as *Science, Nature, Sky and Telescope, Natural History, Scientific American,* and others. The independent study aspects of the course plus their having selected their own projects enable the students to approach their work with a verve and enthusiasm which are not always present in more rigidly structured secondary science courses. No examinations are given, and grades are based on participation as well as accomplishment.

One of the major objectives of the course is to give the students an opportunity to engage in meaningful research that could add to the general body of scientific knowledge. To date, six of our group projects have been in this category, and four of them have been considered worthy enough to receive outside recognition. Two of the reports have been accepted for publication in the NSTA journal *The Science Teacher,* and two others received monetary grants from the William and Sophia Casey Foundation. In addition, one of the published reports dealing with the lunar surface led to the receipt of a NASA–NSTA award, and one of the grant projects involves our serving as a data-gathering station for the Air Pollution Division of the Nassau County Department of Health.

The first published article, "Surface Features of the Moon: Interpretation of Photographs from Lunar Orbiter II"(*The Science Teacher,* October 1967, pp. 40-43), was authored by four high school students (Stephen Reininger, Jon Pendleton, Peter Siegel, Hillary Solnick) and me. It described the first published evidence of lunar igneous dikes and columnar joints observed in the Copernicus crater and also dealt with shield volcanoes of the Marius region of the moon.

The second article accepted for publication, "Do Meteors Influence Precipitation? A Correlation of World Precipitation Increase with the Great Leonid Meteor Shower of November 1966" (*The Science Teacher,* February 1969, pp. 34-37), was authored by four other high school students (Vicki Bressan, Janet Botte, Michele Barrett, Ann Sewell) and me. Two other students, Anthony

LoPinto and James Waide, also contributed to the data analysis of this report. Our research showed that a significant increase in world precipitation shortly after the Leonid Meteor Shower of November 1966 could be attributed directly to the nucleating effect of the meteor particles after they drifted down into the lower atmosphere two to six weeks later. Since our literature check showed that a correlation existed between syzygy lunar phases and precipitation increases, we were careful to show that syzygy alone could not have accounted for the increases we tabulated from over 900 weather stations in various parts of the world. In doing this work, we had the benefit of consultation with meteorologists from the U.S. Weather Bureau.

One of the projects that won a $250 foundation award for students Janet Botte, Janice Garrison, Ann Sewell, and Jane Wytzka is being carried out with the cooperation of the Nassau County Air Pollution Division. Air sampling equipment (purchased with the grant money) has been installed on the school roof and is being operated by the girls in conjunction with the county's regular sampling stations. Local pollution levels in Garden City are monitored on a regular basis and compared with adjacent areas. After gathering data for several months and correlating their information with the other county stations, the students plan to submit a report of their work for future publication.

Another project that won a $200 foundation award for students James Getchell and Gregory Van Gelderan involves investigating reflective and refractive mirages before and after sundown. The boys use a transit and other equipment to measure the very small angles of mirages under various weather and ground-surface conditions. They, too, expect to submit a report of their research for possible publication in a suitable journal.

Additional projects which are or have been actively worked on by the students and me include pesticide pollution hazards to humans, livestock, and aquatic faunas; oil pollution hazards in estuaries and marine waters; methods of reducing earthquake destruction in seisimically active regions; the scientific bases for American Indian myths and legends; the lunar cycle's effect on physiological and psychological behavior of humans and other organisms; volcanic activity evidence on the planet Mars; the Coriolis Effect as an insurmountable obstacle to Project Skyhook; and radiation hazards to Apollo VIII and IX astronauts on lunar missions during the peak solar-flare period 1968-69.

The students and I meet daily in the earth science room where each project group carries out its own work. In addition, individual students come in during their study or lunch periods (while I am teaching other classes) or after school to continue their research. Each project has sufficient space allotted to it in a small adjoining room so that the youngsters can work on their own at any time during the day. A small but highly selective library is also available to them in the research room. Whenever necessary, trips outside the school are taken in the afternoon or on weekends.

No pressure is placed upon any student to "produce" at any predetermined level. There are no examinations and no assignments other than the work load imposed by each student on himself. Grades of "B" or "A" are disbursed depending on the combined qualitative and quantitative aspect of the student's activities. A student whose interest tapers off to the point where he is no longer participating would be asked to withdraw from the course. Thus far, however, the students spend more time and effort on their research projects than on some of their other courses – to the point where I have to remind them not to fall behind on their other work. Apparently, the stimulation and interest generated by this type of course is sufficient to engender learning for the sake of knowledge rather than merely for the sake of grades.

While similar research courses in secondary earth and space science areas could easily be instituted as second-year programs (following a first-year course) by schools in other localities, I would think that research programs geared to precollege levels could also be adapted in the biology, chemistry, and physics areas. Under proper guidance, high school students *are* capable of contributing useful knowledge in the fields of science. Certainly, the elemental techniques of research and of information communication they gain in such a course lay valuable groundwork for future advanced work they might engage in at college or beyond.

☆☆I have to remind [the students] often not to fall behind on their other work.☆☆

Stimulating Creativity Through Chemistry

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Science is a creative process in which imagination plays a powerful role. James B. Conant makes this abundantly clear in *On Understanding Science.* [1] Industry and the armed forces have been teaching courses in creative problem solving for years. However, in educational circles, particularly at the secondary level, this important area of creativity continues to be ignored. While it is true that the new science curricula have devised ways to impart information in a more interesting manner, this is not enough to qualify them as teaching for creative development. There is little evidence that the new media are helping the student to create from the knowledge he acquires. Nowhere in the academic program is there greater opportunity for teaching creativity than in the sciences.

Science teachers should be aware of the growing volume of research studies which show that (1) stifling creativity leads to tension and mental ill-health; [2] (2) many things can be learned creatively more economically than by authority; [3] (3) there is practically no correlation between scores on achievement tests and creative ability; [4] and (4) imagination and creative skills can be taught. [5]

Working on the premise that mastery of subject matter can be accomplished concurrently with creative growth, I have incorporated a number of techniques into the usual first-year high school chemistry course with gratifying results.

Building on Innate Curiosity

Young children never stop asking questions. High school students ask very few questions. In order to stimulate the questioning attitude early in the course, each student is asked to make a list of things he wonders about. Many of these questions can be used for laboratory activities. Some examples are:

1. Why do leaves change color in the fall?
2. Why does a cookie stick together?
3. How can a record reproduce sound?
4. Why does molasses become thick in cold weather
5. If mental illness is chemical, does attitude stimulate production of harmful chemicals?
6. Why are sodium chloride crystals cubic?
7. Why is the grass wet on some mornings and not on others?
8. How does a match work?
9. What causes the color regions of a burner flame?
10. Why does wood warp?

Once every two weeks we have a laboratory period devoted to individual work on questions raised by the students themselves. Many such periods are used for problem-solving on questions raised by required experiments. For example, the experiment on single replacement reactions invariably causes students to ask: Will the reactions proceed in the opposite direction? or Why does the copper sulfate solution lose its color?

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[1] Conant, James B. On Understanding Science. Yale University Press, New Haven, Connecticut. 1937.

[2] Patrick, Catherine. What is Creative Thinking? Philosophical Library, Inc., New York. 1955.

[3] Ornstein, J. "New Recruits for Science," Parents' Magazine 36: 42; February 1961.

[4] Torrance, E. P. Creativity. Proceedings of the Second Minnesota Conference on Gifted Children, Minneapolis. University of Minnesota, Minneapolis. 1959.

[5] Parnes, Sidney J. Creative Behavior Guide book, Charles Scribners' Sons, New York. 1967.

Once students learn that they will have an opportunity to pursue questions that are of particular interest to them, they accumulate more things to do than class time will permit. Many of them spend extra hours in the laboratory after school and on weekends. This has a double benefit: (1) It creates high interest in the required experiments, and (2) it stimulates creative planning in devising ways to test the hypotheses proposed by the students.

