PROBLEM-SOLVING ABILITY, FROM A PIAGETIAN PERSPECTIVE, IN COLLEGE BIOLOGY LABS USING A PROCESS MODEL APPROACH

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Biography

The author is a graduate student completing a Master's degree in Biology. He attended Appalachian State University 1968- 1973 to obtain the Bachelor of Science- High School teaching certificate. His plans are to continue research in cognitive development while pursuing a doctoral degree in science education. Mr. Helseth and his wife, Debra Hardin Helseth, live in Boone, N. C.

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Abstract

This study analyzed the intellectual operations used by 30 female college students to solve Piagetian-styled problems in an open-ended biology laboratory. A process model approach was developed and used in order to compensate for motivation and other variables not considered by product model approaches. Subjects in this study were: (a) more capable of controlling than combining variables; (b) consistently more capable of combining variables when the variables had been identified and when there was no interaction of independent variables; (c) inconsistent in demonstrating formal-operational thinking ability.

Problem-Solving Ability, from a Piagetian Perspective, in College Biology Labs Using a Process Model Approach

Research applying Piagetian theory to high school and college instruction is not plentiful. Lawson and Renner (1975) found a significant relation between levels of student thought (partitioned into seven levels from concrete IIA to formal IIIB) and success on a paper-and-pencil measure of problem solving in science. The strategy of this and other investigations (Renner and Stafford, 1973; Renner and Lawson, 1973; Lawson and Blake, 1976; Renner, 1977; Lawson, 1978) was to classify students into some developmental stage, using a Piagetian task as the measure, and correlate this with other measures of performance. There are two areas of potential difficulty in such a strategy: the measure of intellectual development and the measure of performance.

Many investigators fail to clarify the assumptions made in assigning students to intellectual stages. Often the first assumption is that there can be a large number of stages within the stages identified by Piaget. In this study of college students classification is limited to the stages IIB, IIIA, and IIIB and there are no intermediate stages between these. Investigators have frequently used the name "transitional" for an intermediate stage between Substage IIB and Substage IIIA, and other substages, as a means of classifying those students that are not operating at the formal level nor the concrete level of thought. A second assumption is that students using formal operations are at the stage of formal thought. A distinction must be made between students at the stage of formal thought and students that use formal-operational thought processes. Those students that consistently use formal operations within a combinatorial system employing reflective thinking processes are at the level of formal thought. There is a transitional period, not a stage or level of thought, that exists when the student's intellectual structure primarily consists of concrete operations and a few formal operations. Such students in a transitional period can appropriately be called transitional students.

The operations a students can use must be determined before either a concrete or a formal level of thought can be assigned. It is necessary that the investigator have valid measures that can be used in complex situations. In such situations, the investigator is forced to use a process-oriented research design rather than a product design which is concerned with only the input (measure of intellectual level) and the output (measure of problem-solving ability) with no thought as to what went on in between. A process model, which allows for the effects of major variables influencing the student's use of a mental operation, is necessary to understand student performance in a problem-solving situation.

Research in complex situations often prevents any attempt to compensate for the effects of uncontrolled variables because the variables studied would be affected by the researcher's attempt to control the environment. This study was conducted in such a way that the instructional goals of the course were not altered and the only change was to require the students to work individually rather than in small groups of two or three studetns. The investigator has designed a method of evaluation that has provision to compensate for any major effects due to extraneous influences that may enter the open-ended laboratory.

The process model is a theoretical sequence of steps that students must take logically in problem-solving situations. If the student is to succeed in solving the problem there are four questions that must be answered affirmatively by the researcher. These questions are presented as a process model in a flow chart, Figure 1. Each Step of the model allows one to assess the progress of the students in solving a problem by observing how much of the problem-solving process the students completed. The rationale for dividing the problem-solving process into four steps was twofold: the sequence of questions seemed appropriate to show the events that arise when a student is asked to solve a problem; secondly the model provided the investigator with a tool to assess problem-solving ability in the open-ended laboratory where the effects of variables present could not be controlled.

Insert Figure 1 here

Steps A through D of the model should be independent measures of ability though some situations will not allow this condition to be met. When independent measures can be obtained for each of the steps then Step A can be prerequisite for any of the following Steps B, C, or D. Step A is essential in evaluating a student's ability to solve a problem. That the student does not attempt the problem is not proof that the student does not possess the ability to solve the problem. Motivation may be lacking, or the student may not understand the problem and may therefore make no attempt to solve it. No attempt is defined as the student has the opportunity to try the problem but turns in a blank sheet for the problem. Step B allows one to compare problem-solving ability in the present situation with a similar situation requiring the same mental operation. This step also provides a measure of consistency in different problem-solving situations; an important observation if the student is to be classified as formal-operational.

