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ABSTRACT

The population for which this instructional program has been found to be effective includes preservice and inservice elementary teachers who teach science. At the end of this instructional module, the participants should be able to: (1) given a set of data and a set of statements about the data, distinguish between those statements of fact and those of interpretation; (2) construct a systematic analysis of an event when given a set of data about that event; (3) state a question which can serve as a basis of further investigation and describe a plan for investigating that question. This module serves as an overview of those modules dealing with complex thinking behavior: "Meaning of Data", "Formulating Hypotheses", "Defining Operationally". The instructional component of the modules consists of: pre-appraisal, instructional activities, and post-appraisal. Other components are: objectives, rationale, references, materials list, and duplicated materials. The estimated time period required for this instructional module includes three hours for planning and 100 minutes for teaching. (BR)

ORGANIZING TO INVESTIGATE

1st Experimental Edition

The Research & Development Center
For Teacher Education

THE UNIVERSITY OF TEXAS
AUSTIN

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ORGANIZING TO INVESTIGATE

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Science Education Center
and
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I. PERFORMANCE OBJECTIVES:

At the end of this session, the participant should be able to:

1. Given a set of data and a set of statements about the data, distinguish between those statements of fact and those of interpretation.

2. Construct a systematic analysis of an event when given a set of data about that event.

3. State a question which can serve as a basis of further investigation and describe a plan for investigating that question.

II. RATIONALE:

Though the individual is given an array of observational data about an event, it does not necessarily follow that he will automatically spring into a meaningful investigation. The creative minds of the past 100 years have been so characterized because they saw new combinations in old events. They saw the unusual in the very usual that their colleagues had passed by.

In The Art of Scientific Investigation, Beveridge (in the preface) supports his purpose for training "would-be" investigators:

Research is one of those highly complex and subtle activities that usually remain quite unformulated in the minds of those who practice them. This is probably why most scientists think that it is not possible to give any formal instruction in how to do research. Admittedly, training in research must be largely self-training, preferably with the guidance of an experienced scientist in the handling of the actual investigation. Nevertheless, I believe that some lessons and general principles can be learnt from the experience of others. As the old adage goes, "the wise man learns from the experience of others, the fool only from his own." Any training, of course, involves much more than merely being "told how." Practice is required for one to learn to put the precepts into effect and to develop a habit of using them, but it is some help to be told what are the skills one should acquire. Too often I have been able to do little more than indicate the difficulties likely to be met -- difficulties which we all have to face and overcome as best we can when the occasion arises. Yet merely to be forewarned is often a help.

Scientific research, which is simply the search for new knowledge, appeals especially to people who are individualists and their methods vary from one person to another. A policy followed by one scientist may not be suitable for another, and different methods are required in different branches of science. However, there are some basic principals and mental techniques that are commonly used in most types of investigation, at least in the biological sphere. Claude Bernard, the great French physiologist, said:

> "Good methods can teach us to develop and use to better purpose the faculties with which nature has endowed us, while poor methods may prevent us from turning them to good account. Thus the genius of inventiveness, so precious in the sciencies, may be diminished or even smothered by a poor method, while a good method may increase and develop it. ...In biological sciences, the role of method is even more important than in the other sciences because of the complexity of the phenomena and countless sources of error."*

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*Bernard, Claude. An Introduction to the Study of Experimental Medicine. New York: Macmillan & Co., 1927.

Beveridge continues:

> The rare genius with a flair for research will not benefit from instruction in the methods of research, but most would-be research workers are not geniuses, and some guidance as to how to go about research should help them to become productive earlier than they would if left to find these things out for themselves by the wasteful method of personal experience. A well-known scientist told me once that he purposely leaves his research students alone for some time to give them an opportunity to find their own feet. Such a policy may have its advantages in selecting those that are worthwhile, on a sink or swim principle, but today there are better methods of teaching swimming than the primitive one of throwing the child into the water.
>
> There is a widely held opinion that most people's powers of originality begin to decline at an early age. The most creative years may have already passed by the time the scientist, if he is left to find out for himself, understands how best to conduct research, assuming that he will do so eventually. Therefore, if in fact it is possible by instruction in research methods to reduce his non-productive probationary period, not only will that amount of time be saved, but he may become a more productive worker than he would ever have become by the slower method. This is only a conjecture but its potential importance makes it worth considering. Another consideration is the risk that the increasing amount of formal education regarded as necessary for the intending research worker may curtail his most creative years. Possibly any such adverse effect could be offset by instruction along the lines proposed.

Beveridge suggests that a typical sequence for investigating a problem would be:

(1) review related literature in a critical manner, for possible fresh approaches;

(2) assemble complete data from field and laboratory testing;

(3) organize the information so that specific questions are identified as components of the problem;

(4) make as many educated guesses as possible to answer the questions;

(5) design experiments to test the questions, beginning with the most probable guess concerning the most critical questions.

Though hypotheses, which indicate the need for additional observing and testing, serve as the primary tools of the intellect in research; so also, curiosity and imagination participate in the evaluation of problem solutions, according to Beveridge.

The importance, too, of chance as a valuable contributor to discovery cannot be over-appreciated. For example:

> It was not a physicist but a physiologist, Luigi Galvani, who discovered current electricity. He had dissected a frog and left it on a table near an electrical machine. When Galvani left it for a moment someone else touched the nerves of the leg with a scalpel and noticed this caused the leg muscles to contract. A third person noticed that the action was excited when there was a spark from the electric machine. When Galvani's attention was drawn to this strange phenomenon, he excitedly investigated it and followed it up to discover current electricity.

This module will serve as an overview to those modules dealing with more complex thinking behavior:

Meaning of Data
Formulating Hypotheses
Defining Operationally

It should be preceded by:

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

The instructional activities of this module are based on the sequence illustrated in Figure 1.

