DOCUMENT RESUME

ED 038 295 SE 008 199

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TITLE Formulating Hypotheses, 1st Trial Edition.
INSTITUTION Texas Univ., Austin. Research and Development Center for Teacher Education.; Texas Univ., Austin. Science Education Center.
PUB DATE [70]
NOTE 30p.

EDRS PRICE EDRS Price MF-$0.25 HC-$1.60
DESCRIPTORS Cognitive Processes, *Elementary School Science, *Elementary School Teachers, *Instructional Materials, *Science Activities, *Teacher Education, Teaching Guides

ABSTRACT

At the completion of this instructional module participants should be able to: (1) distinguish between statements that are hypotheses and those that are not; (2) construct a hypothesis, given a set of observations and/or inferences; (3) construct and demonstrate a test of a hypothesis; (4) identify data from a test which supports or does not support a hypothesis; (5) construct a revision of a hypothesis on the basis of data collected from a test of the hypothesis. This module should be preceded by the following five modules in this series: "Observing, The Basis of Science", "Describing Observations", "Comparing Observations", "Reasoning About Observations", and "Meaning of Data". The population for which this instructional program is intended includes preservice and inservice elementary teachers who teach science. Estimated time required for this module includes planning for instruction: three hours; teaching: two hours and forty minutes. The module includes a rationale, references, materials list, and duplicated materials. (BR)

FORMULATING HYPOTHESES

1st Trial Edition

The Research & Development Center For Teacher Education

THE UNIVERSITY OF TEXAS
AUSTIN

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FORMULATING HYPOTHESES

Gene E. Hall

Science Education Center
and
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I. PERFORMANCE OBJECTIVES:

At the completion of the following activities the participant should be able to:

1. Distinguish between statements that are hypotheses and those that are not;
2. Construct a hypothesis, given a set of observations and/or inferences;
3. Construct and demonstrate a test of a hypothesis;
4. Identify data from a test which support or do not support a hypothesis;
5. Construct a revision of a hypothesis on the basis of data collected from a test of the hypothesis.

II. RATIONALE:

A scientist often goes beyond his observations, not only to infer causes and relationships about particular observations, but also to extend causes and relationships to all possible situations of a broad class. A generalized statement of this type is called a hypothesis. A scientist formulates a hypothesis not because he thinks it *is* true, but because he thinks it *may be* true, or because he thinks it may be false, or sometimes just becuase it is a useful way to think about that class of situations. No scientist would ever think of a hypothesis (his own or that of anyone else) as true at face value. A hypothesis is a provisional statement which must be tested before anything can be known about its truth.

A hypothesis about a phenomenon should be in accord with all of the best observations that have been made and also in accord with the reasonable inferences based on the observations. A hypothesis should suggest tests that have not heretofore been made and, when carried out, will either increase or decrease confidence in the hypothesis. If confidence is decreased, we may be faced with the need to modify the hypothesis to fit the array of new and old observations and reasonable inferences available at that time or to invent a totally new hypothesis which is more acceptable.

It is usually not possible to prove that a hypothesis is true because to do so would mean testing every single possible case. However, when a great many tests have been made all of which result in evidence that supports the hypothesis, we can say that the probability of its being true is high. If there is general agreement among scientists that the tests were properly carried out and that the evidence strongly supports the hypothesis, then the general statement is no longer called a hypothesis, but rather, a theory or law.

It would seem to be much easier to disprove a hypothesis than to have it accepted as a theory or law. Only one counterexample is necessary to disprove a hypothesis. In fact, however, scientists often cling to a hypothesis even in the face of apparent contradictions. Their first thought is to question the data, since data are usually not the simple look-see observations to which we are accustomed in everyday experience.

The evaluation of data for accuracy and precision is not dealt with systematically in this module. For this reason, and because the data collected by the participants in these activities will be fairly straightforward, it is suggested that participants' hypotheses be subjected to modification or rejection in the face of contradictory evidence so long as reasonable care was exercised in making the observations and inferences.

In summing up the purpose of instruction on hypothesis formulation for elementary students, Gagné (1965) says:

> The objective of such instruction is to make the student capable of formulating reasonable hypotheses regarding the causes of the observed phenomena. He should be able to distinguish the hypothesis he makes from the observations from which it has been drawn, and also from the observations required to test it. The latter requirement implies that the student is able to make operational definitions of the 'intervening variables' which form a part of his hypothesis. Making good hypotheses, we are told, is a matter of (1) avoiding tautologies, in which one simply gives a new name to a phenomenon without explaining it, and (2) devising explanations which are generalizable to other phenomena, rather than being narrowly specific.