Step C is a measure of how well students understand the application of an operation. If the measure presents the student with an unfamiliar situation can the student make the transformation necessary to apply the mental operation? This step can measure motivation as well as ability. If the problem demands that the student spend a great deal of time and effort, using the required mental operation, does the student choose a less appropriate procedure to solve the problem simply because it is shorter? Does the procedure show that the student realized all possible, and appropriate, conditions that could exist in the problem and made the necessary provisions for them in solving the problem? Step D measures the ability to execute the mental operation. It can indicate whether the mental operation has been recalled from past experience and applied without understanding its significance in solving the problem or has been properly applied in solving the problem. This step can distinguish between the student that makes a logical error or a manipulative error. The former indicates that the student cannot perform the required operation but the latter does not imply the same inability.

Method

Subjects. The subjects of this investigation were 30 female students enrolled Fall semester, 1977, in Biology 1107, an introductory course designed for elementary education majors at Appalachian State University. Sixty students were taking the course but only 30 completed all of the measures used for evaluation. Only the laboratory sections of the course were used for evaluation since the open-ended structure of the laboratoty would allow the exercises to be conducted as closely as possible to "real" problem-solving experiences.

<u>Procedure</u>. The laboratory exercises for the introductory biology course are process oriented, having as their main objective to develop and encourage the skills of investigating biological systems and the problems that arise. Many of the exercises involve group work which does not allow the investigator to identify individual effort, a prerequisite for evaluation by the process model. Consequently the three labs chosen, in which individual effort could be identified, required the students to make decisions concerning the procedure that they would use and also to employ some thinking at the formal level.

The first lab entitled "Plant Hormones" asked the students to design an investigation that would determine the effect of a plant hormone on the growth of plants they were growing. With a minimum of information about plant hormones and how to apply the hormone, the student was required to write a procedure for solving the problem and turn in a carbon copy to the instructor before proceeding further. This carbon copy, called the "Design Sheet," was used as a measure of the student's ability to control variables. The second lab, "Movement of Insects," required the student to choose or modify the procedure given to show how temperature and another variable (light, moisture, or density) would affect the movement of insects. Control of variables and interaction of variables were the major operations measured by the Design Sheet in this exercise. The third lab, "Growth of Bacteria," required both control of variables and combination of variables when the students were asked to make culture media with various chemicals added to see whether the chemicals would retard or accelerate the growth of airborne bacteria. A Design Sheet and a "Prediction Sheet," which asked the student to make logical conclusions from data similar to that which she might get, were used to determine the students' problem-solving ability. Another measure of thinking ability used, besides the Design and Prediction Sheets, was the lab report of the student's results. With the exception of the lab on insect movement the lab reports were not turned in during the lab period in which the exercise began. Thus this measure was essentially usable in only one lab.

A "Lab Skills Test" was given at the end of the semester as an instrument designed to measure some of the thinking skills needed in the laboratory. The Lab Skills Test included measures that were designed to assess the student's ability to control variables, combine variables perform ratio and proportion problems, use propositional logic, understand a syllogism, and conserve volume. Another measure included in the Lab Skills Test to assess the student's ability to combine and to control variables was the "Worms Problem" (Renner, 1977, p. 57) where the student had to make a conclusion about how worms respond to light and moisture using the information given in four diagrams. The Worms Problem also required the student to suggest any other ways to test the worms' response to light and moisture.

The Lab Skills Test was used to determine the number of students in each of the categories: formal students, those students that were successful on all items and used formal operations to solve the problems; transitional students, those students that were successful on some measure(s) that required formal operations to solve the problem; concrete students, those students that failed all measures which required formal operations to solve the problem.

Each measure was given equal weight in the scoring procedure. The criteria used for assigning scores was that a <u>one</u> was given when the student demonstrated the ability to use the required operation, a <u>zero</u> when the student failed to use the required operation successfully, and a <u>blank</u> when the student did not attempt the measure.

The score for each of the six measures obtained from the laboratory exercises was summed to give the lab score. The six scores for the Lab Skills Test measures were added to give the lab skills test score. The same procedure was used to obtain (a) combination of variables scores for the measures in the laboratory exercises and for the measures in the Lab Skills Test, (b) control of variables scores for the measures in the laboratory exercises and for the measures in the Lab Skills Test.