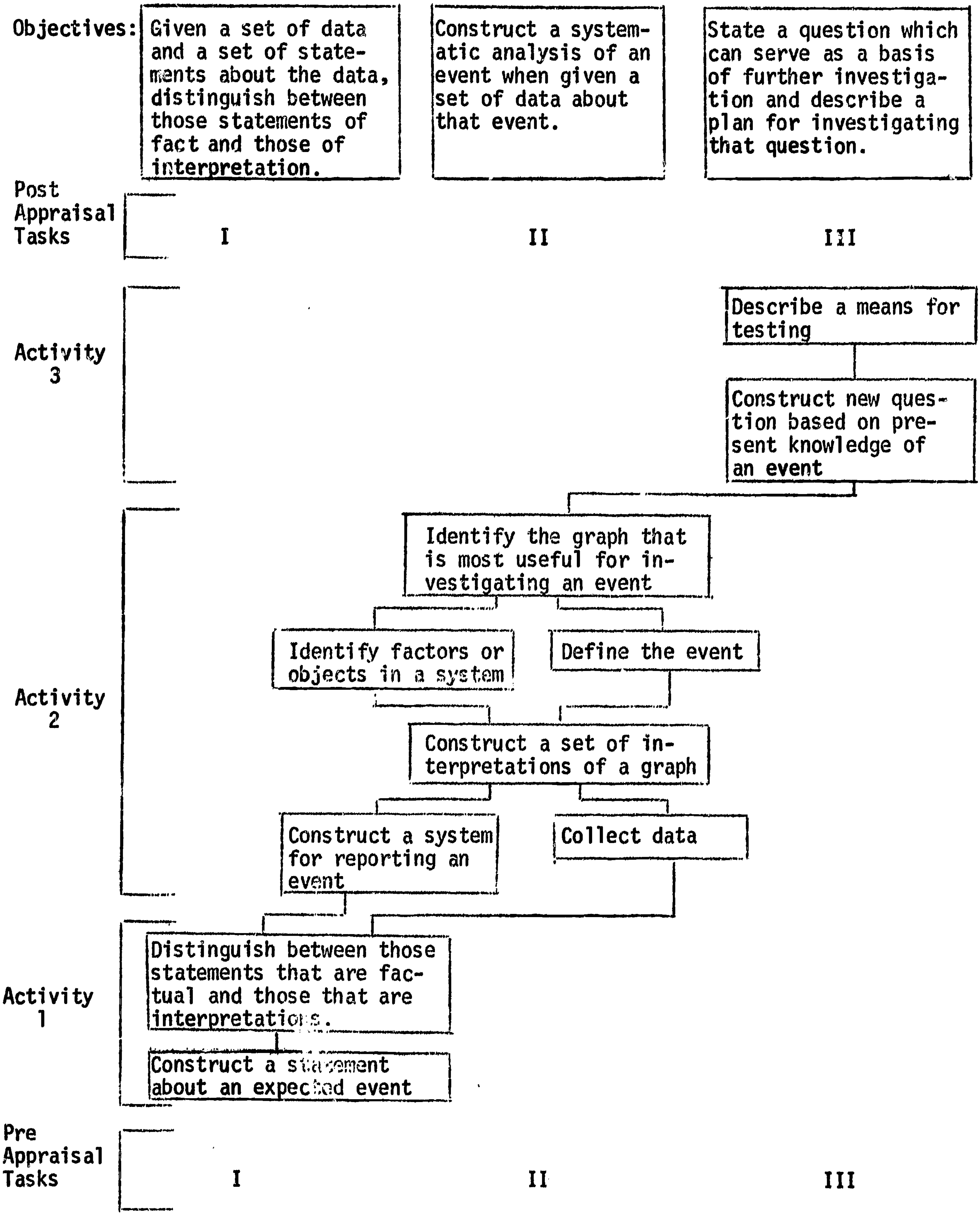

Objectives:
Given a set of data and a set of statements about the data, distinguish between those statements of fact and those of interpretation.
Construct a systematic analysis of an event when given a set of data about that event.
State a question which can serve as a basis of further investigation and describe a plan for investigating that question.
Post Appraisal Tasks
I
II
III
Activity 3
Describe a means for testing
Construct new question based on present knowledge of an event
Activity 2
Identify the graph that is most useful for investigating an event
Identify factors or objects in a system
Define the event
Construct a set of interpretations of a graph
Construct a system for reporting an event
Collect data
Activity 1
Distinguish between those statements that are factual and those that are interpretations.
Construct a statement about an expected event
Pre Appraisal Tasks
I
II
III

Figure 1

The general pattern of instruction in this module is one of presenting the situation with as little instructor-direction as possible. After the participant has generated data, then the sequence provides illustrations of how the instructor could guide the discussion toward a meaningful interpretation of the data gathered.

Because of the diagnostic data available in the pre-appraisal experience, it is possible to determine which instructional sequence appears to be most appropriate for which student. Experience indicates that if 80 percent of a group performs well on an appraisal task, the related instructional activities <u>should</u> be omitted. For this instructional module, this is illustrated as:

Objective	Appraisal Task	Instructional Activity
1	I	1
2	II	2
3	III	3

<u>Evaluation Data</u>:

The population for which this instructional program has been found to be effective includes pre-service and in-service elementary teachers who teach science.

The results of students involved in the instructional experience as described in this module are as follows:

The time periods required for this instructional module include:

A. Planning for instruction: Estimated 3 hours

B. Teaching: Estimated 100 minutes

Suggested time periods for the module are as follows:

A.	Pre-Appraisal	20 minutes
B.	Activity 1	10 minutes
C.	Activity 2	30 minutes
D.	Activity 3	20 minutes
E.	Post-Appraisal	20 minutes
	Total	100 minutes

III. REFERENCES:

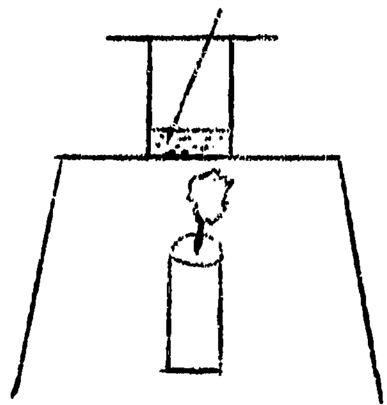
Beveridge, W.I.B. The Art of Scientific Investigation, New York: Vintage Books, 1950.

Science Curriculum Improvement Study, Interaction (Teacher's Guide). Boston: D.C. Heath and Company, 1967.

Science Curriculum Improvement Study, Subsystems (Teacher's Manual). Berkeley: University of California, 1966.

IV. MATERIALS LIST:

Pre-Appraisal	OI #1 (1 per participant)	
Activity 1	Materials A (1 per 4 or 5 participants)	Includes: candle, matches, wire stand, can, can cover, thermometer, and water in varying amounts in the cans: Can A - 50 ML B - 150 ML C - 200 ML D - 250 ML E - 300 ML



Activity 2	Large chart paper (1 per 4 or 5 participants) Felt pens (1 per 4 or 5 participants)
Activity 3	Transparency A
Appraisal	OI #2 (1 per participant

V. INSTRUCTIONAL ACTIVITIES

Pre-Appraisal (Approximate time: 20 minutes)

(Directions: Distribute OI #1 to each participant.)

1. These sheets will give you an opportunity to check on yourself. They describe an experiment with ice cubes. Read and follow directions for Tasks I, II, III on pages 1 and 2.

This diagnostic instrument serves to determine the participants' ability level. Allow 15 minutes for their responses.

2. Let's review our progress.

   If you have #1, 4, 5, 7 marked F, circle Task I.

   If you have five objects listed, such as:
   ice cubes
   pan
   hot plate, or source of heat
   thermometer
   clock, or timing device,
   circle Task II.

   If you asked a question about one of the objects described in Task II, and if your plan includes using it as a manipulated variable, circle Task III.

3. With which tasks did you have the most difficulty?

Review, by sharing, the acceptable responses and tally the participants' performance by tasks on the chalkboard.

Task	Number Having Acceptable Responses
I	
II	
III	

You and they now have a clear diagnosis of which activities are needed as learning experiences. Acceptable performance is defined as 80% of the group performing the task. If the group demonstrated acceptable performance of a task, you may wish to omit the corresponding activity. For those tasks in which performance is less than 80%, the activities related to that task should be included in this section.

The following table illustrates the relationship between pre-test tasks, objectives, and activities.

Correlation of Objectives,
Appraisal Tasks, and Instructional Activities

Objective	Task	Activity
1	I	1
2	II	2
3	III	3

Activity 1 (Approximate time: 10 minutes)

Performance Objective: Given a set of data and a set of statements about the data, distinguish between those statements of fact and those of interpretation.

(Directions: For each group, masterials A should be distributed and arranged prior to participants' arrival in the room. See description of materials.)