Prior to the special laboratory periods students submit for approval the following plans: the purpose of their investigation, materials needed, and their proposed procedure. This enables the teacher to have materials readily accessible for the student and to check on safety. These "fun labs" provide practice in devising experiments, proposing hypotheses, recording observations and data, evaluating information, drawing conclusions warranted by observations, and improving experimental design. Extra credit is given for all special laboratory work after the final report is submitted. The improvement made by individuals in their ability to set up controls and to interpret data is reflected in improved quality of required laboratory work.

Sharpening Awareness

Anything which encourages enthusiasm encourages creativity. Students need to realize that their own imagination provides them with a power to discover and to create knowledge. Imagination requires exercise just as muscles do. We discuss how to do "mental calisthenics" and frequently have a five-minute warm-up. This includes such activities as:

1. Imagine laboratory apparatus in unusual shapes: a rectangular test tube, a spherical beaker, etc.
2. Imagine a burner flame being solid.
3. Imagine doing an experiment to a musical rhythm.
4. Imagine hydrogen sulfide smelling like hot rolls.
5. Imagine a polka-dot solution.

To make students more conscious of how much in our surroundings is commonly overlooked, they are asked to do the following:

1. Walk a very familiar route and list all the objects never noticed before.
2. Sit in a familiar place and note all the sounds of which you had not previously been conscious.
3. Be acutely aware of the taste of foods throughout one entire meal.
4. Take a walk and record as many different odors as possible.

Once students become sensitive to their environment and realize that they can use and discipline their imagination, they recognize sensitivity and discipline as powerful forces for the generation of new ideas. They learn to trust their imagination as an aid to proposing hypotheses and devising new approaches to problem-solving in the laboratory.

Skill in Proposing Hypotheses

Many short activities can be used in class to improve skill in proposing hypotheses and to add interest and variety to the course. For example, early in the year the property of density is studied. After considerable work has been done on this concept, the following demonstration is performed:

To an empty 100 ml graduate, 10 ml mercury, a small iron bolt, 10 ml carbon tetrachloride, a moth ball, 10 ml water, and a small cube of wood are added in this order.

Students are given a sheet of paper on which they record:

Purpose of Demonstration:
Observations:
Explanation for Observations:
Plans for Testing Explanation (Hypothesis):

Papers are read at one sitting and rated. Those mentioning density rate highest, those talking about "weight differences" rate lower, and so on. Then we have class discussion on how to propose a reasonable hypothesis and the importance of imagination in devising tests for it. The point is made that credit will be given for any hypothesis if it meets these criteria: (1) It is based upon actual observations and (2) it is testable. In the beginning, students fear this type of test, but with experience their confidence grows and they become more skilled until they look forward to such tests.

Suggestions for other demonstrations which test ability to propose hypotheses are:

1. Iodine crystals placed in water, alcohol, carbon tetrachloride. Explain the color differences.
2. Remove the stoppers from bottles of concentrated HCl and NH_4OH. Explain formation of white cloud.
3. Mix 25 ml water with 25 ml alcohol. Explain why the total volume is less than 50 ml.
4. Place colored water in a set of capillary tubes. Explain the difference in levels after a short period of time.
5. Light a burner above and below a piece of screen gauze. Explain why the flame occurs only on one side of the gauze.
6. Heat a crystal of copper sulfate pentahydrate. Explain the change in color and texture.
7. Place a piece of cardboard in a vertical position in the center of a bunsen flame. Explain the scorch pattern.
8. Place a few iodine crystals in a 250 ml beaker. Cover with an evaporating dish containing water. Heat the beaker gently. Explain the changes that occur.
9. Float a needle on water. Explain why it does not sink.
10. Make a boat of tin foil. Float it on water. Then crush it into a small wad and return it to the water. Explain why it floats in the first instance and sinks in the second.
11. Fill a glass milk bottle full of water, place a piece of screen gauze in the place where the cap fits, and invert the bottle. Explain why the water does not run out.
12. Place a beaker of water containing 5 drops of phenolphthalein and an identical beaker containing an equal volume of dilute NH_4OH under a bell jar. Explain the appearance of the pink color in the beaker of water after a short period of time has elapsed.
13. Obtain a bottle of soap bubble material from the dime store. Blow bubbles. Explain why the bubbles are always spherical in shape.
14. Mix two colorless solutions (sodium chloride and silver nitrate). Explain the appearance of the white solid. Explain the rapid darkening of the white solid.
15. Place some table sugar in a beaker. Pour a few milliliters of concentrated sulfuric acid over it. Explain the change that occurs.
16. Place two or three moth balls in a tall graduated cylinder to which water, citric acid, and soda have been added. Explain the rise and fall of the moth balls.
17. Insert a glass tube at the base of a burner flame. Ignite the end of the tube. Explain the fact that burning occurs both at the end of the glass tube and at the burner.

Devising Experiments

Students must be given practice in devising experiments. A simple exercise to start them in this direction, which offers a sound basis for discussion, is described although many others work equally well.

Given: 5 sugar cubes, test tubes, water, alcohol, mortar and pestle, burner, test-tube holder, stirring rod.

Problem: Devise a controlled experiment to determine the factors which affect the solubility of sugar.

Points to stress in discussion after results are turned in:

1. Importance of using equal volumes of solvent;
2. Importance of a control;
3. Importance of varying only ONE factor at a time.

Practice and help of this nature is important early in the course so that students become aware of the points to consider in devising their own experiments.

Suggestions for similar activities: Devise an experiment:

1. To determine whether single replacement reactions will occur in reverse;
2. To determine whether the diameter of the tube affects the operation of a mercury barometer;
3. To determine the cause of "heat waves" over a radiator;
4. To determine the density of marble using $CaCO_3$ chips (sand or sugar may be substituted for marble);
5. To show that pressure is a function of the depth of water.

Descriptive Ability

The ability to describe accurately is essential to the science student. Some assignments which can be used effectively in 15-minute blocks of time are:

1. Describe music to a person deaf from birth.
2. Describe a rainbow to one blind from birth.
3. Describe the feel of velvet to one with no sense of touch.
4. Describe the odor of freshly cut grass to one with no sense of smell.[6]

There are many different exercises which enable the teacher to evaluate the creative thinking ability of students. For example:

1. If an equipment manufacturer offered $100 for suggestions which might lead to improvement of laboratory apparatus, what piece of apparatus would you select and what ways could you suggest for improving it?
2. Select one experiment from the past unit and tell how it might be made: (a) more interesting, (b) more meaningful, or (c) more of a discovery activity.
3. What would happen if a reaction occurred in which matter and energy were NOT conserved?
4. What would happen if you could observe a chemical reaction on the atomic level?

[6] See Appendix I for illustrative answers.

Scoring is done on the basis of such criteria as:

a. Fluency
b. Number of responses
c. Unusual approach
d. Surprising or unexpected answers

For example, if a student answers Question 4 above by saying we would have to revise our present concepts of chemical activity he should rate much higher than if he simply stated that we would see electrons moving from one energy level to another. In fact, the latter answer might indicate poor teaching in that the student cannot distinguish the model from reality!

Other Types of Creative Activity

Each student was encouraged to submit a variety of original material throughout the term. Poetry, articles, essays, experiments, test questions, posters, bulletin board displays, art work, cartoons, and models – *all science related* – were produced. Many students did a large number of these activities, thereby gaining experience in several media of creative expression.

Grading

Industry rewards creative work with high salaries. Grades are the medium of exchange in the classroom. Therefore, it

☆☆ One student wrote, "Before taking chemistry,

I took everything for granted without question." ☆☆

was understood from the beginning of the course that the following grading system would be in effect:

a. One-third of the grade was based upon required laboratory work,

b. One-third was based upon understanding of textbook material, and

c. One-third was based upon creative work.

For grading purposes, creative work was defined as (1) scores on special experiments designed and performed by the student, (2) scores on demonstration quizzes, (3) scores on activities involving hypothesis proposal, (4) original writing, art work, bulletin boards, and other works.

This system works fairly for all students. Those with great facility in learning "facts" are stimulated to develop their latent creative talents and students with an initial high degree of creativity are stimulated to master the chemical subject matter, for they soon realize that the more knowledge they possess about chemistry the more different ways it can be used.