Applying the process model. If the process model is to be used as a tool for comparing problem-solving ability in different situations, there are several conditions that must be understood. First, one should have reliable independent measures for Steps A through D. Second, when the model is used in other areas of research the measures used for each step of the model can vary with the type of investigation. Frequently the same instrument can be used for one or more steps of the model. Third, when the model is used to compare performance in two situations it is possible that a student may fail in the first situation yet succeed in the second. If the measures used are reliable one would not expect a student to fail using a mental operation and then succeed in another situation requiring the same operation. In this investigation Step A and Step B were used in one problem-solving situation while Step C, D, and E were used as measures of ability in a similar situation. Students that failed Step A yet succeeded in the other situation may not have been motivated to try nor understood the first problem. Those students that failed Step B but succeeded in the other situation are called reversals. The inconsistency of reversals suggests they have not mastered a formal operation and are not capable of applying it in different problem-solving situations. Thus there is an apparent reversal of ability to use formal-operational thought processes. However, the inconsistency may be a product of factors influencing performance other than ability.

Due to the structure of the laboratory exercises used for this study it was not possible to obtain independent measures for Step D. The investigator made the assumption that when a student used the required mental operation in solving a problem that was sufficient proof to indicate that the student saw the need to use the required mental operation. This assumption allowed the investigator to combine Step C and Step D into a single Step CD and to use one measure of problem-solving ability for the second situation.

The measures used to assess the student's thinking ability in different situations are given in Table 1. These measures are classified by the mental operation evaluated in both situations, laboratory exercises and Lab Skills Test.

Insert Table 1 here

Results

The lab skills test scores showed that 3.3% of the students were formal students, 3.3% of the students were concrete students, and the remaining 93.3% of the students were transitional students. Of the 93.3% transitional students 66.7% of them succeeded on three or more of the Lab Skills Test measures. With such a large number of transitional students one must use a process model approach to examine the student's problem-solving ability.

The Cochran Q Test was used to determine whether the probability of success in each situation was equal to chance or whether the probability of success in each situation differed according to problem-solving ability and other factors (Siegel, 1956, p. 161). The value of Q for situations 1, 2, 3, and 4, $Q(3) = 34.43$, $p < .0001$, and for situations 5, 6, 7, 8, 9, and 10, $Q(5) = 49.68$, $p < .0001$, are significantly different from chance; the alternative hypothesis must be considered.

A product model approach frequently uses the Pearson product-moment correlation as a measure of association. The correlation values between the lab skills test scores and the lab scores using a product model approach are given in Table 2.

Insert Table 2 here

The correlation values obtained by the product model approach indicate that success in each situation did not depend upon problem-solving ability and other factors but instead upon chance alone, $df = 29$, $p < .05$. Since a product model approach is not concerned with the affects of other factors upon performance one should not be surprised that the correlation values are small. Results of the Lab Skills Test and the Cochran Q Test both indicate that problem-solving ability should be assessed by a process model approach.

A process model approach compares thinking ability demonstrated in Step B with that in Step E; while a product model approach compares the performance in Step A with Step E. Figure 2 shows the progress of the 30 students in the different problem-solving situations when the process model is used to assess the student's ability to combine variables.

Insert Figure 2 here

Figures 3 and 4 show the progress of the 30 students in the different problem-solving situations when the process model is used to assess the student's ability to control variables. In Figure 3 the Lab Skills Test problem reqiured the student to control one variable and provide an explanation of the solution. In Figure 4 the Worms Problem of the Lab Skills Test required the student to control two independent variables and the interaction between them. The Worms Problem also required the student to provide any other tests that might solve the problem.

Insert Figure 3 here

and

Figure 4 here

Table 3 contains the correlation values obtained when the process model approach compared the student's problem-solving ability in the laboratory exercises with the Lab Skills Test measures. Only the measures in Situations 1 and 5 were not significantly different from chance in showing the relation between the student's problem-solving ability in the laboratory and the testing situations.

Insert Table 3 here

Discussion

The purpose of this investigation was not to classify the student's level of thought as formal or concrete but to determine the student's problem-solving ability. This distinction brought about the necessity of studying the mental processes the students used in solving problems, and finding a means of assessing those processes.

When students are consistent in demonstrating an ability to use formal-operational thought processes and the measures used to assess thinking ability are reliable, then a product model may be the appropriate approach. If, as in this investigation, students are not consistent in demonstrating ability to use formal-operational thought processes, then an alternative approach must be used. A process model approach can be used successfully in complex environments such as the open-ended biology laboratory, where students have many procedural options and tend to be inconsistent in using them.

The students' problem-solving ability can be understood best by analyzing their ability to use the formal operations combination and control of variables. The investigator found that the students were more capable of combining variables when the variables had been identified for them (r= .793 compared to .459, Table 3). They also were more capable of controlling variables than combining variables. When the problem required only control of variables the students were more capable in solving the problem than when there was an interaction of independent variables in addition to controlling variables (r= .905 and 1.00 compared to .458 and

.498, respectively, Table 3).