4. | Perhaps you've noticed the materials placed in your groups. What do you think will happen if we heat the water in the cans?

On the chalkboard collate the participants' responses. Probably their description of this event (what will happen) will be: the temperature of the water will go up. (Possible answers: the water will boil; the water will evaporate.)

5. | What reasons might account for the water's temperature going up?

Note reasons on chalkboard.

6. | Which of these statements are factual observations and which are interpretations?

Activity 2 (Approximate time: 30 minutes)

Performance Objective: Construct a systematic analysis of an event when given a set of data about that event.

7. Let's light the candle and record the temperature for 10 minutes, at 2 minute intervals.

It may be desirable to indicate a "timer" who will call out each two minute period.

(Directions: Distribute large chart paper and felt pens.)

8. Record your results for sharing. You may decide how to do this; however, there is one constraint: you cannot say a word when sharing with the other groups.

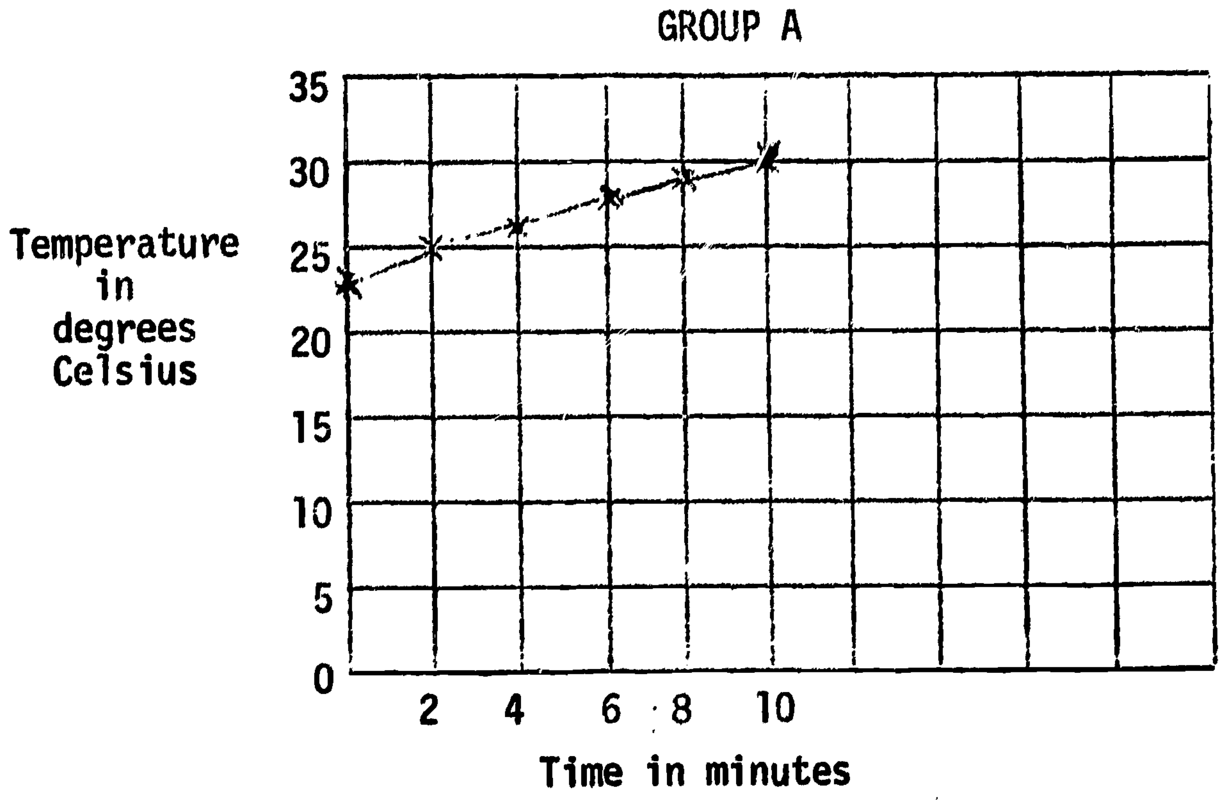
Groups will decide how to present their results. Probably most will use a graph.

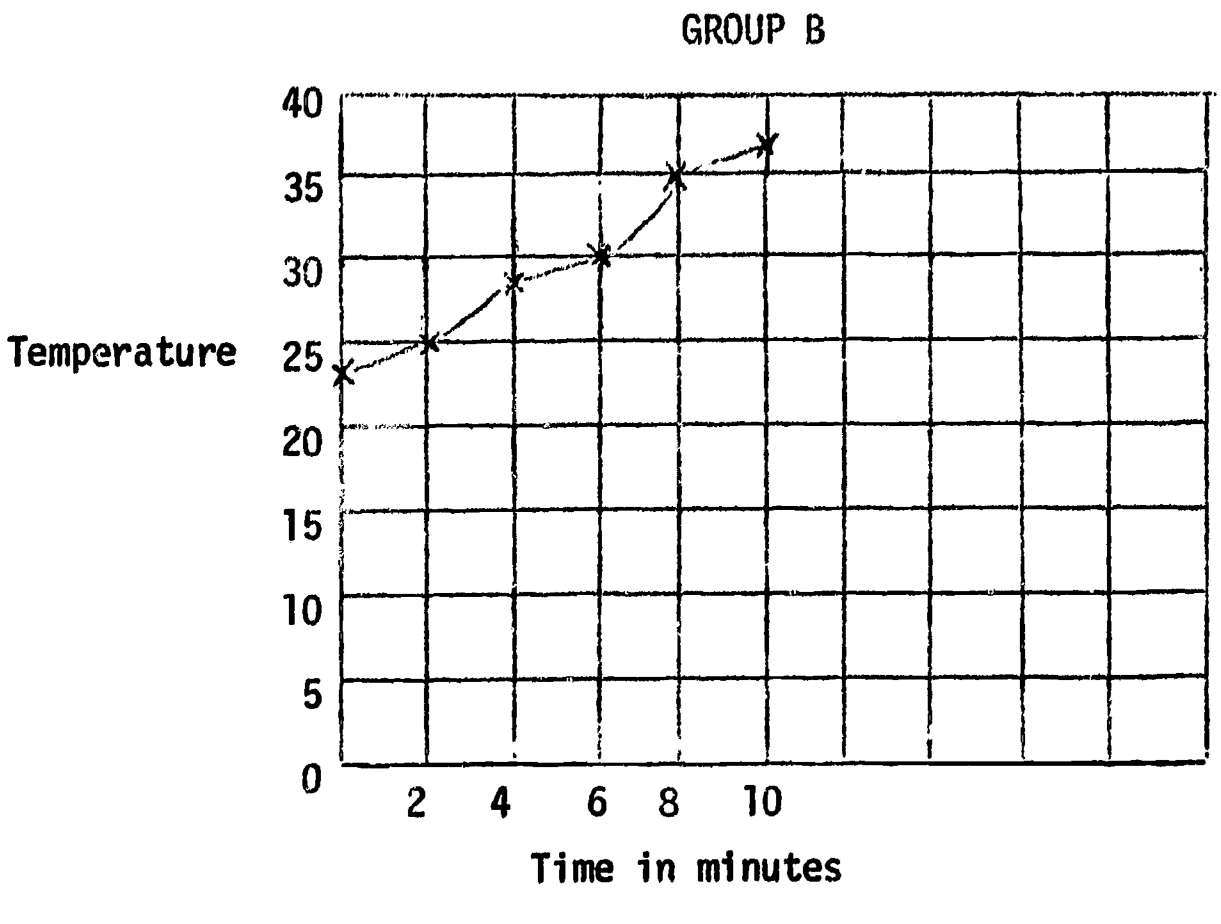
(Directions: Post the charts where all may be seen.)

