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ABSTRACT

This handbook was prepared for use in any classroom to aid the student in understanding how to become a better learner and how to learn meaningfully. This program is based on Ausubel's cognitive learning theory which places emphasis on the differences between meaningful learning and rote learning. To acquire knowledge meaningfully means that the learner must incorporate new knowledge into concepts the learner already has. The program is designed to extend, modify and elaborate these concepts, partly through providing instruction in new relationships among concepts that the student already has, and partly by providing new relevant concepts about learning. Included are: (1) the learning process, (2) the nature of knowledge, and (3) how to extract meaning from materials studied. Also included are instructions on how to make concept maps and the use of Gowins Knowledge "V". (Author/DS)

TEACHER HANDBOOK for the

LEARNING HOW TO LEARN PROGRAM

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HANDBOOK FOR THE LEARNING HOW TO LEARN PROGRAM

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TABLE OF CONTENTS

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I. INTRODUCTION

MEANINGFUL LEARNING

THE KNOWLEDGE "V"

CONCEPT MAPPING

MEANINGFUL LEARNING

The "Learning How to Learn Program" is designed for use in any classroom together with the regular program of instruction. Although the materials in this handbook were prepared for junior high science teachers, they might be used by teachers at other grade levels and in other subject matter fields.

To understand how to become a better learner, students need to gain some understanding of (1) the learning process, (2) the nature of knowledge, and (3) how to extract meanings from materials studied. This program is based on Ausubel's (1978) cognitive learning theory which places emphasis on the difference between meaningful learning and rote learning. In fact, the major objective of this program is to help students learn <u>how to learn meaningfully</u>. To acquire knowledge meaningfully means that the learner must incorporate new knowledge into concepts that the learner already has. Our program is designed to extend, modify and elaborate these concepts, partly through providing instruction in new relationships among the concepts that the student already has, and partly by providing new relevant concepts about learning.

THE KNOWLEDGE "V"

We have found that students gain in their understanding of meaningful learning when they acquire knowledge about the knowledge-making process. To accomplish this, we have found a simple device invented by Gowin (1979) to be helpful. We teach students to understand each of the elements represented on Gowin's "V" shown in Figure 1.* At the "point" of the "V" are objects and events, and these occur in the natural world or are made to occur by people (as in a laboratory experiment). At this point, our key conceptual activities come together with our methodological activities. We define a concept as a regularity in

*A more extensive treatment of the "V" and its accompanying terms can be found in section IV in this handbook.

events or objects designated by a sign or symbol. For instance, to study digestion of starch by saliva, we need concepts of enzyme, starch, digestion, maltose, sugar, solution, and others. Students begin to see that even to set up a meaningful experiment, or to be selective in observing objects and events, we must use concepts.

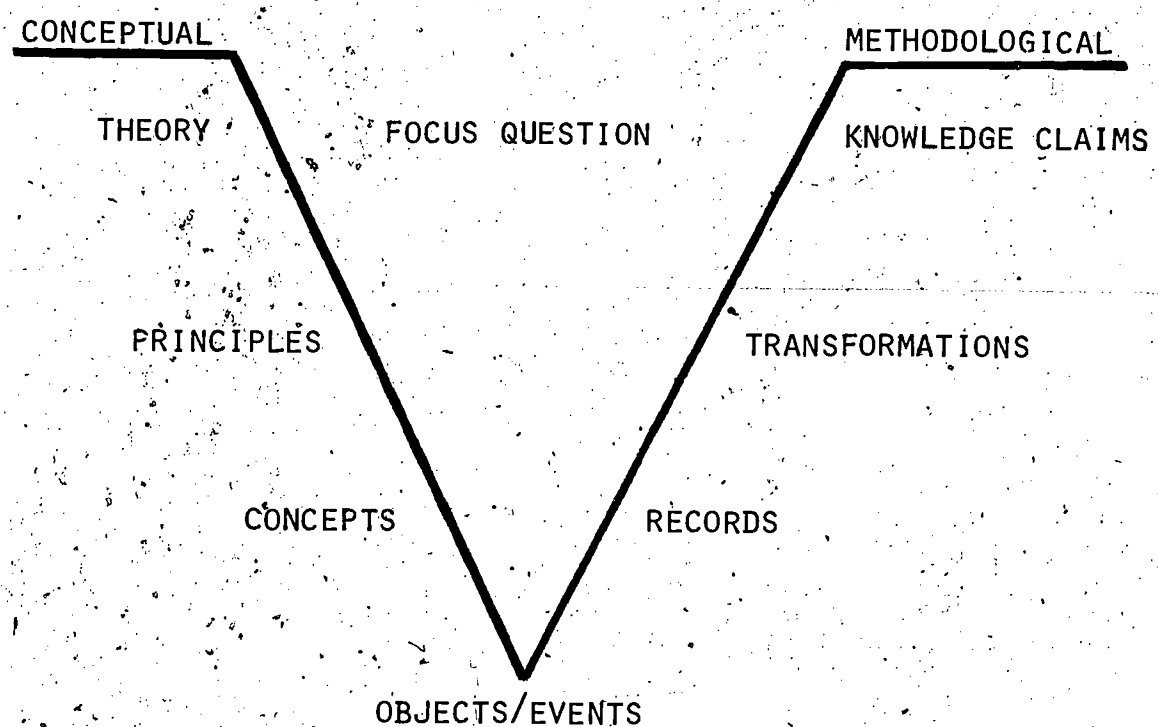


Figure 1. Gowin's Knowledge "V" (1979) used with seventh and eighth grade students as a heuristic device to help in understanding how knowledge is produced in the sciences.

The V-shape of this device serves to emphasize that both conceptual and procedural or methodological elements are brought to bear on objects and events in the process of knowledge production. A "focus question" serves to direct the process of knowledge production.

Concepts can be linked together to describe a specific regularity, such as, "the sun rises every morning." This kind of statement or proposition is often called a principle. Principles, in turn, may be related together in broader, more inclusive ideas that we call theories, such as the atomic theory or the theory of natural selection.

Concepts, principles, and theories also guide the methodological activities on the right-hand side of the "V". These activities include record-making, such as gathering instrument readings or notes on observations, and transformations, such as graph or chart preparations or statistical analysis. The knowledge claims represent what has been constructed through the active interplay among the concepts, principles, and theory we use and the records and transformations about the events and objects we have examined.

CONCEPT MAPPING

Another device we have found useful is to have students construct concept maps. Concept maps help students understand that concepts derive their meanings through "connections" or relationships with other concepts.

