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ABSTRACT

These three booklets are outlines of teaching procedures, using living material, designed for elementary school children. While emphasizing science, many opportunities are provided for exercises in mathematics, art, and writing, thus integrating the curriculum. All booklets contain exercises on data collection and organization; two have exercises designed to give practice in estimating population sizes from samples. Brine shrimp are used to provide experiences with life cycles and interactions with environmental factors. Minnows provide data needed to build a mathematical model: the relationship between temperature and activity. Emphasis is placed on testing predictions (interpolated and extrapolated) to check the validity of the model. Collection of pond water, and observations of changes in numbers and variety of organisms in a micro-aquarium is intended to make children aware of the general applicability of the concept of change in natural communities. This last activity also introduces the necessity for sampling under standardized conditions. Some theoretical background material is included. This work was prepared under an ESEA Title III contract. (AL)

SUCCESSION IN A MICRO-AQUARIUM

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SUCCESSION IN A MICRO-AQUARIUM

BACKGROUND

The natural and the man-made world is divided into relatively discrete units called communities. Each community may be characterized by its qualities — those features which serve to set it apart from other communities. Thus, one easily recognizes some obvious differences between a prairie and a forest, a pond and a stream.

Communities are rarely stable entities. With time they undergo a variety of changes, transforming themselves perhaps into completely different units. Short term changes — day, night, and seasonal — may also be observed.

A patterned sequence of change in a community is called succession. Changes occurring during succession in the community are usually irreversible. For example, the progression of events which occur as a small town develops into a large city do not reverse themselves. Once economic and social forces are given proper impetus, growth in a population center is ordinarily a self perpetuating process. The same is true of natural communities. Certain patterned events occur which cause a pond to become a marsh. The marsh may with time be transformed into a prairie or forest.

As certain dominant features of a community undergo change so do its members. The pond mentioned above may have contained a sizeable number of fish at one time. As it is transformed into a marsh the kinds of fish it supports will change. Eventually all fish will disappear. But new life forms will be found in the marsh. Deer will now rest in or near it whereas previously they were only transient visitors.

Successional studies are usually carried on over periods of years because community change is a relatively slow process. Some studies, however, may take only a few weeks or months. This lesson describes a method for investigating community changes which may occur in a short period of time — a micro-aquarium study.

The activity which children observe in a micro-aquarium may in some senses be considered representative of that which would occur in the larger body of water from which their samples were drawn. But, it must be remembered that conditions in an aquarium are not the same as those in a pond, stream, or water-filled ditch. Thus, as changes occur in the aquarium the children must be careful in drawing parallels between their micro-communities and the natural community.

In this lesson children will collect and periodically examine water samples. Changes in numbers and types of organisms collected will occur over a period of time Exactly what will happen cannot be predicted because it will depend upon the contents of the original source of water. Generally speaking, though, certain organisms may be at first very abundant and then "appear" to die off. A different type may then occur in large numbers only to eventually "disappear." The children may also observe that one or more organisms are always present in large numbers while others appear and disappear from time to time. Also, there is no guarantee that what happens in one micro-aquarium will happen in another.

Perhaps the most exciting aspect of the lesson lies in the fact that specific events and relationships are not predictable. Yet, the general pattern of events is not a haphazard one either. Through observation and discussion the children should come to realize that there is a kind of pattern to be found among the various events occurring in their aquaria. And while the activities of this lesson are primarily directed toward investigating those particular events, the material for study should suggest a wide variety of related investigations. These may be carried on concurrently with succession studies, or follow them as your schedule permits. Suggestions for further activities will be found at the end of this lesson.

MATERIALS

Item	Description	Source	Quantity
Quart jars & lids	mayonnaise, peanut butter, etc.	home	1/student
Water		pond, roadside ditches, mud puddles, etc.	1 quart/student
Microscopes	200X, elementary school variety of child's own	school, home	1/3 students if possible
Hand lens	10X & 15X type	school, supply house	1/2 students
Microscope slides and cover slips		school, supply house	2/student
Methyl cellulose (optional)		biological supply	1 jar
Soda straws		school	1 carton
Cotton		drugstore, grocery	1 package
Bucket	plastic	school, home	1 or 2
Plastic bags		grocery	1 or 2/student
Thermometers		school	1/2 doz

PROCEDURE

Part 1: Pre-Field Trip

Before the children do their collecting, it is advisable for you to investigate and identify a nearby source of water. A pond, water-filled ditch, marsh or swamp are all excellent sources of water rich in micro-organisms. Estimate the time needed to get to the area and back so that you may plan your field trip schedule. Other factors to be considered in selecting the site are those of accessibility for children, depth of the source, and ownership of the property.

Several days before the field trip ask the children to bring to class a container which could be used as an aquarium. Peanut butter, mayonnaise, or baby food jars are all suitable for use as small individual aquaria. Each should be labeled with its owner's name and set aside for the time being. Jar lids are not necessary; other materials may be used to cover the jars and prevent evaporation. Gather together the other equipment needed so that children may begin their observations immediately upon returning from the field.

WATER SAMPLE COLLECTION CARD

Student Name ______________________________

Date ______________

Collection site description (pond, stream, ditch surrounded by field prairie, etc) (Estimated depth of water, collection depth, etc.)

Weather (Temperature, moisture, cloudy, sunny, etc.)

____

Condition of water (Clear, cloudy, odorless, color, temperature, etc.)

____

Part 2: Field Trip

Organize the class for their visit to the water site. They should be told before leaving to observe any special precautions necessary if the water is deep. Children should wear clothing appropriate for the field such as old shoes, jackets, boots, etc.

Each child should be given a plastic bag, a rubber band, and a water sample collection card. Additional materials such as thermometers, nets, and buckets may be distributed among the children to take along.

Once the class reaches the site you may wish to remind them to be careful before they begin collecting. If the body of water is sufficiently large, each child should select a site along the bank or shore which offers easy access to the water. Plastic bags should be dipped into the water and half filled. Debris such as mud, leaves, and sticks should also be collected. (Half a handful would be sufficient.) Many organisms cling to these things providing a rich sample of varied organisms.

Water temperatures should be taken in various spots along the bank. Depending on the depth of the water, you may find some differences between surface and sub-surface temperatures. As readings are taken the children should record them on their collection cards. They need only to record a temperature for the site their sample was taken from.

When each child has obtained a sample, the bags should be closed with a rubber band. They should then take a few minutes to fill out the collection cards describing the site, weather, and other information needed to complete the card. If time permits, you may want them to return to class immediately so that they may begin to examine their water.

Before leaving, collect one or two buckets of water for yourself. Be sure to include some mud, sticks, stones, etc. If you have an aquarium or a gallon jug in the class room, you can use these to set up larger samples for class observation.

Part 3: Class Room Activities

A. Preliminary Observations

Upon immediate return to the classroom the children should transfer their samples to their jars. Jars should be labeled with names.

Before beginning microscopic examinations, the children should have the opportunity to make gross examinations of their samples. Distribute hand lenses and paper with the direction to draw or describe in words some of the things they see. Some children may become so involved in observing that they will not at this time want to record what they see. Consequently, if such an assignment seems to interfere with their natural inclinations to "just look," encourage them to continue observing. Eventually you will want them to collect their observations in a notebook so that they may be used for reference purposes. The notebook may be started on the next day.

The children will expect you to be able to identify everything they see. Very few biologists know the names or can recognize all of the organisms in a sample of pond water. Thus, you should not be expected to know them either. Make it clear to the child who questions you that a name does not change the organism, make it any more understandable, or easier to observe. In fact, a name rarely has anything to do with what is important and unique about an organism. The children may assign any name they wish to what they see, however, when they become more familiar with their cultures they should be careful not to change names. The only rule about naming, then, is to be consistent. For the interested child, you may make available some of the reference materials listed in the bibliography.

When the children have completed their initial observations on this first day, their aquaria should be loosely capped or pieces of construction paper should be placed over the jars to prevent evaporation. When the materials are put away, encourage them to share their observations with one another. They might enjoy describing what they saw or perhaps they could draw some of the organisms on the board for others to see. This would be a useful exercise since eventually the children must come to a point of agreement among themselves about what is seen. This means that each must recognize an organism as being the same thing other class members have seen.

B. Continued Observation

Several days should be spent in rather casual observations of the water. During this time the children will become familiar with their samples, will begin to recognize organisms they have seen before, and will accustom themselves to the use of the microscope as an observation aid. Encourage them to make large drawings of the things they see, especially the forms which are commonly found from day to day.

Proper use of the microscope should become a class goal during this period. Some children who have their own may require little help. Others, using them for the first time, may need much instruction. Also, your own familiarity with a microscope and its use will be helpful to those who cannot seem to get the "knack" of it. It would be advisable for you to spend some time making your own observations so that you might anticipate problems the children will encounter with the microscope. Often many students have difficulty distinguishing between air bubbles, scratches on a slide or cover slip, and living organisms. Remember that few things of nature are perfectly round (air bubbles) or perfectly straight (some scratches).

Learning to use a microscope involves its proper care. Children should clean them before use. They should understand that few microscopes are usable if abused (dropped, etc.). Common sense and gentle reminders are helpful to children who have had little experience with them.

In addition to learning the use of the microscope while making continued observations the children should be introduced to some other useful techniques. In surveying the water for smaller organisms, special methods must be employed to decrease the motility of the organisms. Methyl cellulose is a chemical which can be added to a drop of culture water in order to retard motion. If one drop of this solution and one drop of water are put together on a slide the desired slowing affect will be achieved. If methyl cellulose is not available, threads plucked from cotton and applied to a slide are also effective in trapping some of the larger micro-organisms. Experiment with the amount of cotton required.

Once the students have become familiar with these techniques, they may be employed throughout the lesson. Students should recognize that examinations of the water are most easily made when the quantity used is no more than a single drop. Soda straws are excellent sampling devices. Children should practice (with tap water) obtaining a single drop from a straw sampler. For some students cutting a straw in half makes it a more manageable device.

Mention has been made briefly of the role of drawings and descriptions in this study. All too often these kinds of assignments become the focus of attention rather than an aid to investigation. The children should understand that records are kept simply because one cannot recall everything. Records are reminders; they are written evidence of observations and provide material for visual communication with one another. Thus, it would be most helpful to begin the development of a "gallery" of organisms — pictures of the forms seen. As they are produced, they may be posted on the bulletin board and used as references during class discussion.

Notebooks, kept on a day to day basis, are recommended for keeping track of those events occurring in a culture which do not lend themselves to drawings. Color, odor, and turbidity (cloudy, clear) changes in the water are important observations to be made daily. When it becomes necessary for the children to be more systematic about their observations, written records should be somewhat standardized in order that each child collects the same kind of information.

Much of the foregoing observation may be done without your direct help. The excitement of exploration and discovery should maintain the interest of the class for at least a week. You may expect a great deal of casual sharing of observations and discoveries — most children want others to see what they have found. Encourage them to share their findings with others and with you. What seems to be noise and chaos during this period is, more often than not, the sound of excited, involved children (usually) engaged in productive activity.

Part 4: Planned Investigation

A. Predictions

After several days or a week of casual observation, some of the children will want to know what to do with the pond water. A few might suggest some experiments, others will want to feed the organisms, and several may noticeably lose interest. When you feel most of the class is ready to become involved in more directed study this would be the time to introduce them to several procedures which they will use in their investigation of succession.

Few children have acquired the degree of sophistication needed to appreciate the concept of standardized procedures. Experiments children perform are often inconclusive because they do not conduct them in a systematic way. In addition, experiments suggested by the teacher and over which she exerts control, may prove to be unexciting to the child whose interests lie elsewhere. Thus, for many reasons, standardized controlled experimentation is often unsuccessful with elementary school children. Your role then will be to exert only that degree of control required to achieve results but which will not interfere with the natural interests of the children.

One way to maintain interest would be to encourage the children to identify and conduct experiments of their own choosing while they are also involved in the succession study. In addition, encourage them to discuss their (succession) data from time to time noting some of the changes which have occurred. If you maintained your own micro-aquarium you could determine the timing of such discussions. When you observe a rather dramatic event such as an over-night change in numbers or a sudden appearance of many new forms, find out what is happening in the childrens' cultures. You may also expect the children to raise questions concerning some changes they have observed. Use these discussion sessions as a means of maintaining interest and excitment.

The day before the class is ready to begin the study each culture should be fed with several grains of rice, a pinch of brewers dry yeast, or a few (3 - 4) flakes of cereal. Do not use all types of food suggested, just one. After this initial feeding do not have the children feed them again. Ask them to predict what they think will happen now that the organisms have been fed. This question should set the stage for the study.

B. Sampling

Succession involves a change in numbers and types as mentioned in the background section of this lesson. Casual observations reveal changes in numbers: the water turns cloudy when many forms are present or it clears when they die. Gross observations, though, are not sufficient for knowing what form "bloomed" suddenly or what form died. Also, bloom and/or death could occur in one part of an aquarium but not in another. This suggests that the water must be carefully sampled to ascertain the nature of a change. If samples are drawn from different parts of the culture they are apt to yield the presence of different types of organisms as well as different numbers of those types. Ideally, the most accurate method of sampling would involve just that. But for children this would become rather tedious. What is suggested then is that the children determine the most populous portion of their cultures and hereafter select samples from that area only.

To introduce the idea of the standardized sampling recall their predictions about what might happen when the cultures were fed. How will they know if something happend? Why might it be a good idea to follow the events in the culture for several weeks? How would each propose to do this? Many suggestions will probably be forthcoming. You will want to lead them into suggesting a standard sampling method as part of their proposed study. Thus if they suggest the cultures be examined every day, you could, ask how they would examine them. Can they possibly examine the entire contents or, if not, what part could be checked? Have they any ideas about a "best" part of their culture?* If not, or if some are uncertain, ask what they think might constitute the "best" part. Would it be where many or few things are found?

Perhaps "bestness" can now be determined if each child carefully draws a sample from relatively distinct areas within his aquarium. These areas might be the top, middle, and bottom portion. Another might be somewhere in the midst of the debris. Area sampling can be accomplished simply by not opening the straw sampler until it reaches the desired spot.

Once the samples are drawn it will be the task of the children to evaluate them. Questions such as "where are the greatest numbers found?" or "which spot seems to contain the greatest variety?" should cause each child to attempt to discriminate among his samples. No doubt this activity will cause some questions to be raised about why the organisms "prefer" one spot to another. Suggest to those interested that they try experimenting with some other water to see if they could discover possible explanations.

After the children have made their determinations they should agree to sample only from the spot they chose as the "best." It is assumed that this spot would contain a diversity of forms occurring in relatively large numbers. (The chosen area will not remain stable in terms of numbers or diversity. If questions about changing spots arise, suggest that they continue sampling there to see what happens.)

This method of determining a means of sampling and choice of site is a comprimise but hopefully the children will develop some awareness of the need to standardize the procedure. It would be advisable to raise the issue with them at the termination of the study — what might they have found if they had not chosen a single spot to sample daily.

C. Population Estimation

After the class has determined a sampling procedure, a method must be devised for estimating the numbers of individual organisms in each sample. Estimates should be relative — it is almost impossible to count each individual. Also, counts should include primarily those organisms which are recognized most easily by the children.