9. Was the task clear?

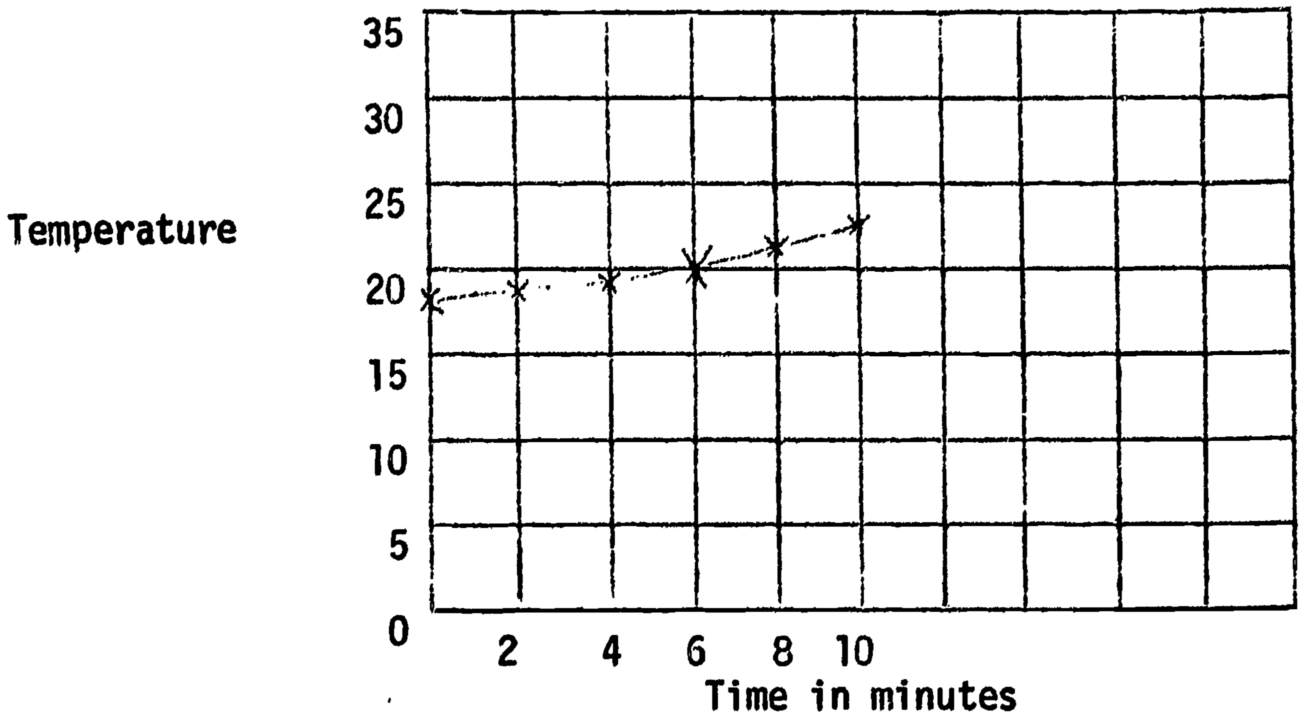
If the task was clear and every group followed the same procedure, then this factor is eliminated as a cause of the varying results.

Following are four typical graphs:

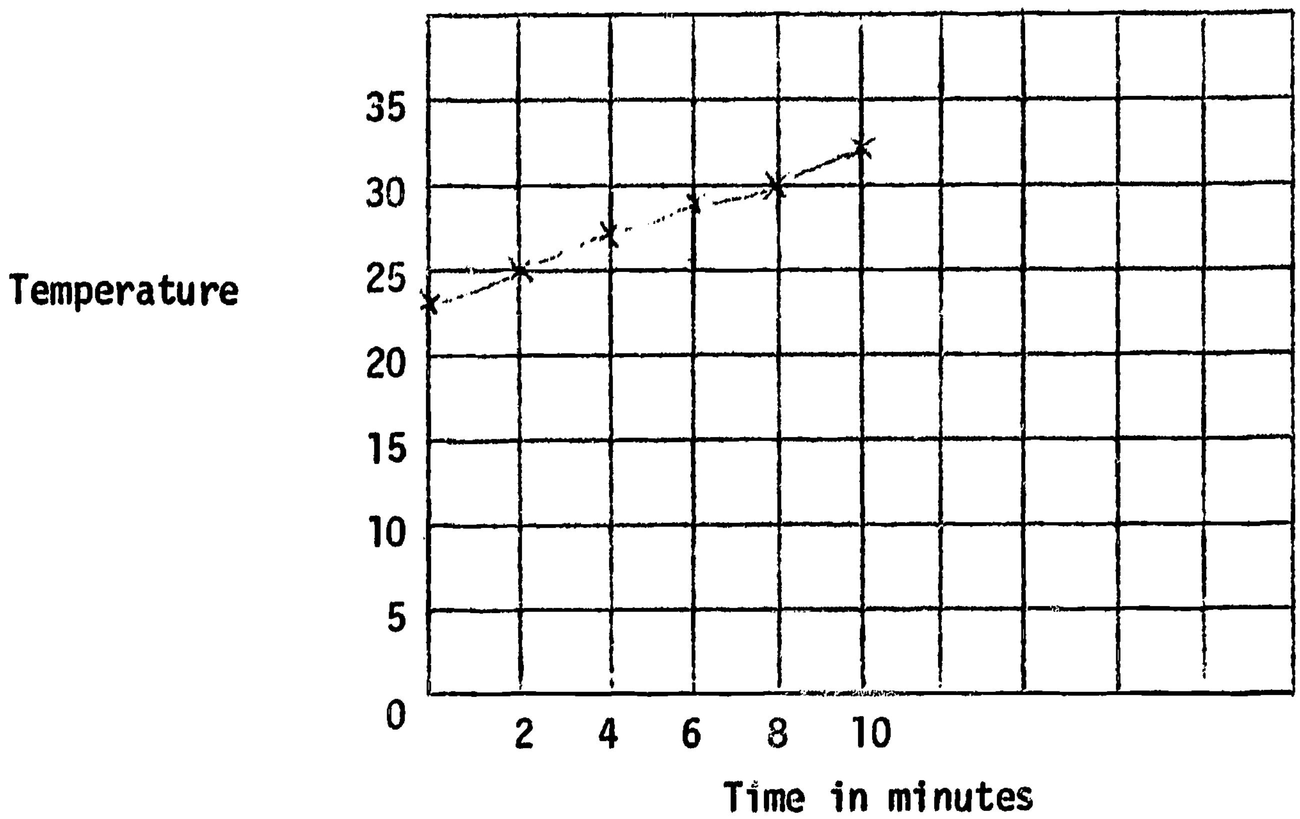

GROUP A
35
30
Temperature in degrees Celsius
25
20
15
10
5
0
2
4
6
8
10
Time in minutes


GROUP B
40
35
30
Temperature
25
20
15
10
5
0
2
4
6
8
10
Time in minutes

GROUP C



GROUP D



10. | As we look at the charts, in what way are they similar or different to each other?