Evidence That Creativity Can Be Stimulated

There is not sufficient evidence from this preliminary study to determine whether creativity can be taught. However, there is abundant evidence that creativity and imagination can be stimulated and encouraged. The evidence lies in several areas:

1. Comparison of the *quality* of creative work submitted by the same individuals at the beginning of the term with that submitted at the close of the term;
2. Comparison of the *volume* of creative work submitted by the same individuals as the term progressed;
3. High level of interest maintained throughout the course as indicated by participation and by the unusually low dropout and failure rate;
4. Comments from students.

According to records kept over the past five years, 14.5 percent of the students enrolling in beginning high school chemistry withdrew or failed by the end of the first semester; whereas, only 7.0 percent made A's. Using the techniques herein described, with the same type of general academic student. 6.5 percent failed or withdrew by the end of the first semester and 12.6 percent made A's.

One paper entitled "Chemistry and Daily Living" submitted as part of the creative work by one student states:

> Chemistry has opened my eyes and my mind to many things. Before I repeat any information I stop and ask myself if it is fact or assumption. Many times I realize it is assumption and I do not pass it on. Before taking chemistry, I took everything for granted without question. Now I find that I am curious about most things I encounter throughout each day and am constantly trying to learn how, why, what if and so on. In addition, chemistry has set my imagination in motion. It helps me figure ways out of personal difficulties, to dream up topics for English themes, and to improve my wardrobe on very little money.

Another student who has great artistic talent has developed an interest in science and is now planning to major in both with the aim of becoming an illustrator for a publishing house which specializes in medical books.

If we can provide this kind of self-discovery for our students, then education can truly become a life-long, sustaining process. Students will retain the capacity for childlike wonder, a persistent curiosity, and a sense of excitement in living. Those who are so inclined will be better scientists because they will develop their creative imagination along with their acquisition of facts. Those who do not enter the scientific community will at least have a more realistic view of the nature of science as a creative endeavor. All may stand taller and walk with assurance, because they will have learned that within themselves lies the power to live creatively.

Appendix I

Examples of creative answers to descriptive exercises:

a. Music is like beautiful colors flashed on a screen in rhythm, varying in shades, patterns, and speed. Sad music is like the colors on a cloudy winter day– grey and faded. Happy music is like a sunny spring day – bright with color in bird, flower, and tree.
b. Music is poetry in sound.
c. Music flows like a clear, rushing stream.
d. Sweet music is like rich chocolate pudding tastes; sad music is black and presses down on bent shoulders.

a. Freshly cut grass is like drinking a glass of lemonade with too much sugar.
b. As the rose is beautiful to see, so freshly cut grass is beautiful to smell.
c. The smell of freshly cut grass is sharp like sticking pins in your arm.
d. The smell of fresh cut grass can be described as like the feeling one has when he has finished all his tests and is preparing for a long weekend. It is like being reborn.
e. Fresh cut grass smells like steel wool feels.

a. You have heard the slow moving creek and the sound of birds singing. The rainbow is like these. It runs across the sky with gay and happy tones of color.
b. A rainbow is a multicolored arc in the sky that looks like the different flavors of ice-cream taste.
c. To the blind a rainbow would be like high music that ascends into the heavens and descends to the earth forming a gigantic playground slide.
d. The rainbow is made of colors which cling together like the closeness of a family.

a. The feel of velvet is like seeing a picture of someone you love which has been slightly blurred.
b. Love is warm and gentle and tender. The feel of velvet is like this.
c. The feel of velvet is the contentment of a child when he jumps into a pile of soft hay.
c. The smoothness of velvet is comparable to the smoothness of flowing cake batter.
e. Velvet feels like a kitten looks.

Examples of improvement in creative writing:

Student A:
First attempt:

Quatrain on Density

Mass over volume is equal to density.
I've studied this fact with utmost

intensity,
But still I can't grasp this flagrant propensity.
The mass of my brain is too teensy-wensity!

Six weeks later:

How Do You Lose Me?
(With apologies to
Elizabeth Barrett Browning)

How do you lose me, Chemistry? Let me count the ways.
You lose me to the depth and breadth and height
My mind can reach when feeling out of knowledge
For the volume of a gas at STP.
You lose me at the formula of every problem's
Most simple calculation involving the General Gas Law.
You lose me rapidly, as I strive for molar volume,
You lose me quickly as I turn to Boyle's Law;
You lose me at the mention of pressures
Whether they be partial, barometric, or standard.
You lose me with data I cannot plot
With my tired brain – you lose me with the volumes,
Laws and properties of all thy gases!
And if God so choose,
You shall but lose me even till my death.

Student B:
First attempt:

Chemistry

You got to think and you've got to read,
And you have to have everything you need,
And you've got to remember all you see
Just to do good in chemistry.

Two weeks later:

Chemicals

Chemicals are wonderful things.
They can be used to clean bathtub rings,
To clear the drain,
To make it rain,
And to produce cellophane.
All these favors just to show
That we use everything we know
To make the world a better place
To support the human race.

Student C:

Moth Balls

I walked into class the other day
To be confronted with moth balls that wouldn't stay
On the bottom of that glass jar.
I said to myself, "She's gone too far!"
All period we pondered and worried
About why those little moth balls scurried
Up and down in the water.....

Student D:

Can You See?

Did you see the bubbles rise?
Or even more to your surprise,
Did you note the time involved
As your sugar cube dissolved?

Are you aware of what is there
When HC1 and foil become a pair?
Did you see the foil burn? Strange,
But that, too, was a chemical change.

Student E:

Chemistry

Chemistry is not just a course in school.
It distinguishes you from many a fool,
Aiding you as you endure
It helps your mind to mature.

☆☆Imagination

requires exercise

just as

muscles do.☆☆

A gas is formed as part of the fate;
And suddenly we see a precipitate.
Checking composition, change, and learning to see
Is something very strange and new to me.

Observing while a sugar cube dissolved
I found myself getting quite involved.
If this is chemistry, then I must admit
It is one course I will never quit!

Student F:

Perfection

Reaching perfection can be used as a simile. Just as the hyperbola can never reach its asymptotes, so can people never reach the asymptote of perfection. But even though one can never reach the axes of perfection, one can come so near to it that the difference is negligible. Therefore, if you cannot reach perfection, there are no asymptotes restraining you from being your best.

Student G:

The Unknown World
of the Lab

As I clumsily stumbled into a world of the unknown, I became exceedingly baffled. There was before me the vast extent of the laboratory which I had never known. The excitement was within me and I stared at strange gas jets and rocking balances. After fumbling with the lock on my desk, I carefully pulled out the containers and noted an abundance of strange glass objects. Not only that, but pieces of red and blue paper and an empty tin can were there to increase my sense of wonder. Suddenly, the lab was bustling with activity and students as confused as I were trying to perform their first experiment with professional abandon. Solutions reacted and we recorded observations, but as we left the atmosphere of jingling glass and odd smells, our thoughts were mixed as to what we had learned.

Demonstrate with an Overhead Projection Air Table

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Frictionless air tracks, troughs, tables and other like pieces of laboratory equipment are making a positive impact on the science classroom. Not only are these devices valuable teaching aids for the science student, but they generate much enthusiasm among all students. Crowds gather anytime one of these science playthings is in use. Surely some of today's science enrollment can be attributed to the curiosity and interest developed by the fascinating toys of the laboratory, and the frictionless devices are a welcome addition to this collection.

The purpose of the overhead projection air table is the qualitative demonstration of physical phenomena. The projection air table is best used to stimulate student interest, desire, and investigative curiosity about scientific ideas. Students should be motivated to avail themselves of the more sophisticated measuring instruments in the science laboratory.

The projection air table is used with an overhead projector to show frictionless motion on the screen. It is a piece of Plexiglas® with many holes in the top. Air is forced through these holes to give the box a frictionless surface. Coin-sized pucks of colored Plexiglas® can be used on this surface to demonstrate many scientific principles. Laboratory compressed air, a vacuum cleaner, or even a hair dryer is used to supply air for the table. No permanent modification of the projector is necessary, so the air table and other teaching aids can be used alternately.