The process model approach provides the investigator with the following observations about the student's ability to consistently use the operation control of variables: (a) at least 16 of the 30 students used control of variables consistently; (b) at least 8 of the 30 students used control of variables when there was an interaction of the independent variables. The number of students classified as reversals was much higher when the Worms Problem was used as the measure for Steps A and B than when the Lab Skills Test problem for control of variables was used as the measure for Steps A and B. The Lab Skills Test problem for control of variables required the students to do less to solve it than the Worms Problem required for success; thus the Lab Skills Test problem proved to be a better measure of ability to control variables. The number of reversals was smaller when the Lab Skills Test problem for control of variables was used to assess problem-solving ability than when the Worms Problem was used. Theoretically the number of reversals should be zero when one uses reliable independent measures for comparing problem-solving ability. In this study there were three students that were classified as reversals for the situations which required control of variables. These students succeeded in solving the Worms Problem, which required more effort, yet failed the Lab Skills Test problem which has been determined to be the better measure of ability. They also succeeded on a majority of the other measures of problem-solving ability. The investigator feels that the factor of motivation is responsible for their failure on the simpler measure of ability to control variables, although there may be additional factors.

Obviously the information gained by using a process model approach provided the investigator with a better understanding of the student's problem-solving ability, from a Piagetian perspective, than could have been provided by a product model approach.

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Table 1

Problem-Solving Situations Classified by the Mental Operation Evaluated by Each Measure

Situation		Mental operation: Measure used
		Combination of variables
1	Laboratory	Insect Movement lab report
2	Laboratory	Growth of Bacteria Design Sheet
3	Test	Lab Skills Test problem
4	Test	Lab Skills Test Worms Problem
		Control of variables
5	Laboratory	Insect Movement lab report
6	Laboratory	Growth of Bacteria Design Sheet
7	Laboratory	Growth of Bacteria Prediction Sheet
8	Laboratory	Plant Hormone Design Sheet
9	Test	Lab Skills Test problem
10	Test	Lab Skills Test Worms Problem

Table 2

Correlation Between Student Thinking Ability in Problem-Solving Situations Using the Product Model

Situations			
Laboratory		Test	Correlation
Mental operation: Combination of variables			
(1+2)	and	(3+4)	.23
Control of variables			
(5+6+7+8)	and	(9+10)	.26

Table 3

Correlation Between Student Thinking Ability in Problem-Solving Situations Using the Process Model

Situations			
Laboratory		Test	Correlation
		Mental operation: Combination of variables	
1	and	3	.203
2	and	3	.793[a]
1	and	4	.351
2	and	4	.459[a]
		Control of variables	
5	and	9	.101
6	and	9	1.000[b]
7	and	9	1.000[b]
8	and	9	.905[b]
5	and	10	.119
6	and	10	.459[a]
7	and	10	.459[a]
8	and	10	.498[a]

[a] df= 29, $p < .05$

[b] df= 27, $p < .05$

Figure Captions

Figure 1. A process model for problem-solving situations.

Figure 2. Number of students at each step of the process model in situations requiring combination of variables.

Figure 3. Number of students at each step of the process model in situations requiring control of variables.

Figure 4. Number of students at each step of the process model in situations requiring control of variables.

Step A--	Will the student(s) attempt the problem? *	Yes ( ) →	No ( )
Step B--	Can the student(s) perform the mental operation(s) required to solve the problem?	Yes ( ) →	No ( )
Step C--	Did the student(s) see the need to use the required operation(s) to solve the problem?	Yes ( ) →	No ( )
Step D--	Was the mental operation used properly to solve the problem?	Yes ( ) →	No ( )
Step E--	Student(s) solved the problem.	Yes ( )	No ( )

* Step A can be prerequisite for any of the Steps B, C, or D, when they are independent measures. Any path taken by students other than those shown by arrows, or dealing with Step A, are called reversals.

Success		Steps of process model in			
		Test		Lab	
		A →	B →	CD →	E
	Situations	3	3	1	1
Yes		30 →	19 →	2 →	2
No		0	11	17	28
	Situations	3	3	2	2
Yes		30 →	19 →	16 →	22[a]
No		0	11	3	8
	Situations	4	4	1	1
Yes		30 →	11 →	2 →	2
No		0	19	9	28
	Situations	4	4	2	2
Yes		30 →	11 →	8 →	22[b]
No		0	19	3	8

Reversals: a 6 from Step B

b 14 from Step B

Success		Steps of process model in Test: A	→ B	Lab: → CD	→ E
	Situations	9	9	5	5
Yes		28 →	22 →	1 →	1
No		2	6	21	27
	Situations	9	9	6	6
Yes		28 →	22 →	16 →	22[a]
No		2	6	6	6
	Situations	9	9	7	7
Yes		28 →	22 →	17 →	22[b]
No		2	6	5	6
	Situations	9	9	8	8
Yes		28 →	22 →	16 →	21[c]
No		2	6	6	7