Some used graphs; some may have used tables. As you look at the graphs it will be obvious that they do not all show the same results.

11. | In checking the graph, what was the initial temperature for each group? The final temperature? The change in temperature?

Review these results.

12. | What might be the reason for the differences in the groups?

List the various reasons as described for the groups, i.e.,

different size of candle
different height of flame
different distance between flame and can
different distance from air conditioner
thermometers not functioning properly
handling by different people
different amounts of water.

13. | These are reasons for what event?

Secure a clear definition of event and place it to the right of the list of differences between the groups.

14. | What might be a label for these things on the left side?

Objects, factors, reasons, etc. (Suggest that you use factors or objects.)

15. What label might be used for the right side?

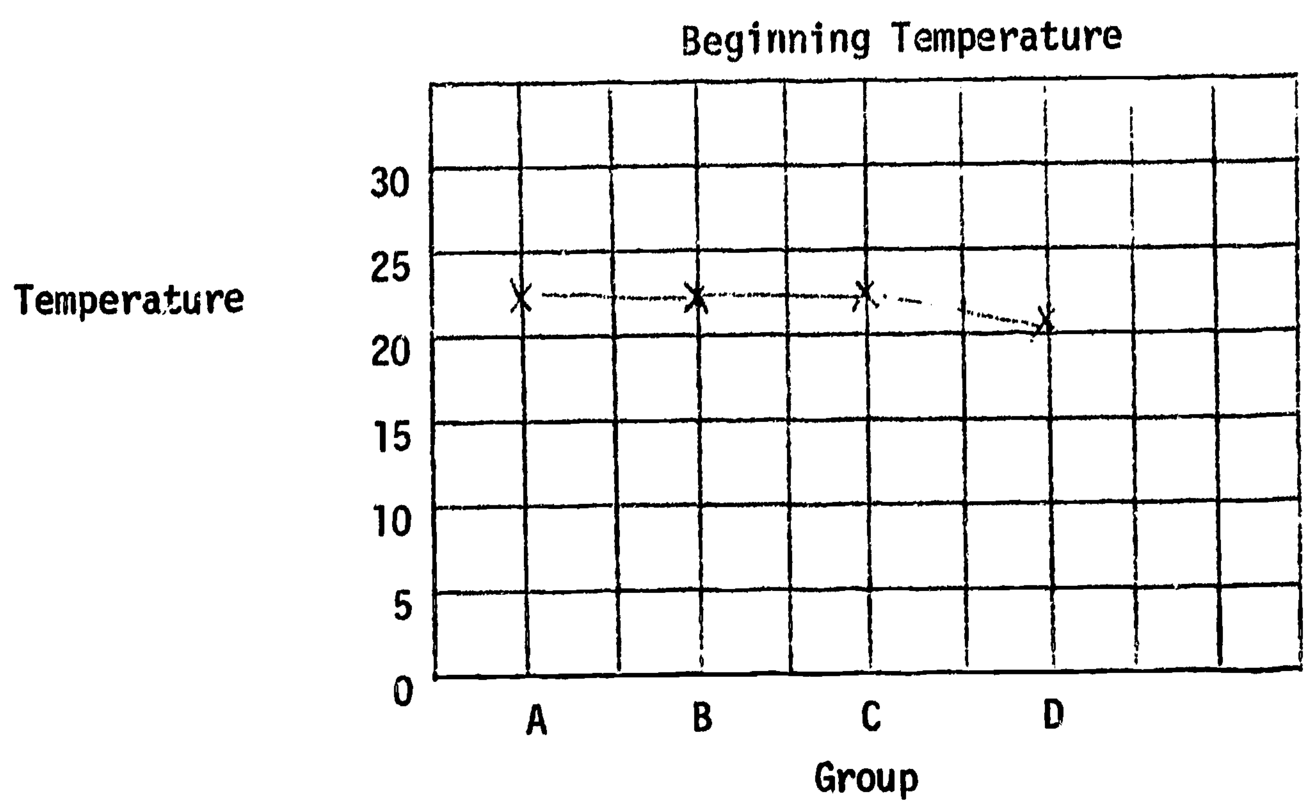
Event.

16. Note that this entire chart is a systematic analysis of the event.

17. Look again at our definition of this event, "Temperature of the water will go up." How can we combine data from all the charts to best picture this event?

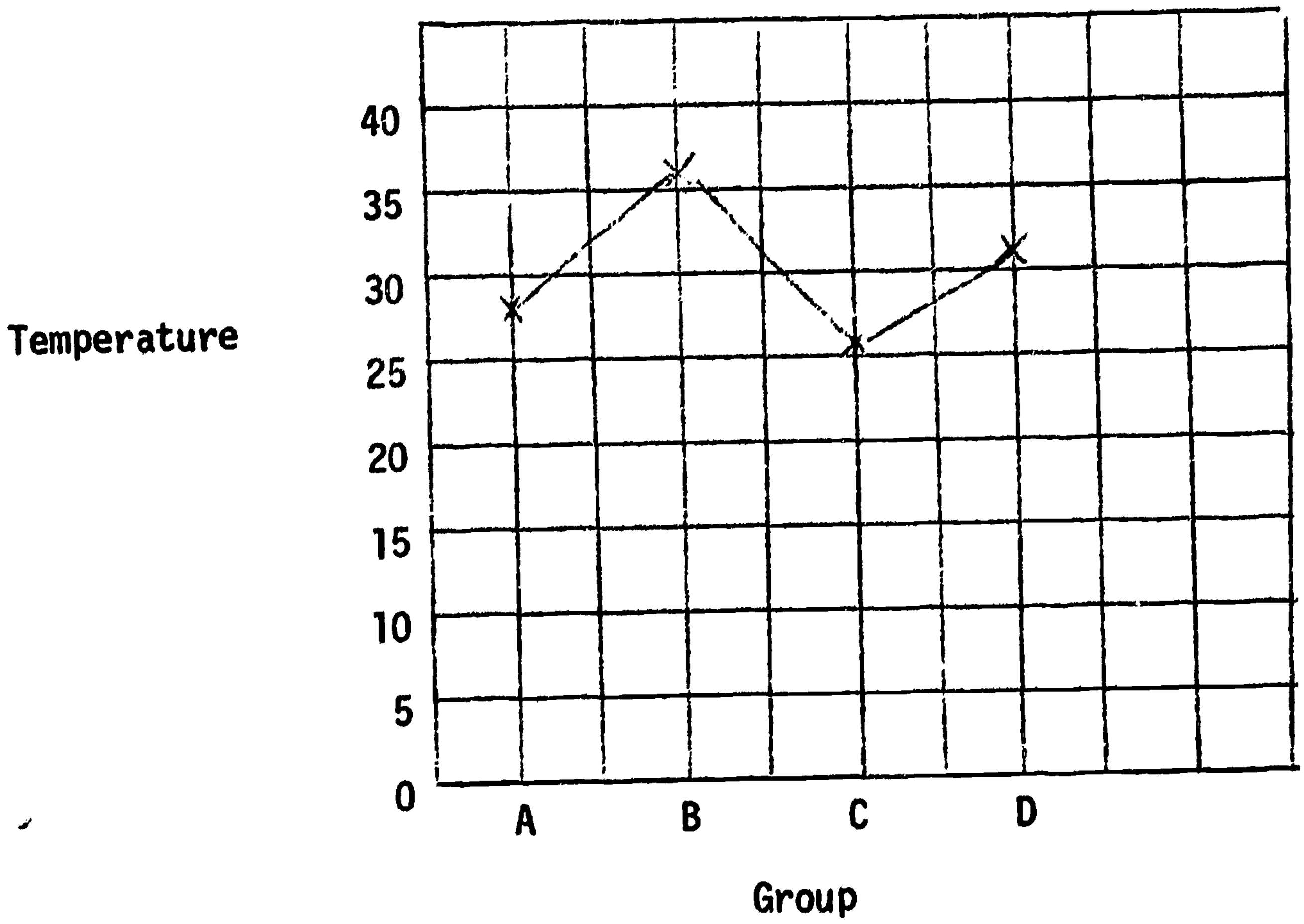
Typical suggestions from participants with sample graphs follow.