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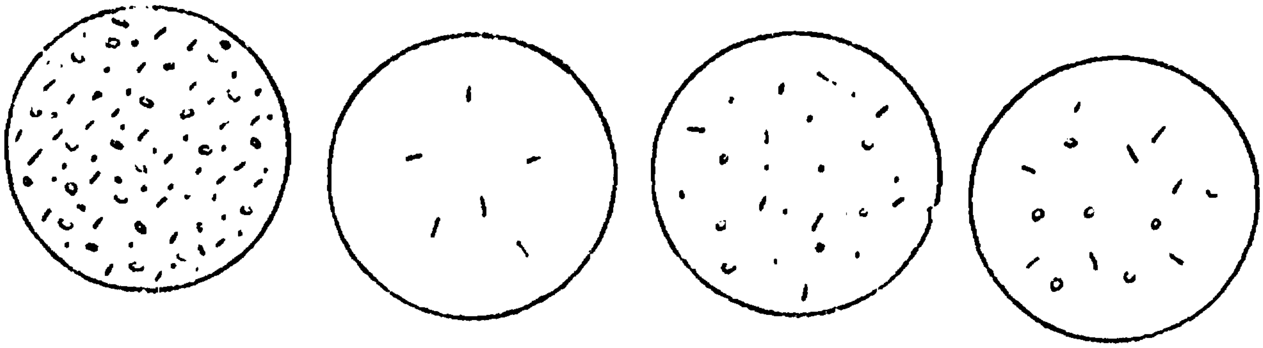
*The use of the word "best" is certainly arbitrary. Children do think in a qualitative rather than quantative fashion although they may mean quantity. When they determine "bestness" another descriptive term should be substituted.

One way to establish a method of estimating would be to develop some arbitrary standards.* Observe the drawings below:



Each drawing represents a different microscopic field at the same magnification. Place similar drawings on the chalkboard for the children to observe. You might ask if they could suggest what the drawings represent. Once the meaning is understood, ask the class to put them into some order. Is there only one way to do this? The children will probably see several ways.

The most obvious method would be to order according to the number of forms contained in each field. The other way would involve ordering on the basis of numbers of certain types. For the time being, concentrate on the first method; the other will be examined later.

After the drawings are ordered, assign a letter or number to each for use later. What else do the drawings reveal? How many types of organisms are represented? Are they the same size in each drawing? What does this imply about the way they were drawn? If the answer is not clear, perhaps the following activity will clarify the reasons for purposely depicting the forms at the same magnification.

Have each child prepare a slide for examination from their sample area. All microscopes should then be adjusted to the same power. Direct them to estimate how many forms are seen. Guesses will vary widely both with samples and with the childrens' ability to estimate. The estimation should be recorded; microscopes should be readjusted to a higher magnification. Now, how many are seen? (Estimates should be lower.) If they were to make daily estimations, which power would they choose? Or is it the choice of a specific power which is important? Probably not, except that at higher magnifications fewer organisms are seen, making estimates easier. Of greater significance is standardizing the magnification so that the field size is the same each time estimates are made.

*This method is chosen for explanation since it would probably be the most workable with younger children. Older students should suggest their own methods.

To return to the idea of ordering the drawings, have the children select a magnification which seems to be the best for estimating. After they are focused on a field, ask them to compare what they see with one of the drawings. They must think in terms of the density — numbers — of organisms. Do they see very few or many? If each made a comparison between what is seen and one of the drawings on the board, which drawings would they select as most representative of their field? After they have made selections, suggest that they check one another's. Provide sufficient time for checking and comparing. Determine to what extent they seem to agree with one another's choice for comparison. Why is a certain amount of agreement desirable

The class has now been provided with a relative means of estimating total population in a drop of water. This is by no means the only way to arrive at estimations. You may want to suggest that they think of other ways.

Another type of estimation which can be made is that of the relative number of a certain form in a mixture of organisms.* Few slides will show only one kind of organism, rather several to many will be visible on most slides. The key to estimating their relative numbers lies in the childrens' ability to recognize their differences. Since this is not easy to do, don't insist upon a great deal of proficiency. They should be familiar enough with many of the forms, however, in order to make a fairly good guess as to which one seems to be more abundant at a given time. A good means of assessing these estimates is to again have the children check one another's slides to see if they agree.

D. Keeping Records

There is little need to standardize observations if careful records are not kept of them. Casual records have probably been kept by some of the students, but now the entire class should become involved with each student collecting the same information daily or every other day.

Their records should consist of several items: (1) date, (2) total population in a given sample, (3) relative numbers of different types in the same sample, (4) general observations of the water.

The simplest method for keeping records is to construct some sort of a data chart where observations are entered at the appropriate place daily or whenever they are scheduled. Below is a sample chart of the type the children could construct.

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*Identification of each type of organism may also be relative. For example, all "tiny" forms may be considered one "type," all forms having similar characteristics, e.g., legs, "feelers," etc., could constitute another type. Absolute classification is not required, nor desired for this study.

Date	Organisms Observed	Relative numbers of different organisms	Compared total population of sample	Water Condition
	A B C D	Most numerous Very few Next most numerous Several	type A	Clear, no odor, no color

Under the heading "organisms observed" the children would enter the designations they have chosen for commonly appearing organisms. Under "relative numbers of different organisms" any terms descriptive of quantity may be used. "Compared total" refers to the comparisons made to arbitrary standards selected by the class (See Part IV, Section B "Population Estimates"). The final column is included so that some correlations between populations and water condition may be made at the conclusion of the lesson.

These records will eventually reveal the fact that changes took place in the micro aquaria. The children may have to collect data for a month or more to observe succession. As they become proficient in collecting data, more time may be devoted to other investigations of their own choosing. They should not use their own water samples for any additional experiments however, these should be left undisturbed, except for sampling.

Part V. Discussion of Results

You will have to exercise your own judgment as to when the investigation should be concluded. Check the records from time to time to ascertain if changes are occurring. When you feel a sufficient number of changes have occurred to illustrate the point of the lesson you should begin a discussion of the results. Refer to their initial predictions made after the cultures were fed. Did anyone find his prediction to be correct or approximately so?

During the discussion the children will want to relate to you and to the class what they found. As they report, try to discover whether they noticed any cycle of events occurring.

This idea may be brought out if each reports his results according to the daily sequence of events. Beginning a day or two after the cultures were fed, what happened? And after three or four days, etc. As reports are made, check to see how many children found about the same things happening at the same time. Record their reports on the board so that the entire class may see one another's results. Perhaps the reports could be grouped in some way so that recording each is not necessary.

The major point to elicit through class discussion is that change occurred. In fact, two types of change may have been observed: (1) changes in total numbers of organisms, and (2) changes in types of organisms. Did there seem to be any pattern or sequence to the changes?

It is difficult to predict what type of pattern may have emerged because the factors which affect that emergence vary widely from class to class and depend to a great extent upon the contents of the water samples. This is not to say that some sort of generalized pattern does not exist. Many investigators have found the following sequence to be characteristic of the events observed in their studies:

1. Initial phase before feeding; a few tiny organisms plus some larger multicellular forms. Water clear.
2. After feeding; profusion of the very tiny organisms. Water turns cloudy.
3. Several days later; appearance of larger single celled forms. Water turning clearer.
4. One week to ten days after feeding; predominance of large single celled forms such as the Paramecium and related organisms.
5. Three weeks after feeding; beginning of mixed form stage, water clear, fewer Paramecia and increasing numbers of larger multicellular forms such as rotifers, small crustaceans, etc.
6. Month later; mixed population, fewer numbers of everything. This stage resembles the initial phase.

The above is a very general description of what might have happened. It is by no means the only sequence of events possible. Some of the phases may not have appeared in your class samples, others may have lasted for a considerably longer or shorter period of time and, lastly, there may not have been any obvious phasing at all.

Once all the data is put in a generalized form and what happened is clear to the students, you might ask them what would happen if they again fed their cultures and followed events much as they have in the foregoing weeks. Would they see similar things happening? Do they think the pond has changed since they were there? Should the events in the micro-aquaria be expected to mirror those in the pond? What are some of the important conditions of life in the pond which are not present in the micro-aquaria? The children should be aware of the fact that natural conditions of existence cannot be wholly duplicated in the class room. But they would not be in error if they suggested that the kinds of things which happen in the natural setting are similar to those in the class room.

Is change characteristic of ponds alone or is it observable in other parts of the natural world? What are some other examples of change the children have observed? Perhaps the most common and dramatic changes which will occur to the class are seasonal ones. They are very good examples since these changes are predictable and recur. In this sense, they are similar to the cyclic changes which occur among pond organisms.

Through discussion the children should become aware of the general applicability of the concept of change as it relates to events in the natural community. If you wish you may extend the discussion to include man-made communities. Finally, the class might observe and describe changes in other micro-communities such as rotting logs, forest floor litter, or other decaying vegetable matter.

Part VI. Additional Investigations

1. Altering the environmental conditions:
   A. Light (keep cultures in the dark)
   B. Temperature (maintain some in a refrigerator)
   C. Condition of the water (see what affect the addition of a pinch of baking soda has on the successional pattern)
   D. Food supply (will too much food adversely affect a culture)
   E. Air (observe the events in a tightly capped micro-aquarium)

2. Investigation of a single organism

3. Other events in the aquarium
   A. Food chains
   B. Growth and reproduction of organisms
   C. Role of plant life
   D. Behavior of larger forms

Productive investigations are those conducted under controlled circumstances in which standardized techniques and methods are employed. It is important that the children develop an awareness of these aspects of science. You cannot expect them to fully understand or appreciate the necessity for systematic investigation solely on the basis of this study. However, you might expect them to become more careful in their work as they proceed through it. Your guidance is critical to the refinement of experimental techniques. Judicious exercise of control over these investigatory activities will help the children realize more productive and conclusive results.

BIBLIOGRAPHY

The following books contain pictures and descriptions of many micro-organisms; you may find them useful references for both yourself and the class.

Buchsbaum, Ralph, Basic Ecology, Boxwood Press, 1957

Eddy, Samual, Hodson, A.C., Taxonomic Keys (To common animals of the North Central States) Burgess Publishing Co., Mpls., Minn., 1967.

John, T.L., How to Know the Protozoa, Wm. C. Brown Co., Dubuque, Iowa, 1949

Needham, J. G., Needham, P. R., A Guide to the Study of Freshwater Biology, Comstock Publishing Associates, Ihaca, New York, 1955.

Instructional materials which could also be used in conjunction with this lesson are listed below.

Pond Water, Elementary Science Study of Education Development Center, Newton, Mass.

Small Things, Webster Division, McGraw-Hill, St. Louis, 1967, (Another Elementary Science Study Unit)

Organisms, D.C. Heath and Co., Boston, Mass, 1968. (An instructional unit developed by the Science Curriculum Improvement Study, Berkeley, Calif.)

MINNOWS AND MODELS

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Preface

The minnow unit is an outgrowth of the combined efforts of the Environmental Science Center Staff and is an example of <u>but</u> <u>one</u> type of product to be developed within the curriculum operation of the Center. Although the unit has been trial taught, its present form is preliminary and subject to further revision as a result of additional trials with children. It is hoped that those who teach it will offer comments and criticisms useful in its further refinement.

The unit materials are grouped into two categories denoted by the use of colored paper. The blue section contains background information for the teacher, the white section is a teacher's guide to be used with children. In the future when a substantial sequence of units is developed, The Schematic Representation of Some Ecosystem Factors, found in the blue section, will serve to place that sequence in proper perspective relative to a larger body of knowledge. The second schema (Behavior Schema) depicts a possible sequence of units covering the behavior factor found on the ecosystem schema. It further shows lesson by lesson, the scientific operations covered in this unit.

Additional background materials provide the teacher with some fundamental scientific knowledge relative to the content of the unit. A final inclusion in the background section offers some suggested approaches to the teaching of the unit.

Contents

BACKGROUND INFORMATION

Introduction: TEACHING THE UNIT

The activities of this unit are designed to provide the students with the opportunity to construct a model of a system whose components are initially unknown but which can be determined through investigation. That model, as briefly discussed in the background paper, is a representation of the interrelationship between heat and breathing rate in fish. The extent to which you pursue the idea of a model with your students or discuss with them the concept of respiration must depend both on theirs and your background.

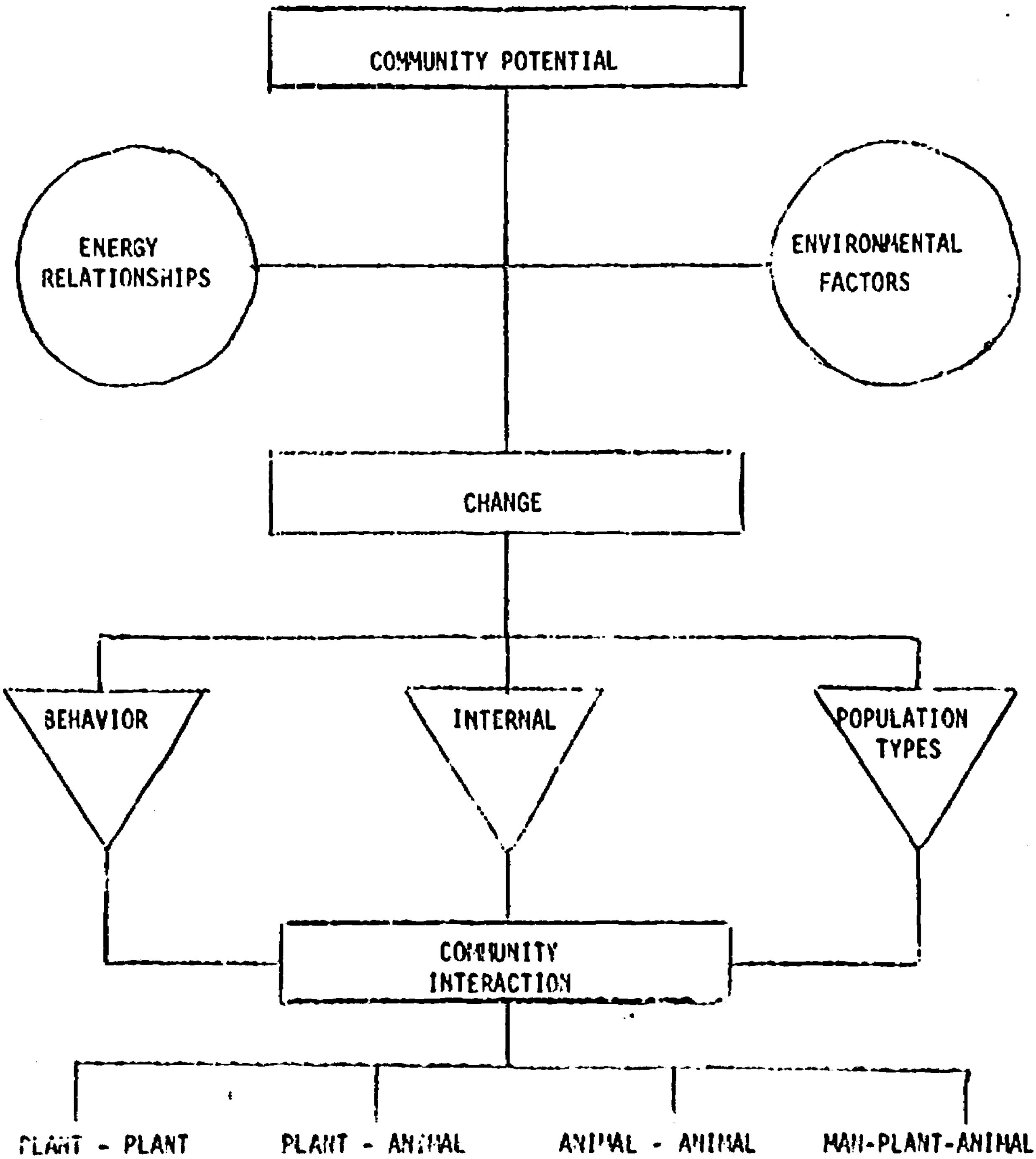
Children may begin the unit with a casual observation of fish behavior, perhaps investigating the affects of several environmental stimuli upon their behavior. One or several lessons will probably be sufficient for preliminary observations. From this point, the students will move into a study of a specific stimulus and its affect upon one aspect of fish behavior — breathing rate. Here their observations will be confined to an indicator system "invented" for them in Lesson II (Developing the Model). The study and measurement of that system will lead to the construction of a model (a graph of the aforementioned interrelationship) at the end of the lesson. Lesson III (Refining the Model) will call for a verification of the model, while Lesson IV (Applying the Model) examines the applicability of the model to more general biological problems.