This module should be preceded by:

Observing, The Basis of Science
Describing Observations
Comparing Observations
Reasoning About Observations
Meaning of Data

The mental operations required by this module are somewhat more complex than those required for most of the prerequisite modules. For this reason it was felt that repeated exposure to the concepts embodied in the performance objectives should be provided in various contexts. The correspondence of objectives, appraisal tasks, and instructional activities is illustrated as follows:

Objective	Pre-Appraisal Task	Instructional Activity	Post-Appraisal Task
1	I, II, III, IV, V	1	I
2	VI	1, 2, 3	II - A
3		2, 4	II - B
4	VII	2, 4	III - A
5		2, 4	III - B

If 80 per cent of the group performs well on pre-appraisal tasks I-VI, the instructor may wish to omit Instructional Activity 1, as well as the post-appraisal task I. High performance on pre-appraisal tasks VI and VII may warrant abridgment of Instructional Activity 2.

Evaluation Data:

The population for which this instructional program is intended includes preservice and inservice elementary teachers who teach science.

Time required for this module include:

A. Planning for instruction: Estimated 3 hours
B. Teaching: Estimated 2 hours, 40 minutes

Suggested time periods for the parts of the module are as follows:

A.	Pre-Appraisal	20 minutes
B.	Activity 1	35 minutes
C.	Activity 2	10 minutes
D.	Activity 3	15 minutes
E.	Activity 4	1 hour
F.	Post-Appraisal	20 minutes
	Total	2 hours, 40 minutes

III. REFERENCES:

American Association for the Advancement of Science. Science - A Process Approach, Part E, Formulating Hypotheses 1. AAAS/Xerox, 1968.

American Association for the Advancement of Science. Science - A Process Approach, Part Seven, Fourth Experimental Edition. AAAS Miscellaneous Publication 67-13, 1967. pp. 127-133.

American Association for the Advancement of Science. Science - A Process Approach, Commentary for Teachers. AAAS Miscellaneous Publication 65-22, 1965.

Beveridge, W. I. B. The Art of Scientific Investigation. New York: Vintage Books, Random House, 1950.

Gagné, Robert. The Psychological Bases of Science - A Process Approach. AAAS Miscellaneous Publication 65-8, 1965, p. 31.

Toulmin, Stephen. The Philosophy of Science. New York: Harper and Brothers, 1960.

IV. MATERIALS LIST:

Pre-Appraisal

30	FH #1

Activity 1

1 spinning bucket device	(description follows)
1 large dishpan	
1 balloon	
1 springing device	(description follows)

Activity 2

(no special materials needed)

Activity 3

1 marble-fall device	(description follows)

Activity 4

6-8 ml. containers
6-8 250 ml. containers
4 500-1000 ml. containers
22 or more marbles of assorted colors
22 or more plastic vials with snap or screw caps, wide enough to admit a marble

Activity 4 cont'd.

4 or more Viscous liquids
suggested:

1 pint mineral oil
1 pint corn syrup (full strength)
1 pint 80% corn syrup
1 pint 60% corn syrup

