DOCUMENT RESUME

ED 040 862 SE 008 852

AUTHOR	Van Deventer, W. C.; Duyser, Lucille
TITLE	Idea-Centered Laboratory Science (I-CLS), Unit A, How a Scientist Studies His World.
INSTITUTION	Grand Rapids Public Schools, Mich.; Western Michigan Univ., Kalamazoo.
PUB DATE	69
NOTE	77p.
EDRS PRICE	EDRS Price MF-$0.50 HC-$3.95
DESCRIPTORS	*Curriculum, *Fused Curriculum, Instruction, *Instructional Materials, Interdisciplinary Approach, *Science Activities, *Secondary School Science, Teaching Guides

ABSTRACT

This document includes the introduction to and unit A of "Idea-Centered Laboratory Science" (I-CLS). The introduction describes the objectives, the basic assumptions and suggested teaching procedures of I-CLS. The basic theme of unit A is "How a Scientist Studies His World." Laboratory experiences consist of investigations into: (1) idea of observing, (2) idea of asking questions, (3) idea of hypothesis forming and testing, (4) idea of objectivity and tentativeness, and (5) idea of natural law. The 18 laboratory experiences in this unit, as in all I-CLS units, are inquiry related and designed primarily to develop an understanding of how a scientist expects his world to behave. The format for each laboratory experience is as follows: Introduction, Materials and Equipment, Collecting Data, and Follow-up. (BR)

IDEA-CENTERED LABORATORY SCIENCE

(I-CLS)

Wm C. Van Deventer

Professor of Biology (Science Education)
Western Michigan University
Kalamazoo, Michigan

Lucille Duyser

Middle School Science Consultant
Grand Rapids Public Schools
Grand Rapids, Michigan

1969

Idea-Centered Laboratory Science (I-CLS)*

Idea-Centered Laboratory Science (I-CLS) is designed as a structured three-year program, based on a scientist's approach to the natural world, and what he expects to find in it. Ideas which cut across two or more fields of science are taught by means of open-ended laboratory experiences. The objectives of the program are goals of understanding. The learning of facts and the acquisition of skills are looked upon as means to the end of understanding Ideas, rather than ends in themselves.

Laboratory experience is equated with problem-solving. The laboratory, therefore, is thought of as being not limited by four walls and as being only indirectly related to specific equipment and materials. Wherever problems are being attacked, there laboratory is, so long as the problems possess reality for the students who are trying to solve them. While illustrative experiences, and experiences designed for the development of skills, are recognized as legitimate, valuable, and often necessary, they do not contribute directly to the goals of the I-CLS program.

The laboratory experiences are inquiry-related. For purposes of this program, inquiry is defined as inquiring, asking questions, with the questions directed toward the Idea being taught. The teacher asks questions of the students, and students ask questions of the teacher. Valid questions are recognized as lying along a gradient which extends from those which are easily answered to those for which we have no answers as yet. Whether or not a question can be answered has no relationship to its relevancy. Only by asking (and permitting) questions at all levels can a teacher bring students to approach the frontier of the advance of science. Galileo described science as "asking nature simple questions one at a time, and writing down the answers."

The proposed evaluation of student achievement under the program is an extension of the inquiry process. It is based on the hypothesis that the extent and quality of students' thinking in relation to an Idea can be determined more effectively through the questions that they ask than through the answers that they give to questions that are asked of them.

The following is an outline of the I-CLS program:

"First Level": A Scientist and His World

Unit A. How a scientist studies his world

1. Idea of observing
2. Idea of asking questions
3. Idea of hypothesis forming and testing

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*Idea-Centered Laboratory Science (I-CLS) is a continuation, revision and expansion of the Michigan Science Curriculum Committee Junior High School Project (MSCC-JHSP).

4. Idea of objectivity and tentativeness

5. Idea of natural law

Unit B. How a scientist behaves toward his world

1. Idea of categorizing (classifying)

2. Idea of quantifying

3. Idea of model making

4. Idea of developing terminology

Unit C. How a scientist expects his world to behave

1. Idea of consistency and uniformity

2. Idea of cause and effect

3. Idea of parsimony

"Second Level": The Kind of World a Scientist Thinks He Has Found

Unit D. A scientist assumes the existence of variation and change

1. Idea of normal curves: a way of picturing variation

2. Idea of gradients: directional variation

3. Idea of extrapolation and interpolation: predicting from a gradient

4. Idea of directional change: a gradient in relation to time

5. Idea of cyclic change: sequences that repeat themselves

6. Idea of dynamic equilibrium: interacting changes that result in balance

Unit E. A scientist thinks in terms of relationships rather than absolutes

1. Idea that measurements express relationships

2. Idea that patterns govern relationships

3. Idea that frames of reference determine relationships

4. Idea that interdependence consists of relationships

5. Idea that heredity and environment are necessarily related

6. Idea that rates and changes are necessarily related

7. Idea that man and his tools are necessarily related

"Third Level": A Scientist Finds That His World Has Limits

Unit F. Science is Limited by How We Feel About the World

1. Idea that we can look at our world two ways

2. Idea of complementarity

Unit G. Science is Limited by What We Believe About the World

1. Idea of continuous discovery

2. Idea of social limitation

Basic Assumptions of the I-CLS Program

1. That children of junior high or middle school age can and should begin to make contact with some of the major Ideas of science.

2. That they can do this successfully (a) if the Ideas are presented to them in language that they can understand, and (b) if the Ideas are tied to experiences which are meaningful to them.

3. That the most effective approach to these Ideas is through open-ended laboratory experiences directed toward them.

4. That in carrying on these laboratory experiences students must not be "over-directed," and must be accorded the "right to be wrong."

5. That each Idea being taught must be discussed with the students before, kept before them during, and, by way of summary, reiterated for them following the laboratory experiences. Any Idea to be specifically learned, must be specifically taught.

6. That in evaluating the extent and quality of students' thinking in regard to an Idea, the questions that they ask give a better indication than the answers that they give to questions asked of them.

Suggested Procedure for Teachers Using the I-CLS Program

1. You will have best results, at least to start, if you approach the material and teach it one Idea at a time. Finish one Idea, then go to another, and then another. At a convenient and desirable later point, you may wish to tie several Ideas together.

2. Make sure that you yourself understand the Idea, as it is expressed in the Idea-Bridge. This is the writers' statement of the Idea, as it is used in the materials, and tells what the writers mean by it.

3. Communicate the Idea to your students. Let them read the Idea-Bridge for themselves, but if you feel that it is not stated in language that they can understand, "translate" it for them. This translation job is your responsibility. Furthermore, in doing this, you will become better acquainted with the Idea yourself. Remember that students with different levels of ability may require different "translations." The Idea can be translated, however, in some intellectually honest form for students at any ability level.

4. Spend up to a whole period discussing the Idea with the students. Help them relate it to their own past experiences. Give them an opportunity to ask questions freely concerning the Idea, and do not worry as to whether or not the questions are answerable. Don't be afraid to say, "I don't know."

5. Write the Idea on the chalkboard in abbreviated form. You will need to "boil down" the statement in the Idea-Bridge to do this. Leave it on the board, if possible, while you are working with the laboratory experiences directed toward the Idea. If you must remove it, write it on the board again frequently.

6. Work out the laboratory experiences which look toward the Idea. As you do so, direct the students' attention to the Idea by asking them leading, open-ended questions of your own devising related to it. These will supplement the questions included in the laboratory directions. As far as possible, the questions should be "why" or "how-why" questions, rather than simple "how" or "what" questions.

7. Let the laboratory experiences be as open-ended as possible. Allow the students to arrive at wrong answers sometimes, while seeking for right ones. Give them "the right to be wrong." It is always possible to correct a wrong answer, but it is very difficult to rectify a "cookbook" method.

8. Spend up to a whole period again with the students after the laboratory experiences are completed, going over the Idea with them by way of summary, and giving them a further opportunity to ask questions about it, this time with emphasis on the laboratory experiences directed toward it.

The way in which students' questions are used to evaluate their thinking includes the following steps:

1. After the final summary and review session with the class (Step 8 above), ask the students to write down as many questions as they can which are related to the Idea that has been studied. Be sure that a brief, clear statement of the Idea is on the chalkboard while they are doing this.

2. From the students' written questions, prepare two lists:

   a. Those questions that in your judgment apply to the Idea.

   b. Those questions that in your judgment do not apply to the Idea.

   c. Discard any questions that do not clearly belong in one list or the other.

3. Select 15-30 questions (the same number) from each list. Choose what you believe to be the "best" questions from each list. The questions should all be valid questions, but they do not need to be answerable.

4. Scramble the 30-60 questions that you have selected into a two-choice test. Ask the students to distinguish between the questions that do apply to the Idea, and those that do not apply. They do not need to answer the questions. Tell them that half of the questions do apply, and half do not apply. Place at the beginning of the test the brief statement of the Idea that you have used before, so that they can refer to it while they are marking the test.

Several methods have been tried experimentally for keying a test of this type. A teacher or group of teachers may simply set up a key on the basis of individual or collective judgment. The original classification of the questions used in preparation of the test may be followed as a key, or it may be modified on the basis of the judgment of other teachers.

Another method is to use an item analysis of collective student judgment after giving the test as a basis for making a key, modifying this as necessary on the basis of individual or collective teacher judgment. One teacher allows the students to discuss the test items, a few at a time, in small committees before marking the test, then follows with an item analysis of the collective judgment of the entire class, and finally makes modifications on the basis of teacher judgment. In general, it is probable that the broader the basis for judgment in making the key, the better the key.

Idea-Centered Laboratory Science (I-CLS)

Experimental Testing Program

Would you or other members of your staff be interested in trying out the I-CLS materials, following the Suggested Procedure, and participating in the experimental testing program?

I-CLS is prepared to enter into the following arrangement with those teachers who wish to take part in a cooperative program:

1. The cooperating teacher, after completing a series of laboratory experiences directed toward one of the Ideas, following the Suggested Procedure, will collect student questions, categorize them in two groups (those that do apply to the Idea and those that do not apply to to it), and mail both groups to the writers of the program.

2. The writers will process selected questions into a test of the type described in the Suggested Procedure, and will return the test to the teacher, along with a suggested key for grading.

3. The teacher may make any modifications in either the test or the key that he thinks necessary, prepare mimeograph stencils or ditto masters, and run off as many copies of the test as he needs.

4. After giving the test, the teacher will send to the writers of the program:

   a. Three copies of the test as he has given it, and the key which he has used with it.

   b. The raw test scores from the class(es) in which he used the test, and any analysis of these that he has made.

5. The writers of the program will send to the teacher any new materials that may be produced by the program, and the results obtained by any other schools using the program.

6. Send materials to:

Dr. W.C. Van Deventer
Professor of Biology (Science Education)
Western Michigan University
Kalamazoo, Michigan 49001

Criteria for Writing Laboratory Experiences

A. Ideally laboratory experiences should:

1. be open-ended. Students should not be able to find answers by reading only, although the information so found should be helpful, and may well suggest possible answers. More than one correct or acceptable answer may well be possible.

2. look toward a specific idea or understanding. This idea should be either clearly stated or readily apparent. Unless laboratory experiences can be so directed, they are probably a waste of time.

3. give as few directions as possible except for necessary procedural ones. As far as possible, the information necessary for the experience should be derived from the experience itself. Only in this way can the "research approach" be made real to the student.

4. mainly ask questions, including:

   a. some which can be answered readily from the experiences at hand, together with general knowledge.

   b. some which can be answered only after considerable investigation and thinking.

   c. some which cannot be answered with certainty by either student or teacher.

   d. some which cannot be answered at all, with our present state of knowledge.

Answers are generally less important than the process by which the student arrives at them. The student should be accorded the privilege of arriving at a wrong answer while seeking for a right one. Mistaken conclusions are more easily corrected than faulty methods, and when a student is told the right answer or is able to look it up in a textbook, this is not really laboratory at all.

B. To be effective, laboratory experiences must be:

1. within the capabilities of the teacher

2. within the capabilities of the students, and

3. within the limits of possible accomplishment, given the laboratory or field situation.

They should utilize as simple, easily obtainable and inexpensive equipment as possible. There is no virtue in the use of elaborate equipment as an end in itself. If a simple laboratory experience will lead to a significant idea as readily as a complex one, the simpler one should be used. All laboratory experiences should be tested for value against the ideas which they produce.

C. Laboratory procedure should always involve the recording and interpretation of data, which, so far as possible, should be based on weighing, measuring, counting, or other type of quantitative determination. Mathematical treatment, however, should be kept as simple as possible. Simple percentages and graphs often tell a more effective story than expressions of complex mathematical relationships. Mathematical treatment, like elaborate equipment, involves the possibility of becoming and end to be pursued for its own sake rather than a means to an end.