There are many ways to introduce the activities of this unit to the students. How you do it will depend upon what has preceded it and what is planned to follow. As you read through the unit, you will find that the activities might very well serve as an introduction to some studies of respiration; they could be used as a part of a sequence on animal behavior, or they might fit into some work on measurement. Also, the unit need not be taught in its entirety; some activities can be removed and used in conjunction with other aspects of your program. However you wish to use it, we believe you are the best judge of its appropriateness in terms of your students and objectives.

It is hoped that you will not view these lessons as applicable only to your science program. Lesson II (Developing the Model) may provide material for your mathematics program, written reports of student investigations could be a part of a language arts writing assignment and the implications of the construct developed might be discussed in conjunction with certain social studies problems. Our intent is to develop materials with cross-discipline possibilities so that one aspect of a curriculum can serve as a reinforcement to another. In this way, it is possible to provide for more science in a total program without having to allot additional time for it. Therefore, it is advisable to read through the entire unit before it is taught to identify those activities which might be useful elsewhere in your program.

While the sequence of activities is important for the development of the construct, the procedures recommended may be changed or modified as needed in order to make them more suitable to your particular situation. Although the unit has been designed for upper elementary children, you may wish to use all or part of it at other grade levels. At the conclusion of the unit you will find suggestions for further activities. These suggestions are optional. Perhaps they might be of use to some students interested in additional activities with the fish, or they could provide material for independent investigation for the entire class.

SCHEMATIC REPRESENTATION OF SOME ECOSYSTEM FACTORS



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INVESTIGATING THE COMMUNITY

If one should look at a woods, a marsh, a stream, or a meadow and note general differences, it becomes apparent that there are many KINDS of things found living together in these areas. Perhaps most readily apparent is the variety of plants. Animal life is sometimes less obvious, but closer observation usually reveals evidence of their activities.

Local populations of plants and animals constitute a COMMUNITY which is roughly analogous to the one in which we live. There are many people engaged in a variety of occupations, each of which is important. Plants and animals also have many different "jobs" within their respective communities. Our food is produced by farmers; food for a natural community comes primarily from green plants. The aforementioned PRODUCERS are an essential element in any community. Other organisms may get their food by eating plants or other animals. They play a role similar to ours in the utilization of material from the producers and may be called CONSUMERS.

Any study of a community must of necessity include the abiotic factors also. Weather, winds, climate, temperature, soil type, and available water are considered to be in this category. Interactions among living organisms may be largely affected by combinations of the above-mentioned environmental conditions. Birds migrate, water habitats freeze, photosynthesis ceases periodically in temperate zones with few exceptions, and food sources change in both type and availability.

Just as our human community shows seasonal change, the natural community will also reflect seasonal modifications. People and animals change their seasonal wear; fresh vegetables become more scarce for our consumption and food for some birds and animals becomes inaccessible when freezing occurs; we heat our homes when the snows blow and the muskrat must build a substantial "house" of reeds to serve as shelter and a food source until the waters thaw and plants once again grow in profusion.

The environmental scientist is concerned with energy flow into a community and the subsequent interrelationships resulting from "parcelling" and exchange of these energy units by life forms which constitute the community. A rich variety of interactions occurs. One can be concerned with parasites, nutrition and health; scavengers, decomposers and pollution; or transformers and agriculture. It can be demonstrated in both the classroom and field that community potential for development is dependent upon the above energy relationships and environmental factors which effect change for both the human societal community and the community of Nature.

Changes wrought by the aforementioned factors are manifest as modified behavior, life chemistry, and types of organisms found in a community. Thus, the communities of northland Eskimos, temperate metropolitan dwellers, and tropical tribesmen reflect these environmental interactions just as do the plant and animal life forms. Combinations of these factors direct the relationships found within the community structure and resulting modifications are directed toward the establishment of a stable, self-regulating system.

A schematic representation of these interactions has been prepared to illustrate the general cause-effect relations that exist within an ecosystem. Realization of the potential development of a community is dependent upon "food" and available energy in the form of sunlight. This initial requisite is directly influenced by abiotic factors such as water or climate.

Combinations of the above modify an initial potential and direct the development of a community by elimination of those life forms which cannot function under the existing conditions. As living things are eliminated or added to the community in accordance with their tolerance for the system, the interrelationships among the organisms must also change. A few of the common categories are listed on the schema.

It is hoped that the schema will prove to be useful as an aid in clarifying factors involved in the integration of an ecosystem, but it is not meant to limit your investigations. Studies can be initiated at any point within the structuring and the direction one takes is dependent upon the purpose of the unit. It is possible to study an individual facet also, but placing the body of knowledge in its proper perspective will make that study more informative.

Study of a community need not be limited to the biology classroom or science curriculum. In addition, the concept of the community can be a pervasive theme throughout the social studies curriculum. A rich variety of factors is involved in community maintenance which suggests material for many units in social studies. Physical science may be approached from a community point of view through the study of those geological, climatic, or other physical factors affecting community potential.

The diversity of topics subsumed under the general title of community and revealed in the schema offers the student many avenues of approach to an understanding of the concept. Teachers are encouraged to explore these possibilities as opportunities arise in any area of the curriculum.

BACKGROUND INFORMATION — BEHAVIOR

The continued survival of living things is dependent upon adjustment to their surroundings and the changes that occur within it. A second factor to be considered is the interrelationship between the organism in question and other life forms found in the community. Let us call this set of responses BEHAVIOR and consider some of the factors involved.

Many animals migrate when the environmental conditions change enough to impose hardships on that organism in terms of food-getting or other activities. The migration may be of an extensive nature as demonstrated by ducks and songbirds, or limited to a change of depth by fish seeking cooler waters in the summer. Scientists have also shown that toads "migrate" downward during the winter months to avoid the advancing frost line. This behavior is of SURVIVAL VALUE and is necessary for the continued success of the organism.

In addition to adjusting to their surroundings, many animals demonstrate modified behavioral patterns which reflect relationships with other organisms in their community. Periodically the lemming will mass migrate toward the sea. This emmigration greatly diminishes the populations of lemmings on the northern tundras, reducing available food for the Snowy Owl. Many of these birds will be found far to the south of their usual ranges in search of small rodent "substitutes" for their normal prey. One can see a parallel between this bird's plight and that of the Irish after the great potato famine in Ireland which resulted in large numbers of those people moving to the United States in search of new homes and means of supporting their families.

At this point it may be appropriate to discuss how living things KNOW when the environment changes and how they BEHAVE in relation to this change. Obviously the organism must be able to "sample" the environment to determine existing conditions. This necessarily implies communication with its "parts" and possession of the biological machinery for coordinating these activities.

Functional sampling of environmental conditions is accomplished by means of RECEPTORS. In highly developed life forms such as mammals, the receptors are connected to a NERVOUS SYSTEM which transmits information to a center responsible for interpretation and subsequent reaction to the STIMULUS. This center is, of course, the BRAIN. Plants are more dependent upon subtle chemical changes which are initiated by modifications in the physical environment in excess of some critical value. These values vary from species to species. Spring and fall flowering phenomena are examples of day-length influencing the production of chemical substances which lead to flower formation.

The behavior of living things relative to stimuli is called RESPONSE. Activity may take the form of avoidance such as sow bugs seeking moist, dark places or the earthworm's tendency to burrow into the ground and escape dessication resulting from exposure to sunlight. Scientists have also found that increasing day-length is responsible for the sexual activity of some bird species. Mating, with associated activities such as nest building, song and establishment of territory, is dependent upon this changing factor.

Combinations of environmental factors will therefore influence the behavior of organisms. Many of these responses can be noted in the field and laboratory by casual observation supplemented with minimal equipment requirements.

INVESTIGATING THE EFFECTS OF TEMPERATURE ON FISH

Lowering the temperature effects a general reduction in the rate at which chemical reactions take place. Sometimes it is possible to observe this effect in an indirect manner. Perhaps you have already noticed that cold fingers become "stiff" or that earthworms move more slowly when chilled.

Organisms which cannot maintain a constant body temperature are more sensitive to heat changes than you and I. Fish, for example, can be used to observe the effects of environmental temperature changes by a rather casual observation of their gill cover or mouth movements.

Have you wondered just <u>how</u> a fish breaths? What conditions must exist in the water? What is the <u>mechanical</u> process used to obtain the oxygen necessary for continued existence?

Mouth movements not associated with feeding are actually an active "swallowing" of water which is expelled through the gills. (Observe a fish and note how the gill covers move as the mouth is closed.) The water is analogous to our "air" —dissolved oxygen is extracted and carbon dioxide is released by the gills. Our lungs serve a similar purpose, do they not?

During exercise, the rate of breathing increases to compensate for the greater rate at which chemical reactions are taking place in your body. Oxygen must be supplied at an increased rate if the accelerated reactions are to continue. In fish, depression of the rate can be effected by lowering the temperature of the water. The reduced temperature slows the chemical rates, hence the oxygen demands are lowered and the volume of water passed over the gills is reduced.

MATERIALS AND PRE-UNIT PROCEDURE

Materials

Item	Source	Quantity
*Minnows — 1-2 inches long	bait shop	at least 1/student
dip nets	bait shop	sufficient for your class
small containers — jars, etc.	home (mayonnaise — peanut butter jars (16-20 oz.)	1/student
centigrade thermometers (12 inch size preferable)	school	1/pair of students
large aquarium	school-home	1
pump and aerator	school	to outfit aquarium
assorted pails or large jars	school-home	2 - 4
ice cubes	cafeteria, store, etc.	10 pounds

Procedure before unit begins :

Obtain the minnows from a bait shop. Before putting them in the classroom aquaria make certain the temperature of the water the fish are in equals that of the aquaria in the classroom. Ask the children to bring in the small containers and have these assembled before you begin the unit. The fish may be fed with Guppie food, but it is not necessary unless you plan to keep them for a long period of time. Thermometers are preferably the twelve inch mercury type. If these are not available, the small metal-backed elementary ones would be suitable.

*The minnows used in trials with children were Shortnose dace Rhinichthys atratulus. Other common species available at most bait shops would also be suitable.

TEACHING GUIDE

Lesson I

Observation: INVESTIGATING MINNOW BEHAVIOR

Introduction to the Activities

Perhaps the presence of the fish in the classroom has already generated a number of questions the children might wish to pursue for a short period of time. These questions would then provide the direction for this first lesson. Obviously, not all questions can be explored or answered, expecially since there just may not be time to do so. However, time spent in searching for some answers should not be considered wasted even though you may feel little was accomplished. The children should get aquainted with their fish. They are then less apt to want to "play" with them when their attention is directed to more specific problems. It is also possible that during this period of rather unstructured observation the children may raise questions pertaining to other unit activities. These questions would afford you a bridge between this first lesson and the remaining ones.

The mechanics of this lesson, that is, everything involved in the procurement of classroom materials by the children can be time consuming if each child is given his own fish to work with. One fish for every three to four children will ease this problem. The children may feel that gravel is a necessary ingredient in their small containers. This is not so; the gravel should remain in the stock tanks. Nothing should be done to the fish that children would not want done to them. Precautions should be taken not to tip the small glass containers; they are easily broken on tile covered cement or other unyielding floors.

The direction and duration of these preliminary periods of observation should be derived primarily from the interest and awareness of the students. Observation and discovery should be enjoyable to them; when it is not, they may be ready for the more specific activities to follow. Your own sense of timing becomes a critical factor in determining the duration of this first lesson.

Materials

Minnows
Small transparent containers — approximately 16-20 ounces in size
Dip nets, in sufficient amount for your class

Procedure

Divide the class into small groups. One child from each group may be responsible for filling their containers with water and obtaining the fish. Following this you may ask them to observe the behavior of the fish perhaps to seek answers to some questions already raised.

During this and the next periods of casual observation, the following kinds of questions may be asked.

Questions	Suggestions
Do the fish always stay together in a group?	Try placing a single fish in each of two small adjoining containers. Observe whether or not the fish orient themselves toward one another. Do they seem to notice other fish? How do they behave? Separate the containers with a book or piece of paper. Does the behavior change?
Do the fish prefer light or dark places?  Note: Support the jar with books to prevent it from rolling off a desk.	Cover one half of a container with black paper or some other material so that part of it is darker. Observe the position the fish takes in the container. (See diagram)
Do the fish always swim near the bottom of the aquarium?	Observe a fish to see if it moves up and down more freely than it does in the aquarium.
What might happen if several fish are placed in the small aquarium?	Place several fish in one container and compare their behavior with a single fish. Are the several fish more or less active than the single fish? (This activity can be done by one group of children. They may share their observations with the class.)

What is happening when the fish opens and closes its mouth?	Observe the mouth opening and closing and then observe whether or not anything else — fins, gills — may also be moving at about the same rate as does the mouth. Count the number of times the mouth opons and closes in a convenient time period. (Experience has shown that four 15-second trials provides a good average count per minute. Two children are required to do this — one to time and one to count.) Count the number of times the gill cover opens and closes in the same time period. Is there any correlation between the two?
How do the fins work?	Observe the action of the fins as the fish moves. Some fins are paired others are not. Notice if one fin in each pair always moves in the same way as the other. Correlate movements of certain fins with swimming actions.

Many other questions have been asked by the children which cannot be answered readily through experimentation, for example:

How old are females when they start laying eggs?
What kind (of fish) are they?
Why does he have scales?
Is this the biggest they get?
Do male fish lay eggs?
How often do you clean the aquarium?

Some discussion may be necessary in order that the students understand what constitutes a <u>testable</u> question. In most cases, the application of common sense rules out the ridiculous questions. Though it is rather difficult to immediately distinguish the ridiculous from the creatively inspired question, under further questioning, a student may reveal his intentions.

Lesson II

Experimentation: DEVELOPING A MODEL FOR CHANGING BEHAVIOR

Introduction to the Activities

In the previous lesson the children raised some questions about fish, investigated some aspects of their behavior and perhaps proposed tentative explanations for what they observed. In this lesson we will direct their attention to one specific investigation: Will the fish behave differently if the temperature of their water environments changed?