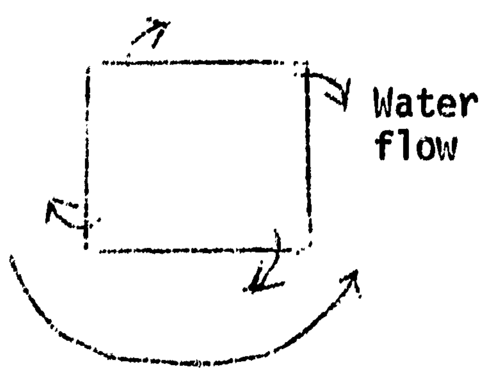
Post-Appraisal

30 FH #2

Spinning Bucket Device

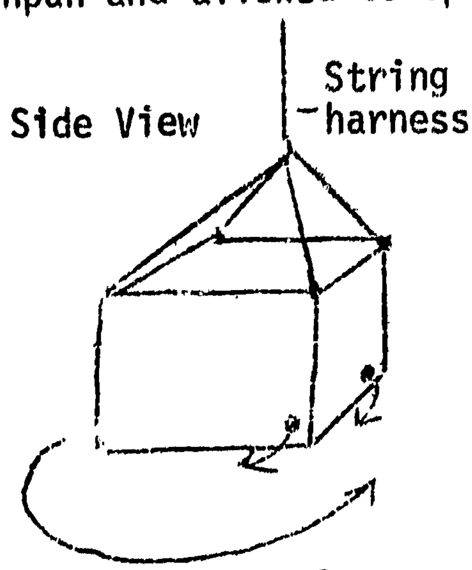
This device consists of a rectangula. container suspended from a string harness in such a way that it may turn easily. A hole (0.5-1.0 cm. diameter) has been made in the lower right corner of each vertical face of the container. When water escapes from the holes, the container spins in a counterclockwise direction, i.e., away from the direction of water flow. The container may be conveniently filled from a large dishpan and allowed to spin above it so that the escaping water is caught.

Top View



Direction of
spin

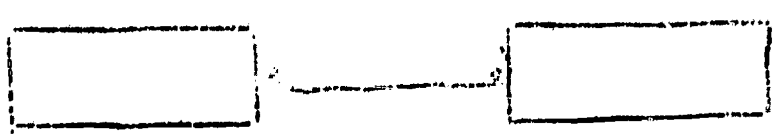
Side View



Direction of
spin

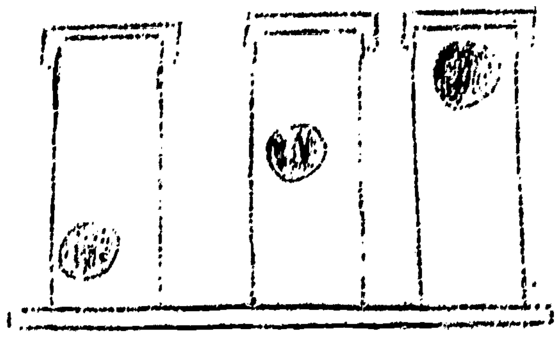
Springing Device

This device consists of two wooden blocks joined by a length of rubber band. The action-reaction principle may be demonstrated by pulling the blocks apart enough to stretch the rubber band slightly and releasing the blocks simultaneously. The instructor should practice this a few times prior to the demonstration in order to get the desired amount of action. Both blocks should spring back to about the original unstretched position. Too much stretching will cause the blocks to crash together on release, obscuring the desired effect.



Marble-Fall Device

This device consists of three vials, approximately 2.5 cm. x 9 cm., capped and fastened to a wooden strip for convenience in handling. (Transparent tape can be used to attach the vials to a wooden or heavy plastic ruler.) Each vial contains a liquid of different viscosity, e.g., water, 60% corn syrup, and 80% corn syrup. Into each vial is placed a marble, all of which have the same diameter (15 to 18 mm.) but different colors. The marbles fall at different rates when the device is inverted.



Corn Syrup Dilutions

60%:	300 ml. corn syrup 200 ml. water
40%:	200 ml. corn syrup 300 ml. water

Mix a few hours in advance, but not more than a day or so before use, to prevent microbial contamination.

V. INSTRUCTIONAL ACTIVITIES:

Pre-Appraisal (Approximate time: 20 minutes)

(Directions: Distribute FH #1 to each participant and allow 15 minutes. Collect the papers and hold discussion on the results. Ask for show of hands for each item and tabulate responses on the board. Hold open discussion when there is disagreement. Do not volunteer any information or respond directly to substantive questions at this time. The purposes of this activity are to gain information as to the level(s) of the participants ability, and to create interest and motivation for the instructional activities to follow.)

(See page 1 for PERFORMANCE OBJECTIVES.)

Activity 1 (Approximate time: 35 minutes)

Objective 1: Distinguish between statements that are hypotheses and those that are not.

Objective 2: Construct a hypothesis, given a set of observations and/or inferences.

(Demonstrate the spinning bucket.)

1. What observations did you make?

List several on the board.

(Blow up a balloon and release it to fly around the room.)

2. What observations did you make?

List several on the board.

3. What inferences can you draw?

List a few inferences for each event.

NOTE: The purpose of the next several items is to elicit a generalized statement about the events. Be prepared to change direction or omit items as needed to make the most of responses from participants, as someone may attempt a general statement before this sequence is completed.