IDEA-CENTERED LABORATORY SCIENCE

(I-CLS)

Unit A. How a Scientist Studies His World

A scientist does not make up his mind easily. He observes and he asks questions. Galileo, one of the "fathers" of modern science in the seventeenth century, defined science as "asking nature simple questions, one at a time, and writing down the answers."

A scientist tries to find dependable explanations for things that he does not understand. In doing this he maintains certain attitudes and holds certain beliefs that shape his actions. He attempts to keep his opinions and prejudices out of consideration when he is trying to solve his problems. He believes that if he does this, he will be more likely to arrive a true understanding of the phenomena that he finds taking place in the world around him. He can then describe these phenomena more accurately.

If his descriptions stand the test of time and further study, he can use them as a basis for knowing what to expect from the world. This knowledge can help him to learn to avoid the world's dangers, make use of its resources, and live in it with understanding.

I-CLS

Unit A. How a Scientist Learns About His World

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Idea of Observing A.1.

Idea Bridge: Using Five Senses

If your teacher holds up a book, how do you know it is a book? Did you say it has reading in it? Well, my cereal boxes have reading on them. Why aren't they books? Did you mention the shape? Isn't a magazine nearly the same shape? Why isn't a magazine a book? What about the "hard covers"? Well, a box has a hard cover sometimes. Is it a book? Why or why not? If you had never seen a book, would you be able to recognize other books after you had seen one? How are all books alike? How do books differ?

If you turn on the water tap, how do you know if the water is hot enough for washing dishes or cold enough for drinking? Do you know one adult who likes coffee much hotter than another adult? Do you know someone who won't drink water without ice in it because they say it is too warm?

When you are served a piece of meat (or other good food) how do you know whether it needs more salt? How do you know it is meat?

Have you ever been told, "Turn down that radio; it is breaking my ear drums," when you were really enjoying the loud music?

What do all these experiences have in common? You are using some of the receptors of your nervous system. What other receptors do you have in addition to the ones you have used?

Using receptors is also called using your senses. There are five of them. They are all of great value in science. Some people talk about a "sixth sense." Is there such a thing? What is it? Is it useful in science? What about "common sense." Is it a sense?

Have you ever tried to read Braille? Why is it so difficult for you, when the blind person can use it? Have you ever known a musician who had "perfect pitch"? What does perfect pitch mean? Why do some musicians have it and some do not? Can all senses be developed through practice? How could you develop one of your senses? Of what value would it be in a science class if your sense of sight were better developed? Your other senses? Why?

LABORATORY EXPERIENCE A.1.a.

Collecting Observations

Introduction:

What is observation? Every day you look at hundreds, yes, probably thousands of things. Is looking at them observation? On your way to school this morning, did you look at any cars? How many? What kinds? How many were of foreign make? What body styles were they? What colors?

How many had vinyl tops? How fast were they going? Were the drivers men or women? How many passengers were in each? How many had tires with white side walls? How many had Michigan license plates?

These and similar questions could all be answered if you had really observed the cars instead of merely looking at them. Of course observation starts with looking, but it does not stop there.

Materials and Equipment:

One or more copies of A Field Guide to the Birds, by Roger Tory Peterson, published by Houghton, Mifflin and Company, Boston.

Various pieces of laboratory equipment.

Collecting Data:

Look about this science room. What things do you see? Hear? Smell? Can you name all the things or are some things new? Would your sense of touch help you in observing in the room? Would you use your sense of taste? Why or why not?

Look out the window. What are your observations? What senses can you use? Go for a walk around the block. When you return, list all the things you saw. Compile a list of all the things seen by members of the class. Did you carefully observe any one thing? Plan to do so before class tomorrow so that you can write a detailed description of it.

After you have completed your description of an object you carefully observed, work with others in the class who observed the same object and write a composite description. How much did others observe that you missed? How much did you observe that others missed? If you had to describe the object to someone else, would all the details be relevant? Which ones might be irrelevant?

On the laboratory (demonstration) table are several pieces of laboratory equipment. Observe each of them carefully. You may measure any part. You may compare a piece of equipment with something familiar. "It looks like a _____ because_____", or "It is different from a _____ because _____."

Have you noticed that you are observing (rather than just looking) because your attention has been directed to observation? What else besides attention does observation require?

Follow-Up:

Consider relevant and irrelevant details to be observed in describing a person.

Get from the library a copy of Peterson's Field Guide to Birds and a picture book of birds. Compare the two in the case of particular birds. Note in the Field Guide how Roger Tory Peterson points out the relevant details for distinguishing similar species without listing all the observed details.

How are caricatures used in cartoons similar to photographs? How are they different? Examine caricatures of men prominent in the national news. Which of their features are exaggerated in drawing the caricatures? Why?

Examine some optical illusions. Are your eyes always dependable in making observations? Are there other sensory illusions? What is the basis for these illusions?

LABORATORY EXPERIENCE A.1.b.

Thanitol: Using Your Sense of Smell*

Introduction:

Individuals differ widely in their ability to detect odors, and in some cases, in their interpretation of them. In this laboratory experience, a red liquid called thanitol is used. When a bottle or vial containing it is opened in a room full of people, such as a classroom, the odor spreads quickly through the room. Those nearest detect it first; those farther from it later.

There are individual differences, however. Some people cannot smell it at all. Of those who are able to smell it, some detect a sweetish odor, like that of certain flowers. Others interpret it as a sharp acid smell, somewhat like vinegar. What do you think may be the result of exposure of your class to thanitol?

Materials and Equipment:

A classroom full of students

A bottle or vial of thanitol

Paper and pencil

Collecting Data:

Your instructor brings a closed bottle or vial of thanitol into the classroom. He shows it to you. He explains that people react to it differently, and how they may do so. Then he opens the vial or bottle and smells of it himself. He holds it in front of him at approximately chest level, leaving it open for approximately five minutes. This allows time enough for the vapor to penetrate to all parts of the room.

As the vapor spreads through the room, hold up your hand when you are able to smell it. Then write down your interpretation of the odor: sweetish, acid, or other. If you do not smell it as sweetish or acid, describe the odor as well as you can. If you are not able to smell anything at all, you should record this fact.

At the end of five minutes, all of the papers will be collected. Your instructor will then discuss the laboratory experience with the class.

Follow-Up:

One heritable human trait is known which involves a difference in ability to detect the taste of a particular substance (phenylthiocarbamide or PTC). How do people's sense of taste react to this substance? How is it inherited?

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*Suggested by Professor Roger Ware, Department of Psychology, Tennessee Wesleyan College, Athens, Tennessee.

LABORATORY EXPERIENCE A.1.c.

Jingling Pennies

Introduction:

Probably your eyes do most of your observation for you. You have found that your sense of smell is not always too reliable. What about your ears? Can you depend upon them? Can there be auditory illusions as well as optical illusions?

Materials and Equipment:

Pennies

Small fruit juice cans with the tops removed

A whistle

A musical instrument

Collecting Data:

The instructor will select four students and station them in different parts of the room. He will give each of them several pennies to jingle and a small fruit juice can in which to put them. He will also select a fifth student to act as a recorder. He will then ask all other members of the class to put their heads down and tightly close their eyes. He will ask the four students holding the coins, one at a time, to jingle them. They will do this at random and in no particular order, waiting in each case to give those listening to them time to react. The instructor will ask the other students as they hear the coins jingle, and without raising their heads or opening their eyes, to point in the direction of the one who is jingling. The recorder will make note of how many point in the right direction, how many indicate very nearly the right direction, and how many seem to be confused as to the direction of the sound. The experience should be repeated several times. Is it always the same students who are confused? Do the same students always point in the right direction? How do you account for your findings?

Now the instructor will ask one student to stand at the front of the room and blow a whistle. He must try always to blow the whistle with the same loudness. With heads down and eyes closed, the other students will try to tell whether he steps forward, steps backward, or remains in the same spot as he blows. Record the results. Is it difficult to determine where sound is coming from? Why? Why must the whistle blower always blow with the same loudness?

Have a student who plays a musical instrument produce two different notes. Are they the same pitch? Is the second one at a higher pitch? Lower pitch? Try this several times. Try a different instrument if possible. What differences do you find in students' ability to detect changes in pitch?

Follow-Up:

Has your mother ever said "Turn down that radio (or phonograph or television)" when you were especially enjoying the music? Why is this?

What happens to the loudness of your voice when you are in a room where there is much noise? Why? What does the other noise do to your ability to observe with your ears?

How are people who are totally deaf taught to detect other peoples' voices? How many ways are there that they may learn to do this? How are they taught to talk?

How do ventriloquists "throw" their voices?

LABORATORY EXPERIENCE A.1.d.

Sharpening Observational Skills

Introduction:

It is easy to distinguish a robin from a bluebird if you know the characteristics of each, but how could you distinguish a streptococcus bacterium from a spirillum bacterium? How could you discover the process of the opening of the petals of a flower? How can astronomers know enough about the surface of the moon to be able to select a landing place for astronauts? Instruments which make small things appear large, slow processes appear speeded up, and far places appear close, help scientists to observe details.

Materials and Equipment:

Newspaper picture of a man

Hand magnifier

Compound microscope

Stiff paper

Collecting Data:

Hold a newspaper picture of a man at arm's length. What features can you see? What details of the face are hard to see? Hold the picture about ten inches from your eyes. What details can you see now that you missed before? What parts are more distinct? Now examine the picture with a hand magnifier. Can you see more details? Are the outlines of the features clear? If you have a stronger magnifier or can use two of them, what happens to the features? To details you noted before? Is it easier to interpret the picture when it is highly magnified? Why or why not?

Now, put a part of the picture on a microscope slide and examine it with low power. (Note: Ask your teacher to help you to set up and use the microscope.) Can you tell what part of the picture you are examining? Why or why not? How do light and dark parts of the picture differ? Does magnification by the microscope assist you in observing an object as large as a picture? Does it assist you in seeing more details? Suppose the objects were too small to be seen without magnification. Would a microscope help in this case? Why? Does a microscope assist you in seeing more details? Are details always necessary? Why or why not? When would more details be relevant? When less so?

Cut a hole the size of your hand magnifier in a sheet of paper. Examine this page through the hole in the paper. Count the number of letters in a line, and the number of lines of print that you can see. This is called your field of vision. Now use the magnifier to examine the same part of this page. Can you see more or fewer letters in each line? Can you see more or fewer lines of print? Is your field of vision larger or smaller when you magnify something? What happens to your field of vision when you use a microscope? Try it. What happens to your field of vision if you slant the page when using the hand magnifier? Why?

Follow-Up:

Examine table salt with your naked eyes, with a magnifier, and with a microscope. What details become more clear as you increase the magnification?

How does a thermometer serve as a means of sharpening your observation?

What about measuring tools? A scale or balance?

Why do scientists use refracting, reflecting, and radio telescopes? What is the difference in these three different kinds of telescopes?

What other instruments help scientists to improve their observations?

A.2. Idea Bridge: Discovering Problems

Science does not consist simply of learning facts. Of course some facts are very important. Those which are most important are the ones that are useful in getting at ideas and solving problems. The scientist uses these facts as tools, but not as ends in themselves.

Laboratory work does not consist primarly of dissecting things, measuring things, weighing things; even though measuring, weighing, and sometimes dissecting often have to be done. The scientist only does these things when he needs to do them to solve problems. Students only are asked to do these things in order to gain information to help solve problems, or to develop skills that will be useful in solving problems

How does the scientist discover problems? There is no way in which he can find a list of them in a reference book. There is no one that he can ask what they are. Where does he go to find them? What does he do?

LABORATORY EXPERIENCE A.2.a.

Seeing Problems in a Recurrence

Introduction:

Each fall the leaves of most broad-leaved trees change colors, and fall off. The regular recurrence of these two related events has led scientists to recognize several problems.

Materials and Equipment:

Although it is not absolutely necessary, it is better if this laboratory experience can be done in the fall, and that some deciduous trees be available for observation.

Collecting Data:

Is there one problem involved here, or are there more than one? Is there a recurrence of these events in the same way every fall? Are they always associated? Could their regular association in the same way each fall lead to problems that would concern scientists? What problems or kinds of problems? Would any exception to their regular association or any deviations observed in connection with their recurrence result in scientific problems? What problems or what kinds of problems?

List all the problems that you can think of that might be related to the recurrent annual events of leaf color change and leaf fall.

What kinds of observations might a scientist make to help solve some of these problems? What kinds of experiments, if any, might he set up to help solve these problems?

Follow-Up:

What are variables? How do they make the solving of scientific problems difficult? What kinds of variables might enter into solving the problems

related to leaf color change and leaf fall?