In order to answer this question, the children will become involved in several scientific operations — experimentation, measurement, and recording data. The end result of these activities will be the construction of a graph depicting the interrelationship between the breathing rate of the fish and changing water temperature. The graph will serve as a model upon which to base future predictions. The opportunity to test the predictive value of the developed model will arise at the conclusion of this lesson and again in the third lesson.

Parts 1, 2 and 4 of this lesson include measurement and recording activities as part of each experiment The success of the lesson will be dependent upon obtaining accurate measurements and systematically recording them in some standard fashion. You will want to discuss these topics with the class before they begin the experiments.

The model will begin to emerge in Part 3 as the children construct a graph based upon data collected in Parts 1 and 2. Part 4 introduces the children to the operation of prediction and ends with an interpretation of the model.

Part 1. Determination of Breathing Rates at Room Temperature

Materials

- Minnows
- Dip nets
- Thermometers, (Centigrade) 1 per pair of students (12 inch size preferable)
- Small individual water containers, 1 per pair of students
- Sufficient supply of aged or aquarium water at room temperature for approximately 8 ounces per pair of students (approximately 6-7 gallons)
- Measuring cups or suitable substitute.

Procedure

A method for determining the breathing rate of the fish was suggested in Lesson I. If none of the children tried that activity, it is suggested they do so now.

The children will work in pairs. Each pair will need a thermometer, a small container, a minnow, and a standard amount of water. (Thermometers break easily; caution the children about their use.) Before they obtain their water and minnows, they must determine the quantity of water to be used. That initial amount of water will be tripled in Part 2 by the addition of iced water. Therefore, the smallest container must be capable of holding three times the standard agreed upon.

Once the class has decided on some standard quantity of water (there must be a sufficient amount for the fish to swim in), they may obtain it from the aquarium or other supply provided. Now, the fish may be placed in the water. Some of the fish will become quite active as a result of the transfer process. Counting cannot be accomplished under these circumstances so it is necessary to delay counting until the fish have adapted to their new environment. The temperature of the water should be taken and recorded.

As was noted in Lesson I, counts will probably be more accurate if they are done for fifteen second time intervals rather than one minute. Thus, four counts of fifteen second duration each should be taken and recorded by each pair of students. The fifteen second counts may be added to give a one minute reading which can be referred to as counts per minute or C.P.M. Another temperature reading should be taken and recorded. Set aside fish and containers for use in Part 2.

When the class has finished, ask if there was any consistency among the four counts each pair obtained? What factors are apt to influence the degree of consistency? Was the water temperature the same before and after? If not, how will they deal with a difference?

In Part 2 the students will obtain additional data on the minnows at lowered water temperatures. Perhaps some ideas for what might be done to cause a change in the C.P.M. could be first elicited from the children.

Part 2. Determination of Breathing Rates at Lowered Temperatures

Materials

Containers with water and minnows used in Part 1, Lesson II
Iced water (about 3 - 4 gallons for class of 30)
Measuring cups

Procedure

The ice water may be placed around the room in several containers so that crowding is avoided. A discussion of standards might precede the activity, but perhaps you will not find it necessary to repeat it here. Each pair of students will be adding to the room temperature water two additional standard quantities of water. The mixture should result in a lowered water temperature of about ten to twelve degrees centigrade.

Fish are apt to suffer some shock as a result of the temperature change but if the cold water is added slowly, the shock to the fish will be reduced considerably. Again, it will be necessary to allow the fish to adjust before proceeding with the counts. Repeat the counting procedure as in Part 1, Lesson II recording temperatures and C.P.M.

Unless a large block of time can be planned for the completion of this entire lesson, the children should replace the fish in the aquarium when the water has warmed to the temperature of the aquarium. If the warming takes place too slowly, the fish could be placed in a plastic bag which can then be put into the aquarium. This procedure will hasten the warming. Put a thermometer in the bag so that you will know when the point of equilibrium is reached.

If the lesson can be completed in one day, the containers with fish can be set aside for the time being while the water warms to a temperature intermediate between the first two.

Part 3. Graphing the Data

Materials

Data from Parts 1 and 2, Lesson II
Graph paper marked with quarter inch or larger squares

Procedure

In this part of the lesson, the children will begin to organize the data collected in Parts 1 and 2. Your approach to this problem will depend upon the experiences your students have had with data organization and graph construction. Thus, the techniques recommended may be modified or omitted as you see fit.

The immediate problem will be to organize the data in some fashion so that the entire class may view one anothers results. Permit the children to suggest how this can be accomplished by asking them to consider some ways of collecting the data so that it can be discussed by everyone. Should one or several students suggest a chart, have him put his ideas on the chalkboard. Perhaps they will produce a chart somewhat similar to the following sample.

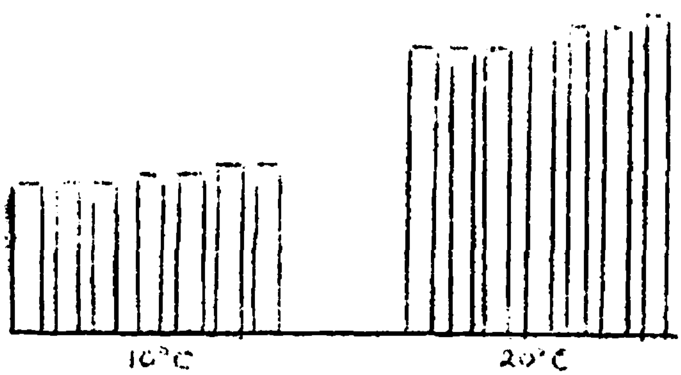
Av. temp	Group 1	2	3	4	5	6	7	8	9	10
10										
20										

The important thing is to make certain that all data appearing on the chart is related to the proper temperature. Supposing no one suggests a chart, then perhaps one person from each group could go to the board, record his data and temperatures in any fashion and then, through questioning be led to see that more organization is necessary in order to discuss the results intelligently. Perhaps at this point some idea of a chart will be forthcoming.

While a chart represents the first step in the organization of the data, depicting some interrelationships between variables, there are yet better ways to do this. Can the children think of any of these ways? Should someone suggest the construction of a graph from the charted data, perhaps others will suggest how the graph can be made. Will the data have to be averaged? If so, should all the data be averaged for one temperature or are there ways to show each group average on a graph?

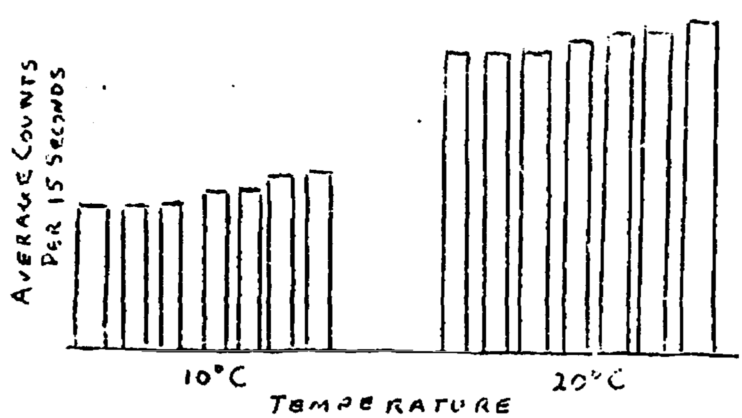
In the event no one suggests a graph or has any notions of how to construct one, you may wish to use some of the following techniques in guiding them through its construction. Perhaps it would be best to begin by asking them why certain observations are often put into graph form. You will want them to see that a graph communicates a great deal of information efficiently. Most all of them have seen graphs and have had to read them also. They probably know that there are many different types of graphs— pie graphs, bar graphs, line graphs — but they may not know that under certain circumstances one type is preferable to another. One type, a line graph, can be constructed from a bar graph and it is often easier for children to begin graphing this way.

A bar graph can be constructed from the data chart quite easily. Supposing that each gill beat or mouth movement equaled 1/2 inch on a strip of paper. If the beat averaged 13 for $10^{o}C$, then a strip of paper 6-1/2 inches long would represent that datum. The children could then cut strips of paper to represent their respective groups' data for each temperature. These could be mounted on the board in order of increasing temperature, as follows:



Note that all bars touch a common base line. This is a "rule" the children should know.

The students know what the strips mean, but without some labels, no one else would understand what they have done. Where can labels be placed to make the meaning clearer to an "outsider?" Each strip could be labeled but that might be confusing; however if labels are placed along the left side and across the bottom, the meaning could be greatly improved. Since the length of the strip is determined by the average gill or mouth beat for fifteen seconds what kind of label would be used to express that idea and where should it be placed? Each strip also represents a temperature. Where might it be appropriate to place a label indicating temperature? The following might be an example of an improved graph.

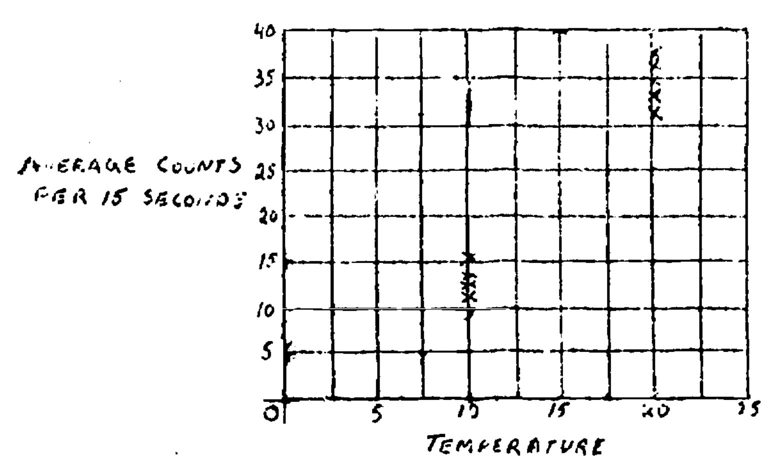


The above graph is not completely satisfactory for class purposes since adding more data to it, for example, counts made at temperatures intermediate between the existing two sets would necessitate moving some of the bars. Some means of simplifying the graph might be explored with the children now.

Substituting numbers and points for strips would be one way to initially simplify the graph. It is possible to replace the strips with two sets of numbers and still retain all of these data. In order to do this, data collected by the children could first be transferred to graph paper as a bar graph. Perhaps each square on the grid could represent one beat. The result would be a reporduction of the paper strip graph, but on a much smaller scale. Also each child would have his own graph.

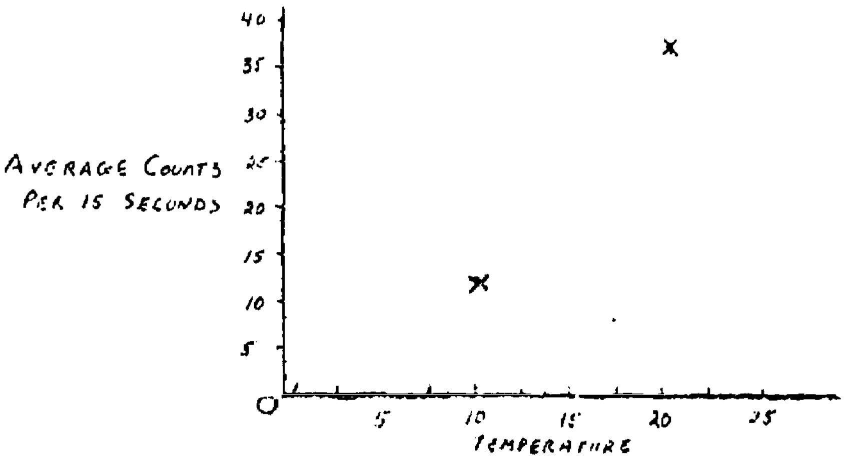
Now ask the children if there would be a way to improve the grid graph so that they might tell more easily what each bar means. The idea of placing a vertical number line at the left side of the graph should emerge from the discussion. Once the vertical number line is established are the bars necessary? What could be done to replace the bars and retain the information? Perhaps the use of points will be suggested. If each count can be represented by a point, is there a way to represent the temperature more easily also? Obtaining an average temperature for each investigated would be the simplest way of dealing with this information. Once the two averages are found, how are these to be shown on the graph? Might another number line be created across the base of the graph to show temperature?

The results of this discussion could be a graph similar to the one drawn below.



If two or more pairs of children obtained exactly the same data from a given temperature, those points will fall on top of one another. Further simplification can be accomplished by averaging the counts for each temperature, however it might be instructive to first discuss some reasons for differences in each set of data.

The final product might appear similar to the graph below where average counts and temperatures have been computed and plotted.



What kind of line can be drawn to connect these points? Straight, curved? What does that line mean in very general terms. Can numbers be associated with its meaning even though they do not appear on the graph?

Now the graph is a model of sorts — a representation of the interrelationship between breathing rate and temperature for the particular fish used, thus it can be said that as the temperature of the water changes, so does the breathing rate of the fish. What is the direction of this change? Does the rate increase or decrease as the temperature is lowered? These observations can be elicited from the children after the graph has been constructed. As a model the graph reveals somewhat more than the fact that a change has occurred in the fish-water system. But in order to be certain of the direction of change, more data must be gathered. Additional data will help to refine the model.

Part 4. Determination of Breathing Rates At an Intermediate Temperature

Materials

Minnows and containers from Part 2, Lesson II (or, a new supply
 of cool water — one part aquarium water to one part iced water — and minnows)
Dip nets, if necessary
Containers
Graphs from Part 3, Lesson II

Procedure

If the students begin this part with a "new" supply of water, have them record the temperature of the water before the minnows are placed in it and predict and record what C.P.M. might be obtained if a minnow was subsequently placed in the water. Their predictions can be verified by testing another minnow. Record the C.P.M. and transfer these new data to their graphs.

How do their predictions compare with the data obtained? What are some of the reasons for error in their predictions? Can the accuracy of predictions be improved with the addition of more data? Discuss these questions before going on to the next lesson.

They are now at the point at which you will want them to be able to read and interpret the graph with some competency. The success of the next lesson will be dependent upon the degree to which they have developed those skills in this lesson.

Lesson III

Verification: REFINING THE MODEL

Introduction to the Activities

Review the events of the preceding lesson and discuss in somewhat more detail, if you wish, the idea that the graph is a model of the fish-water system and that now you wish to verify the usefulness of this model by doing some related activities with the system. When a model is verified it is tested for its applicability. Thus, can the model be used in such a way that it represents reality? Most children have seen models of the solar system or globes of the world. Neither are the real thing, but both are attempts at representation of reality and, as such, can be useful devices.

Our model will prove useful if the students are able to predict with increasing accuracy the results of additional trials, This is then the point of Lesson III.

Materials

Minnows
Dip nets
Thermometers
Warm water, approximately 25°C. (2 gallons)
Cooled water, approximately 16°C. (2 gallons)
Containers

Procedure

At the beginning of class, prepare two sets of containers to be used during the period. Each member of the first set will contain about ten ounces of the warm water and one fish. Prepare seven or eight of these. Each jar in the second set will contain only the cooled water.

Divide the pairs of students into two groups. One group will receive a fish in the containers of warm water. Do not tell them the temperature. The other group will receive the containers of cool water,

Ask the first group to take a gill or mouth rate count as done before and predict the water temperature after obtaining the rate. At the same time, the other group can take the water temperature of their samples and predict a respiration rate if fish were to be placed in the water. What are the results of their predictions? On what were they based? How can their predictions be verified?