Many of the ideas of modern physical science must be taught in the high school laboratory without the use of elaborate and expensive equipment. The projection air table is a handy tool for the descriptive approximation of many atomic and nuclear devices. Rutherford scattering, mass spectroscopy and particle motion can be effectively simulated for an entire class with this teaching aid.

The typical high school class devotes much time, talk, and chalk to the discussion of gases. Magnetic pucks on the projection air table will show the random motions and elastic collisions of a valid two dimensional gas. This method can be used to show Brownian motion, diffusion, and gaseous equilibrium. The two dimensional gas is also useful in developing the gas laws.

Probably the most dramatic effect is observed when the table is used in a tilted position. This gives the student a visual picture of a diluted gravitational system. The degree of tilt is the degree of dilution. Moon-like motions, slow motion projectiles and a pendulum whose period can be shown to depend on gravity as well as length are among the demonstrations possible with the tilted air table.

Polarizing filters placed at right angles above and below the table surface will nearly darken the screen. Pucks coated with cellophane rotate polarized light and are seen on the screen as patches and streaks of multicolored light. This effect is useful in the demonstration of Brownian motion, with stroboscopic photography and other applications where light reversal is of value.

The center of the projection air table can be equipped with a removable pin to accommodate large rotating discs. These discs will spin for a long period of time with no appreciable loss of speed. This is useful in demonstrating rotational motion, simple harmonic motion, and angular momentum. Discs may be equipped with coils, magnets, or coated Styrofoam balls to make demonstration electric and electrostatic motors. A very colorful effect is obtained by coupling polarizing filters with a rotating disc coated with layers of cellophane.

I became interested in projection air tables more for my own amusement than for the eventual student amazement. Drilling the small holes, cutting and bond-

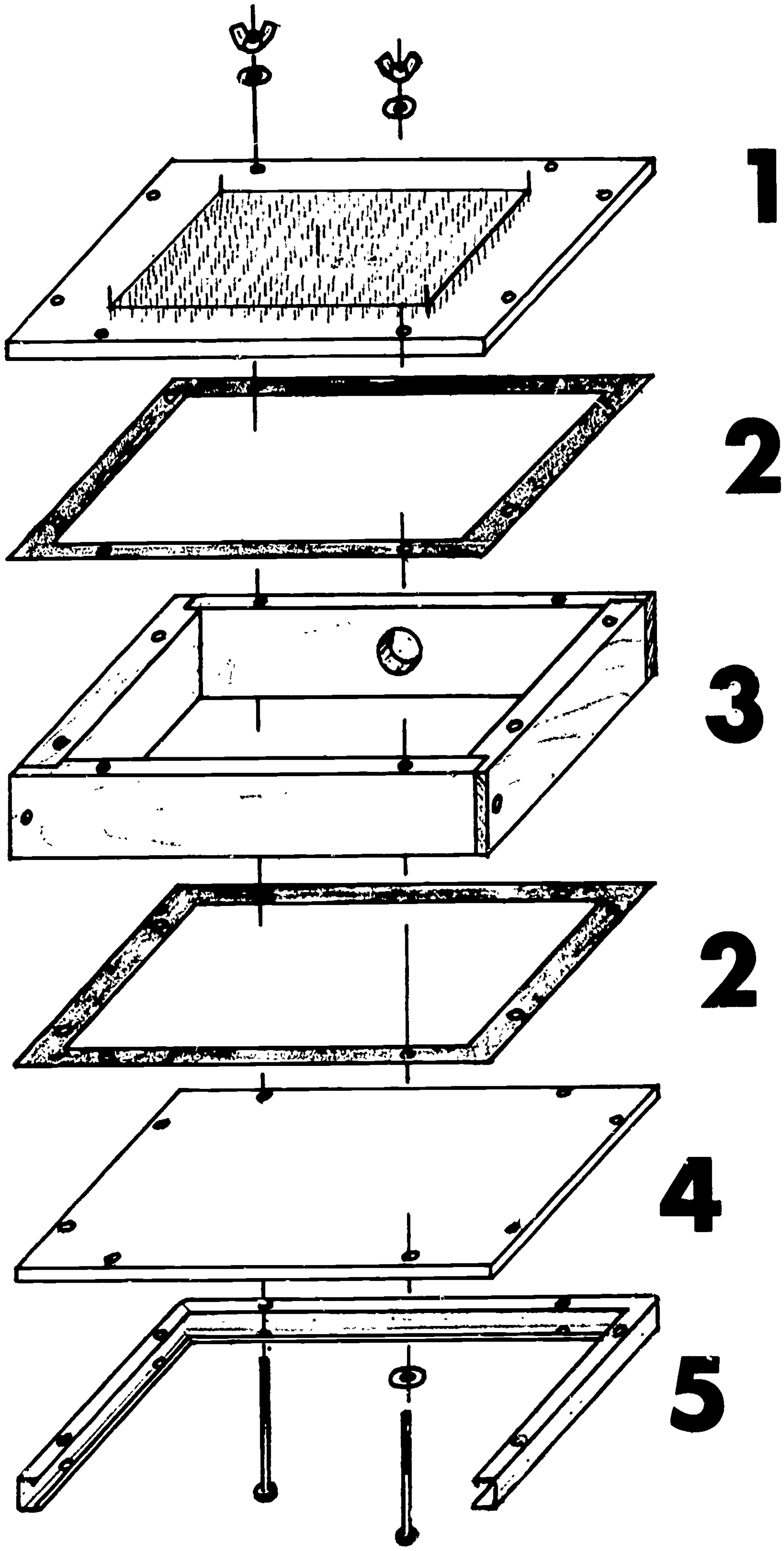


Figure 1. Construction of an Overhead Projection Air Table-Basic Materials (Numbers in parentheses refer to designations in Figure 1)

a. Top (1) 10½-inch-square acrylic plastic Plexiglas®, thickness 3/8 inch.

b. Bottom (4) 10½-inch-square acrylic plastic Plexiglas®, thickness ¼ inch.

c. Frame (3) 1 x 2-inch clear white pine - length varies depending on the type of joints used. Number 8 wood screws (1½-inch) are used to secure corners. (See Figure 5)

d. Gasket (2) 3/16 x 3/4-inch weather stripping —2 are required.

e. Filter Tray (5) ½-inch aluminum shelf track – 3 feet are required. (See Figure 5)

f. Fasteners– machine screws: No. 10-24 (3-inch), 8 required
Wing nuts: No. 10-24, 8 required
washers: 3/16-inch, 10 required

ing Plexiglas®, and finding a suitable air supply were among the obstacles that had to be overcome. I received much help from our school's industrial arts department in solving these and other problems. Building the tables is a continuing project, and each new table has some improvement over the previous models.

As a participant in the Illinois State Physics Project N.S.F. summer institute at De Paul University, I was given the opportunity to demonstrate one of my projection air tables for the other teacher participants. The device was warmly received, and many of the other teachers wanted to take tables back to their classes. Realizing that Plexiglas® cutting and bonding was the most difficult phase in table construction, I devised a simplified version that featured a wood frame. Only screws, nuts, and bolts were required for the assembly. More than thirty tables were built at a cost of about five dollars each. A drill press was the only large shop equipment needed for the construction of this air table.

I have since added and deleted from the plan, but the table can still be built with relative ease. Most schools have drill presses available, and industrial arts departments are usually quite eager to be of assistance. The six to eight hours of construction time is a small price to pay for a very versatile teaching aid.

Plexiglas® can be purchased from a plastic supplier, or often may be obtained through a glass company. The other materials should be available at any hardware store. Hobby or craft shops are the most probable suppliers of small drill bits needed to make holes for the table top.