Have scientists ever really solved the problems connected with leaf coloration and leaf fall? How much is known about these things?

What other recurring events can you think of that might lead to problems for scientists?

LABORATORY EXPERIENCE A.2.b.

Seeing a Problem in a Discrepancy

Introduction:

How does a scientist know "where to start?" Why does he sometimes dissect a dead animal? Why does he sometimes study animals that are in cages in his laboratory? Why does he sometimes go out into the field to observe plants and animals? Why does he sometimes perform experiments? How does he know what experiment to do? What is an experiment? How does an experiment differ from an observation? How does a scientist discover a problem to be solved?

Materials and Equipment:

Four plants growing in flower pots

References on the history of science

Collecting Data:

On the table are four plants of the same kind. How are they alike? List as many likenesses as you can. List what may be irrelevant details as well as relevant details. Now list ways in which they are unlike.

What is one of the most noticeable differences? The scientist would see this as a discrepancy, and he would ask, "Why?" As soon as he asks "Why?", he has recognized a scientific problem. Not all scientific problems ask "Why?", but they are usually stated as questions that begin with "How?", "When?", "Why", or "What?"

State a scientific problem based on the discrepancy that you have noted. List as many other discrepancies as you can, and state problems based on them.

Read about Fleming and his discovery of penicillin. What was the discrepancy that led him to his scientific problem?

Read about Lavoisier and his discoveries about burning. What was the discrepancy in the "phlogiston theory" that led him to his scientific problem?

Read about Louis Agassiz. What was the discrepancy in the "flood theory" that led him to a problem about glaciers?

Follow-Up:

Do you ever observe discrepancies in the behavior of people that you know, and wonder why? How can you solve problems that arise in connection with people's behavior, other than by asking them directly?

When you get home tonight carefully observe your front yard or house, and the yards or houses of your neighbors. Discover a discrepancy. State a problem based on it.

LABORATORY EXPERIENCE A.2.c.

Seeing Problems Under a Microscope

Introduction:

Sometimes even the simplest things can give rise to problems when you look at them in a new or different way. A microscope is an instrument which makes it possible to look at things in a new way.

You have already used a microscope in looking at a picture from a newspaper when it is greatly enlarged (Laboratory Experience A.1.d.). When you looked at the picture in this way, you could see only a very small part of it. When you did this it didn't look like a picture at all.

Anything you examine with a microscope presents you with questions and problems because you are looking at it in a new and different way.

Materials and Equipment:

Compound microscope

Slides

Cover slips (plastic preferably)

Medicine dropper

Human hair

Collecting Data:

Check with your teacher to make sure that you know how to adjust and focus a compound microscope. Be sure, in particular that the light is properly adjusted. Be sure that you know how to focus both low power and high power.

Put a drop of water on a glass slide. Remove a single hair from your head. Lay it on the slide, through the drop of water. Put a cover slip on the drop of water. This will press the hair into the thin layer of water between the cover slip and the slide.

Examine the hair under both low power and high power. Can you focus on the top of the hair and the bottom of the hair at the same time? With low power? With high power? What problem do you have in doing this? Why?

What observations can you make concerning the general appearance of the hair? List your observations. What questions can you ask based on your observations? List your questions.

What questions can you ask about the surface of the hair? Shape of the hair? Cleanliness of the hair? Internal structure of the hair? Color of the hair? What other characteristics of the hair can you ask questions about? Do you have any suggestions about how to find answers to your questions?

What about comparing your own hair with hairs from the heads of other students? Try straight hair and curly hair. Blond hair and dark hair of various shades. Red hair. Compare boys' hair and girls' hair. What differences do you find? Try to relate any differences you have found to these common types of hair. Does all hair of each common type appear the same under the microscope, or are there individual differences?

Can you answer all of your questions from your observations? Or are there some of your questions that are left unanswered? Would the observation of additional examples of hair help to answer your questions? Or would additional observations lead to more questions?

Follow-Up:

Examine different kinds of textile fibers under the microscope. Use the same techniques that you have used with hairs. Look at fibers from your own clothing, and from pieces of textile material brought into the laboratory. Look at cotton, silk, linen, and wool, and also various kinds of synthetic fibers. What differences do you find? Are these differences related in any way to the characteristics of the fabrics made from these fibers?

Examine other simple objects under the microscope. Study their characteristics in the same way. See how much you can find out about them. What problems are suggested by your observation of them?

A.3. Idea of Hypothesis ~~Formation and Testing~~:

Idea Bridge: The Cycle of Proof

The scientist believes that he lives in a dependable world--a world where the things that happen have causes that can be understood. He believes that the same cause always leads to the same effect or to an effect which is clearly related to it. Thus the natural world shows consistent relationships or patterns. These patterns can be discovered by careful observation, and then tested by further observation and/or by experimentation. Descriptions of these patterns, once their existence has been clearly established, constitute natural laws. These laws then can be used to predict the discovery of additional data. "We can judge the future by the past."

We can count on certain well-established patterns: The sun rises in the east every day and does so at a predictable time. The rising and setting and phases of the moon behave according to a definite pattern. The stars in their courses do the same. We know that water boils and freezes at predictable temperatures. Spring, summer, fall, and winter return year after year. All of these occurrences or phenomena vary within predictable limits. The times of rising and setting of the sun, moon, and stars undergo changes in a cyclic fashion. These changes are predictable. Water boils at lower temperatures on high mountains, and freezes at lower temperatures when certain substances are dissolved in it. The seasons vary from year to year, but follow a general pattern. People have always known and depended on these patterns, even before the age of science.

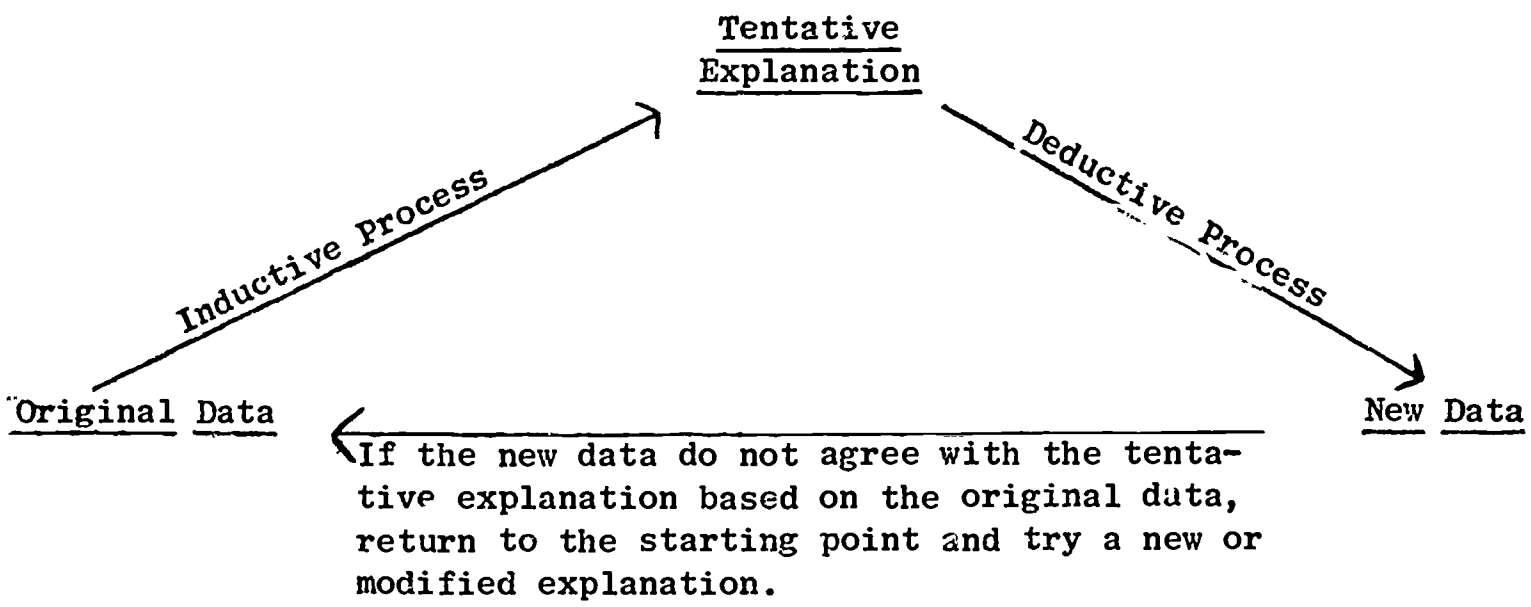
Scientists have studied these phenomena and many others. They have described a vast number of patterns in nature in terms of natural laws. When a scientist is faced with a new set of phenomena he starts looking for patterns in the behavior of these phenomena, and for the causes which lie behind the patterns. In doing this, he is trying to make nature make sense. We all do this, whether we are scientists or not. Nothing is more disturbing than to observe a set of phenomena which do not appear to make sense--to follow the patterns we know. We want our universe to be orderly and explainable.

The scientist has a fairly well-defined procedure by which he attacks this problem of finding a pattern. First, he collects all the data that he can--all the "facts." Then he arrives at one (or more) possible or tentative explanations. Any tentative explanation must account for and agree with all the data that he has. If more than one explanation appears to be possible, he chooses the likeliest one. Then he starts looking for more data--more "facts." Sometimes he does this by planning and carrying out experiments to test his tentative explanation. Experimentation, however, isn't always possible. In such cases, he simply continues his observations.

After further observation or experimentation, he checks carefully to see if the new data which he has obtained agree with his tentative explanation. If they do, then he has taken a step toward proving his explanation to be correct--he has predicted on the basis of his tentative explanation and then has found that the new data which he has collected support his explanation. If they do not agree, however, he must return to his starting point, set up a new or modified tentative explanation that will agree with both his old and new data, and start looking for still more data by further observation or experimentation to test his new explanation.

This behavior on the part of a scientist has been called the Cycle of Proof. It constitutes a kind of common denominator which can be applied to the behavior of anybody, scientist or non-scientist, who is trying to solve a problem.

THE CYCLE OF PROOF



Inductive means to start with data (facts) and arrive at a tentative explanation.

Deductive means to start with a generalization (tentative explanation), and make judgments concerning data (facts) in relation to this generalization.

Not all problems are solved in this way, of course. It is possible sometimes to reach a workable solution to a problem by simply guessing. Your chances of success in solving your problems are considerably greater, however, if you go at it by following the Cycle of Proof. It can apply to all kinds of problems--what to buy, what to wear, how to behave in a group, how to get along with another person--scientists have no monopoly in it. All that they have done is to make a system out of a very ancient way of problem-solving, and give names to certain parts of it.

A tentative explanation for a set of data that present a problem--an explanation which agrees with all of the data that are available--is called a hypothesis. A scientist is not willing, however, to allow a hypothesis, no matter how correct it may appear, to stand untested. It is a part of his normal behavior (his way of looking at the world) that he must try out any hypothesis by further observation or experimentation. Any hypothesis is necessarily tentative and subject to question. If further data are collected which agree with it, and none that seriously disagree with it, it becomes strengthened. Ultimately it comes to have the strength of a natural law.

Even then, however, there is still an element of tentativeness in it. If a hypothesis is an explanation which may be considered "possibly true", then when it has been tested as far as possible, and is called a natural law, it may be considered "apparently true", or "true so far." Even natural laws may be modified or downgraded on the basis of new data or broader understanding.

It is possible for you to carry on simple examples of hypothesis formation and testing in the laboratory. When you do this you can arrive at statements describing patterns of behavior which are very much like natural laws. Also in doing this you will come to have a much better understanding of how a scientist looks at his world, and how he works in finding out about it.

You will also be able to see relationships between the decisions that people make in connection with ordinary living, and scientific problem solving. How would you use the Cycle of Proof in buying a car? How might your thinking in connection with deciding whether or not to go to a movie on Wednesday night when you have a math test on Thursday be related to scientific problem solving?

Does your relationship to another person (a friend or a member of your family) follow a hypothesis as to how this person will behave? How well established is your hypothesis for a particular person? Do you ever come upon "new data" in connection with the person's behavior that cause you to change your hypothesis or make a new one? Do you ever set up something which resembles an "experiment" in order to find out more about a person?

LABORATORY EXPERIENCE A.3.a.

Flipping Coins

Introduction:

If you flip a penny, will it fall "heads" or "tails"? What determines which way it falls? If you flip it a second time, will it fall the same way it did the first time? What determines whether it does or not? What is chance? Is the chance the second time in any way related to the chance the first time? If the first two flips fall the same way, what about a third time? If the first two flips fall in different ways, which one will the third flip be like? Is there any relationship? What about a fourth time?