Verification can be accomplished through supplying the missing components of their systems, i.e. a thermometer and a fish. After verification you may want them to plot the new data on their graphs prior to a discussion of the entire curve. Some questions for discussion follow:

(1) What is the shape of the line; is it straight or curved?

(2) Using only the graph can the students predict what temperature a C.P.M. of 20 would indicate? What C.P.M. might be obtained at 4°C.?

(3) How certain can the students be of predictions which exceed the C.P.M for which they have data?

(The kind of operation called for when predictions go beyond the range of known data is extrapolation. Extrapolation literally means outside the "poles." The "poles" in this case are the first two sets of data collected by the students in Parts 1 and 2 of Lesson II. Those data were obtained for two temperature extremes. Additional data was obtained for temperatures <u>within</u> those established limits in Part 3, Lesson II. When predicting beyond the known limits of the data students must make inferences based upon what is known.

The accuracy of these inferences is often considerably less than the accuracy one obtains through the operation of interpolation — obtaining additional data within the range of known data. Accuracy is also dependent upon the interrelationships between the variables. If it is a straight line, both operations produce accurate data. If the mathematical interrelationship is not a straight line but in reality produces a curved line then extrapolation is not advisable. The students may extrapolate to some extent with their data, but only with decreasing accuracy. It is not recommended that these terms be used with the children, however, it is possible to perform and discuss the nature of the operations without the terminology.)

The next lesson will consider some of the broader implications of the model as it applies to several fundamental problems in environmental science.

Lesson IV

Generalization: APPLYING THE MODEL TO ADDITIONAL PROBLEMS

Introduction to the Activitites

In the preceding two lessons students have devoted some time to an interpretation of the graph. They should understand that the graph is a model of a relationship between breathing rate and temperature change in minnows. This relationship can be expressed by the following generalization: As environmental temperature varies, a corresponding variation in breathing rates occurs. While this generalization is applicable to minnows, will it apply to all fish or are there exceptions? Can this generalization apply to animals other than fish? Further, is variation in breathing rate the only response an animal makes to temperature variation? Finally, what are the implications of the model relative to conservation wildlife management?

These and other questions will provide the focus for a discussion with the students which will lead them into some applications of their model.

If the children are able to apply their model to the "solution" of some rather basic problems in biology they will broaden its significance and begin to develop the power which comes about as a result of understanding. To be able to explain new phenomena in terms of what has been recently learned is a partial test of the degree to which what has been "learned" is also understood.

The text of the discussion section is primarily provided for your benefit. The questions posed can be asked of the children, however. Perhaps you will find it useful to reproduce the graphs for distribution to the entire class.

Materials

Graphs completed in Lesson II

Discussion

Work completed to this point in the investigation of relations between temperature and behavior of the minnow showed that there was a correlation between temperature and minnow breathing rate. Students have already formulated models of this relationship and graphs have been used to predict the results of experimentation. Now the student is ready to generalize and expand his model through induction to increase his understanding of heat and an environmental factor.

Include in the following pages are graphs which present data correlating temperature variation and the behavioral patterns of organisms exposed to these conditions. This information may be given to the student for examination and expansion of the concept may be effected through class discussion. Perhaps the student might wish to take the materials home and try to formulate his own model prior to the class activities.

Data shown in Figure 1 indicates that a relationship exists between the depth of a body of water and the temperature of varying levels. There may well be some students who are already aware of this fact and their experiences can be used to draw the class into a discussion of the possible reason for this phenomenon. Figure 2 also shows that this relationship is continuous throughout the year but subject to modification by the air temperature. One can therefore use these graphs to illustrate the influence of climate on aquatic habitats. Do you think that there is a significant mixing of the lake water occuring in Figure 1? Could the depth of a lake be a factor which influences the amount of mixing that occurs?

Figures 3 and 4 indicate that the response of some living things will correspond to variations in temperature. It can be noted that the depth at which fish are found will vary with temperature gradients and also with the seasons. Is this because the temperature of the water in winter may not be the same as the summer temperatures indicated in Figure 1? Are the tendencies shown in Figure 2 in agreement with your hypothesis? Are some fish represented on the graph affected to a greater degree than others?

Scientists have also demonstrated that there is a correlation between the environmental temperature and cricket song. Data presented in Figure 4 shows that the number of chirps (stridulations) per minute is dependent upon temperature. Now the generalization might be expanded to include other organisms in the animal kingdom. Could this data be used as an incentive for an outside reading assignment in search of the reason for this variation in chirp rate? Do you think that this information might aid the student in the expansion of his model into a more meaningful generalization about his environment? Are there other topics such as hibernation which could be discussed in relation to this unit?

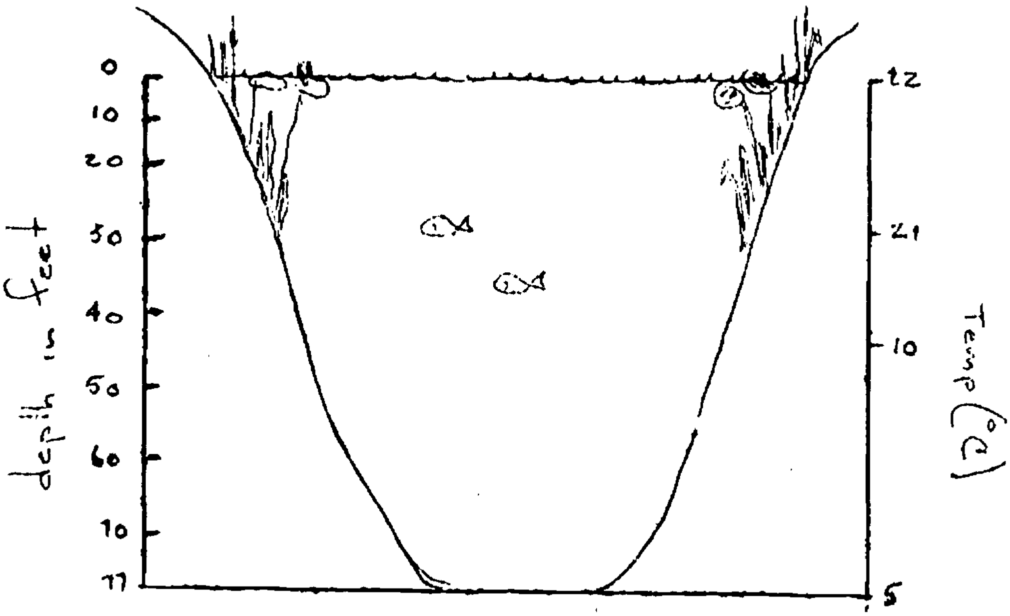


Figure 1. Relation between depth and water temperature in a deep water lake in summer.

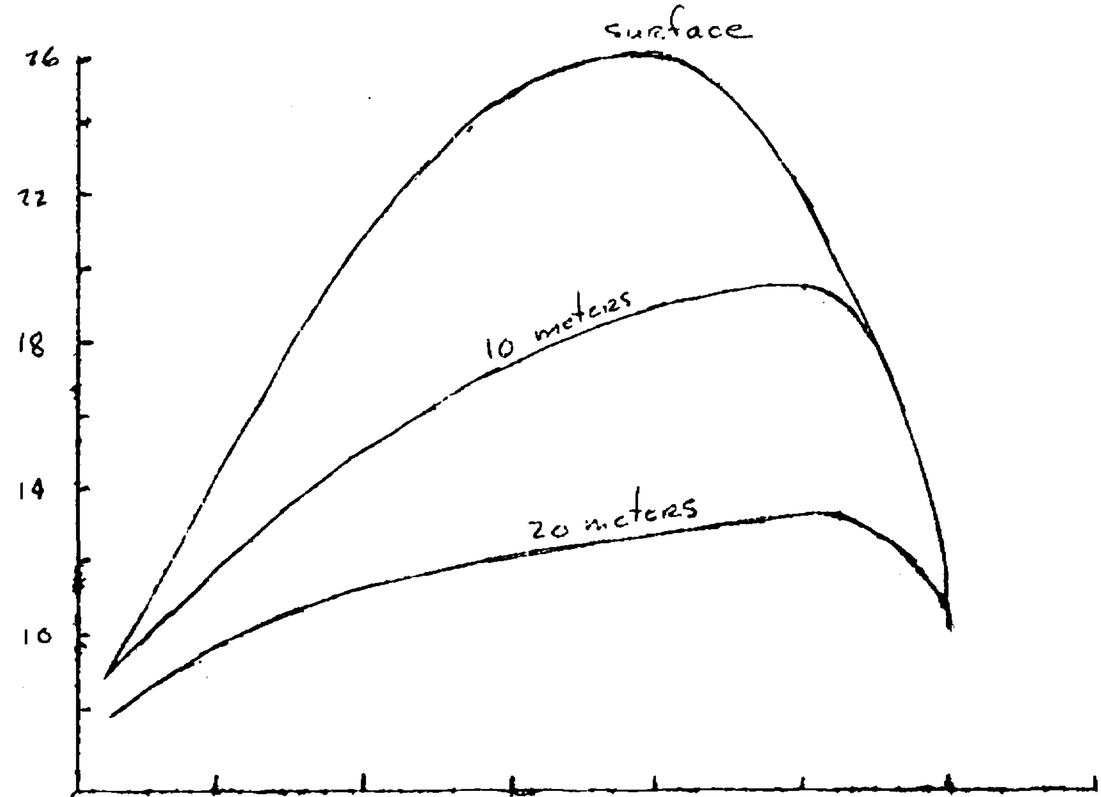


Figure 2. Seasonal change in water temperature at different depths recorded in a midwestern lake.

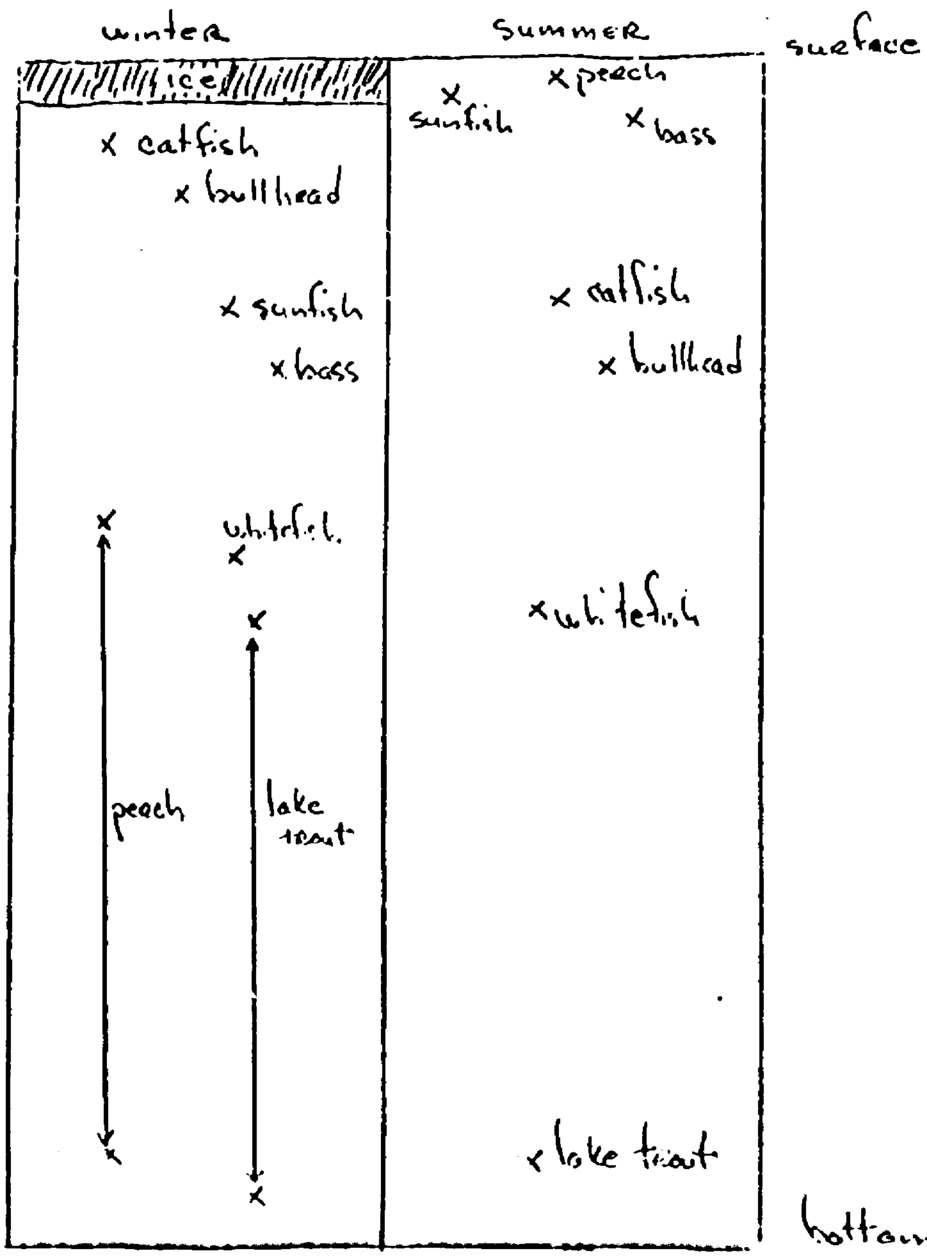


Figure 3. Comparison of the ranges of some fish as related to seasonal temperature changes.

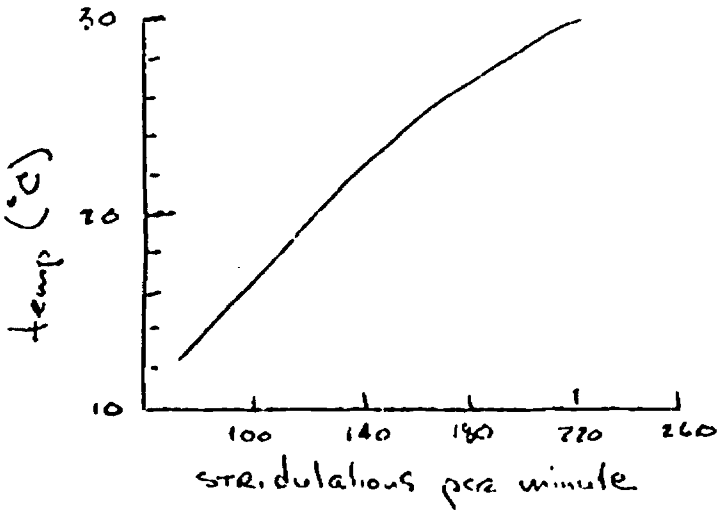


Figure 4. Relation of chirp rate of the tree cricket to temperature.

SUGGESTIONS FOR ADDITIONAL INVESTIGATIONS

These suggestions are offered as ways of increasing the flexibility of this unit. They might provide students with ideas for independent investigations or perhaps their use will also make the unit activities more appropriate for higher grade levels. Some may serve as transitional activities which could come between this unit and what you have planned to follow it.

Minnows and Models is one unit in a possible sequence of units investigating animal behavior in response to stimuli. Other units on behavior will emerge to complete a picture now partially sketched. Finally, a major concern will be the development of materials relating units in a behavior sequence to other areas of investigation in environmental science depicted in the schema accompanying this unit. Some of the following suggested activities could function as "idea-bridges" between the behavior factor and other factors appearing on the schema.