4. Is it possible that one of these inferences listed could apply equally well to the other event? Why? (Or why not?)

It is possible, since an inference is an attempted explanation based on an observation or a set of observations. It is more likely, however, that the wording of each inference is specific to the particular event it attempts to explain. See what the participants do with this question, but don't volunteer anything.

5. How did we decide to define an inference?

The definition should include these points: An inference is an attempted explanation of a set of observations; it goes beyond the five senses in that it involves reasoning, but is specific to the set of observations it attempts to explain.

6. Could we construct an inference that explains both events?

(If necessary)

7. What similarities did we observe about the events?

If necessary, repeat the demonstrations.

NOTE: Someone will probably have a general statement by now. The statement may be classified according to its degree of generality.

Type A (highly general)	"For every action there is an opposite reaction."
Type B (moderately general)	"When a fluid escapes from its container, the container tends to move away from the direction of escape."
Type C (slightly general)	"The escaping fluids pushed the balloon and the carton in the opposite direction."

Record the general statement(s) on the board.

8. We will refer back to this later.

(Pull the blocks of the springing device apart and hold them there.)

9. What do you think will happen when I release these? Why?

Accept all responses but probe for justifications.

(Release the blocks.)

10. Did your general statement based on the balloon and the spinning carton permit you to predict what would happen with the springing device? Why? (Why not?)

If statement was of Type A, yes, because it was phrased broadly to include all events involving action-reaction.

If statement was of Type B, no, because it was phrased to include only events involving fluids escaping from containers.

If statement was of Type C, no, because it was specific to the particular observations on which it was based and could not be extended to account for new events without rephrasing.

NOTE: If statement was of Type A, skip items 11 and 12.

11. Was there anything similar about the springing device event and the other two events?

12. Could you modify your first statement, or construct a new one, to account for all three events?

13. When a hypothesis of Type A has been formulated:

What is there about this statement that is different from an inference?

A general statement covers all situations of the class under consideration.

14. What shall we call this kind of statement?

Accept suggestions but point out that scientists use the name, "hypothesis" (plural, hypotheses).

15. Why should we bother with this? What is the use of a hypothesis?

Hopefully, this will provoke a lively discussion with a number of ideas coming from the participants. One possible outcome is to see the usefulness of hypotheses in making predictions about events not yet imagined, and indeed, stimulating such imagination.

16. Describe some hypothetical events which will be explained by our hypothesis.

17. If there is any difficulty getting the ideas to come, describe some situations and ask for predictions. For example,

What would happen if

a. You throw a ball while standing on a skateboard?

b. An astronaut on a "space walk" gives a sharp tug on his tether line?

c. You dive off the stern of a stationary rowboat?

NOTE: All the events and hypothetical situations mentioned in this activity involve systems where the amount of friction is relatively small or absent. Be prepared to deal with problems in which friction is a factor, should they arise.

Activity 2 (Approximate time: 10 minutes)

Objective 2: Construct a hypothesis, given a set of observations and/or inferences.

Objective 3: Construct and demonstrate a test of a hypothesis.

Objective 4: Identify data from a test which support or do not support a hypothesis.

Objective 5: Construct a revision of a hypothesis on the basis of data collected from a test of the hypothesis.

18. Suppose you had no idea about the diets of animals. One day you notice several horses eating grass. What hypothesis could you make?

All horses eat grass and only grass.

19. Can you make the hypothesis broader, i.e., cover a larger class of situations?

All animals eat grass and only grass.

20. What could you do in order to have more confidence in your hypothesis? How?

Test it by making additional observations.

21. What would you have to do in order to be 100% certain?

Observe every horse (or every animal) that exists, or that ever did exist.

22. Suppose you set out to test "all animals eat grass." You notice many other horses eating grass--also, you see cows, goats, antelope, deer, elephants and yaks eating grass. What does that do for your hypothesis?

It strengthens or supports it.

23. Then one day you see a fish eating another fish.

The hypothesis is not supported. Perhaps it should be rejected or modified.

24. Can you modify it?

One might say, "All animals except fish eat grass," or "All four-legged animals eat grass."

25. This type of testing and modifying can be continued to whatever extent the instructor wishes--perhaps until a fairly refined hypothesis is formulated, e.g., "All hoofed animals eat plant food."

Activity 3 (Approximate time: 15 minutes)

Objective 2: Construct a hypothesis, given a set of observations and/or inferences.