If you toss the same penny 100 times, how many times do you think it will fall "heads," and how many times "tails"? Why? If it falls more times one way than the other, why do you think this might be so? What is a warping factor? How would one work? What do you think one might be in this case?

Materials and Equipment:

Pennies

Paper and pencil

Collecting Data:

Work in pairs. Carry out any of the ideas that you got in the discussion that just took place. Decide with your partner on one experimental procedure. Try it. Keep the conditions as uniform as possible. Why? Record your results. Repeat your experiments. Why? Do you find evidence of any warping factors? What do you think they might be? Can you think of any way to test for their operation experimentally? What about the age of the penny you are using? What about the way you flip it? Any other possibilities? Compare your results with those of other pairs of students. Does this raise any further questions?

With the teacher's help, summarize all of the data from the entire class. Are you able to summarize the data in organized form? Does this help to answer any of the questions that were brought up while you were working with the pennies?

Recognizing Problems---Setting Up and Testing Hypotheses:

With the teacher's help, define or recognize problems (unanswered questions) that remain, or new ones that arise when all the data are put together. Pick one problem for investigation (You may investigate more than one, but do so one at a time.) Suggest a possible solution (or answer). This is a hypothesis. Try it. Is your hypothesis strengthened or weakened?

In case your hypothesis is weakened or proved incorrect, you may modify it, or make a new one and try again. You may do this as many times as you need to or wish to.

Are you able to arrive at a final or definite answer? Is it sometimes necessary to recognize that it is not possible to do so? Why?

Follow-Up:

Do scientists always find solutions to their problems? Do people always find solutions to their everyday problems? Do people ever have to learn to live with unsolved problems? Do solutions to problems which are left unsolved sometimes appear later on?

What is the Law of Probability? How is it related to chance? What kinds of things behave in accord with the Law of Probability?

LABORATORY EXPERIENCE A.3.b.

Guessing and Measuring

Introduction:

How accurately can you guess? What do you really do when you guess? What do you do when you guess at an answer on an examination? When you guess at how much something will cost? When you guess what to buy as a present that will please someone for whom you feel love or friendship? Which does guessing resemble more closely: flipping a coin or making a thoughtful decision? Is a guess really a "shot in the dark?" A throw of the dice?

Do you usually have some evidence on which to base a decision that you make? Much evidence? Little evidence? No evidence? You must make the decision anyway--You have no way to avoid it! Do you try to collect more evidence? What do you do when you have collected all the evidence you can find? How is what you do related to the Cycle of Proof?

Is there really such a thing as a guess? If there is, do you ever make a guess? Under what circumstances?

Materials and Equipment:

Drinking glass

Medicine dropper

BB shot

Forceps

Paper

Twelve inch ruler

Stop watch, or watch with second hand

Collecting Data:

Phase 1. Work in pairs. In general, one partner should carry on the laboratory experience while the other checks his activities and records data. They should exchange jobs at each "break point" in the experience.

Fill a drinking glass with water exactly to the rim. The best way to do this is to fill the glass almost to the rim by pouring water into it, and then transfer the last of the water into it with a medicine dropper. Do not make the surface of the water rise above the edge of the rim. Be sure that the surface of the glass, including the rim, is dry. Why is this necessary? What is surface tension?

Now each partner should guess how many BB shot can be dropped into the full glass, without forcing the water to break over the rim. Record the guesses.

From this point on, one partner should drop BB shot into the glass, picking up each shot with the forceps, and dropping it carefully into the middle of the glass from a point near the surface of the water. The other partner should keep a record of the shot as they are dropped in.

When the surface tension breaks, and the water spills over the edge, the water and shot should be emptied out, the glass dried carefully or a new one substituted, and the experience repeated. At this point the partners should exchange jobs.

The experience should be replicated 10 times (5 times for each partner). (The initial guesses need not be repeated.) Do the results of the 10 trials agree? What is the range of variation? What is the average?

Considering the average of the 10 trials as the tentatively "right" answer, which initial guess---yours or your partner's, was the better? If the entire class has carried on the experience, find the average for the entire class. How close is it to the average that you and your partner obtained? Did any other students guess closer to the tentatively "right" answer than you and your partner did?

Phase 2. Again work in pairs and follow the same general procedure as in Phase 1.

Each partner should mark on a sheet of paper, what he believes to be lines of the following lengths (In the order listed): 6 inches, 3 inches, 8 inches, 4 inches, 7 inches, 2 inches, 9 inches, 5 inches, 1 inch, 10 inches. The partners should then exchange papers, and each should measure the other's lines, recording the results to the nearest quarter-inch.

How many lines were shorter than they should have been? How many were longer than they should have been? Was there a tendency on the part of some individuals to err in one direction or the other? Did you tend to err in the same direction as your partner? Did you err to a greater or lesser extent than your partner? How good a guesser of length were you? Compare all students in the class, as to direction of error, and as to extent of error. Was there a class tendency as to direction? Why would you, or would you not, expect such a tendency?

Phase 3. Again work in pairs and alternate in the roles of guesser and recorder.

One partner should hold the watch, and the other guess the passage of time. The holder of the watch should act as recorder. In the first series of trials, the recorder should allow a period of time to pass (one minute, two minutes, three minutes, whatever he wishes, but using a definite period of time). The guesser should attempt to estimate how long the period has been. The partners should alternate jobs until each has guessed ten times.

In the second series of trials, the guesser should tell the recorder when he thinks a certain period of time (one minute, two minutes, whatever he wishes, but a definite period each time) has passed. Again the partners should alternate jobs until each has guessed ten times.

How many guesses were too long? How many too short? Was there a tendency to err in one direction rather than the other? Did you tend to err in the same direction as your partner? To a greater or lesser extent than your partner? How good a guesser of time were you? Were you a better guesser in the first series of trials or the second? Was the extent and direction of your error the same in both series? Compare with your partner.

Compare all students in the class as to direction of error and as to extent of error, in the first series of trials and in the second series. Was there a class tendency? Why would you or would you not expect such a tendency? Can you suggest any reason for the results that you have found?

Guesses and Hypotheses:

Did your guesses constitute hypotheses? In the case of the BB shot and the glass of water? In your guesses of length? In your guesses of the passage of time? Is there any difference between a guess and a hypothesis? Between a guess and an estimate? How is a belief related to a hypothesis?

On what were your guesses based? How did you test them? Try to apply the Cycle of Proof to your procedure.

Reaching Conclusions:

What kinds of conclusions is it possible to reach as a result of this laboratory experience? Conclusions as to how accurately you can guess or estimate? As to whether one student can guess or estimate as well or better than another? As to whether there are tendencies in student guessing when considered comparatively? As to the nature of hypotheses in general? As to the inadequacy of human judgments?

Follow-Up:

Can we improve the accuracy of our guessing, or our ability to estimate through practice? Try it and see. If we do improve, are we simply accumulating additional data through practice on which to base our hypotheses (guesses, estimates)? Are some people naturally better guessers than others? Why might this be so?

LABORATORY EXPERIENCE A.3.c.

You Touched Me----Where?*

Introduction:

How accurately can you tell where a point on your skin is located when something touches it? Can you tell whether you are touched at a single point or at two points that are close to one another? If you are touched at two points at the same time, how closely can you estimate the distance apart of the two points? Is your skin equally touch-sensitive in all places? if not, where would you expect it to be most touch-sensitive? Where least? Why?

Materials and Equipment:

Compass (such as is used for drawing circles)

Millimeter rule

Round wooden toothpicks, attached with scotch tape or masking tape to the points of the compass

Six inch rule

Scotch tape or masking tape

Directions for Operator:

Sit with the subject seated in front of you. With the compass as nearly closed as possible (points of the toothpicks separated by about two millimeters), touch the subject on the bare skin of the back of the arm. Start in the neighborhood of the shoulder and touch at various places down toward the elbow. Ask the subject to indicate whether he feels that he is being touched by one of the toothpicks or two. Keep a record of the general location of the places touched, the distance apart of the toothpick points, and whether one point is felt or two.

Spread the arms of the compass so that the two toothpick points are separated by 10 millimeters, and try again in the same general locations. Separate the toothpick points by a distance of 15 millimeters and try again. Try again at 20 millimeters. At 25 millimeters. At 30 millimeters, 35 millimeters, and 40 millimeters. Keep a record in all cases.

Now close the compass (to approximately 2 millimeters) and with the subject blindfolded or with eyes closed, try the same procedure on the palm of the hand. Try both right and left palms to see if there is any difference related to whether the subject is right-handed or left-handed. Is there? Try the back of each hand. Try the forehead, both cheeks, the chin, the tip of the nose, the middle of the bridge of the nose. In all these cases start with the points at approximately 2 millimeters apart. Gradually increase the distance a few millimeters at a time. Keep a record of the distance apart in all cases, and the relative sensitivity of the parts touched.

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*Prepared in collaboration with Dr. Jean Lawrence, Associate Professor of Biology, Western Michigan University, and Miss Pamela Hayward, student in the Biology Department.

Now with the points of the two toothpicks set at a distance apart of one inch or greater, touch the subject again on the back of the arm between the shoulder and the elbow. When the subject can feel both points, have him estimate the distance between the points. Measure the distance by placing the points on a six inch ruler. Record the subject's estimate and the true distance. Do this 10 times in different places. How accurate were the estimates? With the subject blindfolded or with eyes closed, try the same thing 10 times on the palms of the hands, on the backs of the hands, and on the face? Is there any difference in the accuracy of the subject's estimates in the different locations.

Estimates and Hypotheses:

Did your estimates of distance between the points in the last part of the experience constitute hypotheses? Why is an estimate a hypothesis? How do you test an estimate? Do you think you could improve your ability to estimate correctly by doing a great deal of it (that is, by practice)? Try it and see. How would you explain any improvement in terms of the Cycle of Proof?

Is there any pattern to the degree of sensitivity to touch on the skin of the arms, hands, and face? What is it? How would you explain it? Can you devise a hypothesis to do so?

Reaching Conclusions:

Does the fact that the eyes are on the front of the head facing forward indicate anything that might be helpful in reaching a conclusion in this experience? Does the fact that we use our hands to help explore our environment and work with tools indicate anything?

Follow-Up:

Did you discover any individual differences between yourself and your partner in regard to touch-sensitivity? Between the two of you and other members of the class? Are some people more touch-sensitive than others? Is this a valuable characteristic to possess? If so, why?

A. 4. Idea of Objectivity and Tentativeness

Idea Bridge: Cultivating Scientific Attitudes

A scientist observes a particular set of phenomena or a series of events. If he finds a discrepancy, he looks for an explanation which will help to "make sense" out of the discrepancy. He sets this tentative explanation up as a hypothesis. He tests this hypothesis. While he is doing so, the situation continues to constitute a problem for him. He examines the problem objectively. This means that he keeps his feelings and predjudices out of consideration, and tries to look at the problem as if it were someone else's.

Even when he thinks he has found a solution, he continues to maintain an attitude of objectivity. Any conclusion that he arrives at is tentative. This means that he does not allow himself to become set in his thinking concerning it. He tries always to be ready to modify his conclusion, or even discard it, if new or additional evidence bearing on the problem becomes available. Such new data may cast doubt on his conclusion, or point to some other conclusion.

Only after a scientist has tested a conclusion many times does he begin to be reasonably sure of it. Even then, however, he does not regard it as final. Probably he never can do so. It would be possible for him to regard a conclusion as final only if he were able to collect and examine all of the possible evidence. In the case of any problem of a general nature he could do this only if he had all of the world for a laboratory, an infinity of time at his disposal, and an infinite number of cases to examine.

All that can be done in the case of most problems is to examine a representative number of cases, a representative sample of the evidence. On the basis of this, he can arrive at a reasonably firm conclusion or solution. Even then, the conclusion is tentative, and must remain so.

It is not easy to be objective and tentative. The scientist must cultivate these attitudes. The non-scientist can make better decisions if he practices them. There are some things, however, about which most people have formed opinions. Most modern people do not believe in ghosts. If you were to see one, could you accept the evidence of your senses? Should you do so?

LABORATORY EXPERIENCE A.4.a.

Do You Believe in ESP?

Introduction:

Extrasensory perception (ESP) is the supposed ability to read another person's mind(telepathy). There are other supposed abilities that may be included in it: the ability to see things somewhere else with a kind of "inner sight" (clairvoyance), and the ability to see how things are going to be at a later time (precognition). The supposed ability to cause objects to move without touching them (telekinesis) is related to ESP.

Do you believe in these things? Most scientists do not. Those who do believe in them think that many people possess these abilities. Do you have any of them? Most of the evidence for their existence consists of deviations from the operation of the law of probability---things which happen which it is difficult to explain on the basis on chance alone. How would you explain them?