(1) Investigating the breathing "behavior" of other fish species.

Guppies, goldfish, or tropical fish may be subjected to the same set of experimental conditions as were the minnows. Data obtained may be compared with minnow data. Inferences about habitats, distribution, and behavior may be drawn through comparisons.

(2) Investigating other organisms whose respiratory responses vary with temperature change.

As mentioned, the respiratory behavior of frogs can be easily investigated by children. The floor of a frogs mouth moves up and down as it gulps either air or water. These movements may be counted as were gill and mouth movements in minnows. Frogs cannot be expected to behave as do fish, thus some very real problems in experimental design will arise to pose a considerable challenge to the students who might undertake such an investigation.

(3) Investigating respiratory responses among animals whose temperature does not vary with their environmental temperature.

One of the easiest organisms to work with would be the student. There is most always a changing temperature in the classroom over the day. As that temperature increases (it usually does) is there a corresponding change in student respiratory rate given approximately the same level of activity over a period of time. A confusion factor may enter here, and that is the relative invariance of body temperature. Respiration rates increase with activity, but body temperature does not. How can these factors be accounted for in the design of such an experiment?

(4) Investigating respiratory behavior in response to stimuli other than temperature variance.

How might the addition of small amounts of salt to the water affect the respiratory rate of the minnows? What might happen to the rate under crowded aquarium conditions? Will the rate vary as light intensity varies?

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BRINE

SHRIMP

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Introduction: TEACHING THE UNIT

"Brine Shrimp I and II are activity-centered units for grades one through five. Most of the experiences will be derived from the interests and motivations of the students rather than from directions set forth in the body of this unit. One activity will merge into another with various concurrent activities. Each child should be permitted to proceed at his own pace according to the degree of his involvement.

The progress a child makes should not be evaluated through comparison with others, but rather on the basis of his estimated interest and manifestation of inquiry behavior. To aid you in an assessment of these behaviors, a check list of questions to ask yourself about each child is included in the Appendix. (Use this with Unit I.) This list may be used at predetermined intervals throughout the teaching of the unit so that the students' progress is charted continuously. If you find it necessary to assign a grade, use the progress charts as one source of information about the child.

The unit is introduced by confronting the children with rather mysterious brown objects — the brine shrimp eggs. Questions will be generated at this point. These questions will lead to closer observation and to some further manipulation of the eggs. The eggs will be hatched, the shrimp raised to adulthood at which time egg production might occur. Once the cycle is completed, the children will have other questions to investigate. You may permit them to experiment as much as your schedule allows and as long as the activities hold their interest. The "content" of the unit will accumulate as children find answers to their own questions.

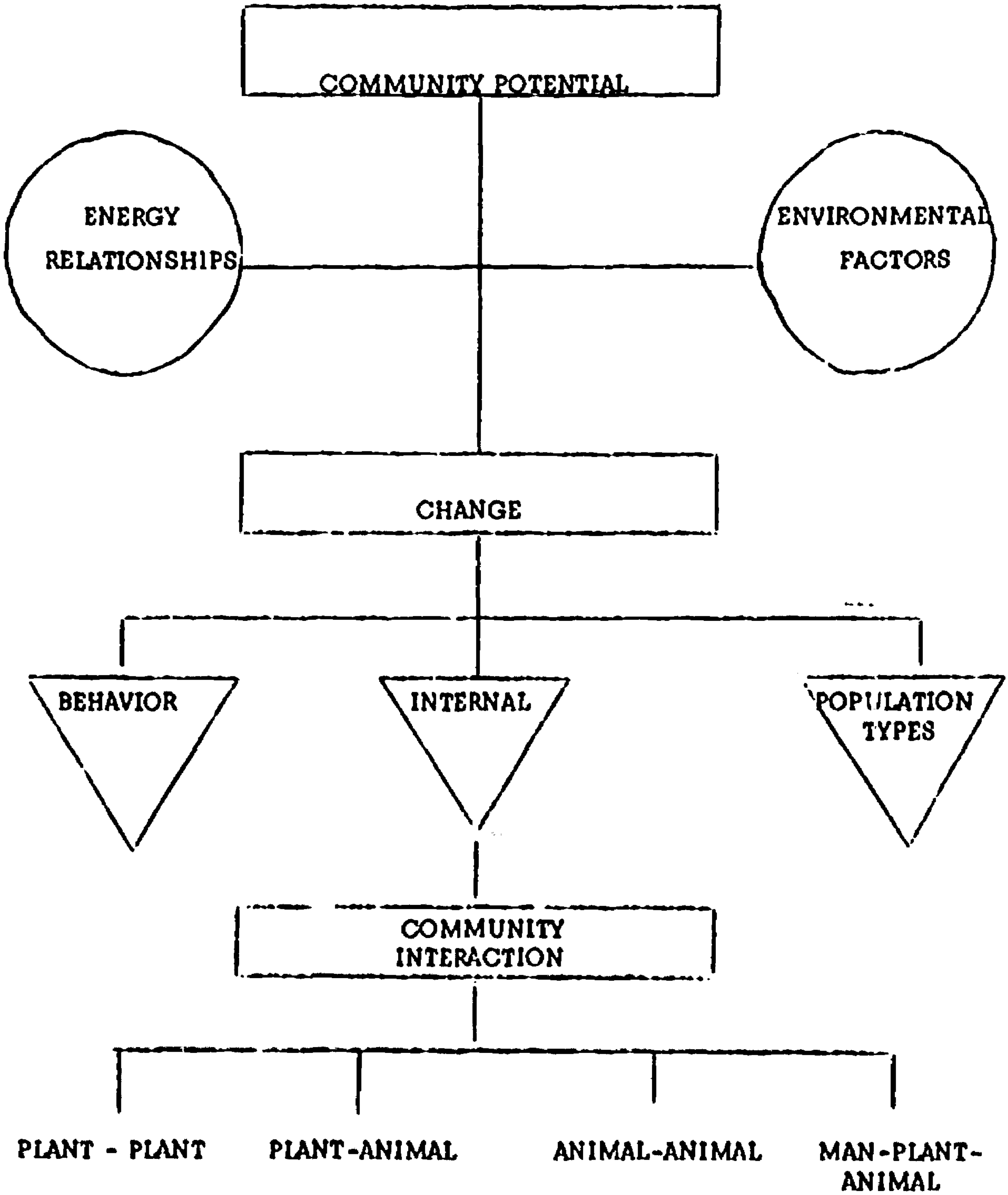
Unit II, additional activities with brine shrimp for grades three to five follows Unit I. Here the children will investigate some of the environmental variables affecting egg viability, population growth, and organism size. As in this unit for younger children, the emphasis is upon student-generated activities although the teacher must provide additional guidance as inquiry becomes more sophisticated.

In this unit you will have more success and sustained interest if you avoid answering all the questions asked of you. Of course, there are times when this is not feasible. For example, the children will want to know what these brown things are and also you will have to instruct them in the egg-watching procedure. Other inquiries are best handled by asking them to find out for themselves. The child who at first seems lost, unable to generate his own questions, is often stimulated by yours. Only you can determine when a child needs your guidance.

Some of the activities in the unit can be coordinated with other areas of the curriculum. Brine shrimp drawings could be done during an art class.

Reports of results could possibly be part of language arts. The children may wish you to read them stories about the shrimp or other marine animals. They may also want to tell you stories of what they have observed. Take every opportunity to practice those skills ordinarily developed in other areas of the curriculum as the children engage in these activities.

Brine Shrimp I is adapted from material written by Mary Lea Sherburne of the Model School Project, Elementary Science Study, Newton, Mass., 1967.


COMMUNITY POTENTIAL
ENERGY RELATIONSHIPS
ENVIRONMENTAL FACTORS
CHANGE
BEHAVIOR
INTERNAL
POPULATION TYPES
COMMUNITY INTERACTION
PLANT - PLANT
PLANT-ANIMAL
ANIMAL-ANIMAL
MAN-PLANT-ANIMAL

Contents

Materials List

Unit I

Item	Source	Quantity
Brine shrimp eggs	Biological supply house, pet store	1 vial or package
Non-iodized salt or crushed rock salt	High school laboratory or grocery store	6 cups
Babyfood jars with caps	Home	1 per child
Larger jars or gallon jugs	Home, school	2 or 3
1 cup measure	Home	4
Teaspoons and tablespoons	Home	Half dozen each
Hand lens (preferably made by Macalaster with higher magnification lens)	School, high school, Macalaster Scientific	Half dozen or more
Stereo-binocular microscopes	School	1 or more
Medicine droppers or soda straws	School, cafeteria	1 per child
Microprojector	High school	1 or more
Crayons	School, home	1 box per child
Paper	School	Sufficient supply for student booklets
Well slides (depression slides)	High school	Half dozen or more
Brewer's yeast	Grocery	2 packages
Light sources (microscope lamps, flashlights, or pen lights)	Home, school	Half dozen or more
Overhead projector	School	1 or more
Petri dishes or other low, flat transparent containers	High school, school	Half dozen or more
Grid paper, quarter inch square or smaller	School	Supply for class

Iodized salt	Grocery	1/2 cup
Non-iodized salt, rock salt crushed	Grocery	1/2 cup
Babyfood jars with caps	Home	2 or 3 per student
Light source (flashlight, microscope lamp)	Home, school	1/2 dozen
Test tube, corks	School, high school	1/2 dozen

Unit I

For Grades One and Two

Lesson I

Observation: BRINE SHRIMP EGGS

Introduction to the Activities

As was mentioned in the teacher's introduction, each activity will phase into another with children either singly or in groups pursuing various activities at once. This could pose very real problems in class control or in providing the necessary assistance especially since you must be aware of every activity. However, you will find behavior less a problem if the activities are of interest to the children. This is one reason for permitting the students to identify their own investigations.

Your teaching objectives in this first lesson will be concerned with providing the type of environment which will foster question-asking behavior. The tone set in this initial lesson will probably have much to do with the success of following activities.

The purpose of Lesson I is to introduce the children to the material they will be working with for the next several weeks. They will first observe the eggs. Many will try to guess what they might be. Guessing and observing could continue over a period of several days. As the children become acquainted with the material they will begin to identify problems for future investigation. Make note of their plans, and begin to use the check list for charting behavior.

Encourage the children to begin making record books. Pictures, drawings, short, written observation can be entered into these booklets. They will be able to take them home when completed and you might want to use them as a partial assessment of progress.

Materials

Brine shrimp eggs — one 1 oz. vial
Hand lens — 1/2 dozen or more (preferably Macalester with higher magnification lens)
Paper
Crayon — 1 set for each child
Stereo-binocular microscope (100x -- Bausch and Lomb), several if obtainable

Procedure

Begin the activity by sprinkling some of the eggs onto pieces of paper placed on each child's desk. This can be done without comment. Questions will arise immediately. You might caution the children not to exhale their breath upon them as they crouch down to get a closer look. The eggs are easily blown away.

After the eggs are distributed discuss any guesses made about what these things might be. There may be one or two who have fish tanks at home where the eggs are often used as food for tropical fish, however, few children will have seen them before.

Take note of their guesses, and then suggest they look more closely using hand lenses. How do their responses compare with their first guesses? Record these and then invite them to describe to you what they see. Here you might want them to suggest some of the physical characteristics of the eggs such as color, size, form, etc. Record these comments and then introduce them to the binocular microscope. (Prepare this set-up prior to class.) Each child should have the opportunity to see the eggs through the binocular.

During the next several days, encourage more observation. Perhaps they could begin their notebooks with a set of three drawings, one representing what is seen with the eyes alone, then through the hand lens, and finally the binocular. If a drawing of each "optical system" (including an eye) appears somewhere on the egg drawing, there will be little confusion about what each drawing represents.

At some point, someone may suggest that these "things" are eggs. You can only agree that they are. Since you cannot expect them to know they are brine shrimp, you might reveal this, but try to avoid describing their appearance. At this point you may move into the next phase of study.

An alternative to the above procedure might be for the children to try testing some of their guesses. For example, if one or several suggest the eggs are seeds, have them plant the "seeds" and observe the results.

Whichever direction is taken, let it be the one reflecting the child's mode of inquiry behavior rather than yours. The tendency might be to push them before they are ready.

Lesson II

Observation: HATCHING BRINE SHRIMP

Introduction to the Activities

A bit of mystery surrounding the identification of the round, brownish eggs may now have disappeared. However, enthusiasm will be regenerated at the prospect of hatching the eggs. Make certain you are familiar with the proper procedures. (Try it before the class becomes involved.) The procedure appears in the Appendix.

You will wish to encourage close observation on the part of the children. This is best accomplished if each child has his own eggs to observe. Should the children wish to compare their cultures, they will be able to do so if each has his own.

While you will provide the class with a general set of directions for successful hatching, permit them the freedom of making some mistakes. Possible sources of error can be discussed when comparisons are made. If they keep careful records of the procedure through drawings they will have a basis for comparing different results.

Materials

Brine shrimp eggs
Small babyfood jars with lids
6 cups of non-iodized salt or crushed rock salt
1 cup measure — 4
Teaspoon and tablespoon measures — half dozen each
30 medicine droppers (1 per child) or soda straws
Paper
Crayons and grease pencil
Microprojector — 1 or more
Well slide — half dozen
Hand lens — half dozen
Stereo-binocular — 1 or more

Procedure

When the time seems appropriate to begin hatching eggs, assemble the materials and display them before the class. Suggest these are the things needed for hatching. Perhaps as the materials are viewed by the class you may wish to discuss their use if questions arise. Inform them that each will be responsible for hatching their own eggs and tell them how you have done it. Demonstrate the procedure for them. Few of them will remember everything you say or do so plan to repeat the directions several times.

Supervise the procedure but limit your do's and don't's to a minimum. Each child may obtain his own jar from the materials on the table. If they possess the manipulative skills, allow them to obtain their own supply of water. Have them add the salt, put the cap on the jar, and shake it. What happens to the salt? Next they may place a "pinch" of eggs into the brine mixture. Finally, their names may be placed on the jars using the grease pencil.

At this point you might ask them when they think something will happen. Obtain time estimates and list these on the board with the corresponding name. Perhaps the child (or children) coming closest could be recognized with an extra cookie during milk and crackers the next day.

Make up several of your own cultures to insure a continuing supply. Encourage the children to draw pictures of the procedure as they make their own cultures.

When they are finished have them discuss what they think is going to happen. Suggest they imagine what the eggs will develop into and draw a picture of it for the entire class to compare and discuss. Perhaps each could tell a story about why they think the hatched eggs will look like their drawings.

Observations of the eggs can be made at intervals during the next two days. Some of the children may wish to view several eggs with the binocular microprojector or hand lens. The use of the first two pieces of equipment will involve removing the eggs from the babyfood jars and placing them on well slides. Using either a medicine dropper or soda straw have them place about one drop of water containing eggs into the depression on the well slides. Place these on the equipment they wish to use. Demonstrate how to use the soda straw as a pipette by inserting it to the desired depth (about 1/4 inch) in the water then placing a finger on the opening. Straws may be cut in half or quartered to accommodate small fingers

When the first egg hatches, try to determine how long it took in hours. Each should record this figure for their own set of eggs. You will probably need to assist them with this.

As more and more eggs hatch, the children will deluge you with questions. Handle them in a way whereby you do not provide direct answers but suggest they make their own observations; answers to many questions can be found by the children themselves. Does the appearance (look) of the shrimp surprise the children? Did any of their drawings remotely resemble the shrimp?