Reversals: a 5 from Step B

b 3 from Step B

c 4 from Step B

Success		Steps of process model in			
		Test		Lab	
		A →	B →	CD →	E
	Situations	10	10	5	5
Yes		30 →	11 →	1 →	1
No		0	19	10	29
	Situations	10	10	6	6
Yes		30 →	11 →	8 →	22[a]
No		0	19	3	8
	Situations	10	10	7	7
Yes		30 →	11 →	8 →	22[a]
No		0	19	3	8
	Situations	10	10	8	8
Yes		30 →	11 →	10 →	21[b]
No		0	19	1	9

Reversals: a 14 from Step B

b 11 from Step B

Appendix A

The laboratory procedures given to the students:

Plant Hormones	1 sheet
Insect Movement	4 sheets
Growth of Bacteria	2 sheets
Growth of Bacteria Prediction Sheet	1 sheet

Bio. 1107 Lab. PLANT HORMONES

Problem: To determine if a given plant hormone has any effect on the rate of growth of plants.

Materials:

Assorted seeds, soil, containers hormone paste(to be applied after the seeds have started growing).

Procedure: Each individual student should outline the procedure that they will take to solve the problem. You can change your mind later if during the experiment you see some trouble with the procedure that you outlined.

Using carbon paper, write down each step that you will take to answer the problem presented in the lab. Number each individual step that you take.

Describe how you will collect the data and how you will analyze the data in order to answer the problem.

After you have outlined the procedure that you will take, turn in one of the carbons to your instructor and get the materials to set up the investigation.

You should turn in individual sheets on how you think you will solve the problem but you can work in groups of two to carry out the investigation.

General Prodedure

On another sheet is the statment of the problem which you will be working with. Since there are 3 or 4 different kinds of problems students will be working with and there are many acceptable ways of doing each problem, don't be concerned if your neighbor is doing something different from you.

1. You should think about the problem assigned to you and figure out the best way of finding out the answer. Some of the procedures suggested in the lab report will be applicable to your problem and others will not.
2. On the lab sheet (the sheet with the problem on it) list the steps that you plan to take in order to get an answer to the problem. If you are going to follow procedure A, for example, you should only list "Procedure A" on the paper and the reason for doing it.
3. If you do something not in any of the procedures, please list that. I would like a written account of how you went about investigating the problem given to you.
4. You do not have to outline the whole prodedure before you start. You may want to start on something and then figure where you go from there after you have done the first part.
5. You should collect data, put it into a chart or graph and come up with an answer to the problem based on the data that you collected.

6. Work individually, not in groups, and hand in a lab report at the end of the period.

Bio. 1107 MOVEMENT OF INSECTS AND PHYSICAL FACTORS

Introduction: Insects are cold-blooded and will be active when it is warmer becoming less active when it gets cooler. Other physical factors such as light, moisture, and density may also have an effect on the movement of insects as well as temperature. In this lab you are to carry out an investigation on the effects of temperature and one other variable on the movement of insects.

Procedure A Measuring Movement

1. Obtain a petri dish with cover and place a piece of filter paper in the bottom of the dish so that the insects can move about without sliding about. Capture some of the insects and place in the petri dish.

2. Count the number of insects that are moving. Do this quickly so that you can see how many are moving at the same time. Wait for about ½ minute or so and count the number that are moving again. Do this for 2 or 3 times until the number that you get are about the same.

3. You can count the number that are moving 2 or 3 times and average the numbers to find out the average number moving. Either way will be adequate.

Procedure B Changing Temperature

1. Obtain a culture dish with some ice water in it and place the petri dish with insects down in the dish being careful not to get water in the petri dish or sink the dish. (See Figure #1)
2. Place a thermometer in the petri dish to record the temperature. You will need to wait for the thermometer to become stable before you check the themperature; a minute or so will be long enough.

3. For warmer temperatures, place hot water in the culture dish and place the petri dish with insects into it.
4. You may want to put plastic blocks under the petri dish in the culture dish so that there will be no chance of the petri dish sinking.

Figure #1

Procedure C Mositure

1. Moisten a piece of filter paper, allowing the excess water to drain off and place in the bottom of the petri dish before adding the insects. This will be considered moist conditions.
2. For dry conditions, place the filter paper in the petri dish without wetting the paper.

Procedure D Light

1. For intense light, turn on the goose-neck light at your lab table and place the petri dish under it, being careful not to let the light get much closer than 6 inches since that will increase the temperature.
2. Leave the petri dish under the light long enough for the insects to become accustomed to the change before you count their movement.
3. For dark conditions, obtain a piece of heavy black cloth and place over the petri dish. When you want to count the number of insects moving, lift up the cloth and quickly count them, replacing the cloth over them.