A deck of ordinary playing cards consists of 52 cards. There are four suits of 13 cards each: clubs, diamonds, hearts, and spades. Therefore, if you attempt to guess the suit of any card chosen at random, you have one chance in four of guessing it correctly. If you shuffle the deck each time before drawing a card and guessing, you should expect to be right in 25 percent of the cases, 25 right out of 100.

Any percentage of correct guesses either higher or lower than 25 percent would seem to indicate one of two things: either (a) inadequate sampling, that is, although this particular trial run showed a significant departure from explanation on the basis of pure chance, if enough runs were considered, the total results would show chance expectation; or (b) the operation of some warping factor of yet undetermined nature. This might be E.S.P.

Materials and Equipment:

A deck of playing cards. The newer the cards the less is the danger of their carrying any identifiable marks or clues.

Sheets of paper with spaces numbered one to 20.

A watch with a second hand.

This set of items will need to be replicated for each team carrying on the experience.

Collecting Data:

Individuals will work in trios. One, the viewer, holds nothing. Two holds a deck of cards and a watch with a second hand. He also has a sheet of paper numbered one to 20, and a pencil. Three, the guesser, holds only a numbered sheet of paper and a pencil.

Two shuffles the cards thoroughly, and holds them while One draws a single card from any portion of the deck. One looks at the card and concentrates on it. Three also concentrates, thinks about the card without seeing it, and attempts to guess to what suit it belongs. Two looks at the watch and allows One and Three to concentrate for a minimum of five seconds. At the end of this time, One shows the card to Two, who writes down the suit of the card on his sheet of paper in the space marked "1". One checks the correctness of the suit that Two has written down. Three writes down what he guesses the suit to be in the corresponding space on his sheet of paper.

The trio repeats this action, shuffling the deck each time a card is drawn, until One has drawn cards, and concentrated on them, and Three has guessed them, 20 times. Then, Two writes One's name on his paper, and Three writes his own name on his sheet, designating himself as "guesser." No comparison of the sheets is made at this time. They are given to the teacher or other person in charge to hold for final tabulation.

The members of the trio now exchange jobs. One becomes Two, Two becomes Three, and Three becomes One. The procedure is repeated, with each person filling a new job. This is continued until each person has filled each of the three jobs at least once. Since it will not be possible to complete this cycle in a single period (Why might it be desirable to do so from the experimental standpoint?) the work should be taken up the following period at the point where it was left off. It would be desirable for each person to serve in each capacity five times (five runs of 20 each equal 100), if this is possible. Any number of times, 20 to 100, may be used, however.

It would be well not to tally the results of the experience as recorded on the sheets until the entire experience is completed. The teacher should then compare the series of sheets prepared by each "viewer" and "guesser" (pair), and tabulate the results for class inspection.

How closely did the results in the case of each student in his role as "guesser" correspond to chance expectation? Were there as many individuals whose guesses were less frequent than chance as there were those whose guesses were more frequent than chance? When the results from all individuals in the class are put together, how closely do they correspond to chance expectation?

Were there any individuals whose guesses were very greatly in excess of chance expectation? If these individuals took part in more than one cycle, on different days, were their results consistently high? Were there any individuals whose guesses were markedly less frequent than chance expectation? If these individuals took part in more than one cycle on different days, were their results consistently low?

Do you think that any warping factors were at work in the card guessing which took place? Do you have any hypotheses as to what these warping factors might have been? Is there any evidence that people can read each other's minds? That some people can read minds, while others cannot? What complications would exist in society if mind reading were generally possible?

Further Experimentation:

Try additional runs for individuals who have shown much-greater-than-chance and much-less-than-chance guessing ability. Have them work with different partners than they did before. Does their performance remain consistent?

Try having One draw the card and concentrate on it without turning it over to see what it is, then, still without looking at it, show it to Two who writes it down. Compare the lists prepared by Two and Three as before. How do the results compare with those obtained when One looked at the face of the card while he concentrated on it?

Try having the "guesser" concentrate on a deck of freshly shuffled cards and guess the suits of each of the top 20 cards as they lie in the deck without removing them. Try the same thing before the cards are shuffled. See if the "guesser" can predict the order in which the top 20 cards will lie after they are shuffled.

How do telepathy, clairvoyance, and precognition differ from one another? What evidence is there for the existence of each?

Conclusions:

Do you believe in ESP? Did you believe in it before you worked through this experience? Did the experience change your belief? Did it influence your belief in any way? How well do you think that your thinking before, during and following the experience was objective and tentative?

It is just as possible to be non-objective and non-tentative in accepting the existence of ESP, as in refusing to accept it.

State a conclusion based on this experience in terms of objectivity and tentativeness.

Try to see if it is possible to influence the fall of a pair of dice by concentrating on them. Figure out the combinations of dice which fall most frequently with normal chance expectancy. How can you do this? Try having one person throw the dice, and another attempt to influence the way they fall by concentrating on them. What evidence is there for the existence of telekinesis?

Do you know what a ouija board is? Have you ever used one? How does one work? Do you believe that it is possible to find answers to questions by asking a ouija board? Why or why not?

LABORATORY EXPERIENCE A.4.b.

Unidentified Flying Objects (UFO's)

Introduction:

The sighting of "flying saucers" is not limited to any one country or part of the world. They are by no means an American phenomenon. They are a phenomenon of the post-World War II world, associated somehow with the nuclear bomb, rockets and space travel, and intercontinental ballistic missiles (ICBM's). They are not all saucer shaped. There are "outbreaks" of sightings of them at different times and in different areas. No one knows what (if anything) they are. There are many who believe that they are natural phenomena, misinterpreted by people with over-active imaginations. On the other hand, a fair number of scientists and other objectively trained people take them seriously.

Do you believe in them? If you do believe, is it because you want to believe? Is it because you would like to think that there is life on other worlds than ours, or that something from outer space, or from the other side of our own world is trying to find out about us? Or do you believe because of convincing and objective scientific evidence? From the standpoint of our interest in the principles of objectivity and tentativeness, it is less important whether you believe or do not believe, than why you believe or do not believe.

Needed Materials:

Accessibility to a library with the Reader's Guide to Periodical Literature, and the backfiles of popular magazines.
Popular paperbacks and trade books
Daily newspapers
Dictionary

Collecting Information:

Look up "Flying Saucers" in the Reader's Guide to Periodical Literature. The references that you find will be in the backfiles of magazines. Not all of these will be available. Look up and read enough of the articles in the magazines which are available to give you an idea of the nature and extent of flying saucer phenomena.

What do they look like? When are they seen? Always at night, or sometimes in daylight? How close have observers been to them? Do they ever leave any evidence of their presence, such as fires? Have they ever been photographed?

Do they exhibit any common or constant characteristics? Color? Size? Velocity? Behavior? Is it possible to detect any pattern in their appearance or behavior? Scientists look for consistent patterns in nature, describe them, and then make predictions on the basis of them. Is there any basis on which this can be done with flying saucers?

Watch the newspapers for articles on flying saucers. Have any ever been sighted near where you live? How frequently do articles telling of flying saucers appear in the news? See if you can find any paperbacks or other books dealing with flying saucers. Do these give you any further information?

What do you think about "Unidentified Flying Objects(UFO's)" after you have found out as much as you can about them through reading? Do you believe in them at this point? Why, or why not?

If you do believe in them, how much of your belief is based on your wish to believe? What kind of evidence would it take to convince you that they really do not exist? If you do not believe in them, what kind of evidence would it take to convince you that they do exist? How objective and tentative are you in your behavior concerning the flying saucer problem?

Follow-Up:

What do you know about poltergeists? Look up the word in a dictionary. What does it mean? Have you ever heard of them before? Have you ever read of them? See if you can find any paperbacks or other books that deal with them? Any articles in magazines (current issues or back files)?

How well authenticated are poltergeists? How frequently do they occur? Is there any pattern to their occurence or behavior? Time? Place? Association with people? Adults or children? With fire? With death? With strong emotion? Are they ghosts?

After you have read all you can about poltergeists, do you believe in them? Why, or why not? How objective or tentative are you being in your belief or disbelief in them?

See if you can find out about the American and British Societies for Psychical Research. What do they do? What kinds of phenomena do they investigate?

Can you be objective and tentative with regard to your consideration of these kinds of phenomena?

LABORATORY EXPERIENCE A.4.c.

Science-in-the-News

Introduction:

We are reminded continually that we live in a science-oriented world. We use the gadgets that science has made possible. How do we know what is happening in science? How do you know what is happening?

You learn about science in school, but the science that you learn there is only what is talked about, or what you read about in the laboratory and classroon. Do you ever read about science in newspapers and magazines? Or do you skip the science articles in the daily paper, and pass over the science section in magazines like Time without reading it?

In order to read science news intelligently, it is necessary to know certain criteria(standards) by which to evaluate (judge) the articles. Not every science article tells a complete and objective story---one that can be depended on. How can you tell a dependable science article from an undependable one? How can you know what to believe?

Needed Materials:

1. A daily newspaper, published in a city with a population of 100,000 or larger.
2. Time or another weekly news magazine that regularly includes a special science section. You should have access to recent issues of the magazine, and backfiles over a period of several weeks.
3. A set of criteria for evaluating science news articles.
4. Filing cards and envelopes for containing clippings.

Criteria for Evaluating Science News Articles:

1. Does the newspaper or magazine report other kinds of news accurately and objectively? Does it mix opinion with its reporting of the news? In general, its science news will be as accurately and objectively reported as other kinds of news.
2. Does the headline or title agree with the body of the article? Does it tell the same story in brief that the article tells? It should do so. Generally, the person who writes the article does not write the headline.
3. If the article tells of recent research, does it give the name of the person who did the research, and does it say where the research was done? It is a better article if it cites name and location.
4. Does the article say that the research was reported at the national meeting of a major research organization (American Association for the Advancement of Science, American Institute of Biological Sciences, American Chemical Society, American Cancer Society, or some other)? It is a better article if it does so.
5. Is the article limited to the facts, or does it go beyond the facts and try to predict by using phrases such as "which may---?" Is it a better article if it is limited to the facts?

6. Is the article signed, carrying the writers name in a by-line just beneath the headline or title? Sometimes articles carry the words "Science Service" as a by-line. Science Service is a news agency (wire service) comparable to the Associated Press (AP) or United Press International (UPI) in the United States, or Reuters in Great Britain, or Tass in the Soviet Union. An article which carries a by-line is more likely to be authoritative than one which does not.
7. Is the article long enough to tell a complete story, or is it only a note? A longer article is more likely to be complete.

Collecting Information:

Survey a daily newspaper published in a city of 100,000 population or larger. Examine all issues, daily and Sunday, for a period of three weeks. Clip all of the science articles that each issue contains. Put each article in a separate envelope. Label each envelope with the title of the article and date of publication. Save the articles for later use, if necessary.

Try to apply the criteria listed above to each article. On the basis of all of the criteria, place the articles in two categories: good and poor. Then pick out one or more articles which you would rate as excellent according to the criteria. Why did you rate the article(s) excellent? Which of the criteria, if any, are still lacking in them? If you would not rate any of the articles excellent, why would you not?

Do you think that the newspaper you have surveyed does a reliable and objective job of science news reporting? Why or why not? What fields of science were dealt with in the newspaper during the period of your survey? Is this an adequate coverage? Why, or why not? Can you suggest any reason for either the deficiencies or the emphases that you found?

Survey the science news in Time or other news magazine which regularly carries a science section. Do this over a period of several weeks. If you do not have the magazine available for clipping, put the title, date and source of each article on a filing card. Also on each card, tell briefly what the article was about; and whether you thought it was a good or poor article according to the criteria, and why. Be specific. Now divide the cards into two groups, good and poor. Pick out one or more cards describing article(s) which you would rate as excellent. Why did you rate the article(s) excellent? What desirable characteristics, if any, are still lacking in them? If you would not rate any of them as excellent, why not?

Do you think that the magazine does an objective and reliable job of science reporting? Why, or why not? What fields of science were dealt with during the period of your survey? Is this an adequate coverage? Why or why not? Can you suggest a reason for either the deficiencies or the emphases that you have found?

Compare the newspaper and the magazine from the standpoint of (1) objectivity and reliability of the science reporting, and (2) coverage of the fields of science.

Follow-Up:

If your school or an available public library subscribes to Science News, survey it, and compare it with the daily newspaper and the weekly news

magazine that you surveyed. Make this comparison from the standpoint of objectivity and reliability of science reporting, and coverage of the fields of science.

Science News is published by Science Service, the science news agency referred to earlier.

LABORATORY EXPERIENCE A.4.d.