(Demonstrate the marble-fall device.)

26. | Write down some observations about this. |

Walk around demonstrating the device so that everyone gets a good look.

27. | Now write down as many inferences as you can which might explain the event. |

Allow 5 minutes.

28. | Now let's see how many different inferences we have. ______________, will you please read us your inferences? Then continue with ________ (the next person) reading any not mentioned before, and so on around the room. |

Select several of the inferences which will lend themselves to generalization and list them on the board.

(Indicate one of the inferences on the board.)

29. | Can we make this inference into a hypothesis? How? |

By generalizing the wording to cover all situations of the type being considered.

30. | Record the group's hypothesis on the board. Repeat the procedure with other inferences to formulate several hypotheses. Examples of what might result are: |

1. Blue objects fall through liquids faster than red objects.

2. Objects fall through thin liquids faster than through thick liquids.

3. The relative rates of fall through liquids of objects of different composition are:

   iron > plastic > glass

4. The heavier an object is, the faster it falls through a liquid.

5. The denser the liquid is, the slower an object falls through it.

31. In which hypothesis do you have more confidence, the one we formulated before (Activity 1), or one of these we have just done? Why?

More confidence can be placed on hypotheses formulated to explain observations of several events than on those generated from observations of a single event. One reason is because we have a better idea of how broad to make the generalization. Participants may suggest this; if not, leave it for now.

Activity 4 (Approximate time: 1 hour)

Objective 3: Construct and demonstrate a test of a hypothesis.

Objective 4: Identify data from a test which support or do not support a hypothesis.

Objective 5: Construct a revision of a hypothesis on the basis of data collected from a test of the hypothesis.

32. Let's figure out how we could test some hypotheses about our falling marbles. Suppose we wanted to test this one: "Blue marbles fall through liquids faster than yellow marbles, but slower than red ones." How could we test it?

Accept suggestions from participants. You may wish to review systematic analysis with the group at this point. (See Activity 2, Organizing to Investigate.)

33. What variables do we need to control?

Examples: composition of liquids
length of tubes
size, shape, weights, etc., of marbles

34. What other kinds of variables should we consider?

Manipulated variable = marble color
Responding variable = speed of fall

35. Here are two hypotheses that you can test: (1) Marbles fall through thin liquids faster than through thick liquids. (2) Marbles fall through dense liquids slower than through less dense liquids. Get together in small groups and decide which hypothesis you want to test.

Allow a few minutes for this. If all the groups choose one hypothesis, ask for one group to volunteer to test the other.

36. Take a look at the equipment available on the supply table and try to plan your tests accordingly. When you have decided what to do, take what you need and begin testing.

Circulate and be available for technical difficulties but do not give direct answers to broad planning problems.

See that each group includes mineral oil as one of their liquids. Oil is the critical variable to distinguish between density and viscosity because it is the only supplied liquid which is at the same time relatively less dense and more viscous than the other supplied liquids. This distinction will become apparent to the group as a whole only when the final reports are given and discussed.

37. After a while, the need for operational definitions of "thickness" and "density" will probably arise. If so:

> What does "thickness" mean to you?

38.

> Think of a very thick liquid and a very thin one. What differences would you notice? How could you distinguish between them?

Pouring characteristics will almost certainly be mentioned.

39.

> Ah, yes! That seems to be what scientists call "viscosity." I wasn't sure until you described it. Can you think of a way to measure it?

There is a good likelihood that a participant will think of a feasible flow volume per unit time measure. If so, omit the next item.

40. If help is needed, however:

> Two suggestions you may wish to consider are these:
>
> (1) Measure the time necessary for some constant volume of liquid to flow out of a syringe barrel (without the plunger).
>
> (2) Put 20 ml. of liquid into a 50 ml. beaker, invert it for ten seconds, and measure the volume of liquid remaining.
>
> Which method would be better if you wanted to distinguish the relative viscosities of alcohol and water? Which for molasses and motor oil?

41. If help in operationally defining "density" is needed, proceed in a similar manner to get participants' ideas. Someone will get the idea of weighing constant volumes of the liquids.

42. After the testing is completed, ask for oral reports from each group, to include these items:

> State the controlled, manipulated, and responding variables. Describe your procedure and results, and state whether your hypothesis was supported, refuted or unaffected (untested). If refuted, could the hypothesis be modified? How?