Procedure E. Measurment of density

1. Density is defined as the number of things per unit area. We then must know the area and the number of things in the area before density can be computed.
2. To get the area of the petri dish in cm^2, first, measure the diameter of the petri dish in cm. Since one diameter is composed of two radi, the radius of the petri dish is equal to $\frac{1}{2}$ the diameter. To find the area substitute into the formula $A = \pi r^2$, where A = area in cm^2, π = pi which is 3.14 and r = the radius in cm.
3. The density can be found by using the following formula: D = # insects/A (Divide the number of insects by the area of the petri dish to get the number of insects per cm^2.)
4. Since the area of the petri dish will not change, one can increase or decrease the number of insects in order to increase or decrease the density. For example if the density is .5 insects per cm^2 one would merely double the number of insects to double the density, making it 1 insect per cm^2.

NAME ____________________

Problem : What is the relation between temperature, density, and movement in insects?

Procedure:

NAME ____________________

Problem: What is the relation between temperature, light, and movement in insects?

Procedure:

NAME ____________________

Problem : What is the relation between temperature, moisture, and the movement of insects?

Procedure:

Bio 1107 Lab GROWTH OF BACTERIA

Problem: (1) to determine where bacteria are (2) to determine if the type of media and the presence of a chemical have any effect on the growth of airborne bacteria.

Part I Where Are Bacteria?

1. Obtain a petri dish and cover the bottom with media. Let the media become solid and then expose the media to various conditions by removing the lid. The conditions may be: air in the classroom, air outside, air in the restrooms, dirt from the floor, hair, spit, finger prints, and any other you might want to try.
2. Try about four conditions, making sure that your neighbor tries different conditions so that both of you will have tried out a lot of conditions.
3. After you have finished with this part, label the petri dish and place in a lab drawer.

Part II Does Type of Media and Presence of Alcohol Effect the Growth of Bacteria from the Air?

1. They are four variables that you may work with: acid media, regular media, alcohol, and no alcohol.

2. Figure out how you could set up an experiment to see if the type of media and the alcohol have any effect on the growth of bacteria.

3. Before you actually set up the experiment, write a brief description of what you plan to do and turn it in.

4. Obtain one or more petri dishes, depending on the design of your experiment, and cover the bottom of the petri dish(s) with media. Since the dishes are divided into four sections, you can change conditions in each section of the petri dish. Try not to put too much media in each of the dishes since it can spill over into other parts of the dish.

5. Let the media cool and become solid. If you are going to test the effect of alcohol, you can pour a small amount of alcohol on the media, just enough to cover the surface, on the plates or sections that are appropriate.

6. After your petri dishes are all set up, remove the cover of the dish

and expose the media to the air for some amount of time (5 minutes should be enough). Cover the dishes and label, placing them with the other dish(s).

7. You will need to come by before a week is out to check the growth of the bacteria. If there is sufficient growth, you will see little dots which are colonies of bacteria which were formed by the presence of one bacteria.

8. Count the number of bacteria in each of the conditions , record the data in a chart or graph, and make a conclusion.

9. After you have finished setting up the lab today, obtain a predicicon sheet from your lab instructor, fill it out, turn it back in before you leave.

PREDICTION SHEET NAME ____________________

This prediction sheet is to be filled out only after you have set up the experiment. It is designed to gain information about the procedure that you used, the data you expect to get and your ability to make logical conclusions from data similiar to that which you might get. This Prediction Sheet will not count as part of yout lab grade, the lab report will do that.

1. Suppose that a biologists wanted to find out if a new chemical was effective in killing bacteria on different kinds of media and he set up the conditions shown in the chart below:

			Bacteria Killed?
Condition #1	Normal media	Chemical present	Yes, No
Condition #2	Enriched Media	Chemical present	Yes, No
Condition #3	Normal media	Chemical absent	Yes No
Condition #4	Enriched Media	Chemical absent	Yes, No

If the biologists found that the chemical did kill bacteria on all kinds of media, in which of the conditions would he expect to find bacteria killed? (Circle either "Yes" or "No" in the above chart.)

2. Was it necessary for the biologists to try out all four combinations? Explain.

3. If it wasn't necessary to use all four conditions, which ones are necessary to see if the chemical did kill bacteria on all types of media?