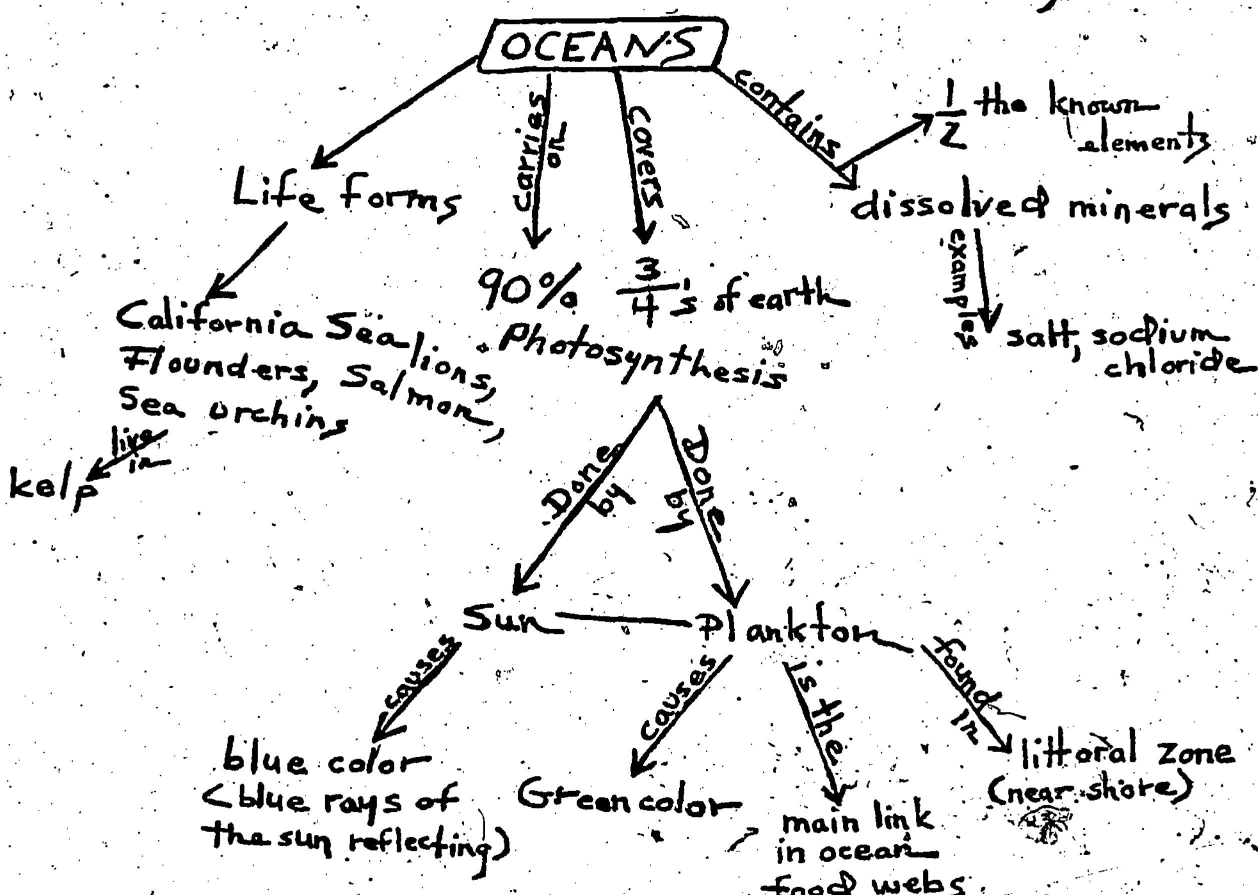


Figure 2: A Concept Map of the biome "Oceans," prepared by a group of four seventh grade students from a section of reading in their text.

To define a pen as a writing instrument is to relate the concept "pen" to the concepts of "writing" and "instrument." Figure 2 shows a concept map constructed by a group of seventh grade students from a textbook reading on world biomes. We will discuss the procedure for teaching and using concept maps in Section III of this handbook.

In summary, the "Learning How to Learn Program" is designed to be used in classrooms to help students understand the nature of knowledge and the nature of cognitive learning.

II. LEARNING

OVERVIEW OF THE AUSUBEL-NOVAK THEORY

ACTIVITIES IN MEANINGFUL LEARNING

SUMMARY

OVERVIEW OF THE AUSUBEL-NOVAK THEORY

Throughout the elementary school program, it is common for students to memorize definitions or procedural rules without relating the meanings of the words in the definitions or rules to ideas they already understand. In fact, students often come to believe that rote memorization of school information is the only way to learn. As teachers, we may want to reduce rote learning, but often find ourselves helpless to achieve more meaningful learning in the classroom. Two major reasons for this dilemma are: (1) the student is not aware that there is an alternative to rote learning, and (2) concepts that are to be learned are presented in such a way as to encourage rote memorization.

The intention of this section of the "Learning How to Learn Handbook" is to provide the student with an alternative to rote memorization by showing him/her that it is more efficient to learn in a meaningful way. Further, this section and the ones that follow will provide the teacher with information about how instruction can be organized to facilitate meaningful learning and discourage rote memorization.

The Ausubel-Novak learning theory attempts to provide a description of how learning takes place in the learner, how the learner processes new information, and how that information is stored. Already, two terms of the Ausubel-Novak theory have been introduced. The first is rote learning. Rote learning occurs when information that is learned is stored arbitrarily within the cognitive structure* of the individual. In other words, the new information or concept has no psychological connection to other concepts and their meanings. Activity #1 in this section is an example of information that is learned rotely. If quizzed on the meaning of the words (concepts) of the Pledge of Allegiance, how many students would be able to give adequate answers?

The opposite of rote learning is meaningful learning. Meaningful learning occurs when the learner is able to link new information to concepts and meanings that s/he already has in his/her cognitive structure.

*cognitive structure is the composite of stored knowledge representing the concepts, propositions, and other information learned by an individual.

In other words, new information to be learned is not taught arbitrarily, but always in relation to what the learner already knows.