Reading Science Fiction

Introduction:

Scientists build on what they know---the facts and relationships that they have discovered. They make hypotheses and theories which set forth the additional facts and relationships which they believe they will discover. This kind of prediction is called extrapolation.

Because of this, it is possible for anyone who follows scientific discovery closely, to state in terms of reasonable certainty that particular scientific developments and discoveries are "just over the horizon", or "just around the corner." At the same time, some other developments must be considered improbable or even impossible on the basis of present knowledge.

For example, to land a manned expedition on the surface of the moon or Mars is a reasonable or justifiable extrapolation. Even to send an expedition to the nearest star (several light years away) is within the range of ultimate possibility. Travel backward through time, however, cannot be based on any presently known scientific principles.

Science fiction constitutes a kind of extrapolation which is in many ways similar to that which takes place in the making of scientific hypotheses and theories. Some science fiction is based on direct extrapolation from the "known" to the "possible" or even "probable", in either the near or distant future. Other science fiction is less directly based on extrapolation. All science fiction, however, is a projection into a "might be" or "might have been" world.

Many present-day scientific developments, some of which are even commonplace, have been foreshadowed in science fiction. Jules Verne, in the late 1800's wrote about a submarine in Twenty Thousand Leagues Under The Sea. H.G. Wells, around the turn of the century, wrote First Men in the Moon. Others wrote stories about airplanes, nuclear weapons and nuclear power, artificial organs and organ transplants, long before these things were developed in fact.

Many scientists are readers of science fiction, and some are authors of it. Most science fiction authors, however, are like the authors of other stories, except that they specialize in this field. Some well-known present-day science fiction writers are Robert Heinlein, Isaac Asimov, Clifford Simak, Poul Anderson, Phillip Jose Farmer, Robert Sheckley, and Ray Bradbury. You may like others better than any of these. You should learn to read science fiction, and discover your own favorite writers.

Needed Materials:

Science fiction short stories in magazines or collections.

Criteria for judging them

Criteria for Science Fiction Evaluation:

1. Is the story based on reasonable extrapolation from presently known scientific facts and principles and present trends in scientific development?
2. If the story is based on extrapolation from presently known science, does it include any major devices or developments for which we do not now have any basis?
3. If the story is laid in a distant future period, does the description of what the world is like at that time constitute a reasonable expectation of what it actually might be then?
4. Given the setting of the story (time, place, people, and how they live), are the events in the story consistent with the setting? Is the behavior of the characters in the story consistent with the setting?
5. If it is a time travel story to a past period of the world's history, are the historical situations and their cultural settings accurate? Is it a good "picture" of the historical period in which it is supposed to happen?
6. Are the characters "believable"? Do you come to feel that they are "real people" as you read the story?

Collecting Information:

Read at least 10 science fiction short stories, and evaluate each one according to the criteria stated above. Try to read as wide a variety of stories as possible. How would you evaluate each story? Its strong points? Its weak points? Do you find any common weaknesses? Has your reading experience given you a broader basis for thinking about science? Has it made you more ready to accept new possibilities?

Follow-Up:

Read some of the history of science fiction. Edgar Allen Poe wrote some of it. H.G. Wells wrote some of it. Jules Verne wrote a great deal. What other early writers wrote stories and books that would fall into the category of science fiction? Read Edgar Rice Burrough's Tarzan books and Mars books. Apply the criteria to all of the early science fiction stories and books that you read. How do they compare to modern science fiction?

What about science fiction in motion pictures and television? Can you apply the criteria to these?

A. 5. Idea of Natural Law

Idea Bridge: Patterns and Natural Law

It has been said that nothing is changeless but change. Everything around us changes constantly. When we say something is "changeless", we mean that it changes so slowly in comparison to most other things that we do not notice the change at all. We have become so accustomed to rapid change, that we often do not notice it either.

If we think about change, and watch it taking place around us, we see that there appear to be at least two kinds: patterned and patternless. We watch fleecy white clouds (cumulus clouds) on a summer day. If we pay close attention to them, we see that they are never the same for any two successive moments. Furthermore, we cannot predict the details of their appearance at any particular moment from knowing how they looked at the previous moment. Their movement appears to be patternless. This is true, however, only of their moment-to-moment changes. When we watch them over a period of a whole day their movements can be seen to follow a pattern.

We can find other examples of changes that at first appear patternless. However, it seems possible that the two kinds of change, patternless and patterned, are related. If we look at details, close-up, moment to moment, change may appear patternless. If we take a larger, longer-term view, however, patterns become apparent.

Variation in nature is universal. It is related to change. Careful examination of the leaves of any particular species of tree will show that no two of them are exactly alike. Even though no pattern of variation is apparent from one leaf to another, all of them when examined together are describable in terms of a general pattern which is characteristic of the species to which the tree belongs.

It is the job of science to discover and describe patterns in nature that operate consistently----that can be depended on----patterns of change and patterns of variation. On the basis of the consistent operation of these patterns in the past, it is possible to predict their operation in the future. Natural laws are descriptions of consistently operating patterns in nature. There are many kinds of factors that operate in nature to produce patterns. Scientists try not only to discover and describe the patterns which exist, but also to determine the factors which produce them and how they operate.

We have to distinguish between two uses of the word law. There are natural laws and civil laws. These are really quite different. Civil laws govern. They prescribe what people must do. If they are disobeyed, the disobedient people are punished. Natural laws, on the other hand, do not govern natural phenomena. They only describe them. They tell what things in nature actually do. If natural phenomena do not behave as they say, scientists do not punish the phenomena, they change or modify the law.

LABORATORY EXPERIENCE A.5.a.

Patterning in a "Population" of Simple Events:

Normal Curves and Warping Factors

Introduction:

You may have thought of the word "population" only in connection with people, or at most with other living things. Thus we might talk about a population of men or mice or robins, or even of daisies in a meadow, or pine trees in a forest. A population, however, may consist of a large group of similar things of any kind. In this laboratory experience we are going to study a "population" of penny flips.

In an earlier laboratory experience ("Flipping Coins" A.1.a.) we saw that when you flip pennies or other coins, it is a matter of chance whether any particular flip falls "heads" or "tails." And each flip is completely unrelated to any other flip. We learned also that there may be a "warping factor" at work, which disturbs the normally expected equal numbers of "heads" and "tails" that should result if nothing but pure chance were at work.

So far, however, we have dealt only with single penny flips, one after another. What will happen if a number of pennies are thrown together, and fall at the same time? Some will fall "heads" and some "tails." Each fall will be independent of the others. If such a multiple penny toss is repeated many times, and the total results are considered together, what kind of a "pattern" will result? Will there be warping factors operating in the population of flips? If so, how will they show?

Materials and Equipment:

Pennies

Masking tape

Graph paper

Collecting Data:

Take an <u>even</u> number of pennies (6-10), and toss them together, counting the total number of "tails" that turn up each time. Do this as many times as you can, up to 100 times.

```
                    x
                  x x x
                x x x x x
              x x x x x x x
            x x x x x x x x x
          x x x x x x x x x x x
Number of tails   0 1 2 3 4 5 6 7 8 9 10
```

Why was it best to use an even number of pennies? Why were you asked to count "tails" only, and ignore "heads?" Could you have done the opposite and been equally effective?

Transfer your results to a sheet of graph paper. You should have something approximating a normal curve. What is a normal curve?

Calculate the total number of single-penny tosses involved in your mass result. Did "heads" or "tails" predominate?

Any deviation from a normal curve is called a skewed curve, and is due to the operation of a warping factor. What warping factor(s) may have been at work here?

Hypothesis:

If it were possible to slice a penny horizontally into a "heads" half and a "tails" half, would the two halves have the same weight? Can you base an answer to this question on an estimate made by simple inspection? Would the age of the penny have anything to do with it? If there were a difference in the weight of the "heads" side and the "tails" side, how would this affect the way the penny falls when tossed? Would the heavier side or the lighter side be more likely to be uppermost when the penny comes to rest? State a hypothesis based on your answers to these questions.

Testing Your Hypothesis:

1. Worn pennies compared to new pennies

   a. Use an even number of pennies (the same number as before). Select the most severly worn pennies that you can find. Toss them the same number of times as before, and record your data in the same way as before.

   b. Use the same number of new pennies; toss them the same number of times as before, and record the data in the same way.

Compare the results of 1.a. and 1.b. Do these results confirm or refute your hypothesis?

2. Taped pennies compared to untaped pennies

   a. Use the same number of new pennies as in 1.b. Put a thickness of masking tape on the head side of each penny. Be sure that the same size piece of masking tape is put on each penny. Be sure also that the tape does not extend beyond the edge of the penny. Toss the pennies the same number of times as in 1.b. Record your data in the same way. Compare with the results obtained in 1.b.

   b. Now add a second layer of tape to each penny, and repeat the experiment. Record your data in the same way. Compare with the results in 1.b. and 2.a.

c. Add a third layer of tape and repeat. Record your data, and compare with 1.b., 2.a., and 2.b.

d. Add a fourth layer and repeat. Compare with 1.b., 2.a., 2.b., and 2.c.

Have you succeeded in warping the "heads-tails" ratio by attaching the tape to the head side? If so, to what extent? Is there any evidence of a progressively increased degree of warping in the same direction? If so, is the change consistent?

Do the results of this series of experiments tend to confirm or refute your hypothesis? Can you arrive at any sort of generalization concerning your results in tossing new pennies and worn pennies; pennies with and without tape; pennies with little tape and with much tape? Try to do so.

Follow-Up:

What kinds of phenomena in biological and physical nature can be described in terms of a normal curve distribution? Can you think of some of these that you might survey or investigate in the laboratory? What about height and weight in adult men and women? In boy and girls of the same age? Any others?

See if you can think of some warping factors that are at work in biological or physical nature. Can you survey the operation of some of these, or try them out in the laboratory? What about degree of cloudiness in relation to temperature in a particular month? What about sex in relation to height in men and women? Any others?

What is the relationship of normal curves and warped curves to the general phenomenon of patterns existing in nature? What other kinds of patterns are there? What kinds of factors produce patterns? What is the relationship of patterns in nature to hypotheses? To natural laws?

LABORATORY EXPERIENCE A.5.b.

Looking for Examples of Patternless Change

Introduction:

What would it be like to live in a world where no one could ever predict what was going to happen next? That would be a world where there were no warping or patterning factors at work, and no natural laws operating. No science fiction writer has ever based a story on such a world, because life on it would be impossible. No life could exist there, not even the life of the humans who landed there. Even the space ship that brought them there would disintegrate The lawless world itself would do so. The ultimate particles of which it was composed would fly apart.

To what extent are we able to predict what is going to happen? Why? On what basis do we do it? What kinds of situations do we find in which we cannot predict? Why?

In this laboratory experience you will have an opportunity to observe an example of change which does not appear to "make sense." What do we mean by "making sense?" See if you can make sense out of what you see.

Materials and Equipment:

Compound microscope

Microscope slides

Cover slips

Medicine dropper

Cake of yeast (Red Star or Fleischman's)

Chalk dust

Collecting Data:

1. Place a piece of yeast no larger than the head of a pin in a drop of water on a glass microscope slide. Tease it out so that the yeast becomes as finely subdivided as possible in the water. Place a cover slip on top of the drop.

2. Look at the preparation under the highest power of the microscope. Note the yeast cells. What do they look like? You will see that they are of different sizes. Are they capable of independent movement? Observe them closely. Do any of them show any kind of motion? Describe any motion that you see. Is the amount of motion in any way related to the sizes of the cells?

3. Place a drop of water on a second slide. Put some chalk dust in the water. Cover with a cover slip.

4. Examine this preparation also under the highest power of the microscope. Look for movement among the particles of chalk dust. Do you see any motion? Is it related to the sizes of the particles?

5. Compare the movement of the yeast cells and the chalk dust particles. What similarities are there? What differences?

6. Try to explain what you have seen in both the yeast cells and the chalk dust particles. Is the movement that you have seen related in any way to life? Why, or why not? To what do you think it is related? What do you think causes it?

7. This kind of movement is called Brownian movement. How would you describe it? Observe it again, closely, both in the yeast cells and in the chalk dust particles. Look at a single cell or particle showing active movement. Can you predict the direction of any of its movements by knowing its previous movements? Are its movements an example of patterned or patternless change? Is the change directional? Is it "getting anywhere?" Is the change cyclic; that is, do the movements constitute a repetition of events in the same order, over and over again? If the various movements could be measured and placed on a graph, would they form a normal curve?

Hypothesis:

Look up the story of Robert Brown, the 18th century scientist who first observed this movement. How did he come to discover it? What hypothesis did he propose to explain it? How did he test this hypothesis? What were his results? What conclusion did he reach? How was his procedure related to the Cycle of Proof? How do scientists explain Brownian movement now? Why is this story a good example of the development of scientific knowldege?