The only difficult operation in building the projection air table is drilling the small holes in the table top. The holes should be spaced at intervals of one centimeter to form a grid no larger than 6 inches square. Most overhead projectors are capable of projecting a full 10 x 10 inch area on the projector stage, but this narrows to only about 8 x 8 inches above the projector at the location of the air table surface. The very small drill bits are not capable of drilling the full 3/8 inch through Plexiglas®, so two drillings are required to produce the holes. (See Figure 2) The first hole is larger and clears away most of the material, while the second hole removes little material and determines the hole size. The edge of the top and all other framing parts are drilled with ¼-inch holes, two to a side. Machine screws through these holes are required to assemble the table. Plexiglas® should be drilled at maximum drill press speed with the protective paper covering removed. The adhesive on this covering causes bits to gum and eventually break. A paper punch works quite well to place holes in rubber gasket material.

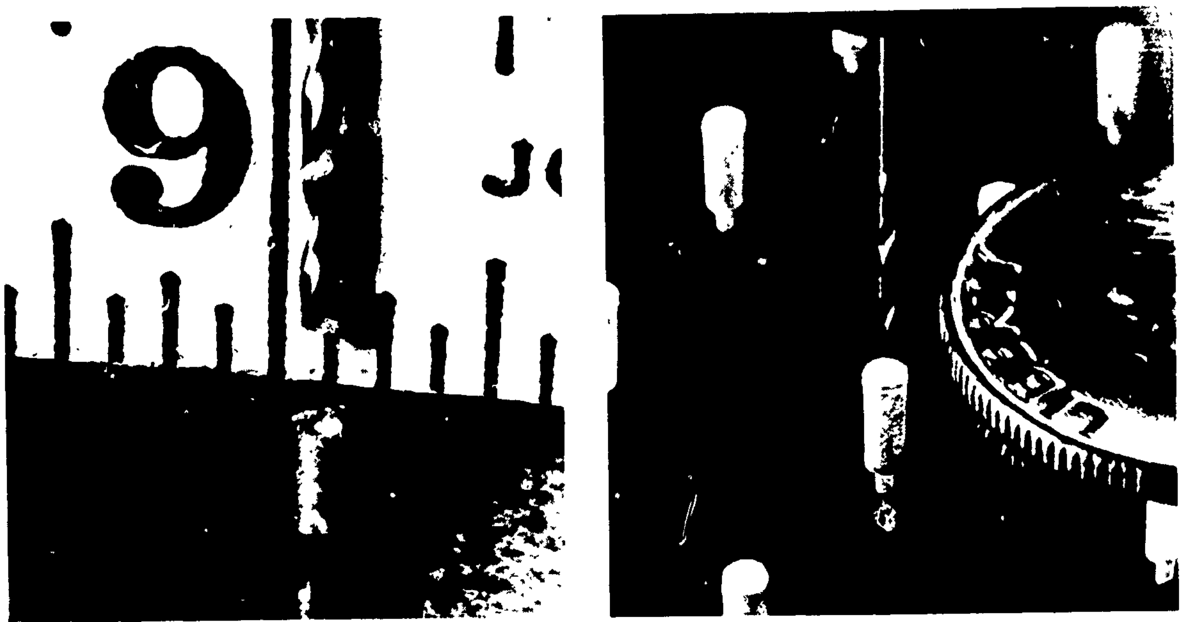
Machine screw and wing nut fasteners are used so the table can be taken apart to facilitate cleaning the inside surfaces. The holes can be cleaned with a fine wire. Simple butt joints, glue, and wood screws can be used to join the frame members, or some exotic type of wood joinery may be attempted. The half lap joint shown in the drawing works well and is airtight without glue.

Leveling Legs and Bumper Cushions

Leveling legs (see Figure 3) are required if level table demonstrations are to be used. Pucks will slide to the edge of an unleveled table. Two of the legs should be placed on the side nearest the screen, and the other leg is centered on the opposite side. Blocks of wood can be placed under the single leg to do the tilted table demonstrations.

Two types of bumper or cushion can be used on the surface of the table. (See Figure 4) A pin can be placed at each corner of the grid, and a rubber band stretched over them to form a bumper. If magnetic pucks are to be used, it is often convenient to build a simple wood frame and fasten magnetic stripping or magnetized refrigerator door gasket to it. This material is also used to form barriers and walls on the table for gas demonstrations. (Figure 13)

The tray for polarizing filters is a section of adjustable shelf track that has been notched and bent to cover three sides of the table. (See Figure 5) The polarizing material should be sandwiched with glass, acetate, or Plexiglas to protect it from scratches. The upper polarizing filter must be attached to the head of the projector. The design of this filter holder depends on the type of projector



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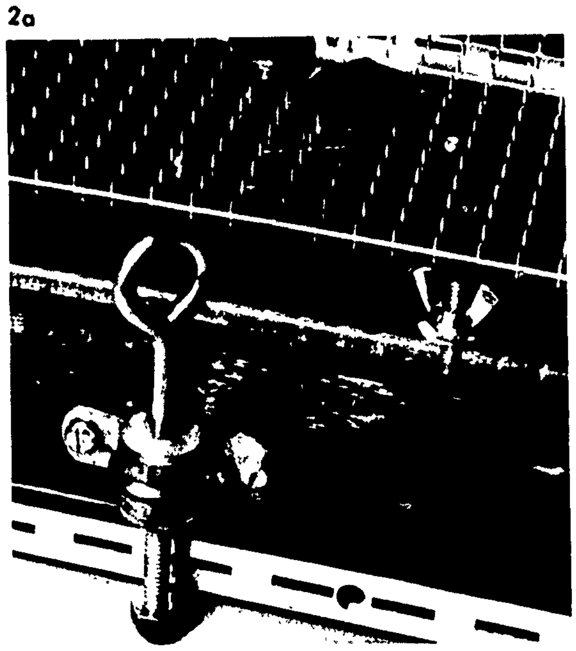

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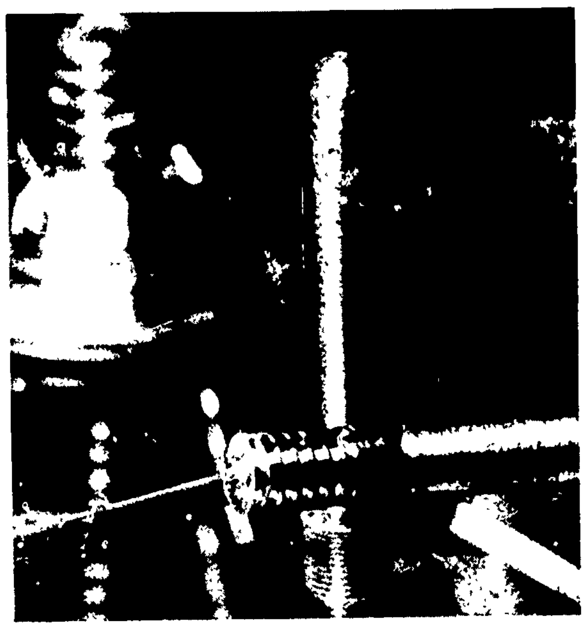

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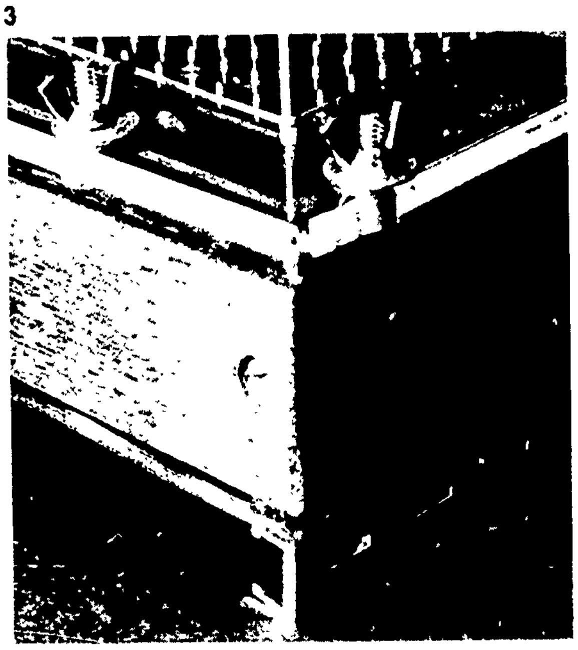

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Figure 2. Drilling Holes in Table Top. a. The first of two drillings uses a 1/16-inch bit to remove all but the last quarter of the material. b. The final hole is drilled through the first hole with a No. 75 or No. 80 drill bit. Ruler and dime are shown for size comparison.