In the following sections, learning activities are suggested that will help students understand the differences between rote and meaningful learning. Activities #2 and #3 illustrate the difference between rote learning and meaningful learning. List #1, on page II-4, requires that the student memorize the terms in a rote fashion. List #2, although the same instructions are given, has the concepts arranged in a more meaningful way. That is, they are already organized according to ice cream flavors, animals, furniture, and colors. While doing this activity, the teacher should find that the group of students with List #2 is able to learn the list of items more quickly than those students with List #1. Lists #3 and #4 on page II-5, demonstrate the distinction between rote learning and meaningful learning is not always a simple one. List #3 gives the names of a group of flowers; List #4 gives the botanical names for parts of a plant. Which one is more meaningful? Which is more rote?

Activities #3, #4, and #5 will demonstrate the use of prior experiences and knowledge to provide the organizing links that make new information more meaningful. Activity #4 does this by giving one group of students an organizing sentence which provides the meaningful link between the prior knowledge and the new information in the paragraph. Activity #5 introduces the idea of concept mapping as a means of organizing the information learned into a more meaningful fashion. And Activity #6 illustrates the idiosyncratic nature of the concepts that a learner possesses. Although each person stores information in an idiosyncratic way, there are enough regularities among the meanings of our stored concepts so that communication can occur.

In the last activity, the distinction between rote and meaningful learning is considered more directly. In this one, the learner is asked to identify those concepts that s/he considers meaningfully learned and those s/he considers rotely learned. The meanings of the concepts, indicated by the regularities we recognize for that concept and the specific events and objects as example of each concept, demonstrate the relative meaningfulness of these concepts to students.

It is hoped that through the examination of the concepts of rote learning and meaningful learning the student can recognize what is required to move toward meaningful learning and away from rote learning. Further, it is hoped that the teacher can begin to re-examine how information is presented to the learner, either in lessons or in textbooks. And that the strategies presented in the "Learning How to Learn Program" can facilitate this transition to the more meaningful, efficient teaching and learning of concepts.

ACTIVITIES IN MEANINGFUL LEARNING

ACTIVITY #1 - Rote Learning

Say the Pledge of Allegiance to the Flag. This is an example of something which is learned rotely. It is shared by everyone, and it must be said exactly as written or it is wrong.

Perhaps you may wish to write the Pledge of Allegiance on the board and circle key concepts, such as "allegiance" and "republic," and ask who knows what these concepts mean.

ACTIVITY #2 - Rote Learning and Meaningful Learning

If some information is going to be learned meaningfully, that information must be linked to existing concepts that the student already possesses. This can be shown in the following exercises. Give List #1 to half the class; List #2 to the other half. Give the following directions: "Here is a list of words. Everybody has the same words. You will be given thirty seconds to memorize the list that you have."

List #1	List #2
vanilla	vanilla
elephant	chocolate
desk	strawberry
yellow	
chocolate	elephant
red	camel
table	horse
camel	
strawberry	desk
green	chair
horse	table
chair	
	red
	yellow
	green

Figure 3. Lists of Organized and Unorganized Words.

After the thirty seconds, have the students list as many words as they can remember. Tally the number of remembered words for each student using List #1 and for those with List #2. The number of words each student remembers is a record of this learning-recall event. Determine the average for each group. The average number of words recalled (usually about 6+ for the group with List #1, and 8+ for the group with List #2) is a transformation of the original records, and serves to illustrate how the learning principles guide the inquiry. (See IV-2 through IV-12 for further discussion.)

Discuss with your students the idea of organization and meaningfulness of the material. List #2 already had the words organized into a pattern of ice cream flavors, animals, pieces of furniture, and colors. List #1 did not have that organization, or at least, the organization may not have been apparent after only thirty seconds. List #2 is meaningful for the student who realizes that the items are categorized.

You may want to try the next two lists to stress the point of meaningfulness for the students. Each list deals with plants, but List #4 may present some difficulties to the students since the terms are unfamiliar. It will be very difficult for the students to learn the list in the last column. This is an example of arbitrary learning or rote learning.

List #3	List #4
petunia	tracheid
gardinia	sclerenchyma
marigold	xylem
zinnia	cambium
goldenrod	epidermis
sunflower	mesophyll
maple	parenchyma
sycamore	pallisade
cottonwood	stomata
walnut	aperture

Figure 4. Lists of Familiar and Unfamiliar Botanical Names.

ACTIVITY #3 - Organizing for Meaningful Learning

How we interpret and relate to a problem often depends on our past experiences. These experiences help us to sort out our new information. On this page and the next are two paragraphs,* identical except for the first sentence. Divide the class once again into two groups, and give them the following directions. "You will be given a paragraph to read. After you have read it, you will be asked questions about the contents of the paragraph, and what the paragraph is discussing."

> This paragraph is about washing clothes. It is actually quite simple. First, you arrange things into different groups depending on their makeup. Of course, one pile may be enough depending on how much there is to do. If you have to go somewhere else due to a lack of equipment, that is the next step, otherwise you are pretty well set. It is important not to overdo any particular part of the job. That is, it is better to do too few things at once than too many. In the short run, this may not seem important, but trouble from doing too many can easily arise. A mistake can be expensive as well. Working the equipment should be self-explanatory, and we need not dwell on it here. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to see an end to the necessity for this task in the immediate future, but then one can never tell.

Figure 6A. Washing Clothes Passage with Organizing Sentence.

*from R.E. Meyer. (1977) THINKING AND PROBLEM SOLVING: AN INTRODUCTION TO HUMAN COGNITION AND LEARNING. Glenville, IL: Scott, Foresman & Company.

It is actually quite simple. First, you arrange things into different groups depending on their makeup. Of course, one pile may be enough depending on how much there is to do. If you have to go somewhere else due to a lack of equipment, that is the next step, otherwise you are pretty well set. It is important not to overdo any particular part of the job. That is, it is better to do too few things at once than too many. In the short run, this may not seem important, but trouble from doing too many can easily arise. A mistake can be expensive as well. Working the equipment should be self-explanatory, and we need not dwell on it here. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to see an end to the necessity for this task in the immediate future, but then one can never tell.

Figure 6B. Washing Clothes Passage without Organizing Sentence.

Questions for the Class:

Who understand the story? Indicate by raising your hand?
Who does not understand the story?
For those who do understand the story, read the first sentence of your paragraph.

Students who had paragraph 6A will generally say they understand the story, and those with paragraph 6B may make some "wild guess" as to what it was all about. This exercise serves to illustrate that we can sometime aid the process of meaningful learning by statements that help to "organize" ideas by linking these ideas to what is already familiar. Meaningful learning is aided by procedures which help students tie new information to knowledge they already understand.

ACTIVITY #4 - Organizing by Means of a Concept Map.