Graph the beginning temperature.



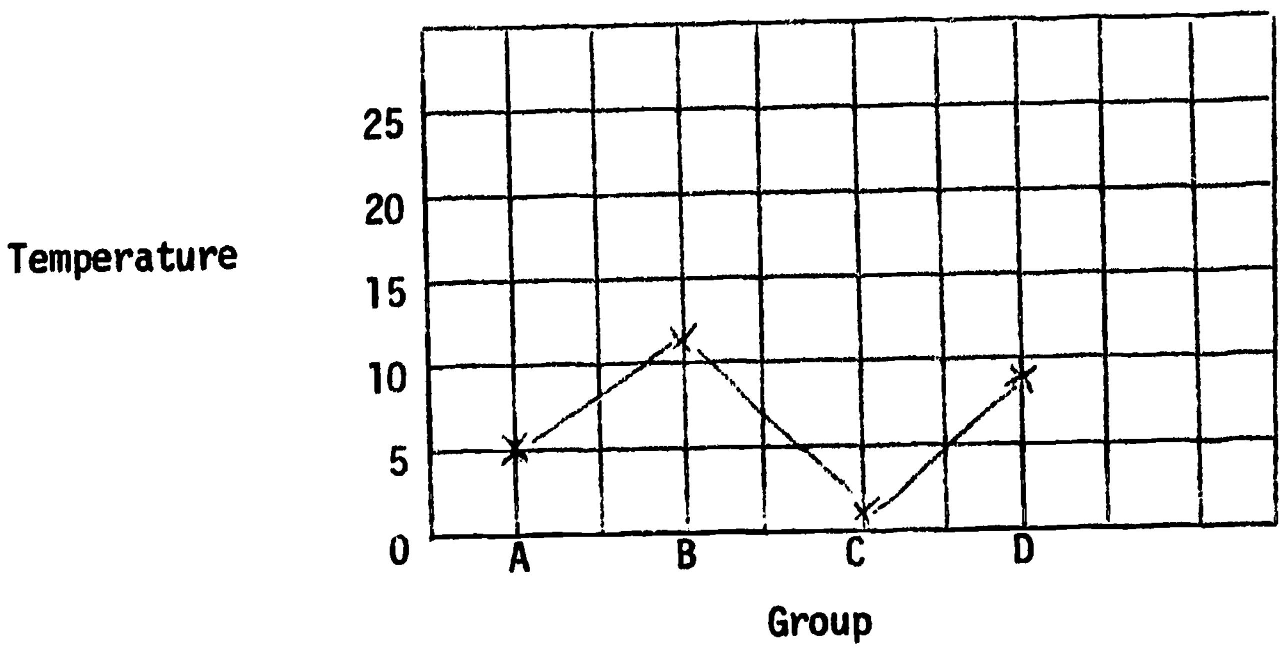
Graph the final temperature.

Final Temperature



Graph the change of temperature.

Change of Temperature



18. From the list of suggestions, each group will work on a different suggestion, organize the data, and prepare a graph.

Assign group tasks and give time for completion.

(Directions: Display these graphs around the room where they may be seen by all.)

19. Which graph best pictures the event?

If participants do not select graph of change,

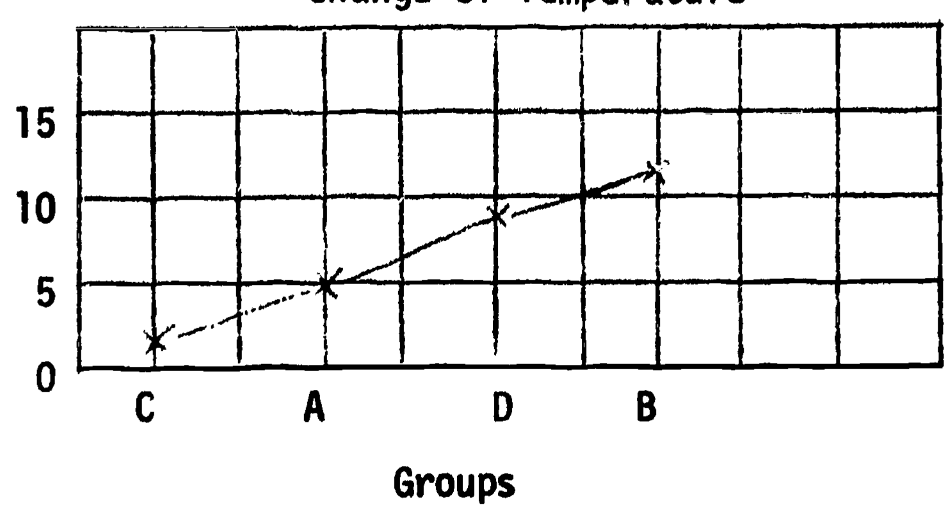
(Directions: Pick out graph of change.)

20. In which group was there the most change? the least? Order the changes.

21. Each group please construct a new graph showing the new order.

Change of Temperature

Temperature



Check graphs for accuracy.

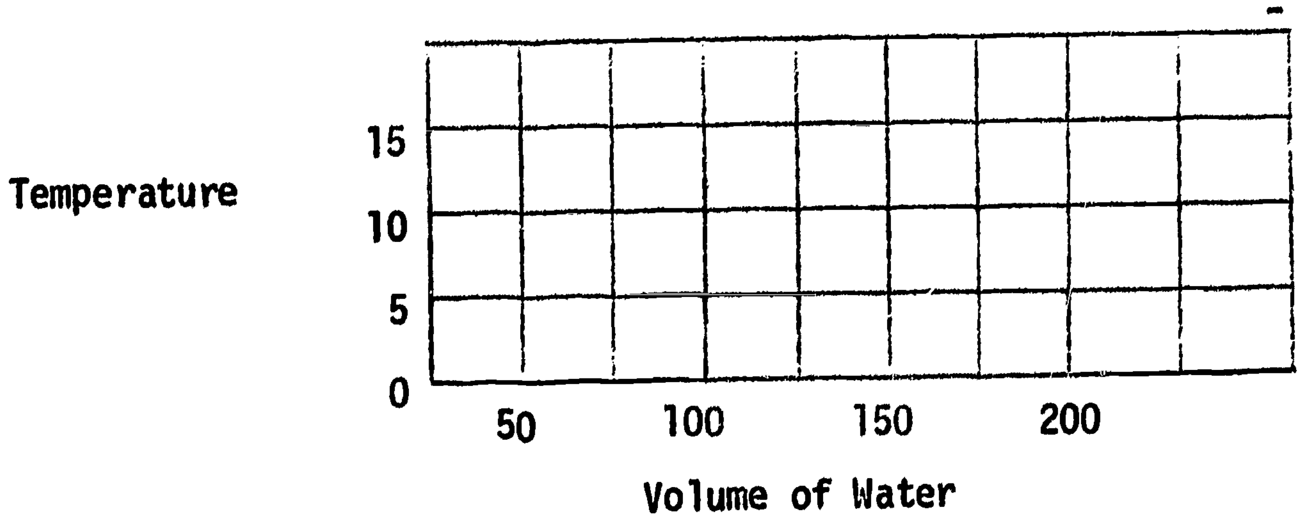
22. What inference can you draw from this new order? (Graph in step above)

Something about the containers is different.