Appendix B

The Lab Skills Test

NAME______________________

LAB SKILLS TEST   LAB TIME ______________________

1. You are raising chickens and wish to find the best food to feed them so that they will gain weight the fastest. You start with 4 different types of chicken food; A, B, C, and D. The chickens are divided into 4 groups, each fed one of the types of food for one month. The following are the results:

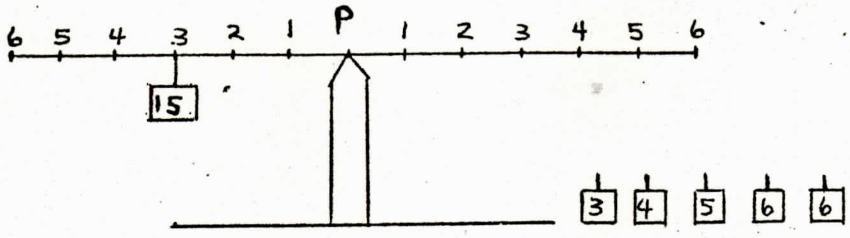
   (1) Type D food was better than Type B
   (2) Type A food was not as good as Type C
   (3) Type A food was better than Type D

   Which was the best type of food A, B, C, or D? ____________
   Explain.

2. A biologist wanted to see what effects environmental variables would have on the growth rate of fruit flies. He decided to work with these variables: (1) size of jar: large jar, small jar (2) temperature: hot, moderate, cold (3) amount of food: much, little. The biologist set up the following conditions:

   Condition # 1: small jar, high temperature, much food
   Condition # 2: large jar, low temperature, little food
   Condition # 3: small jar, moderate temperature, little food

   The three conditions were all that he could think of. (He was not too bright, sniffing ether for years done him in). How many possible conditions are there to use? ________Explain how you figured it out.



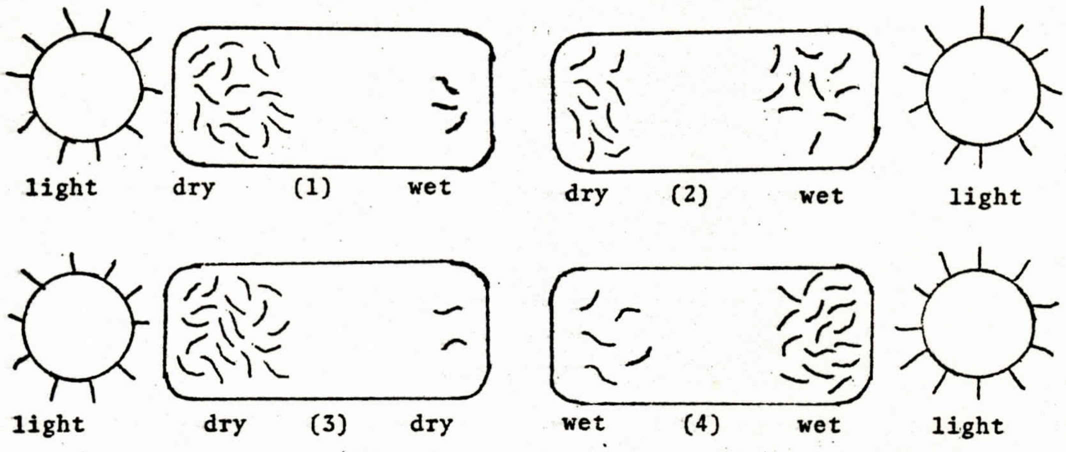
3. The drawing above shows a balance composed of a beam and weights. The beam is uniform weight from one end to the other, and marked off uniformly in each direction from the pivot point (P). The beam has notches at each point along the beam to attach different weights for balancing it. There are several weights available for you to use: 3, 4, 5, 6, 6. You may use any number of weights you feel necessary, but only one weight can be attached to the beam at any one point. The weight 15 will remain on the left side of the beam, though it may be moved in the second part of this question--any other weights added to the beam will be added on the right side only.

A. With the weight 15 three units from the pivot which weight(s) and at what position on the right side of the beam would you use to balance it? Explain why.

B. If the weight on the left was moved over from position 3 to position 5, what weight(s) would you use and at what position on the right side of the beam would you use to make it balanced? Explain why.

4 All insects are animals. All insects have 6 legs. I have an animal which has 6 legs, therefore it is an insect. True________or False__________. Explain why.