The purpose of this activity is to illustrate a valuable strategy for organizing material to be meaningfully learned. It introduces the idea of concept mapping of verbal material.

Again, divide up the class into two groups. Group #1 will receive the paragraph reading; Group #2 will receive the concept map on the next page. Give the students the following directions: "You will be given a sheet of paper with some information on it. The two groups have the same information, but in different forms. Study the piece of paper for four minutes. After that time, you will be given a quiz about the information on the papers."

> Everyone is familiar with metals. Metals that occur naturally are called pure metals. Some pure metals like gold, silver, and platinum are considered precious metals because they are rare. Copper, lead, iron, and aluminum, on the other hand, are considered common because they are more abundant. People have learned to combine pure metals and other substances to create new metals, called alloys. Steel, brass, and bronze are alloys. We see metals every day in cars and buildings (alloys mostly), in jewelry (rare metals) and in plumbing pipes and cooking foil (common metals).

Figure 7A. Metals Paragraph.

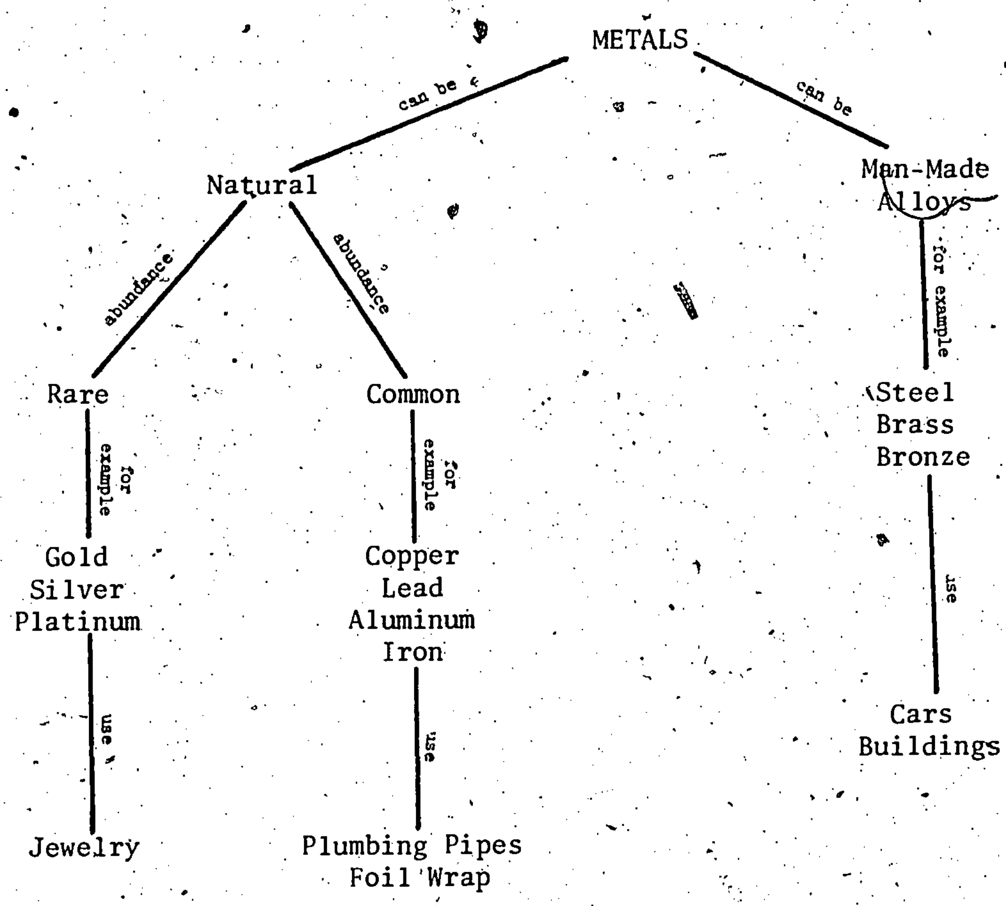


Figure 7B. Metals Concept Map.

Activity #4 Questions for Groups #1 (Paragraph readers) and #2 (Concept Map readers).

1. What is the best word label for the subject of this information?
2. Write the difference between pure metals and alloys.
3. Why are gold and silver called precious metals?
4. List two common pure metals.
5. Choose two from this list that are alloys.

Platinum Bronze Copper	Steel Aluminum

6. Metals used in cars and building are mostly ________.
7. Precious metals are mainly used for ________.

ACTIVITY #5 - Concepts and Stored Meanings

This activity illustrates that meanings are stored and that these meanings are idiosyncratic. That is, not everyone has the same meanings stored for each term. In asking the students to share their definitions of each word, they can come to realize that definitions do not match exactly since it is the meaning that is stored, and not the word. Also, there are aspects of the definitions that students do hold in common. These common features of the definitions could represent the regularities of the concept word. (See Activity #6.)

Ask the students to write their definition for each of the following:

ANIMAL FOOD AIR

Have the students share their definitions.

Questions for the Class:

Where did the information (given in the definitions) come from?

Why doesn't everybody's definitions match exactly? (Because it is their meanings which are stored.)

What are the aspects of the definitions that are held in common? (These could be the regularities of the concept.)

This activity also seems to illustrate that concepts vary in the extent of meaning they have for any one person. Concepts are more meaningful when they are related to larger sets of other concepts through meaningful propositions, such as "animals include vertebrates and invertebrates.". The next activity seeks to help define concepts and to emphasize that each concept symbol or sign represents a specific regularity in objects and events. It is not always easy to describe the regularity represented by a concept label, even when we are very familiar with the concept, as in the examples given above.

ACTIVITY #6 - The Rote-Meaningful Continuum

"The extent to which anyone can learn something meaningfully depends upon, (1) the potential meaning of the material, (2) the degree of development of related concepts by the individual, and (3) the effort to relate the new material to what the learner already knows." These three criteria can be illustrated in this activity. The potential meaningfulness of concepts relates the our ability to see the regularities that those concepts possess, and our ability to point to objects and events which are examples of those concepts. Give students the following directions: "Here is a line which represents a range from meaningful learning to rote learning. Choose eight to ten concepts and arrange them according to how meaningful they are to you. Try to use some concepts that represent regularities in objects and some that represent regularities in events. Those which are most rote should have the least meaning; those which are meaningful should have the most meaning. Indicate what the regularities are for each of the concepts and identify the objects or events of that designated regularity."