23. Suppose you knew the volume of water in

container A is
container B is
container C is
container D is

Relabel your graphs with the water volume.



24. Now using the graph we have produced, predict the change which would occur in 8 minutes for 275 ml of water.

Here the participants have an opportunity to interpolate. Now for extrapolation -

25. Predict the change in 8 minutes for 600 ml of water.

Activity 3 (Approximate time: 20 minutes)

Performance Objective: State a question which can serve as a basis of further investigation and describe a plan for investigating that question.

26. | What do you think is a "process approach" to (teaching) science? What is your definition?

A process approach has been built on the premise that there are specific ways or strategies that a scientist uses to
seek questions
answer questions

27. | What are some of these ways or strategies that scientists employ?

As the group suggests the various processes,

(Directions: Use transparency A.)

28. | Let's relate the strategies, or processes you've suggested, to the experiment we have just experienced. What observations were made?

Typical related processes and activities:

Observing - red line of thermometer
Measuring - time and temperature
Communicating - graph
Numbers - counting of time and temperature
Space/Time - time
Inferring - reasons for different observations
Predicting - temperature at a different water amount

Operational definitions - change
Controlling variables - which to hold constant, which to respond
Interpreting data - our conclusions
Formulating hypotheses - generalized statement

29. Now, do we store this information we have gathered, or is there some way to use what we have? After a scientist finds answers, what then?

Collected data is used as a basis for asking new questions so that, in turn, more answers are discovered.

30. Write down 3 new questions based on the data we have collected.

Give one minute and ask for sharing of responses. Note participants' suggested questions on chalkboard.

31. Let's select one of the questions, and develop a plan for investigating the question.

This is a whole group activity wherein everyone contributes to the research plan.

32. Let's specify another of the questions, and in each small group, design a plan of research for that question.

All groups work on designing a plan for the same question.

33. Let's share plans.

Share groups' plans and note number of different suggestions for investigating the same question.

Appraisal (Approximate time: 20 minutes)

(Directions: Use OI #2.)

34. 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. You may wish to have participants compare their own pre- and post-appraisals.

35. Let's check our responses:

If you have 1, 3, 4, 6, & 9 marked F, circle Task I.

If you have five of the six items listed, circle Task II. For example, incubator, time in incubator, seed type, number of seeds, temperature.

If your question involved use of an object and you used it as a manipulated variable, circle Task III.

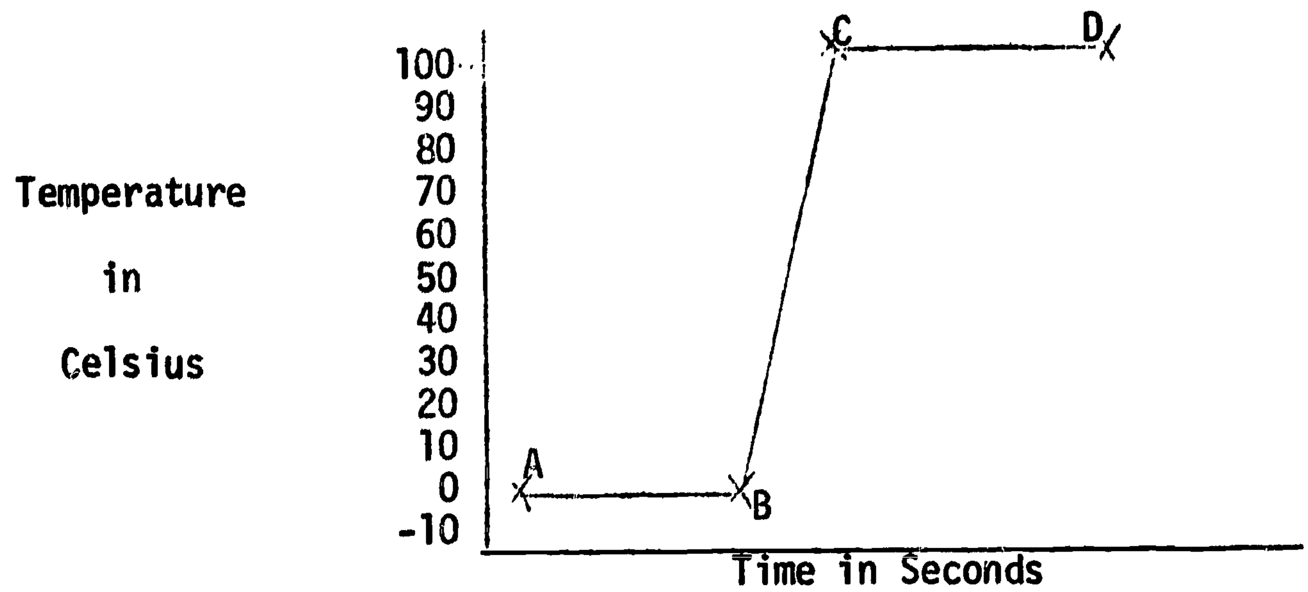
Duplicated Materials -- Without Answers

OI #1

Code ________

ORGANIZING TO INVESTIGATE

A hot plate has been pre-heated for 5 minutes. The temperature switch of the hot plate remained at the same setting during the experiment described below. The experiment involved a pan of ice cubes which were placed on the hot plate. The temperature was recorded every 30 seconds, and the results when graphed looked like this:



TASK I:

Based on the information given, code the statements in the following lists with

_F_ for those that are Facts from the graph.

_I_ for those which are Interpretations from the graph.

_____ 1. The temperature was the same at Point B as it was at Point A.

_____ 2. The hot plate was turned on "high."

_____ 3. The ice disappeared at the time of Point B.

_____ 4. The temperature was the same at Point D as at Point C.

_____ 5. The substance was hotter at point C than at Point B.

_____ 6. Between points A and B the ice melted.

_____ 7. Between points B and C the temperature changed.

_____ 8. At point C the water boiled.

_____ 9. At point D the water was boiling.

TASK II:

Construct a systematic analysis of the experiment.

Event	Objects in System
When a constant source of heat is added to ice, change occurs.	1. 2. 3. 4. 5.

TASK III:

Given the event described in your analysis of Task II, state one question which you could investigate further.

____

____

____

What specifically would you do to find the answer to your question?

____

____

____

____

OI #2

Code ________

This chart describes the result of putting 50 seeds in incubators at 20°C and 30°C.