Follow-Up:

Study other examples of change and variation. Look for other examples of patternless change. Observe the movement of the wisps of vapor that make up cumulus clouds in the summer sky. Is the movement of the vapor patternless or patterned. Think about the points of impact of raindrops on a flat surface? Is their distribution patternless or patterned? What about the fall of snowflakes on a windless day in winter, or their movement in relation to one another as they fall? Can you think of any other examples of this kind? Is this kind of change or variation ever related to patterned change or variation? How do you think it might be related?

LABORATORY EXPERIENCE A.5.c.

Emergence of Patterns

Introduction:

Patterns occur both in physical nature and in living nature. Physical nature, however, is generally simpler and easier to study. The laws which describe its behavior are less complex and are more readily understood. In the development of science the laws of physical nature were discovered earlier, and are generally more firmly established. They appear to be more dependable and to operate with fewer or no exceptions.

The behavior of living nature is more complex and more difficult to study. The patterns which exist in it are more complex. The laws describing these patterns must be stated in broader terms. Even then, they are less dependable, and are more likely to allow for exceptions. The laws of physics and chemistry are firmly fixed and well-known, and have been for a long time. The laws of biology and psychology are less well-established, and are more likely to be called into question and made the subject of controversy. In the fields os sociology and history, many people doubt that natural laws exist at all.

Physical laws are dependable and relatively simple because their operation does not involve many variables, and such variables as there are can generally be readily controlled under laboratory conditions. A variable is a factor which varies within definite limits rather than remaining constant. Such factors are frequently involved in the working out of a pattern in nature. More of them are operational in living nature than in physical nature. For example all of the factors of climate (temperature, light, relative humidity, wind movement, atmospheric pressure) behave as variables.

These climatic factors are very important in living nature. In a laboratory situation these factors can be partially or completely controlled. This can be done in the laboratory for the purpose of experimentation in physics and chemistry, or for studying an isolated fragment of living nature (a plant in a flower pot, a cat in a cage, a frog in a terrarium). When living organisms are studied under natural conditions, as in the field, these factors cannot be controlled. Even in a laboratory situation, where living animals are being studied, it is questionable if the laboratory situation itself does not so greatly disturb the animal that other important variables are called into play that we don't even know about.

In the following experience the emergence of simple patterns is apparent in physical nature in one case, and in biological nature in the other case. The biological case involves the more complex situation and the operation of a much greater number of variables. The results are therefore necessarily less precise.

Materials and Equipment:

Iron filings

Magnet

A sheet of stiff paper

Wind-borne seeds: dandelion, milk weed or other (Confetti cut from very thin paper may be substituted if the wind-borne seeds are not in season, or are otherwise unavailable)

An open area: school ground, vacant lot, roadside, railroad right-of way, or other, having a diversity of habitats, and containing a variety of different kinds of plants.

Collecting Data:

1. Scatter iron filings evenly over the surface of a sheet of stiff paper. Hold the magnet against the lower side of the paper. Observe the behavior of the iron filings. What do they do? Does a recognizable pattern emerge from the formerly patternless condition of the filings? Move the magnet around. What happens?

   Repeat the experience several times. Start in each case with the iron filings scattered evenly over the paper. Is the pattern which is formed consistent in every case? Describe the pattern. What causes it? Is there a natural law which describes this phenomenon?

2. Go into an open area containing as wide a variety of habitats as possible: bare ground, grass-covered ground, low weedy vegetation, tall weedy vegetation, et cetera. Choose a time when a moderate breeze is blowing. Too strong a wind will endanger the success of the experience. Set free at head height the wind-borne seeds from the heads of dandelions, the pods of milkweeds, or other available source. (Note: Confetti cut from very thin paper may be substituted). Watch how the seeds are carried by the wind. Follow them as well as you can until they all settle to the ground.

   Locate as many of the seeds as possible, up to 100. Study the spot where each seed fell. How many different kinds of habitats are represented? How many seeds fell on each kind of habitat? Do you think seeds would grow equally well in all of the habitats? Why, or why not? Would they grow in some habitats and not in others? In which of the habitats do you think they would be most likely to grow? Why? Least likely? Why?

   Was there a pattern in the original distribution of the seeds by the wind? If so, on what was it based? Assuming that the seeds would germinate and grow in some habitats and not in others, would there be a pattern in the distribution of the plants that grew from the seeds? What factors would contribute to producing the pattern? Assuming that the situation which you have observed is typical for areas of this kind, could you describe the pattern of occurrence of the particular species of plant you are studying, and give reasons for it?

   Study the actual distribution of the vegetation in the open area where you scattered the seeds. How many different kinds of plants can you find? (Note: You do not need to identify them.) Are they all evenly distributed over the area, or are some of them found in some places, and not in others? Are there any apparent reasons why they are distributed as they are? Is their distribution consistent? Are they always found in the same kinds of places? Are there exceptions? Frequent? Occasional?

Never? How would you account for their distribution? Would you say that there was (or was not) a pattern in their distribution? Why, or why not?

Is there a pattern in the distribution of the different kinds of vegetation occurring naturally (not planted or cultivated) in your locality, or in any locality with which you are familiar? What factors do you think caused this pattern? Is there a pattern in the distribution of different kinds of vegetation in North America? In the world? What is the nature of the pattern? What factors cause it? Are there natural laws that describe the distribution of vegetation? Why?

2. What similarity is there between the portion of this experience dealing with the magnet and the iron filings, and the portion dealing with the wind-borne seeds and the distribution of vegetation? Why?

Hypothesis:

Try to state a hypothesis explaining the distribution of vegetation in nature on the basis of patterning factors. What are these factors?

Follow-Up:

Can you think of other situations involving patterns in nature to which you might apply the same kind of analysis that you have used in the case of the magnet and the iron filings and the distribution of plants? What about some aspects of human behavior? Of the behavior of other animals? What about weather?

LABORATORY EXPERIENCE A.5.d.

Lookings for Patterns in Human Behavior

Introduction:

We depend on patterns in nature. We regulate our lives by them. We cannot imagine what the world would be like without them. We know that they exist, and this knowledge makes it possible for us to face the future with confidence, based on our expectation that past experience furnishes a good indication of what we may expect in the future.

We set up hypotheses based on our past experience, and make these the basis for our actions. We do not call these projections "hypotheses," however. Usually, we do not call them anything, or even realize what we are doing when we make them. We simply act on them without putting them into words or even thinking about them.

When we say, "I think I'll take this letter down to the principal's office before the noon rush starts," or "I think I'd better get started home before the 5 o'clock traffic begins," we are projecting on the basis of our past experience of threading our way through a mass of students in the corridor just before lunch, or our experience with the traffic jam that regularly occurs at the end of the working day. We are acting on the hypotheses that we have made: that people and cars will behave today in the same way as they have in days past when we have been caught in such rushes.

In the laboratory experience which is outlined here, you may or may not discover a pattern. Do not feel that the experience is a failure if no pattern appears. The important thing is that you will be carrying out a procedure like that by which scientists have discovered and described patterns in the natural world. Perhaps if no pattern appears in this case, you may then be able to think up some other situation in which you can search for a pattern.

Materials and Equipment:

Graph paper

Pencil

Ruler

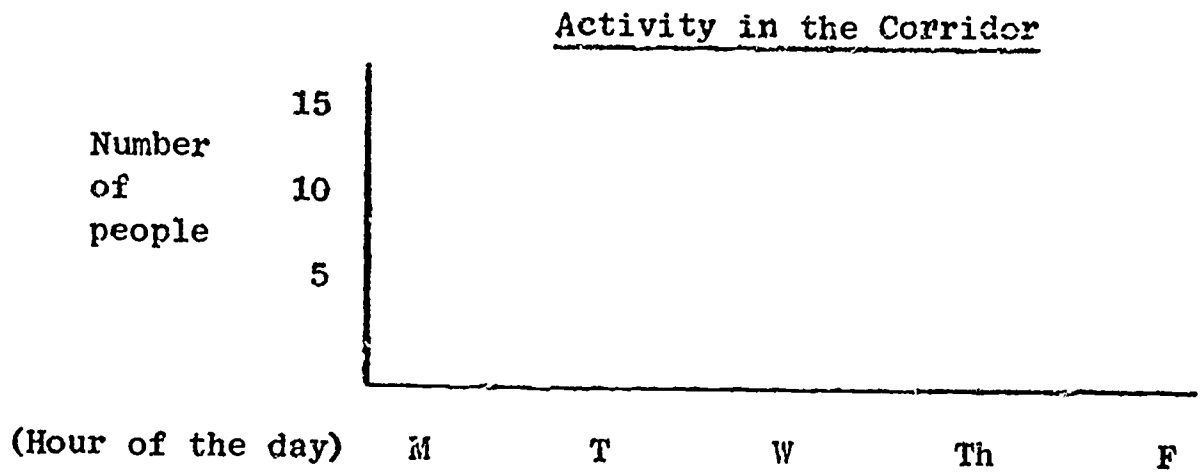
Collecting Data:

This laboratory experience can best be carried out as a class project, with different students being assigned the job of collecting data each day during the three-week period while the study is going on. The graphs on which the data are recorded can be posted in the classroom where the entire class can watch the progress of the study.

1. Select a point in the busiest corridor in the school. Count the number of persons who pass this point at a series of designated times during the school day (e.g., from ten minutes before the end of each class period until the end of the period). If there are too many to count accurately during a particular rush time, such as just before noon, make the best estimate you can.

2. Do this at the same times each day, Monday through Friday, during three successive weeks.

3. Record the data for each particular time of day, through each week, on a graph:



Hypothesis:

Is there a pattern? If so, why do you think it exists? If there is no pattern, why do you think there is none? Set up one or more hypotheses to explain what you have found. Through class discussion select what you believe to be the best hypothesis.

4. Test your hypothesis by continuing your observations on the same basis for one or two additional weeks. If you consider it desirable to collect data concerning environmental conditions, or anything that you think might have been responsible for either the presence or absence of a pattern in your findings, do so.

5. Do your further studies support or refute your hypothesis? Test it further if you wish to do so.

6. Draw a conclusion, or decide that you cannot do so because of lack of sufficient data, lack of sufficient time to test further, or any other reasons.

Follow-Up:

Set up a study of the movement of automobiles and other motor vehicles past a particular point on a street or highway. Use the same type of procedure that has been suggested in looking for a pattern in the movement of persons in a school corridor. Here again, set up and test hypotheses, and try to draw conclusions. (Note: This may be used as a parallel experience to be carried on by one group of students while another group are doing the study of movement of people in the school building.)

IDEA-CENTERED LABORATORY SCIENCE

(I-CLS)

Unit A. How a Scientist Learns About His World

TEACHER NOTES

Wm. C. Van Deventer
Professor of Biology (Science Education)
Western Michigan University
Kalamazoo, Michigan

Lucille Duyser
Middle School Science Consultant
Grand Rapids Public Schools
Grand Rapids, Michigan

1969

I-CLS

Unit A. How a Scientist Learns About His World

TEACHER NOTES

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LABORATORY EXPERIENCE A.1.a.

Collecting Observations

TEACHER NOTES

You may use any piece or pieces of laboratory equipment for observations: equipment for distillation, weather instruments such as a barometer, thermometer, model anemometer. Any of these would be excellent.

A plant or an animal would be interesting.

Another possibility is to plan beforehand to have another teacher send a student to your room, and direct him to ask in a loud voice for something. After he has left, ask students to describe him in detail and tell what he did. Discuss relevant and irrelevant details in such a description.

LABORATORY EXPERIENCE A.1.b.

Thanitol: Using Your Sense of Smell

TEACHER NOTES

This laboratory experience is an exercise in objectivity and tentativeness. "Thanitol" is actually nothing but a solution of red ink in water. The teacher should prepare it well ahead of the class meeting, and if possible, should bring it into the room after the class has assembled. He should set it on the desk or table in full view of the class.

When the teacher opens the vial or bottle, he should bring it near to his nose, sniff it gingerly, possibly passing his hand across the open top, and wafting the odor to his nostrils. He may grimace slightly as he does so. (Presumably, he smells a strong acid odor.)

The teacher should hold the open vial in front of him, at some distance from his body, for approximately five minutes. He should tell the students that when (and if) they detect an odor, they should raise a hand, and write down whether they smell sweetish, acid, or some other odor. The teacher should remind them that some people may not smell anything. If this is true in their individual case, it should be recorded also.

The teacher should record the number of students who detect a sweetish odor, the number who detect an acid odor, those who detect an odor of some other kind, and those who smell nothing at all.