MEANINGFUL ↑	Concept	Regularity	Event/Object
	love	concern, feeling for others	acts of caring and feeling
examples	wind	moving air	air in motion
	fruit	usually edible, soft, food from plants	apples, bananas, tomatoes
ROTE ↓	phone number	assigned number	specific number, e.g. 555-1000

Figure 8. The Rote-Meaningful Continuum, showing examples of concepts, their regularities and the events or objects.

SUMMARY

After these activities are completed, it would be helpful for the teacher to summarize what information has been obtained. The use of the summary is to provide the student with some principles about learning, specifically about how s/he learns in school, and to provide the teacher with some operating principles that can guide the construction of lessons and units in a meaningful fashion.

- Rote learning occurs when new information is stored arbitrarily. That is, the information is not linked to existing concepts that the learner already has.
- Meaningful learning occurs when new information is acquired and linked to existing concepts that the learner already possesses.
- Existing concepts that the learner possesses act as organizing concepts that provide "anchorage" for new information and facilitate meaningful learning.
- The relationships among the concepts in individuals are idiosyncratic. That is, the concept meanings are unique for each individual.
- However, the meanings stored by individuals should have enough regularities to allow communication.
- Concepts gain in meaning when they can be used in more and more meaningful propositions.

III. CONCEPT MAPPING

FEATURES OF A CONCEPT MAP

CONSTRUCTION OF A CONCEPT MAP

SUGGESTIONS FOR TEACHING CONCEPT MAPPING

FEATURES OF A CONCEPT MAP:

Concept mapping is a means by which concepts and the organization of subject matter can be represented. Both students and teachers find that the use of concept mapping helps "see the subject matter more clearly, and learn that subject matter more meaningfully." Two concept maps have already been presented in this handbook; the metals concept map, Figure 7B, page II-9, and a more complex example on the ocean biome, Figure 2, page I-3. Both of these demonstrate the common features of all concept maps, and it is suggested that you refer back to them during the following description.

A concept map is a two-dimensional representation of a discipline or a part of a discipline. (Stewart, et al, 1979) And it is this feature that allows for the representation of the propositional (principle) relations among the concepts. This is a much different perspective than traditional note-taking which is one-dimensional and illustrates no relationships among the concepts. The concept map not only identifies the major points of interest (concepts), but also illustrates the relationships among the concepts in much the same way the links among cities on a roadmap are illustrated by highways and other roads.

Another feature of a concept map deals with its representation of the relationships among the concepts. Not all concepts have equal weight. That is, some are more inclusive than others. For instance, the concept of "natural selection" is more inclusive than any of the propositions that identify that theory. Thus we can see that every concept map should have at its top the most general, most inclusive concept, and progress down through until the least inclusive, more specific concepts or examples are illustrated at the bottom of the map. The ocean biome concept map (Figure 2, page I-3) illustrates "Salt" and "Sodium Chloride" as examples of "Dissolved Minerals." The "littoral zone" further down the map could have the "Long Island shore" as an example.

The next feature of a concept map is that of hierarchy. When two or more concepts are illustrated under a more inclusive concept, a hierarchy is produced on the concept map. Again from our ocean biome example, the concepts of "sun" and "plankton" are more specific concepts for the process of "photosynthesis," and illustrates a hierarchy of the food production in the oceans. In the metals concept map "pure" metals are classified into "rare" and "common" metals. By contrast, the examples of "copper," "lead," "aluminum," and "iron" show a linear relation to the concept of "common" metals, and thus no hierarchy is illustrated.

In addition to the features of being two-dimensional, showing a pattern of general to specific, and indicating a hierarchy, concept maps have other features. These features are more elaborate and discriminating. For a description of these other features, see Section V, the Assessment of Student-Constructed Concept Maps, page V-4.

CONSTRUCTION OF A CONCEPT MAP

To illustrate the points made more clearly, it will be helpful to construct a concept map step by step so that you can see the features and procedures necessary for a map's development. Although general rules are established for map construction, the teacher is advised that these rules will have to be modified and adapted to the particular teaching situation of your classroom.

The concept map that will be constructed is based on the reading to the right, and is taken from a junior high science text.

1. Select a reading from a text that is not too long. At least at first, the reading should be short

Heat and temperature are closely related. However, they are not the same. The kinetic theory can be used to explain expanding, contracting, and changing phase. Can the theory also be used to explain the difference between heat and temperature?

According to the kinetic theory, molecules are always moving. Scientists agree that a moving object has energy because it is moving. This energy is called kinetic energy, or energy of motion. Since each molecule in a piece of matter is moving, each has kinetic energy. The kinetic energy of molecules is the key to explaining the difference between heat and temperature.

Today scientists believe that the temperature of a piece of matter depends on the average speed of its molecules. In any piece of matter some molecules are moving faster than others. If there are more faster-moving molecules than there are slower-moving molecules, the average speed of the molecules in that piece of matter will be greater. The greater the average speed, the higher the temperature.

A cup of boiling water has a higher temperature than a cup of warm water. The difference in temperature is due to the difference in the average kinetic energy of the molecules of water in each cup. The water molecules in a cup of boiling water have more kinetic energy, on the average, than the water molecules in a cup of warm water. So the average speed of the molecules of boiling water is greater than the average speed of the molecules of warm water.

The amount of heat energy in matter is thought of as being the sum of all the amounts of kinetic energy of every molecule in that matter. So the amount of heat in matter depends on two things: (1) the amount of kinetic energy of each molecule and (2) the number of molecules.

Figure 8: Reading from Blecha, Fisk, and Holly. (1976). EXPLORING MATTER AND ENERGY, PAGE 148.

so that the concept map does not become too large and contain too many concepts.

2. Identify the major relevant concepts, that is, science concepts, by either underlining them in the paragraph or by writing them individually on pieces of paper or small cards. The relevant concepts for the reading are shown in Figure 9 below.

KINETIC THEORY, HEAT, TEMPERATURE, EXPANSION, CONTRACTION, CHANGE OF PHASE, MOLECULE, MOVING, ENERGY, KINETIC ENERGY, MATTER, AVERAGE SPEED, BOILING WATER, WARM WATER, NUMBER OF MOLECULES, LESS, GREATER.

Figure 9: Relevant Concepts from the Reading on Heat and Temperature.