Lesson III

Observation: AFTER HATCHING
Investigation:

Introduction to the Activities

When all the children have successfully hatched some shrimp, your task will become one of handling their many questions, guiding investigations, and promoting further observation. Few children will exhibit a lack of curiosity. You can expect a wide range of questions from "Are they alive?" to "What do we feed them?" Permit the children to explore all possible answers to their questions within reason, and try to avoid imposing excessive structure on their investigations. To promote the desired degree of freedom, no formal procedure has been outlined. Instead, various possible categories of observations and investigations are listed and discussed. These discussions together with the background paper on brine shrimp should provide you with the information needed to guide the children through their activities. The lesson concludes with some topics or additional discussion.

In a classroom where so many diverse activities take place at once it is difficult to identify specific learning objectives. Most of the children will make some of the observations, acquire similar skills, and demonstrate comparable attitudes about their work. Use the check list as a guide in formulating your objectives. Add to it any other behavioral categories you feel are appropriate for your class.

Materials

- Brine shrimp, individual cultures
- Hand lens — 1/2 dozen or more
- Stereo-binocular microscopes
- Microprojector
- Medicine dropper
- Light source — optional
- Brewer's yeast — one package

Observations and Investigations

Physical Characteristics	These are easily observed through the hand lens or binocular. The shrimp have two eyes, various numbers of jointed appendages, depending on their age, and a jointed tail section.
Maintenance	The appendix suggests proper care and feeding. If the children wish to try food other than the yeast, permit them to do so but recommend tiny portions.
Behavior and response to the environment	Shrimp behavior, as with all organisms, depends upon both internal and external environmental conditions. Positive and negative reactions to light can be observed using the light source. Perhaps the children can determine if the shrimp also react to varying salt concentrations, each other, temperature changes, etc. One obvious aspect of behavior easily observed is their means of locomotion. They swim on their backs using their appendages as we would use oars. Do the children notice this?
Reproduction	Try to maintain a culture long enough for the shrimp to reproduce. A female's first set of offspring will be born as tiny shrimp. The next set will be eggs.
Life requirements	Some children may want to know if the eggs will hatch in non-salt water or other liquid. Allow them to experiment. Perhaps they might also inquire whether or not the shrimp will live in non-salt water. Transfer some to tap water and have the children observe the results. If someone asks, "Do they breathe?", transfer one shrimp to a small container and have the child observe one closely to see if he can detect anything he thinks is evidence of breathing. Try to get them to observe a single shrimp eating. How do they know it is eating?
Population factors	Some cultures will contain more shrimp than others. One reason would be the initial number of eggs placed in the water.

Other reasons for differences might be the salinity, overcrowding, etc. See if the children can count their own shrimp. If so, they may wish to transfer a known number of them to water containing different amounts of salt to see if salinity has any effect on the populations.

During the course of the activities encourage drawings, stories, and as much discussion of observations as possible. Ask them, when it seems appropriate, if they report what they have seen to their parents or to brothers or sisters. This might be one indication of interest level.

Topics for Additional Discussion and Investigation

The topics for discussion and investigation appearing below represent several levels of difficulty. Select for use only those you feel can be properly discussed and investigated by most of the students in your class.

Many of the children will wish to know where the shrimp live. Since they are collected from salt lakes, the location of these lakes can be indicated on a map. Here is an opportunity to involve the class in some geography. Try to get them to see that salt lakes exist in only certain parts of the country and there are relatively few of them. The distribution of lakes might be further related to other geographical circumstances.

Bring to class some unshelled edible shrimp. Discuss the similarity and differences of the two types. There is also a fresh water tiny shrimp called a fairy shrimp. These may be collected from ponds in the spring and compared with the brine shrimp.

If you have an aquarium with tropical fish, you might demonstrate something about food chains by feeding the shrimp to the tropicals. Wash them first by placing them in a very fine mesh net (nylon hose will work well) under tap water. Recall to the children that the shrimp eat tiny plants found in water. Finally, have them suggest possible predators of the small tropical fish.

Maintain several cultures over the year. A number of different things can be done, for example, hatching and raising several generations in complete darkness or continuous light. Retain some in the refrigerator to note the effects of cooling. Investigate egg viability by subjecting them to prolonged cold, elevated temperatures, etc. Place non-toxic food coloring in the water to discover some of the internal structure. When observing them after they have taken up the coloring, place them in colorless water.

Unit II

For Grades Three through Five

Introduction: TEACHING THE UNIT

Many commercial texts designed for grades three, four, or five contain one or several chapters covering a variety of important ecological concepts. Among these are the phenomena of adaptation, population variation, balance in nature, and the effects of the environment on organisms. Each of these topics is a significant area of study in the environmental sciences and, as such, is important for students to investigate. Unfortunately few texts suggest suitable investigations for intermediate grade children. In order for children to grasp any of the meanings of these concepts they must have had some actual experiences with the phenomena — they must confront data from which can be drawn the generalizations discussed in the various texts.

The unit, Brine Shrimp II, can be used to provide those experiences while classroom texts may be employed as important sources of reading material necessary to supplement the investigations presented here. It is recommended that this unit be taught before the class is referred to the textual material.

This unit for intermediate grades begins with a lesson on sampling and estimating techniques adapted from "Peas and Particles," and published by the Elementary Science Study. [1] The purpose of the lesson is to expose the children to some techniques for dealing with large numbers and their estimation. It is appropriate to teach these ideas because the children will be working with large numbers of eggs and will need to be able to devise ways of counting them as part of the quantification of their data.

Following the lesson on counting techniques, the class will observe and hatch eggs following the procedures outlined in Brine Shrimp I, Lessons I and II. The children will then move into Lesson II of Brine Shrimp II.[2] The recommended sequence of lessons is as follows:

1. Brine Shrimp Unit II
   Lesson I: A Technique for Counting Large Numbers of Objects
2. Brine Shrimp Unit I
   Lesson I: Brine Shrimp Eggs
   Lesson II: Hatching Brine Shrimp Eggs
3. Brine Shrimp Unit II
   Lesson II: The Effect of Environmental Variables on Brine Shrimp Eggs and Live Shrimp

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[1] "Peas and Particles," Elementary Science Study, Watertown, Mass., 1966

[2] Adapted from "Indoors and Outdoors," Science in Action Series, No. 12, Department of Public Instruction, Commonwealth of Pennsylvania, Harrisburg, 1964.

Lesson I

Measurement: A TECHNIQUE FOR COUNTING LARGE NUMBERS OF OBJECTS

Introduction to the Activities

This is a lesson on large numbers and estimations. Its purpose is to give children an understanding of what large numbers mean through informal activities. Once they have developed an understanding of the techniques, they will apply them to their work with brine shrimp eggs and the hatched organisms.

In most areas of formal instruction, such as arithmetic, there is a precise answer from which any departure is incorrect; here they will come to see the usefullness of rough estimations in many situations. Similar but more sophisticated techniques are used by scientists when population samplings are a part of their experiments. The government employs methods of estimation in taking its ten year census of the population. Perhaps the children will encounter this latter information in social studies. They will most certainly deal with some sampling methodologies in mathematics when they begin more advanced classes in high school.

The lesson begins with a game of guessing how many, then moves into developing techniques to refine guesses, and ends with applying the methods employed to the problem of brine shrimp eggs. Here the children will establish a class standard for an egg measure.

The entire lesson will probably take about a week to teach and requires gathering many materials prior to its teaching. Plan upon setting aside a rather large block of time — a month — for covering the entire unit.

Materials

4 bags of colorful hard candy
1 bag of large marshmallows
2 pounds of dry whole green peas
1/2 pound of dry breakfast cereal (puffed wheat)
1/2 pound of large elbow macaroni
2 pounds of rice
3 vials or packages of brine shrimp
7-8 quart jars (mayonnaise or mason jars)
At <u>least</u> 50 half pint milk cartons, tops cut off
At <u>least</u> 50 flat bottom 4 ounce paper drinking cups
At <u>least</u> 50 each, souffle' or medicine cups in various sizes
Picture cut from a magazine showing 8 to 10 objects which are all the same (animals, automobiles, etc.)
Construction paper, dark color, one per student

Procedure

Part I. Estimating Handfuls

Fill the quart jars with the marshmallows, peas, cereal, macaroni, and rice. (You may wish to fill additional jars with other interesting objects.) During the week before you introduce the unit, place the jars around the room for the students to examine. They will begin to make estimates among themselves about the numbers of objects in each jar. Should they question you, which they will surely do, try to be fairly vague about it all and build some suspense.

On the day you start the lesson, begin by giving them a quick look at the picture of objects you have cut from a magazine or other source. When the class has seen it, ask them to report to you how many objects they saw. Question them as to the certainty of their guesses. Next, select a small number of objects — the candy — and ask the class how many they think are in your hand. Gather the class in a circle so each can see and throw your objects onto a piece of dark construction paper, asking again for a quick glance and an estimate. After an instant, cover the objects and ask for estimates.

Have each child write down his estimate. When they have done this, appoint someone from the class to count the objects. Who came the closest? Did more underestimate than overestimate? Did anyone get the number exactly right? Repeat this procedure several times, gradually increasing the number of objects in your hand until you throw out a handful. Continue to ask them to guess the number and after each throw, count to see who was closest.

Now divide the class into groups of three or four; distribute several handfuls of the candy to each group. Have them repeat what you were doing, taking turns guessing and counting. Make certain they start with small numbers and work up to larger ones. Circulate about the room to see that they understand the game.

After about one half hour of this, bring the groups together and discuss the game. Did they find that the longer they played, the more accurate their guesses were? What were their sources of error? Could they estimate even larger numbers, for example children in the school? If so, how would they do it? Send someone to the office to get the correct number.

Discuss other estimations, for example, books in the library, cars in the parking lot, light bulbs in the entire school. Have them approach each estimate with a means for finding out the answer.

Part 2. Estimating Objects in Jars

The next several periods will be occupied with estimates and counts of the objects in the jars. Before they begin, have each of them prepare a worksheet similar to the following:

Worksheet

What's in the jar?	Number Guessed	Number Counted
1		
2		
3		
4		
5		

Next, permit them to wander around the room, examining the jars, naming the objects they contain and making estimates of the number of objects in each. Names and numbers should be recorded on the worksheets. When each child has completed that much of his worksheet, ask if they can think of ways to verify their guesses. After they have discussed several ways, direct them to apply the methods to counting the objects. They should not be concerned with the accuracy of their counts, but should concentrate on finding as many methods for counting as possible.

Depending upon the number of available jars, the children should organize themselves as they wish. In the event someone should prefer to work alone, try to supply him with his own set of materials. As they count, move about the room asking questions and seeing that no one misunderstands the directions. Remind them to record their counts as they are made.

It is very important that the students develop their own method for counting. When it becomes necessary for them to count live brine shrimp, they must work out their own procedure. While none of the methods suggested here may be particularly appropriate for use with the brine shrimp, they will at least be familiar with the problem of large numbers and with some specific strategies for dealing with them. A discussion of some methods other children have used for dealing with large numbers of objects follows.

Methods

1. Counting one by one — With large numbers, the children will soon find this to be unsatisfactory and will no doubt go to another method.

2. Taking a sample — The sampling method uses an easily counted part of a group of objects to indicate how many are in the whole group. Provide as many different containers, such as the milk cartons, souffle cups, or bottle caps for those who wish to try this method. Let the children select their own units if they wish.

3. Counting by area

This method might be useful when counting shrimp eggs. It can be done using grid paper on which to spread the objects. Objects are counted in each cell of the grid; then cells are counted and multiplied by the number in each cell. Uniform distribution of objects is necessary. Larger objects may be laid out on grid paper with one object per cell. Length of paper (in objects) may be multiplied by width (in objects) for obtaining the area.

4. Halving

This method involves cutting a sample in half each time part of it is counted. It is also a good means of counting many tiny objects.

5. Weighing

A balance will be needed for this method. Elementary school pan balances are good as are baby scales or balances obtainable from the high school. One sample is counted and weighed. Successive samples are taken, each weighing the same as the first standard sample. The number counted in the first sample is then multiplied by the number of equal weight samples found to be in the jar.

6. Ratios

This method involves judging a volume difference between two different objects. For example, if two pieces of puffed wheat equal one pea in volume, then there would be twice as many pieces of cereal in one jar as peas in another.

Discussion

After completing the counts, bring the class together for discussion. Which jar contained the most? Which contained the least? How did they count? How did their guesses compare with their results? Compare the accuracy of various methods; which ones work best with which general size of objects?

The discussion can take many directions, but you will want to move them into Part 3 on estimating brine shrimp. Begin Part 3 when you feel you have discussed most of the significant aspects of this exercise and the importance of the techniques used.

Part 3. Estimating Brine Shrimp Eggs

The same methods may be used here as in Part 2. (Don't tell the class what these objects are.) The difference will be developing a class method for counting eggs. The method decided upon by the class will be the standard technique employed in Lesson II, Unit II. Perhaps they will all agree upon a standard volumetric method, for example, a bottle cap full. A word of caution, however, and this should be pointed out to the class, the eggs are so tiny that most of the measures they have used so far are probably much too large for their purposes. (A bottle cap is probably much too large.)

Once this problem is appreciated, have them devise a small standard measure which all the class may use. The measure may possibly be nothing in existence, thus it may have to be created by the class. New problems will be faced when they need to count live shrimp. Have them devise a counting procedure for this situation when it arises.

When they have developed a method that is workable for use with the eggs, you may proceed according to the recommended lesson sequence, suggesting at the appropriate time (after the eggs have hatched) that they consider methods for counting the live shrimp.

Lesson II

Experimentation: THE EFFECTS OF ENVIRONMENTAL VARIABLES ON BRINE SHRIMP EGGS AND LIVE SHRIMP

Introduction to the Activities

When the brine shrimp have hatched, you will have several alternatives from which to choose as the children begin this lesson. They are now ready to start their investigations of the shrimp's response to its environment. You may (1) permit them to devise their own experiments, (2) select several of those included in this lesson for the entire class to do, (3) have different groups select their own from those included here if they have no ideas, or, (4) choose a combination of the above approaches.

Should two or more groups do the same experiment, have them compare their results and discuss their findings with one another. If they do not obtain the same results, encourage them to seek reasons for the differences. Stress the record-keeping aspect of these activities so that accurate comparisons can be made.

When the class has completed its investigations, perhaps the students might compile a class notebook containing reports of their work, including descriptions of their experiments, results, and conclusions. The notebook would provide a rather valuable reference for the children if and when they should return to their textbooks for background reading. Relating their experiences with brine shrimp to textual material which emphasizes the concepts presented in the introduction to this unit should provide children with considerable breadth <u>and</u> depth in exposure to these concepts.