Post-Appraisal (Approximate time: 20 minutes)

(Directions: Distribute FH #2.)

43. To check on how well you have done, here is a learning diagnosis instrument. You will have 15 minutes in which to respond.

When the task is completed, give immediate feedback to the participants by providing acceptable responses. Tally the results of the group, as for the Pre-Appraisal. Note again the correspondence of performance objective with appraisal task:

Objective	Task
1	I
2	II-A
3	II-B
4	III-A
5	III-B

DUPLICATED MATERIALS -- WITHOUT ANSWERS

PRE-APPRAISAL

A sixth grade teacher asked her students to observe a demonstration and then write a report on what they saw. The teacher performed the demonstration silently, with no comment or explanation. The teacher produced two glasses containing clear liquid of identical appearance. The glasses were labeled "A" and "B." Into glass A she dropped an object which looked like an ice cube. The object dipped below the surface and then came back up and floated. Into glass B the teacher dropped an object identical in appearance to that dropped into glass A. The object dropped into glass B sank to the bottom.

I. Below are some statements from a student's report. Some of the statements involve inference. Mark each statement (I) for inference or (NI) for not inference.

Set A

______a. Two glasses of clear liquid appeared to be identical.
______b. An object was dropped into glass A.
______c. The object appeared to be an ice cube.
______d. Another ice cube was dropped into glass B.
______e. The object dropped into glass A floated.
______f. The object in glass B sank.
______g. The object in glass B must have been something different from an ordinary ice cube.

Set B

______h. The object in glass B is heavier than the object in glass A.
______i. Heavy objects sink and light objects float.
______j. Things that sink don't have any air in them.
______k. Holding air makes a thing light in weight.
______l. The object in glass A had more air in it than the object in glass B did.
______m. There was more water in glass A than in glass B.
______n. It takes more water to hold up a heavy object than a light object.

II. What do the NI statements in Set A have in common?

III. What do the NI statements in Set B have in common?

IV. Give a name to the type of statement characterized by the NI statements in Set A.

V. Give a name to the type of statement characterized by the NI statements in Set B.

VI. Assuming that statements (a) through (f) are true, construct a generalized explanatory statement which would also explain the floating of ships and the sinking of marbles.

VII. What additional information would give you more confidence in your explanation?

POST-APPRAISAL

Task I

A sixth grade class is studying the effects of yeast on apple juice. Below are some statements taken from their reports.

Write a letter "H" before the statements that are hypotheses and "NH" before those that are not hypotheses.

A. A tiny bit of yeast cake was added to each flask of apple juice.
B. Flask A was kept warm and it became cloudy.
C. Flask B will get cloudy if we leave it out of the refrigerator.
D. Yeast cells need warmth and sugar in order to multiply.
E. The yeast cells in Flask B must have died.
F. A good way to kill yeast cells is to chill them.
G. In order to grow in the cold, yeast cells must have something more than Flask B had.
H. The stopper of Flask A is bulging up because fermentation produces gas.
I. If we continue to warm Flask A, it will give off more gas.
J. In a yeast culture there is a direct relationship between temperature and volume of gas produced.

Task II

A. Given the following observations, construct two alternate hypotheses:

Several beans are planted in separate containers in the classroom. After two weeks, some of the seedlings appear green and vigorous, while others look pale and sickly. Several beans did not sprout at all.

Hypothesis 1:

Hypothesis 2:

B. Describe how you would test your Hypothesis 1.

Task III

A. When a small battery-powered fan was hand-held behind a large model sailboat, the boat moved forward in the water. When the fan was fastened to the deck of the boat behind the sail, the boat remained motionless in the water. The fan was operating full force both times.

Hypothesis: Added weight makes a boat harder to move.

Indicate for each of the following sets of data whether the hypothesis is supported or not supported.

Fan Position	Other Conditions	Speed of Boat in Knots	Hypothesis Supported or Not Supported
Hand-held on boat		+2.0 0	
Hand-held	Weight equal to fan placed on boat.	+1.0	
On boat	Weight equal to fan removed from boat's cabin.	0	
Hand-held	Sail lowered	+0.5	
On boat	Sail lowered	-1.5	

B. Construct a revised hypothesis to fit all the data.

DUPLICATED MATERIALS -- WITH ANSWERS

PRE-APPRAISAL

A sixth grade teacher asked her students to observe a demonstration and then write a report on what they saw. The teacher performed the demonstration silently, with no comment or explanation. The teacher produced two glasses containing clear liquid of identical appearance. The glasses were labeled "A" and "B." Into glass A she dropped an object which looked like an ice cube. The object dipped below the surface and then came back up and floated. Into glass B the teacher dropped an object identical in appearance to that dropped into glass A. The object dropped into glass B sank to the bottom.