3. While the list above generally shows how the concepts appear in the reading, this may not necessarily represent how the concepts are related to each other in the discipline. The next step then is to order or rank the concepts from the most inclusive (general) to the least inclusive (specific). Each reading, or section of text chapter, or even the entire chapter should have some concept which, because of its inclusiveness, is selected as the most general, or inclusive, of all the concepts presented. Sometimes, though, the inclusiveness depends upon the learner who uses his/her stored meanings to designate the most general concept. The examples will form the bottom of the concept map. What lies between the most inclusive concept and the examples at the bottom will be the intermediate concepts. Although these are not arbitrarily assigned to positions on the concept map, their positions on the map are less crucial to the overall function of the map. On the next page is a chart showing the range of inclusiveness of the concepts presented in the reading on previous page.

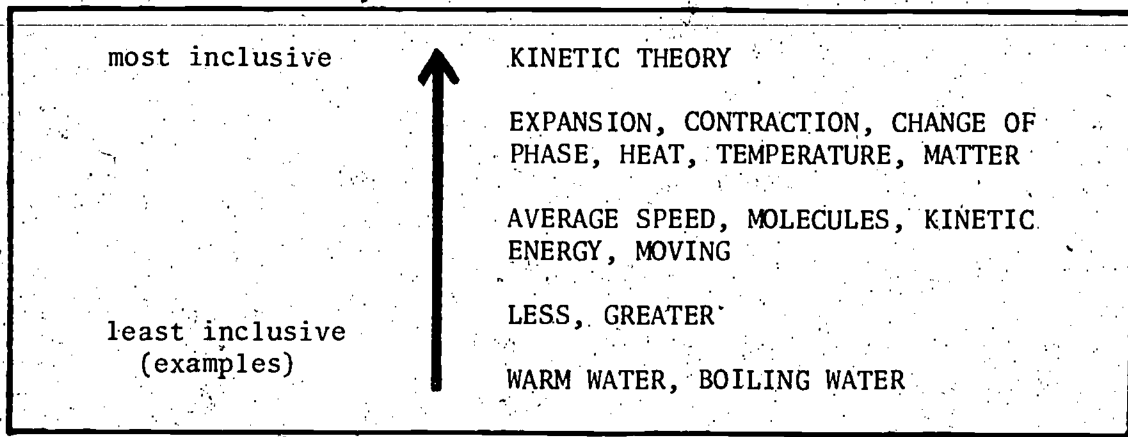


Figure 10: Chart of Ranking of Concepts from the Reading on Heat and Temperature

4. Now begin to arrange the concepts on a table or piece of paper, starting with the most inclusive at the top, followed by the next most inclusive.
5. This same procedure continues until all the concepts have been laid out. The connections among the concepts must now be established. Lines are used to connect the concepts and a statement is written on the line that indicates what the relationship is between any two concepts. The completed concept map for the reading on heat and temperature is shown on the next page in Figure 11.
6. The teacher is now encouraged to examine some of the teaching materials they have and to prepare concept maps for short sections of that material. Practice is the key to good concept mapping: proficiency will come as the map constructor makes a number of attempts.

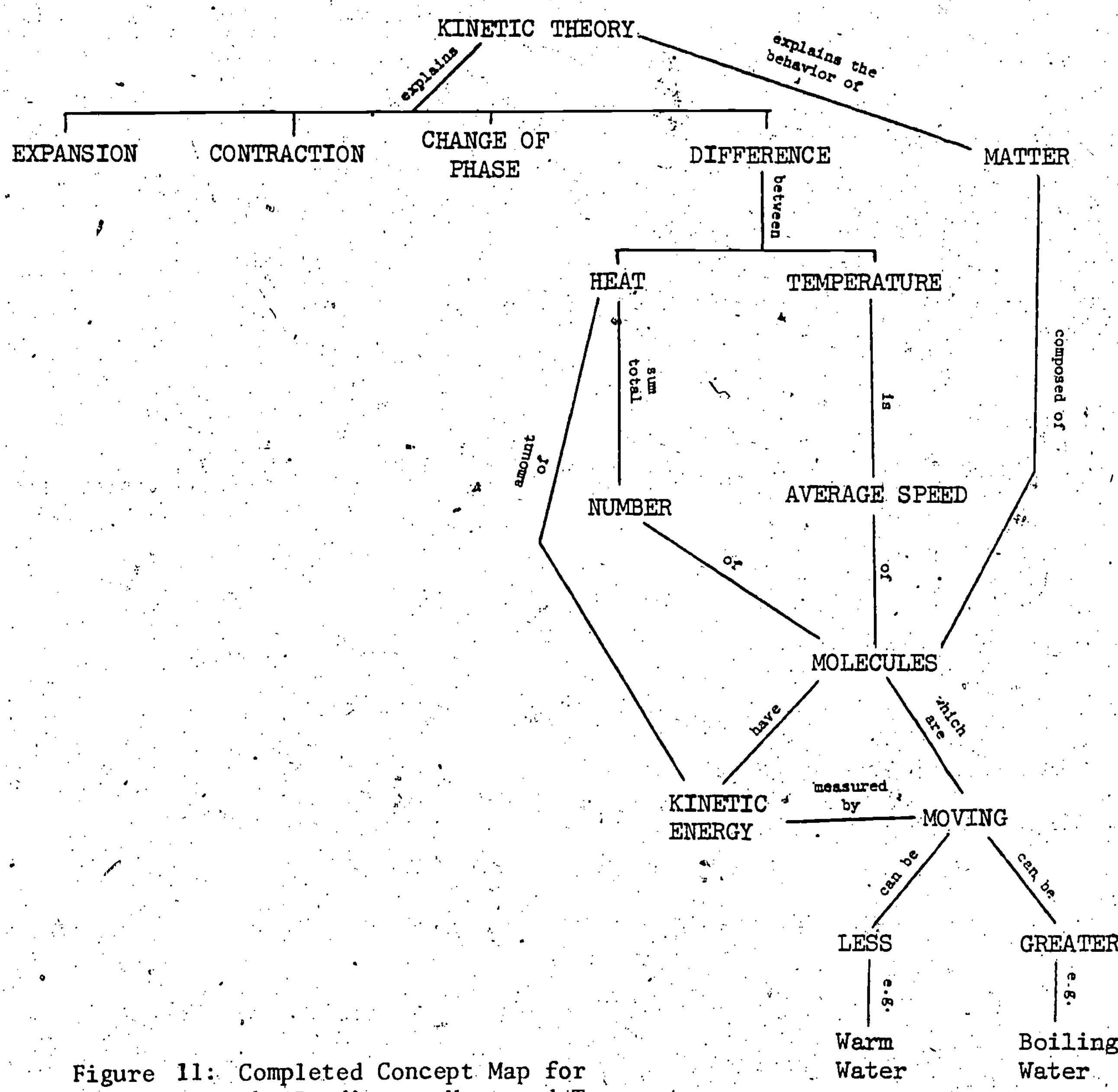


Figure 11: Completed Concept Map for the Reading on Heat and Temperature

There are some elements to a concept map that are not mentioned in the rules for their construction. These are given to facilitate the development of concept maps by both the teacher and the student.