Time after putting seeds in incubator.	Total number of seeds that had germinated up to a certain time.	
Hours	20°C Incubator	30°C Incubator
0	0	0
3	0	0
6	0	1
9	1	10
12	5	39
15	23	47
18	36	48
21	41	48
24	44	48
27	47	48
30	47	48

TASK I:

Based on the information given code the statements in the following lists with

F for those that are Facts.
I for those that are Interpretations.

____ 1. More seeds germinate in the 30°C incubator than in the 20°C incubator.

____ 2. The incubators were the same size.

____ 3. At 6 hours the seeds in the 30°C incubator had germinated.

_____ 4. The number of seeds in the incubators were the same.

_____ 5. All seeds in the incubator had the potential for germination.

_____ 6. At 15 hours nearly twice as many seeds had germinated in the 30°C incubator.

_____ 7. Lima bean seeds were used for this experiment.

_____ 8. Water was added every 4th hour to a container inside the incubators.

_____ 9. At 27 hours the seeds in both incubators had germinated about the same.

TASK II:

Construct a system analysis of the experiment.

Event	Objects in the System
Heat affects the germination of seeds.	1. 2. 3. 4. 5.

TASK III:

Describe one question your analysis in Task II suggests that you could investigate further.

____

____

What would you do to find the answer to this question?

____

____

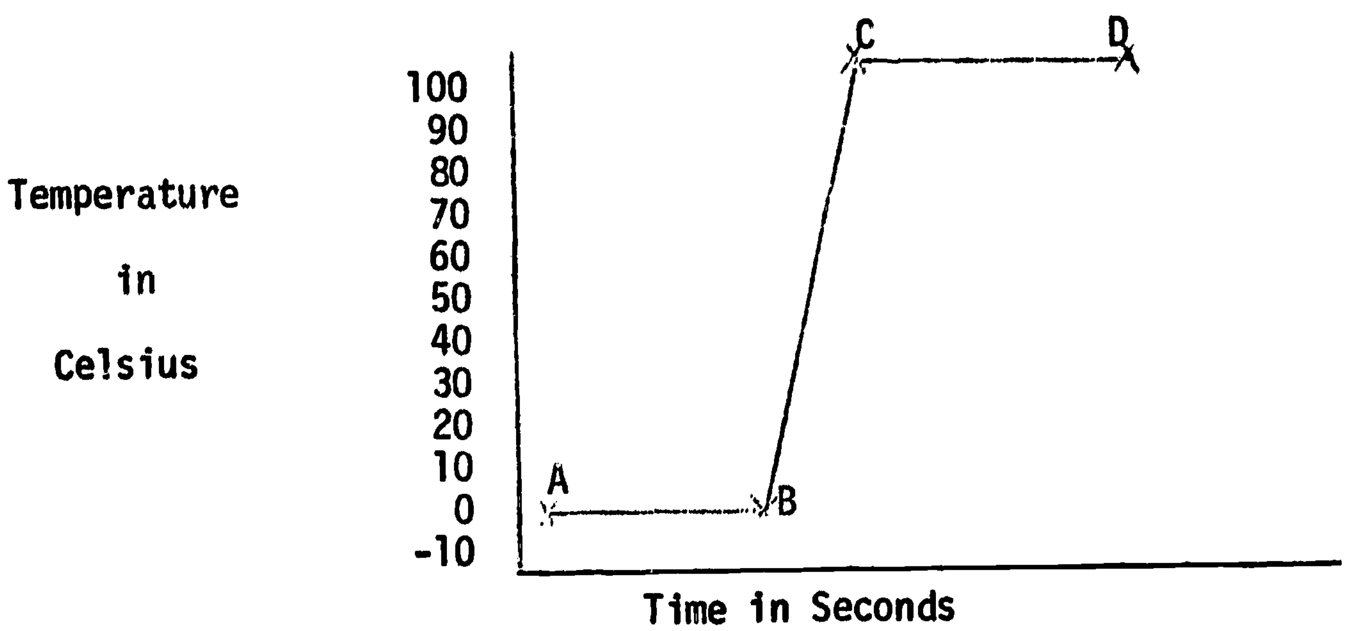
Duplicated Materials -- With Answers

OI #1

Code __________

ORGANIZING TO INVESTIGATE

A hot plate has been pre-heated for 5 minutes. The temperature switch of the hot plate remained at the same setting during the experiment described below. The experiment involved a pan of ice cubes which were placed on the hot plate. The temperature was recorded every 30 seconds, and the results when graphed looked like this:



TASK I:

Based on the <u>information</u> given, code the <u>statements</u> in the following lists with

_F_ for those that are Facts from the graph.

_I_ for those which are Interpretations from the graph.

_F_ 1. The temperature was the same at Point B as it was at Point A.

_I_ 2. The hot plate was turned on "high."

I 3. The ice disappeared at the time of Point B.

F 4. The temperature was the same at Point D as at Point C.

F 5. The substance was hotter at point C than at Point B.

I 6. Between points A and B the ice melted.

F 7. Between points B and C the temperature changed.

I 8. At point C the water boiled.

I 9. At point D the water was boiling.

TASK II:

Construct a systematic analysis of the experiment.

Event	Objects in System
When a constant source of heat is added to ice, change occurs.	1. Ice cubes 2. Pan 3. Hot plate, or source of heat 4. Thermometer 4. Clock or timing device

TASK III:

Given the event described in your analysis of Task II, state one question which you could investigate further.

DOES THE AMOUNT OF ICE MAKE A DIFFERENT IN THE TIME BETWEEN B AND C?

IS THE SOURCE OF HEAT IMPORTANT TO THE EVENT?

What specifically would you do to find the answer to your question?

THREE PANS WITH 1 CUBE HEAT AND GRAPH RESULTS

5 CUBES

15 CUBES

OI #2

Code ________

This chart describes the result of putting 50 seeds in incubators at 20°C and 30°C.

Time after putting seeds in incubator.	Total number of seeds that had germinated up to a certain time.	
Hours	20°C Incubator	30°C Incubator
0	0	0
3	0	0
6	0	1
9	1	10
12	5	39
15	23	47
18	36	48
21	41	48
24	44	48
27	47	48
30	47	48

TASK I:

Based on the information given, code the statements in the following lists with

F for those that are Facts.
I for those that are Interpretations.

F 1. More seeds germinate in the 30°C incubator than in the 20°C incubator.

I 2. The incubators were the same size.

F 3. At 6 hours the seeds in the 30°C incubator had germinated.

F 4. The number of seeds in the incubators were the same.

I 5. All seeds in the incubator had the potential for germination.

F 6. At 15 hours nearly twice as many seeds had germinated in the 30°C incubator.

I 7. Lima bean seeds were used for this experiment.

I 8. Water was add every 4th hour to a container inside the incubators.

F 9. At 27 hours the seeds in both incubators had germinated about the same.

TASK II:

Construct a system analysis of the experiment.

Events	Objects in the System
Heat affects the germination of seeds.	1. Incubator 2. Time in incubator 3. Seeds, type 4. Number of seeds 5. Temperature

TASK III:

Describe one question your analysis in Task II suggests that you could investigate further.

WILL THE SAME EVENT OCCUR AT 10°C?

WILL THE SAME EVENT OCCUR AT 50°C?

What would you do to find the answer to this question?

REPEAT THE EXPERIMENT AT 10°C, 20°C, and 30°C.