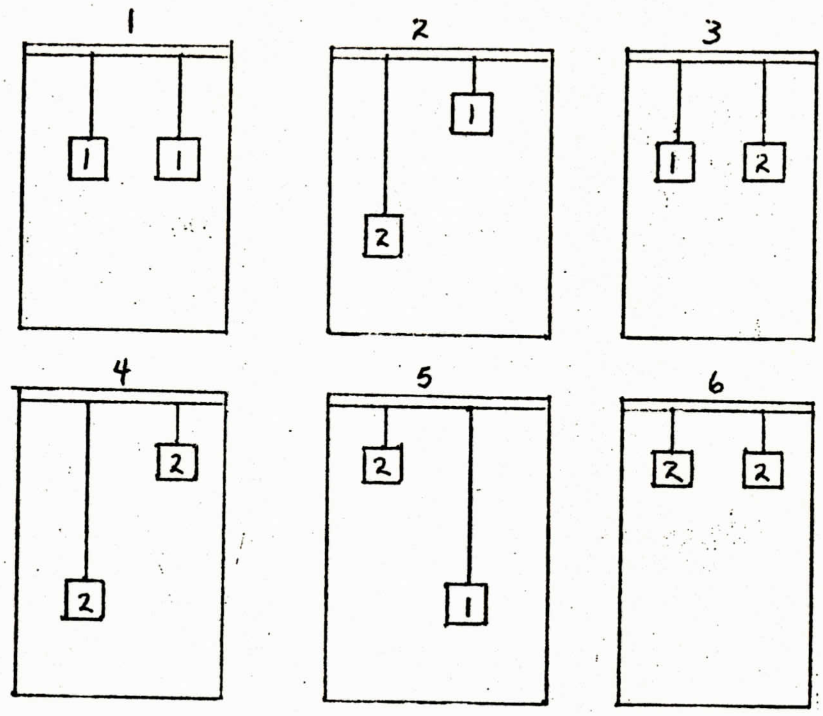
5. A scientist wanted to test how worms act in light and moisture. To do this she set up four boxes as shown in the diagrams below. She used lamps for light sources and watered pieces of paper in the boxes for moisture. In the center of each box she placed 20 worms.



One day later she returned to count the number of worms that had crawled to the different ends of the boxes. The diagrams tell you what the scientist observed in the four different trials.

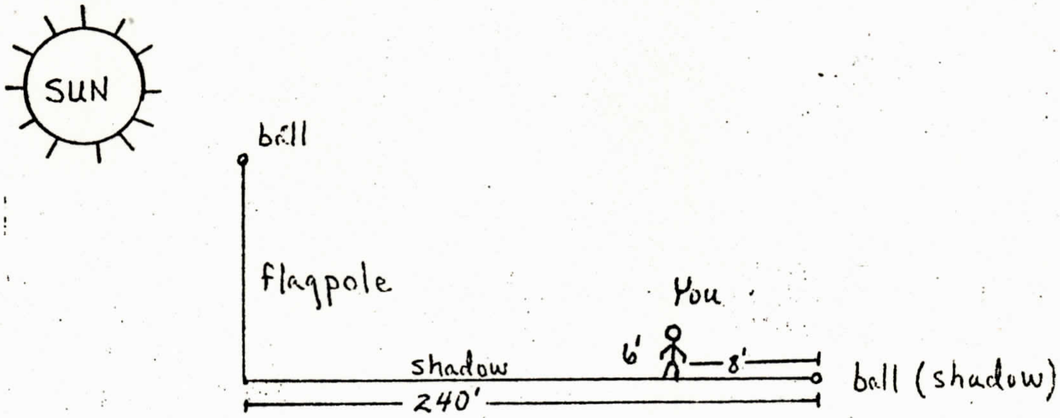
What does the information from the diagrams tell you? What else could you do to test the worms' reaction to light, dryness, and wetness?

6. Each of the six drawings depicts a situation in which two weights (measured in kilograms) are suspended by a string from a support. Each can be swung - dropped from whatever height you want and at any force.



A. Which one condition (drawing) is necessary in order to find out if the difference in weight has any difference in the time the pendulum swings? Explain why you chose the one you did.

B. Which one condition (drawing) is necessary in order to find out if the difference in length of string has any difference in the time the pendulum swings? Explain why you chose the one you did.



7. Being an inquisitive person, you find yourself in the following situation: You are standing in the shadow of the flagpole and can see the sun right behind the ball atop the flagpole. You are holding a stick that is 6 feet tall and you observe that the distance between the bottom of the stick and the shadow of the ball atop the flagpole is 8 feet. You know that the length of the shadow is 240 feet and you think that you can calculate the height of the flagpole from this. How could you calculate the height?

   If you can't solve the problem with the information given what additional information do you think that you need?

8. A student figured out a procedure in lab for finding out if a big fish was at the top of a small aquarium or at the bottom without having to look at the fish. The student thought that if the fish were at the top of the aquarium (but not out of the water) the water level would be slightly lower than if the fish were at the bottom of the aquarium. Would this work? Explain.

9. A student while walking by a stream found what she thought was an unusually large footprint of some animal. She found a stick and measured the footprint to be 2 1/2 sticks long. Later she measured the worm, using the same stick, and found it to be 1 1/2 sticks long. On the way home she lost the stick, but the next day she went back and measured the footprint and found it to be 23 cm long. She didn't even try to find the worm since she knew she could figure out how long it was. How long was the worm in cm? Explain how you found out.

10. A biologist had a hypothesis that green germs caused a person to be sick. The following are situations that could happen. Which one (only one) of the four situations would have to be true in order for one to say that green germs do not cause a person to be sick?_______________
Explain why you chose the one that you did.