Figure 3. Four-inch eye bolts are used for leveling legs on the table frame. Electrical conduit clamps are used to secure plastic cylinders which have been drilled and tapped to accomodate the eye bolts. Acorn nuts are used on the ends of the eye bolts.

Figure 4. Rubber band bumper held by four corner pins placed just outside the table grid. The pins shown here are cut from sections of 1/8-inch brass brazing rod. They have threads cut to fit the holes; however, straight pins can be held in place with airplane glue.

Figure 5. A corner of the assembled table showing the tray for polarizing filters.

Figure 6. Coin-sized pucks of colored Plexiglas® (or clear pucks coated with colored acetate) are used on the air table. The center drill bit of a conventional holesaw is removed to cut the discs. Ceramic magnets (shown here) or coated styrofoam balls may be glued to the top of the pucks.

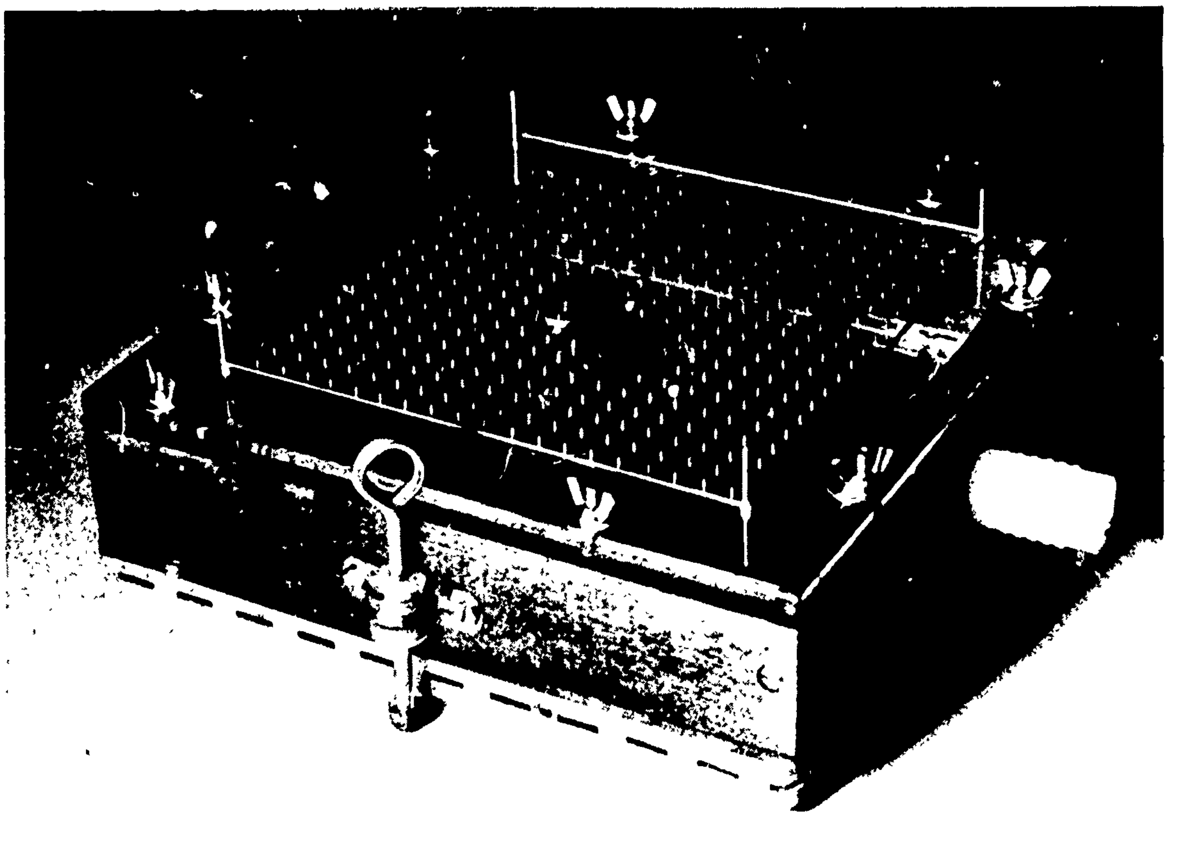

Figure 7. The completed overhead projection air table. A 1-inch plastic pipe connector is the air inlet valve. This valve should be centered on one side of the table.

used. The Vu-Graph (Bessler Co.) and other projectors with cylindrical lens barrels are easily adapted to filter attachments. A hollow section of plastic electrical conduit will slide over the lens, and the polarizing material is fastened to this conduit. This will allow the filter to be removed easily, and it can be rotated to adjust the light transmission.

Large rotating discs and irregular shaped pucks (see Figure 8) can be cut on a jigsaw, band saw, or by hand with a coping saw. The rough edges can be removed with sandpaper or a fine metal file.

Demonstrations

Many demonstrations involving the conservation of momentum in a collision can be accomplished in addition to the one illustrated. Two magnetic pucks can be placed close together with the air supply turned off. A short burst of air will cause them to separate, and their positions can be used to discuss their relative momenta. Pucks of differing masses can be used to collide with stationary pucks. The motion of the striking puck can be used to illustrate that both momentum and kinetic energy are conserved in an elastic collision.

A simple gravitometer may be built to accompany the tilted table demonstrations. A massive puck can be suspended from the top of the tilted table by a soft spring. The extension of the spring is a measure of the relative gravitational field.

Projectile motion can be demonstrated on the tilted table by tapping pucks diagonally upward from the lower corner of the table. The puck follows the path of a smooth parabola. The polarizing filters can be used here if stroboscopic photography is desired.

Rutherford scattering can be demonstrated with the tilted table and magnetic pucks. A small magnet is placed on a Plexiglas plate just above the surface of the table. As pucks are 'dropped' toward this magnet, they will deflect due to magnetic repulsion. Dropping the pucks from different parts of the table will vary the degree of deflection.

Mass spectroscopy is very important in the development of the CHEM Study program. It can be shown with the same arrangement as the Rutherford scattering, with the magnetic poles reversed. The

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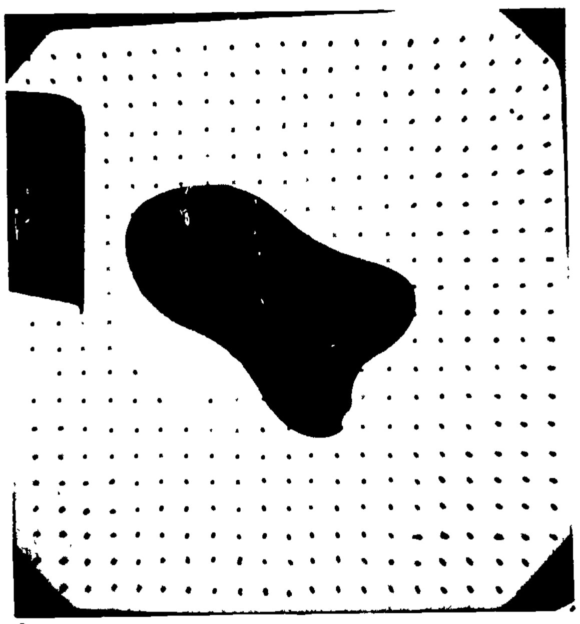