Part I. Hatching the Eggs in Various Liquids

Materials

Babyfood jars, 1 per student
Non-iodized salt, 2 tablespoons
Iodized salt, 2 tablespoons
Pre-boiled water, 4 quarts
Tap water
Four quart jars
Other containers and jars
Vinegar, 1 cup
Alcohol, 6 ounces
Salad oil, 1 cup
Other liquids

Procedure

Prepare or have pupils prepare the following liquids and solutions:

1. Unsalted tap water
2. Unsalted preboiled water
3. Tap water, properly salted with iodized salt
4. Preboiled water, properly salted with iodized salt
5. Tap water, properly salted with non-iodized salt
6. Preboiled water, properly salted with non-iodized salt
7. Tap water that has as much iodized salt in it as it will dissolve — saturated
8. Preboiled water, saturated with iodized salt
9. Tap water, saturated as 7, but with non-iodized salt
10. Preboiled water, saturated with non-iodized salt
11. Vinegar
12. Alcohol
13. Salad oil
14. Other combinations of liquids and solutions

Assign each team of pupils a solution in which to try to hatch eggs. Place approximately the same amount of eggs in each solution. To do this, you must establish a consistent measure. All pupils should use the same measure, scraping excess eggs from the measure with a card to get a flat measure.

Place the containers in approximately the same location to keep external conditions as nearly the same as possible. Have pupils make guesses as to which liquids will hatch the eggs the best. Stimulate such guessing by questions like, "Do you think the eggs will hatch in all containers?" Have pupils record their guesses. This is a good place to discuss the value of hypothesizing — making intelligent guesses — in science.

Label each container and observe every few hours for live brine shrimp. Have pupils keep accurate records. After two days, compare the number of live brine shrimp in each container. Discuss ways of counting the live shrimp so that accurate comparisons are made.

Discuss the results with the children. Were there solutions or liquids in which no eggs hatched? Were there some containers in which more eggs hatched than in others? Was there much difference between the tap water solutions and the preboiled water solutions? Did the amount of salt seem to make a difference? Did the iodized salt keep eggs from hatching? Can you make any general statements about the solutions in which brine shrimp eggs will hatch? Do not allow pupils to make statements that are not supported by the evidence. Repeat portions of the experiment that your pupils feel were not conclusive. This would be a good place to discuss the value of experimentation where results are not definite and no general statement can be made.

Have pupils compare results of the experiment with the guesses or hypotheses they made earlier. Discuss how scientists must sometimes give up "pet" ideas when the results of their experiments do not support them.

Continue to observe for two weeks. Are there any live shrimp in solutions where there were none before? If so, what does this indicate about the time it takes brine shrimp eggs to hatch? Did any statements made by the class have to be revised?

Part 2. Hatching Eggs in Differently Salted Solutions

Materials

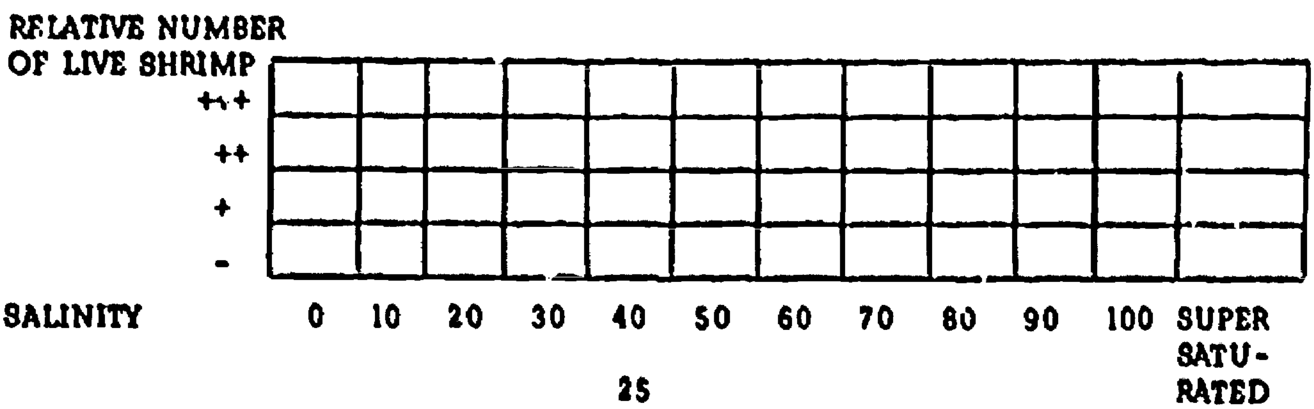
For each team of two pupils:

Babyfood jars
Preboiled water
Non-iodized salt
Measured amounts of brine shrimp eggs
Salt measure

Procedure

This experience is an extension of the last one. Place the same amount of preboiled water in each container. Direct each team to dissolve a certain amount of salt in the water in its container. Each container will have a different salt solution. The range of salinity in the classroom should be from unsalted to saturated. (A saturated solution is one in which the sale no longer dissolves but precipitates out of solution.) If your containers are small, you may use the egg measuring device for measuring the salt. Place the same amount of eggs in the container. Place container in approximately similar places and have pupil teams keep records similar to those used before.

After two days, compare the number of live shrimp in each container. This time arrange the containers in order of salinity. You may simplify the record keeping by establishing a scale and symbols for estimating the number of live shrimp. A minus sign (-) stands for no live shrimp; one plus sign (+) for very few (1-10); two plus signs (++) for many; and three plus signs (+++) for very many. Construct a bar graph using this scale, to record the results at the end of two days.



Discuss results with the children. Can you make any general statements as to how salinity affects the hatching of brine shrimp eggs? Continue to observe and record for two weeks. Groph results after one week and again after two weeks. Graphs may be simple histograms. Discuss results. Were there containers in which no eggs hatched? Were there containers in which few eggs hatched? How did the salinity affect the time it took the eggs to hatch? Were there any statements made after two days that had to be revised after a longer period of observation produced new data?

Part 3. Hatching Eggs Under Various Conditions

Materials

Babyfood jars, with caps
Hatching solution — preboiled water
Brine shrimp eggs
Measuring device
Medicine dropper
Black construction paper

Procedure

Do brine shrimp eggs need air, light, or warmth in order to hatch? For this activity the hatching solution should be kept in full sealed containers so that almost no air can re-enter the solution after it has been removed by boiling. Place the same amount of hatching solution in each of the six containers. Measure out and place the same amount of eggs in each container. Place one container in a warm light location. Place a second container next to it, but keep the air excluded by carefully covering the surface of the solution with a half-inch layer of salad oil. Place two more containers — one with and one without a cap — in the same location, but exclude light by covering with boxes of black construction paper. Place two similar containers in a refrigerator. Label appropriately:

Container 1: Warm, Light, Air
Container 2: Warm, Light, No Air
Container 3: Warm, Dark, Air
Container 4: Warm, Dark, No Air
Container 5: Cold, Dark, Air
Container 6: Cold, Dark, No Air

Observe for two weeks. Which container or containers seemed best for hatching eggs? In which container did the eggs hatch first? Were there containers in which no eggs hatched? Compare the containers that were warm with those that were cold. Does temperature affect the hatching of eggs? Compare the containers that were in the light with those that were in darkness. Is light necessary for the hatching of eggs?

Compare those containers which were exposed to air with those from which the air was excluded. Do the eggs need air to hatch? In the last comparison, be sure to make a distinction between hatching and continuing to live. Eggs may hatch without air, but live shrimp soon die. With some classes it may be possible to discuss the fact that a cold, light combination of conditions was not included and how much conditions could be explored.

Part 4. The Effect of Light on Live Brine Shrimp

Materials

Flashlight
Test tube with a cork — any small long narrow transparent container will do
Black construction paper
Live brine shrimp

Procedure

Fill each test tube within one-half of the top with solution containing live brine shrimp. Cork tightly and place tube on its side, supporting it so it will not roll. Shine a flashlight on the tube at right angles so that its beam illuminates only one end of the tube. Leave the light on for several minutes and observe the behavior of the shrimp. Now move the flashlight so that it illuminates the other end of the tube. Observe.

Make a black construction paper sleeve to cover one end of the test tube. Cover one-half of the tube and leave the other half in daylight. Carefully remove the sleeve after one-half hour and compare the number of shrimp in each half. Discuss results with the children.

Part 5. Conditions Needed for Brine Shrimp to Grow

Materials

For each team of two pupils:

Two babyfood jars with caps
Live brine shrimp
One-half of a paper straw or a medicine dropper

For the class:

Black construction paper
Hatching solution that has been kept in full-sealed jars

Procedure

This activity is an extension of Part 3. The same six conditions are set up, but with live shrimp instead of eggs.

Assign each team to compare just one condition — 2, 3, 4, 5 or 6 — with condition 1. Each team places some live brine shrimp in an open container that is kept in a light, warm place. This container used a control group instead of shrimp. Discuss what a control group is and why it is needed in a scientific experiment. The experimental group of shrimp are placed in the other container. Exclude light and air as you did in Part 3.

Keep records of observations over a two-week period. Discuss the results with the children. Graph results where possible. How long did the shrimp survive without air? Did darkness affect the shrimp in two weeks? How long did the refrigerated shrimp survive?

This experiment should establish some of the conditions necessary for brine shrimp to grow. This would be a good time to discuss conditions under which various organisms prosper. Discuss the need of all living things for air and food.

Set up a "shrimparium." Any large jar will do. If possible, aerate the solution with an aquarium aerator. Try to raise shrimp until they produce a new batch. How large do brine shrimp get?

Part 6. Effect of Various Liquids on Live Brine Shrimp

Materials

Several similar containers of brine shrimp
Medicine droppers
Alcohol
Vinegar
Aspirin dissolved in a small amount of water
Clorox
Carbonated beverage — 7 Up
Other clear liquids

Procedure

Place one drop of alcohol into the containers of shrimp. Observe for a few minutes. Repeat with other liquids in other containers. Keep adding liquids, one drop at a time. Which liquids affected the brine shrimp most quickly? Did all liquids finally kill the shrimp?

Part 7. Examining Dead Brine Shrimp

Materials

Microprojector or microscope
Microscope slide — preferably one with a depression
Live brine shrimp
Medicine dropper
Vinegar

Procedure

Place a drop containing live brine shrimp on the slide and add a drop of vinegar. After several minutes, place the slide under magnification and observe dead brine shrimp. What body parts can you identify? Notice the black spot on the head. Observe the orange portion of the body. Observe the antennae and the two large "legs. Have pupils draw pictures of a brine shrimp.

How are the brine shrimp adapted for their environment? Where would you expect to find brine shrimp in nature?

APPENDIX

Hatching, Feeding, and Caring for Brine Shrimp

In order to hatch the shrimp, a general "recipe" to follow would be to use eight teaspoons of non-iodized salt per one quart of water. For larger or smaller quantitie of the "hatching solution" use one teaspoon of salt per every two ounces of water. It would probably be a good idea to age or pre-boil the water to remove chlorine. Non-iodized salt may be found in most groceries, however, if it is not available, rock salt used for melting ice in the winter is recommended.

After the salt and water are mixed, preferably in a large flat (2" depth) container for aeration, sprinkle the eggs onto the surface of the water. Depending on the temperature of the room, the eggs will hatch in 24 to 48 hours. The higher the temperature, the more rapid the hatching. Some sources recommend temperature around 80 degrees for the most rapid hatching. Stir the eggs from time to time to ensure proper aeration.

The eggs will hatch into a Nauplius stage of development -- a form many crustaceans take before developing, through successive molts, into an adult form. If you have success in getting the shrimp to reproduce, the first set of new organisms will be born alive, the second set will be produced as eggs. These will need to be dried before they can be induced to hatch.

After the shrimp hatch, they will live for some time before they require food, but this does not mean they need not be fed at all. The most easily obtainable food is brewer's yeast. Small pinches of it may be fed once or twice a week. For best results in obtaining large adult shrimp, make certain the cultures are not crowded. Over-population of the culture results in decreased oxygen supply and accumulation of wastes producing small shrimp. Small (1/2 teaspoon) amounts of bicarbonate of soda maintains the alkalinity of the water counteracting the effects of accumulated carbon dioxide produced by the respiring organism.

Some Notes on Appraisal

A checklist of those behaviors considered to be characteristic of positive inquiry behavior has been developed to help you with the problem of appraisal. Score it in a way which seems appropriate for the grade and maturity level of your class. With very young children unable to easily express themselves, their classroom activity is of greater significance than their verbal response.

Checklists such as these require close observation of the children. Observation may become overly subjective especially in the light of your previous experiences with certain children. Avoid prior judgments; perhaps the materials and your own attitude will have some very positive effects on problem students.

Gather other forms of evidence before assigning grades. Student notebooks provide you with another source. Do not emphasize concept of content learning at this stage; most will be unable to express generalizations or repeat their knowledge. It must be assumed that many of the experiences the children will have will be retained however, retrieving by test any information gained through experience may not be too successful.

Checklist of Inquiry Behavior

Student Name	MAKES A CULTURE	OBSERVES CULTURE	DRAWS SPONTANEOUSLY	DRAWS AT YOUR REQUEST	RELATES OBSERVATIONS SPONTANEOUSLY	RESPONDS TO YOUR QUESTIONS	ASKS OWN QUESTIONS	DISCUSSES RESULTS WITH CLASSMATES	EVIDENCES ENTHUSIASM	SUGGESTS INVESTIGATIONS	HELPS OTHERS	REMAINS PRODUCTIVELY OCCUPIED	ACTIVITY PURPOSEFUL	CAN SOLVE OWN PROBLEMS

BACKGROUND INFORMATION

The brine shrimp (Artemia salina) is a member of the phylum Arthropoda and the class Crustacea. Arthropods share the common characteristic of jointed, movable appendages. Crustaceans possess a chitinous exoskeleton typified by the external coverings of crayfish and lobsters. With the exception of lobsters and the king crab, most crustaceans are small, not exceeding one-eighth to one-half inch in length. Fresh water relatives of brine shrimp are the fairy shrimp, (a "look-alike" organism found in most ponds), and Daphnia, which is also found in ponds and utilized as fish food.

Salt lakes, sinks, and ponds in the western portion of the United States are the primary sources of brine shrimp eggs. They are found less frequently in the ocean. Great Salt Lake in Utah is an especially rich source of shrimp eggs where, blown by the wind and consequent wave action, they accumulate on the lee side of the lake. There the eggs are gathered and packaged for pet supply stores and biological supply houses.

Adult females will produce young in your cultures when cultivated under optimum conditions. Their first batch will be born as tiny immature forms; the second will be produced as eggs. Examination of the eggs reveals them to be small, indented spherical structures which must be dried before they will hatch. Drying is a means of survival for these organisms. Their ability to withstand lengthy periods of drought ensures the preservation of the species. It has been estimated that some dried eggs may remain viable for periods of approximately ten years.

Upon soaking in a salt solution (brine) the eggs swell, burst, and a tiny pre-adult form of the shrimp called a Nauplius emerges. Increasing the salinity of the water shortly after the shrimp are hatched provides a more favorable environment and contributes to the rapid growth of the organisms. Successive molts produce a mature adult whose form and behavior is somewhat different from the Nauplius. With proper care and feeding, the adult may reach an overall length of one-half inch within six weeks after hatching if the temperature is kept at approximately 28 degrees C. (The organisms are killed by heat in excess of this amount.)

If you examine a mature brine shrimp with a stereo-binocular microscope, you will see that it characteristically swims on its back, exposing six to eight pairs of appendages. These structures function both as a means of locomotion and as gills for breathing. The number of appendages increases with the age of the shrimp.

Upon hatching, the young have been observed to gather where the most light is available. A shrimp has two compound eyes which are thought to perceive light, shadow, and movement but not images as do vertebrate eyes. The adults, however, respond negatively to light. It is interesting to speculate upon the survival value of various responses to light at different stages in the development of the organisms.

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