I. Below are some statements from a student's report. Some of the statements involve inference. Mark each statement (I) for inference or (NI) for not inference.

Set A

NI a. Two glasses of clear liquid appeared to be identical.
NI b. An object was dropped into glass A.
NI c. The object appeared to be an ice cube.
I d. Another ice cube was dropped into glass B.
NI e. The object dropped into glass A floated.
NI f. The object in glass B sank.
I g. The object in glass B must have been something different from an ordinary ice cube.

Set B

I h. The object in glass B is heavier than the object in glass A.
NI i. Heavy objects sink and light objects float.
NI j. Things that sink don't have any air in them.
NI k. Holding air makes a thing light in weight.
I l. The object in glass A had more air in it than the object in glass B did.
I m. There was more water in glass A than in glass B.
NI n. It takes more water to hold up a heavy object than a light object.

II. What do the NI statements in Set A have in common?

They are observations.
They reported only what was seen.

III. What do the NI statements in Set B have in common?

They are general statements.

IV. Give a name to the type of statement characterized by the NI statements in Set A.

Observation.

V. Give a name to the type of statement characterized by the NI statements in Set B.

Hypothesis.

VI. Assuming that statements (a) through (f) are true, construct a generalized explanatory statement which would also explain the floating of ships and the sinking of marbles.

A solid object will float in a liquid if the weight of the object is less than the weight of the liquid displaced by the object; it sinks if its weight is greater than that of the liquid it displaces.

VII. What additional information would give you more confidence in your explanation?

Some examples of the weight and volume (or density) of some sinking objects and of some floating objects, and the weight and volume (or density) of the liquids in which the objects float or sink.

POST-APPRAISAL

Task I

A sixth grade class is studying the effects of yeast on apple juice. Below are some statements taken from their reports.

Write a letter "H" before the statements that are hypotheses and "NH" before those that are not hypotheses.

NH A. A tiny bit of yeast cake was added to each flask of apple juice.
NH B. Flask A was kept warm and it became cloudy.
NH C. Flask B will get cloudy if we leave it out of the refrigerator.
H D. Yeast cells need warmth and sugar in order to multiply.
NH E. The yeast cells in Flask B must have died.
H F. A good way to kill yeast cells is to chill them.
H G. In order to grow in the cold, yeast cells must have something more than Flask B had.
NH H. The stopper of Flask A is bulging up because fermentation produces gas.
NH I. If we continue to warm Flask A, it will give off more gas.
H J. In a yeast culture there is a direct relationship between temperature and volume of gas produced.

Task II

A. Given the following observations, construct two alternate hypotheses:

Several beans are planted in separate containers in the classroom. After two weeks, some of the seedlings appear green and vigorous, while others look pale and sickly. Several beans did not sprout at all.

Hypothesis 1: Bean plants need factor X in order to produce green and vigorous growth.

Hypothesis 2: "Sick" beans have difficulty in sprouting, or produce only pale and sickly growth.

B. Describe how you would test your Hypothesis 1.

Plant beans under identical conditions (use necessary controls), with and without factor X.

Task III

A. When a small battery-powered fan was hand-held behind a large model sailboat, the boat moved forward in the water. When the fan was fastened to the deck of the boat behind the sail, the boat remained motionless in the water. The fan was operating full force both times.

Hypothesis: Added weight makes a boat harder to move.

Indicate for each of the following sets of data whether the hypothesis is supported or not supported.

Fan Position	Other Conditions	Speed of Boat in Knots	Hypothesis Supported or Not Supported
Hand-held on boat		+2.0 0	S
Hand-held	Weight equal to fan placed on boat.	+1.0	S
On boat	Weight equal to fan removed from boat's cabin.	0	NS
Hand-held	Sail lowered	+0.5	NS
On boat	Sail lowered	-1.5	S or NS

B. Construct a revised hypothesis to fit all the data.

When a fan is producing wind or push in one direction, there is a reverse force produced against the object to which it is attached.

OR: For every action there is an equal and opposite reaction.