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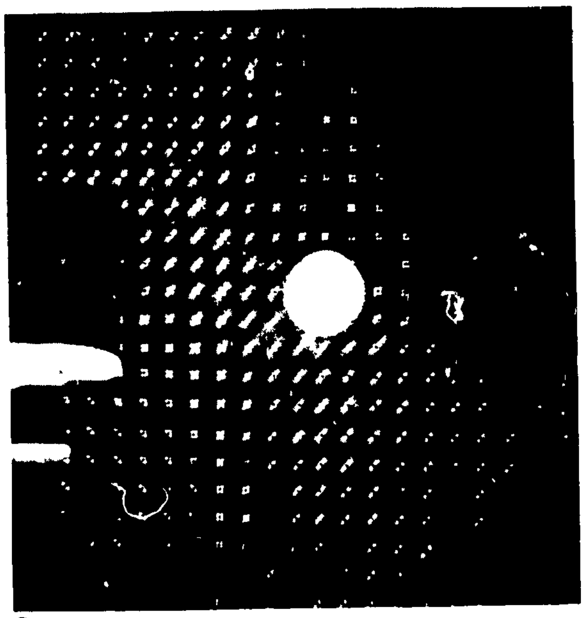

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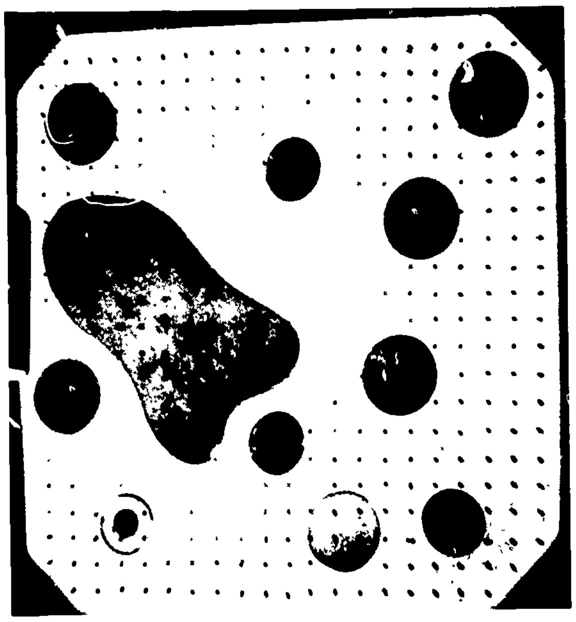

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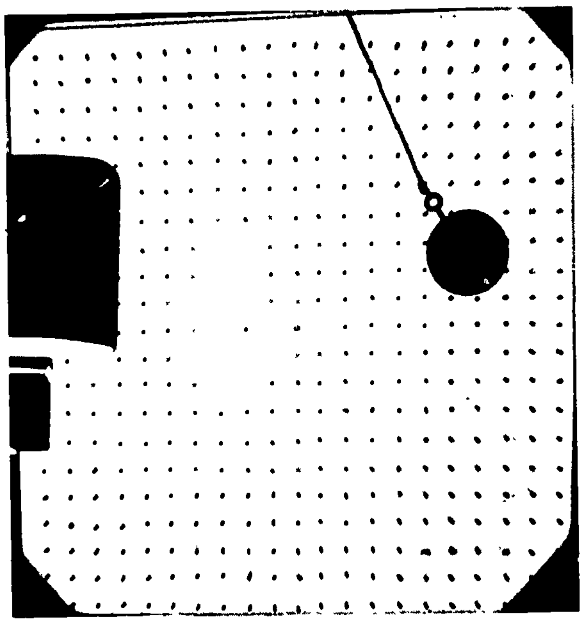

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Figure 8. An irregular-shaped puck is used on the air table to demonstrate the center of mass. Several pins are located at points on the top of this puck - one of these pins should be at the center of mass. As the puck is pushed by any pin other than the center of mass pin it will undergo both rotational and translational motion. If the force is applied to the center of mass pin, the puck will not rotate. If the puck is given a spinning motion, the center of rotation will be the center of mass pin.

Figure 9. Light-dark reversal is shown on the screen if a polarizing filter is placed below the projection air table, and another filter is located on the projector head. Acetate-coated pucks will rotate the polarized light and give a colorful effect.

Figure 10. Magnetic pucks coupled with sides of magnetic tape or refrigerator stripping allow the projection air table to be used to demonstrate a two-dimensional gas. Here the center of mass puck is shown as a 'dust particle' in the demonstration of Brownian motion. This takes on more meaning if polarizing filters are used -- the random motions of the large puck will be the only visible spot on the screen.

Figure 11. A slow-motion pendulum can be demonstrated on a tilted projection air table. The period of a pendulum is dependent on both the length and gravitational attraction. The projection air table allows for the varying of both length and gravity. Demonstrations with low gravity are a very important and impressive feature of the overhead projection air table.

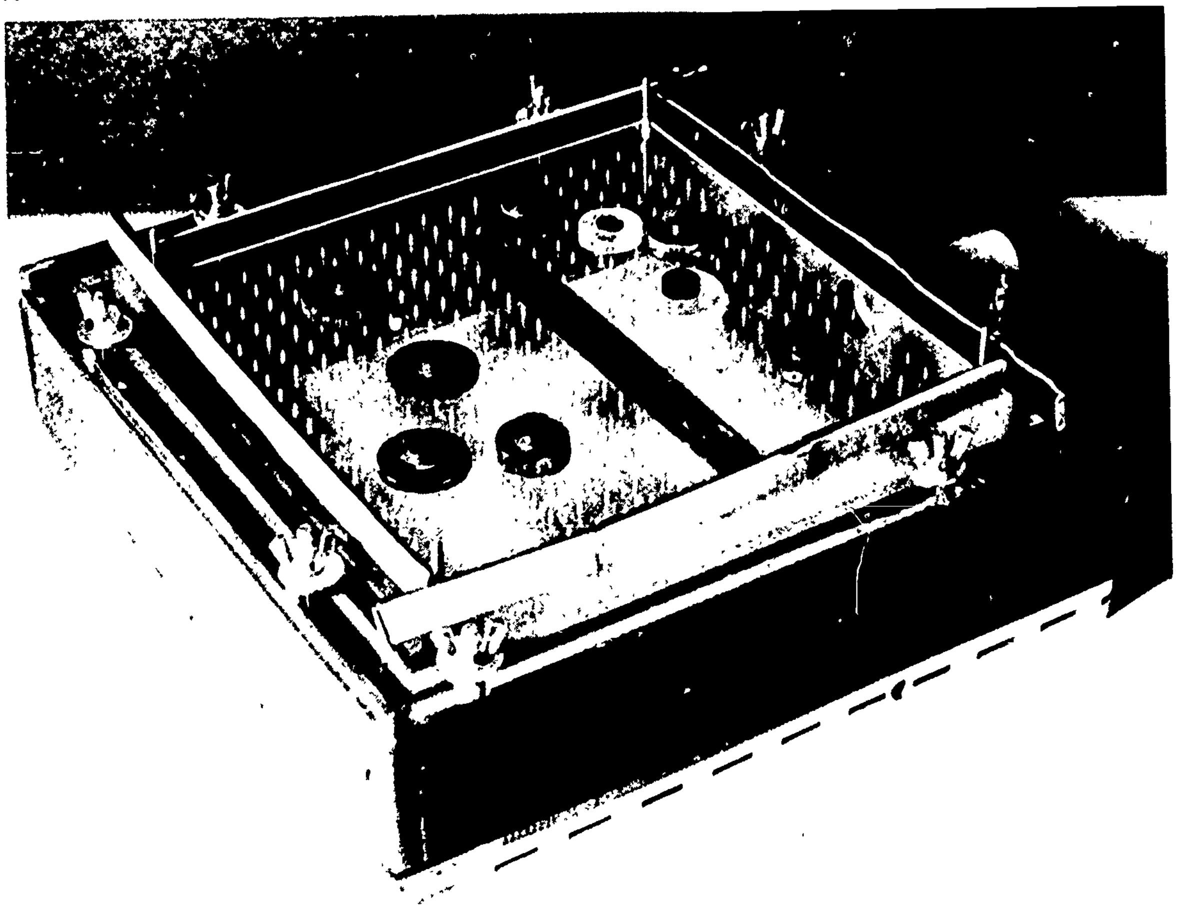

Figure 12. A magnetic barrier can be used with the "gas molecule" pucks to demonstrate diffusion. If several pucks of two different masses are placed on one side of the barrier, the student can observe the lighter pucks clearing the barrier at a faster rate. An equilibrium may be demonstrated if pucks of different colors are placed on the table and allowed to move back and forth.

mass of the pucks, rather than dropping position, should be used to develop this idea.