After these data are summarized, the teacher should open the vial or bottle, and place it on the desk or table. He should invite all students to come forward and smell it at close range.

In connection with this closer examination, some doubts may arise as to whether the red solution actually possesses an odor or not. The teacher should allow this discussion to continue, without forcing a conclusion. If the true nature of the laboratory experience has not been arrived at by the students by the end of the first period, the teacher, at the beginning of the following period should make up a new solution of "thanitol" in sight of the class, and explain that the experience was based on a deliberately prepared olfactory illusion.

LABORATORY EXPERIENCE A.1.c.

Jingling Pennies

TEACHER NOTES

With a little imagination various examples of auditory illusions can be set up, and the relative accuracy of auditory judgments can be tested. Practicing ventrioloquism can be fun and good experience. Try it yourself, and then, whether you can do it or not, let the students try it. See how accurately you or the students can locate a sound made in the hall, or otherwise outside the classroom. Put various small objects, one at a time, in a box (such as a shoe box), and see if the students can determine the nature of the object from the sounds made by moving it around in the box.

The basic function of this laboratory experience is to give students an opportunity to test the accuracy of their auditory observations. How do they compare in accuracy to other sensory observations?

LABORATORY EXPERIENCE A.1.d.

Sharpening Observational Skills

TEACHER NOTES

This is an excellent opportunity to introduce the skill of using the microscope. Other objects such as hairs may be examined also. If hairs from different individuals are examined, compare blonde hair with brunette hair, boys' hair with girls' hair, fine hair with coarse hair, curly hair with wavy hair and straight hair. Many interesting details will be observed.

The teacher should not allow the class, however, to become "sidetracked" from the real objective of this experience, which is to recognize that while instruments serve to sharpen the scientist's powers of observations, any increase in degree of magnification serves to bring out some details, but at the same time obscures others.

LABORATORY EXPERIENCE A.2.a.

Seeing Problems in a Recurrence

TEACHER NOTES

The teacher will do well to read any available material in books on botany and plant physiology dealing with: (a) what substances constitute the basis for leaf coloration, and the changes which take place in it in the fall; (b) what is the physical mechanism of leaf fall, and (c) the effect of light, the shortening of the days, the lowering of temperature, and the scarcity of available moisture on leaf fall. Some knowledge of these relationships on the part of the teacher will be helpful in connection with this laboratory experience. Nothing about it, however, is inherently difficult, and it can be done by the children with no special help from the teacher, and no special equipment. It is an exercise in observation of relationships, and in logical thinking.

LABORATORY EXPERIENCE A.2.b.

Seeing a Problem in a Discrepancy

TEACHER NOTES

You will need four plants of the same kind, but not necessarily of the same stage of growth. Three of them must be as nearly erect as possible. The fourth must be asymetrical, showing some evidence of phototropism. They may be moved into the laboratory from wherever they have been growing. The laboratory experience does not involve watching them grow.

The students will at first be looking for big differences. You may find it necessary to direct their attention to small differences. In any case be sure that they become aware of small differences. You may also need to direct their attention to various kinds of differences.

It must be remembered that this is an experience in observation, not in botany.

LABORATORY EXPERIENCE A.2.c.

Seeing Problems Under a Microscope

TEACHER NOTES

Once students learn to use a microscope, they like to "play" with it. This is excellent experience for them if they do it properly. Looking at their own hair is a natural, spontaneous thing to do. They will often do it "on their own" if they are let alone.

All that this laboratory experience does is to channel this natural curiosity, and make a directed inquiry experience out of it. Improvement in the skill of using the microscope is incidental to this experience but very real.

Furthermore, this is an open-ended experience from your standpoint as well as from that of the students. You may carry it as far as their interest and yours may make it desirable to carry it.

LABORATORY EXPERIENCE A.3.a.

Flipping Coins

TEACHER NOTES

When a coin is tossed or "flipped" there is an equal chance that it will fall either "heads" or "tails", unless some factor having to do with the coin itself, or with the way it is tossed or flipped, warps the result. Each separate fall is an independent event, not being influenced by the result of any prior fall.

It is probable that the "head" side of a penny, at least when it is new or unworn, is very slightly heavier than the "tail" side. This would serve to make the coin fall more frequently "head down" than "tail down." This tendency might become apparent, however, only in the case of as many as 1000 flips or tosses.

The Law of Probability is the mathematical expression of what is commonly called "chance." One of its common expressions is a normal or bell curve. Many things in nature, when measured, exhibit this type of expression. People's height and weight, scores on intelligence tests and other types of tests, sizes of seeds and other natural objects are examples.

Firm results are not possible in this laboratory experience. The sizes of the samples examined are not large enough in any case to support reliable conclusions. The students will set up and test a wide variety of hypotheses. Even though most of these will lead to nothing, students should be given free rein. The experience is one in scientific methodology, not an attempt to discover or verify a set of facts. Sometimes it is possible to see a trend or suggest the presence of a particular warping factor when the results of the entire class, or of several classes, are combined. Even in such cases, however, the nature of the trend may vary from one occasion to another. Consistent results should not be expected.

LABORATORY EXPERIENCE A.3.b.

Guessing and Measuring

TEACHER NOTES

The function of this laboratory experience is to give the student an opportunity to understand the relationship between guesses and estimates. Unless one flips coins or throws dice as a means of choosing an answer, there is really no such thing as a guess. Nearly all so-called guesses are really hypotheses based on the best evidence we have, whether this be much or little. A decision based on very limited data may even be arrived at subconsciously. We tend to use the word "guess" in cases where we feel that the data on which we are basing our decision are so scanty that our proposed answer is too precarious and inadequate to justify any degree of certainty.

Students may profitably discuss this relationship, and their own use of the word "guess." They may come to recognize that most of their so-called "guesses" are actually hypotheses.

In this laboratory experience the testing of the hypothesis takes place when some type of quantitative trial or determination is applied: when BB's are dropped into the water and counted; when an actual measurement is made; when the span of time is checked with a stop watch.

The conclusions which are reached as a result of the experience as a whole have to do with the inadequacy of human judgments, when unsupported by quantitative data. Possibly, as a side issue, individual differences in the accuracy of the estimates that people make may furnish an interesting conclusion. A pattern may or may not be apparent among the cases that are examined.

LABORATORY EXPERIENCE A.3.c.

You Touched Me----Where?

TEACHER NOTES

The differences in touch-sensitivity in different areas of the body are due to the distance apart of the pressure-receptors (sense organs of touch) in the skin. In general, they are closer together in those portions of the body surface which are most likely to come in contact with new aspects of the environment as the organism moves forward. This means generally the face and front of the body. The face is the most sensitive area because of the ancient orientation of the body in the four-footed animal with the head thrust forward, encountering new aspects of the environment first. In the human the hands can become highly touch-sensitive because of their role in exploring the environment and using tools and other devices.

This emphasis on touch-sensitivity in those areas which first make contact with new aspects of the environment is a result of evolutionary adjustment. The individuals which had a more sensitive touch mechanism in those areas were more likely to be warned of danger, and to collect data which formed a basis for making decisions (of withdrawing, of turning aside, of going forward) which led to survival. Therefore, they left descendants in more cases than those individuals which lacked such sensitivity.

LABORATORY EXPERIENCE A.4.a.

Do You Believe in ESP?

TEACHER NOTES

Theoretically, it should make no difference whether an increase in the number of runs is achieved by consideration of a series of great many runs carried on by the same person, or by combining the results of a large number of single runs carried on by the members of a large group, such as the students in a class.

If both of these methods of achieving an increase in the number of runs are used, and the results of the two methods are compared, the possibility of discovering the operation of a warping factor in the guesses of a single individual can be investigated. Each individual in the group can be detached from it and studied in this way.

If such a warping factor appears to be operating in the case of one or more individuals, the case for or against its existence can be tested by greatly increasing the number of runs for these individuals. If no warping factor is operating, the results would be expected to revert to chance expectation when this is done. If chance expectation fails to appear eventually, then the case for the existence of a warping factor is greatly strengthened.

The nature of such a warping factor, if one appeared to exist, would, however, still not be ascertainable.

LABORATORY EXPERIENCE A.4.b.

Unidentified Flying Objects (UFO's)

TEACHER NOTES

In teaching this laboratory experience, you yourself must read the suggested materials, and make up your own mind objectively and tentatively with regard to belief or disbelief in the phenomena being considered. Many people have strong prejudices with regard to UFO's, and even stronger prejudices with regard to poltergeists and other psychic phenomena. You may be one of these.

The materials for this laboratory experience were chosen because of the strong prejudices that they excite. If you and/or the students can be objective and tentative with regard to these phenomena, you and they probably can be objective with regard to other controversial things and issues.

LABORATORY EXPERIENCE A.4.c.

Science-in-the-News

TEACHER NOTES

This is a laboratory experience in the development of an attitude of objectivity, which is a behavioral characteristic that scientists cultivate in themselves. Reading and evaluating any kind of news involves practicing this attitude. This is true of national and political news and of international news. Learning to read science news and evaluate it objectively, furnishes a good basis for reading and evaluating all other kinds of news.

A valuable experience for students is to watch a teletype work. It would be well if a field trip could be arranged for the class to see how the news comes in and is dealt with. Newspaper plants, and radio and television stations are places where these machines are in use.

Work with science-in-the-news can be made the basis for weekly reports and other class activities. Teachers must feel free to exercise a high degree of originality and creativity in working with this experience.

LABORATORY EXPERIENCE A.4.d.

Reading Science Fiction

TEACHER NOTES

The teacher will need to become somewhat familiar with the literature of science fiction in order to teach this laboratory experience effectively.

If you are not already a reader of science fiction, start in the same way that the students are asked to start, by reading a limited number of selected stories. Try different authors, and different types of stories. Read into the history of science fiction as the students are asked to do. Keep abreast with or beyond the reading experiences that the students are having.

Your success (and that of your students) with this experience will depend in large part on the extent to which you (and they) become interested in it. Can you cultivate objectivity in your evaluation of science fiction? If you can, they are more likely to develop it.

LABORATORY EXPERIENCE A.5.a.

Patterning in a "Population" of Simple Events:

Normal Curves and Warping Factors

TEACHER NOTES

Do not expect firm conclusions to emerge as a result of this laboratory experience. Too many variables are involved in the working out of it (how the pennies are thrown, the height to which they are thrown, the surface on which they fall, their age and/or degree of wear, and probably other factors). In any case, the number of flips is not enough to furnish an adequate statistical sample. The students should not be led to expect firm conclusions, and they should even be shown the necessity of tolerating contradictory results if these are indicated.

The value of the experience lies in the fact that normal and/or skewed curves will result, and students will have an opportunity to study them and form and test hypotheses for explaining their behavior. This is a simple example of patterning, and an understanding of the relationship of hypothesis-formation to the operation of patterning and warping factors should result from it.

LABORATORY EXPERIENCE A.5.b.

Looking for Examples of Patternless Change

TEACHER NOTES

This laboratory experience affords an opportunity to present a simple case study of the operation of the Cycle of Proof, and the Principle of Tentativeness, drawn from the history of science. Students should look up data on "Robert Brown," and "Brownian movement" in a good encyclopedia. This should furnish all of the information necessary for their consideration of the case. If you wish to go into the Kinetic-Molecular Theory, you should feel free to do so, but this should be done by way of verbal presentation, with careful explanation, and ample opportunity for student questions.

LABORATORY EXPERIENCE A.5.c.

Emergence of Patterns

TEACHER NOTES

The nature of variables, and their relationship to the firmness, dependability, and occurrence of exceptions in the natural laws of the physical, biological, and social sciences, is an important concept, but one that will require thorough discussion, with ample opportunity for student discussion and questions. This may be done at any time, before the laboratory experience, during it, or following it.

If confetti is used in place of wind-borne seeds, you should experiment with it yourself before you use it with the class. Factors making for success in its use have to do with (a) the weight of the paper, and (b) the size of the pieces. Try different weights and sizes. Wind-borne seeds in nature are light enough to float or be carried in the air under almost windless conditions. This characteristic has been survivable for them. The confetti, however, will require a fair breeze to distribute it.

LABORATORY EXPERIENCE A.5.d.

Looking for Patterns in Behavior

TEACHER NOTES

Because of the nature of this experience, it is possible to carry it on, both in its "corridor" form and its "street" form, while other work is proceeding in the classroom. This makes possible continuing it for a long enough period (three weeks) to obtain sufficient data to permit the drawing of fairly firm conclusions. In this way it is even possible to carry on the observations for two or three additional weeks to further test the original hypothesis, or collect information on additional hypotheses if this is desired. A few motivated students may wish to do this, and should have an opportunity to do so.