1. A concept map does not have to be symmetrical. The concept map on page III-5 is lop-sided to the side of "Heat" and "Temperature." This should be of little concern. (You will notice, however, that if the concepts of "Expansion," "Contraction," and "Change of Phase" were developed in the same reading, that other side would have been developed more completely.)
2. Remember that a concept map is visually efficient. That is, it is a shortcut way of representing the concepts of the discipline. This should remind us that, as we first develop concept maps, we find that a final map comes only after a few tries. These attempts represent an effort to show the details of concepts and their relationships in the most efficient and consistent way.
3. As you examine the concept map on page III-5 more closely, you may realize that some of the concepts are not in the same form as they were in the reading. For instance, "Expansion" and "Contraction" were changed from "Expanding" and "Contracting." Generally, it has been found that changing the verb concepts to noun concepts facilitates the map's construction without losing any of the intended meaning.
4. It is sometimes advisable to add certain concepts, even though they are not "relevant" science concepts. Their purposes are to clarify the intention of the map, and more faithfully represent the form of the reading. The concept "Difference" was added for just these reasons.
5. Finally, it must be remembered that there are no perfect or correct concept maps, only maps that come closer to the meanings of the concepts for the map maker and others who read them.

SUGGESTIONS FOR TEACHING CONCEPT MAPPING:

In the last part of this section on concept mapping, suggestions for teaching this technique to students is discussed. The pacing of the introduction of concept mapping depends upon the local conditions in the school, the level of the student, and the difficulty of the subject matter.

1. When concept mapping is introduced, it is advised that the teacher make up the map prior to coming to class and hand out copies to the students. Let the students study the map along with their reading. This will give them an idea of what a concept map is, how it is structured, and how it can be used.
2. When the students are ready to attempt a map construction on their own, choose a reading which is particularly short and that contains concepts that are familiar to the students already.
3. Instruct the students to identify the major concepts in the reading, rank them in order of importance, and construct the map from the information they have. (It might be helpful and interesting for the students to use small pieces of paper or "1x3" cards to write the concepts on. Students, in our studies, have said that making concept maps is like puzzle fitting, and perhaps the teacher should approach the task from that standpoint.)
4. The teacher should expect that there can be reasonable differences among concept maps that the students develop. Not all the concepts will be identified, some will not follow the "general to specific" rule, while others may have difficulty identifying the most inclusive concept. As the students become more familiar with concept maps and their construction, these difficulties usually disappear. Students can usually produce very adequate concept after only a period of two to three weeks of exposure to this technique.

5. You may want to have students develop a concept map with you on the chalkboard or the overhead projector.
6. Sometimes groups of students can work together and construct a concept map of a section of text material. The ocean biome concept map on page I-3 is an example of a cooperative effort by four seventh grade students.
7. As the students become more proficient with the construction of concept maps, the teacher should begin to examine closely the line connections among the concepts on the map. Because these lines represent the relationships among the concepts, it is important to assess the students' understanding of these relationships. Two forms of criteria have been designed to assess concept maps done by students. One form has what can be described as a large "field of view" which attempts to give an overall picture of how the students are progressing in their ability to make concept maps. The second form has a small "field of view" and magnifies some of the features of concept maps by establishing more stringent criteria for the map's assessment. Refer to Section V, under "Assessment of Student-Constructed Concept Maps," for these techniques.

Ultimately, the objective is to have students coordinate what they have learned about concept mapping and the Knowledge "V" (discussed in more detail in the next section). Essentially, a concept map can represent the left-hand, conceptual, side of the "V" and already you may have noticed the correspondence between the terms for concept mapping and some of the terms on the left-hand side of the "V".

In the next section, the terms of the "V" are discussed, examples are given, and suggestions for introducing and teaching the "V" to students are provided.

IV. THE KNOWLEDGE "V"

INTRODUCTION TO THE KNOWLEDGE "V"

BACKGROUND INFORMATION AND DEFINITIONS OF TERMS AROUND THE "V"

USE OF THE "V" AS A PRE-TEACHING, TEACHING, AND LEARNING TOOL

SUGGESTIONS FOR INTRODUCING THE KNOWLEDGE "V"

INTEGRATION OF THE "V" AND CONCEPT MAPPING

INTRODUCTION TO THE KNOWLEDGE "V"

The nature and organization of cognitive structure not only plays a major part in our individual learning, but also forms the basis of the collective knowledge in the sciences (as well as other disciplines). The nature of knowledge and the analysis of knowledge can be taught through the use of Gowin's Knowledge "V". Briefly, Gowin defines two types of concerns that are used in conjunction with the intent of reaching or arriving at some knowledge claim. They are the conceptual and methodological activities. The left-hand, conceptual, side of the "V" indicates the appropriate questions to ask, and what theories, principles, and concepts bear on that question. This conceptual side is balanced with a methodological side which identifies what has been observed, gathered, and manipulated in the laboratory so that records and data are accumulated to substantiate the knowledge claim. What binds these two activities together are the objects and events that occupy the bottom of the "V".

Nine terms are associated with the "V". In the following pages, these terms will be defined, and examples from actual laboratory exercises will be given. The skeleton form of the "V" and its accompanying terms are given below.