Acknowledgements

I wish to thank Eugene Aimone, Jim Kendall, Byron Urbanick and Bill Warren of the industrial arts departments of Oak Park and River Forest, Illinois, high school. Their mechanical help and technical assistance was of great value.

Credit goes to Mark Williams, a junior technical drawing student in Mr. Urbanick's class, for the drawing of the projection air table.

The photography is by the author. A canon FTQL was used for all pictures. The closeup photography required the use of the Canon bellowscope, a 100mm telephoto lens, and Kodak Tri-X film.

Development of a "Teacher Aides for Science" Program

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The elementary science curriculum has been in a state of neglect for many years. It has borne the brunt of criticism from many sources. Until recently, the critics have not had much to offer for immediate improvement of the situation. The Teacher Aides for Science Program has been developed to help provide more learning resources for the elementary science teacher. It has grown from a simple beginning into an exciting and effective means for improving the elementary science curriculum.

This project developed from a series of informal discussions between elementary teachers and the science coordinator concerning the present elementary science program. These elementary teachers indicated a desire for more science for their children. They were frustrated by lack of background preparation, lack of confidence in teaching science, and lack of materials necessary to implement the science text materials which emphasized inquiry and student investigation.

Further analysis of the program indicated that science instruction was primarily aimed toward acquisition of knowledge with very little opportunity provided for feeding children's natural curiosity about the world around them. There was no provision for the child to make his own observations, ask his own questions, perform his own experiments, and draw his own conclusions. Science activities were designed for teacher convenience. For example, the teacher would outline the chapter on the blackboard, and the children would copy the outline into their notebooks. Everything was neat and orderly; there were no messes to clean up, and the children had excellent practice in writing and outlining. They also did quite well on tests for knowledge acquisition but had extreme difficulty in the higher levels of cognitive learning.

Several elementary teachers volunteered to attempt to break with this approach and develop a program that would allow more participation for their children. To supplement the student investigations, the science coordinator suggested borrowing such materials as microscopes, balances, metric weights, and relief maps, from the high school laboratories, since many of these items were not in continuous use. Arrangements were made for high school students to transport selected materials from the high school to the elementary buildings. Students who had demonstrated interest and enthusiasm for science were selected to provide this transportation service. Arrangements were also provided for high school science teachers, who would be subject-matter specialists, to serve as consultants in their subject areas in the elementary buildings.

This approach solved the problems of access to augmentable materials and provided a change of pace for the elementary children. But the presence of the consultants was, of necessity, too infrequent. And, because many of the elementary teachers lacked either confidence in the use of the equipment or the necessary knowledge for their incorporation into the classroom, neither the consultants nor the equipment were used effectively.

For a period of time the high school students were asked to use their free periods to devote more time in instructing the elementary teachers in the operation of the equipment. This arrangement did not prove successful since few of the elementary teachers had released time for this type of instruction. Instead of the high school students teaching elementary teachers, the enthusiastic high school student now began to work directly with the children and the elementary teacher provided supervision.

This was like lighting a firecracker; the student "toters" provided the spark and the elementary children exploded with excitement about science. There was no uncertainty about rapport. It was immediate and effective. This had been the problem in communication – not a breakdown in communication but rather a lack of communication. The teacher and the elementary children had not been using the same language! When the "toter" began instruction, one could feel the excitement; these elementary children literally tingled with interest and enthusiasm for science. And so began the Teacher Aides for Science Program.

In its first year the pilot program allowed experimentation with many innovations. The student teacher aides moved from the role of technical assistants in the operation of the equipment to the presentation of background information prior to a laboratory exercise, to demonstrations of fundamental principles, to post-laboratory discussions, to collection of specimens for dissection, and so on. The science teacher aides were given as much latitude as possible so as to establish guidelines for continued operation of this program.

Initially, the science coordinator transported the students between buildings. Transportation now became a problem since the students were assigned during their free periods, which did not coincide with those of the science coordinator. This has been solved by securing permission from the parents of the student teacher aides. The permission form outlines the program and the responsibilities of the student teacher aide, explains why he has been selected for the program, and mentions some of the expectations for his future and the future of the teacher aide program. Emphasis is made both to the parent and to all personnel involved in the program that the teacher aide is not responsible for the elementary classroom but is serving as an invaluable assistant in the teaching of science.

At present, teacher aides are selected from various groups: student laboratory assistants, science club members, students who are enrolled in advanced biology, or those who have completed a three year science program. They must have maintained a B average in their science courses and have a 2.5 cumulative grade average (on a 4.0 scale) in all subjects. They must be interested in participating in this program and they must have a free period during the school day.

The science coordinator contacts students in the spring, explains the program, and has them complete a questionnaire concerning their interest in this program. By making use of the questionnaire, grade point average, science grades, personal interviews with potential teacher aides, and recommendations from teachers who have had contact with these students, selection is completed. When these students return to school in the fall, their schedules are examined to determine when they will be available for instruction.

In September, the science coordinator meets with the elementary teachers at the builds to be served. (Ten elementary buildings are scattered over a large area, and four can be reached easily.) After a schedule is arranged with these teachers, the teacher aides meet with their respective teachers. The elementary teacher and the teacher aide establish a tentative time schedule, decide what topics are to be taught, and approximately how much time is to be spent in each area. The teacher aides then return to the high school to begin their preparation. During a week of scheduled meetings, the science coordinator works closely with each teacher aide, first acclimating them to the elementary program, then providing copies of the teacher text, resource materials, and ideas for instruction. For example, when to schedule a field trip, whom to contact for a walking tour, where the various pieces of apparatus are kept, and so on. The elementary teacher and the science coordinator then assist the student teacher aide in developing lesson plans for each six-week period. Approximately one period per week is spent in plan development leaving four days per week for actual instruction.

Never has the feeling developed that these high school students are in charge of the elementary classroom science program. And yet, if the teacher aide has

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been late for his appointment or has not made prior arrangements for absence, interest has waned considerably. One student, who had been doing an excellent job, was absent for several weeks due to illness. The teacher commented that her classroom just didn't seem to have quite the usual enthusiasm for school until the teacher aide returned!

Numerous evaluative sessions were held during the first year with the teacher aides, elementary teachers and principals, and the science coordinator. From these discussions, attempts have been made to improve the program. The group developed a code of behavior for these future teachers, "Be-Attitudes for Teacher Aides" (Be prepared, Be enthusiastic, Be prompt, Be ethical, Be cooperative.) A more coordinated program among the various elementary buildings will provide for more efficient use of the supplementary equipment and materials.

This program is in its third year of successful operation. The response from teachers, students, parents, and supervisory personnel has been tremendous. An initial program that started with three high school students and five elementary teachers will involve more than thirty high school students and twenty-five elementary classrooms this year. Other subject-matter supervisors have expressed interest in the program and contemplate use of student assistants in their elementary programs next year.

The contributions of this program have been many and varied. Typical comments from elementary teachers include: "Science is not one of my strong areas and Mr. Waller has been able to motivate the children much more ably than I could"; "Mr. Anderson was extremely well-organized and his knowledge and enthusiasm for science made his lessons interesting and challenging for the children." From a high school student: "I didn't realize that teaching could be fun; this experience has been challenging but also enjoyable." From the superintendent: "...an excellent program, not only of immense value to our elementary children but to our total program."

The full value of this program may never be fully measured. Certainly there has been an increase in the interest of both the elementary children and of these future teachers. The elementary teachers have shown renewed interest and enthusiasm. The teacher aide program has made a difference in the elementary teachers' and administrators' approach to elementary science; they are beginning to see the need for complete revision of their present elementary science curriculum to provide a child-oriented program. The small degree of success being enjoyed with the teacher aide program will certainly have far reaching effects on the total program for many years to come.