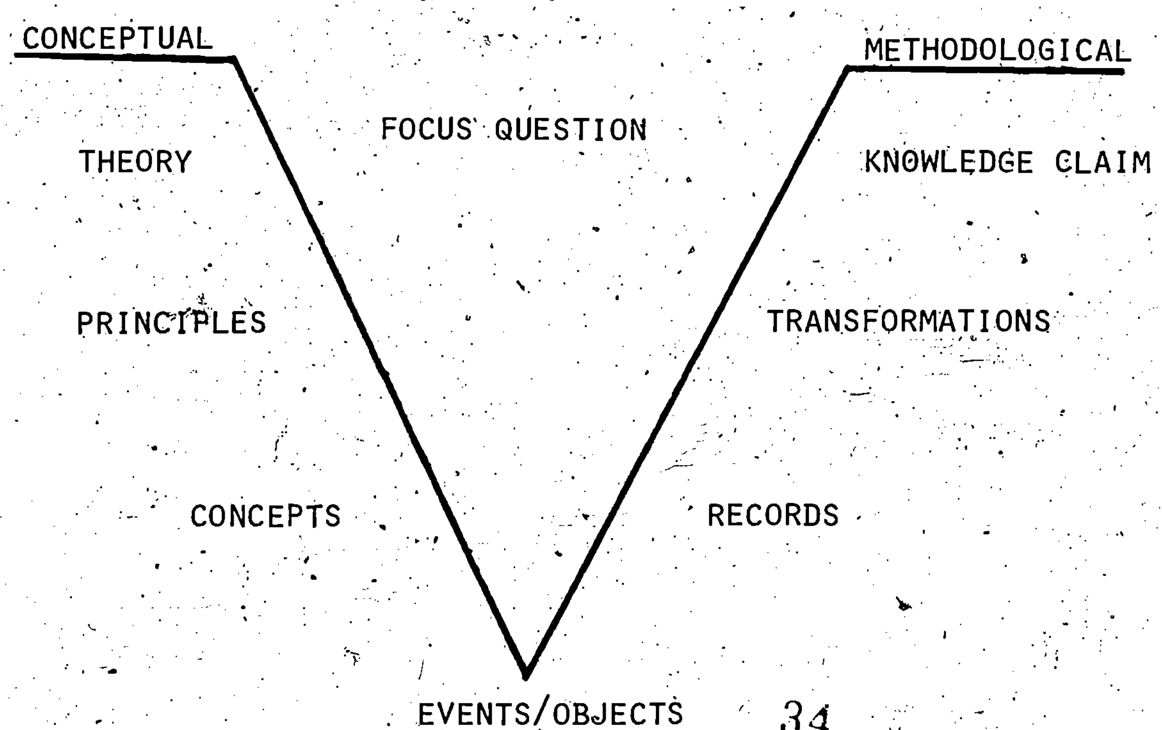


Figure 12: Gowin's Knowledge "V"

BACKGROUND INFORMATION AND DEFINITIONS OF TERMS AROUND THE "V"

The introduction of the "V" into the classroom requires that the teacher modify some of the definitions that are normally used. Although there is a great deal of commonality from the previous definitions associated with the so-called "scientific method" and the "V", some clarification of these terms is necessary. The following is written to accomplish the task of acquainting the teacher with the terms and definitions around the "V" and to facilitate the smooth introduction of the "V" as a teaching and learning strategy in the classroom. Two laboratory exercises have also been included, and will serve as reference points as the definitions are discussed. The first example is a laboratory exercise that was taken from a published laboratory handbook designed for a junior high physical science course. The lab exercise was laid on the "V" for analysis by the class. It is taken from the laboratory manual (pp. 27-28) which accompanies Blecha, et al. (1976) EXPLORING MATTER AND ENERGY.

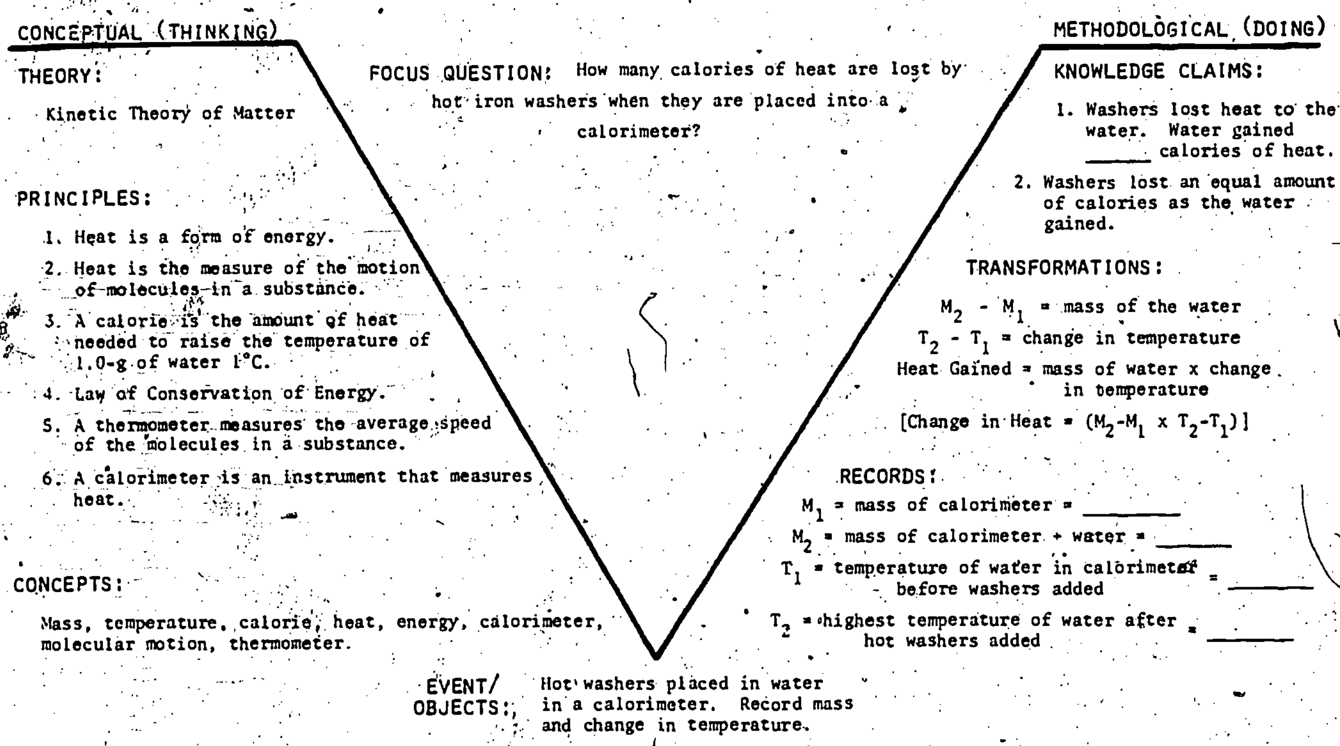


Figure 12. Sample "V" #1, produced from an exercise published in a laboratory manual.

The second example, for the purpose of contrast, is a laboratory exercise developed by a teacher for a seventh grade biological science course.

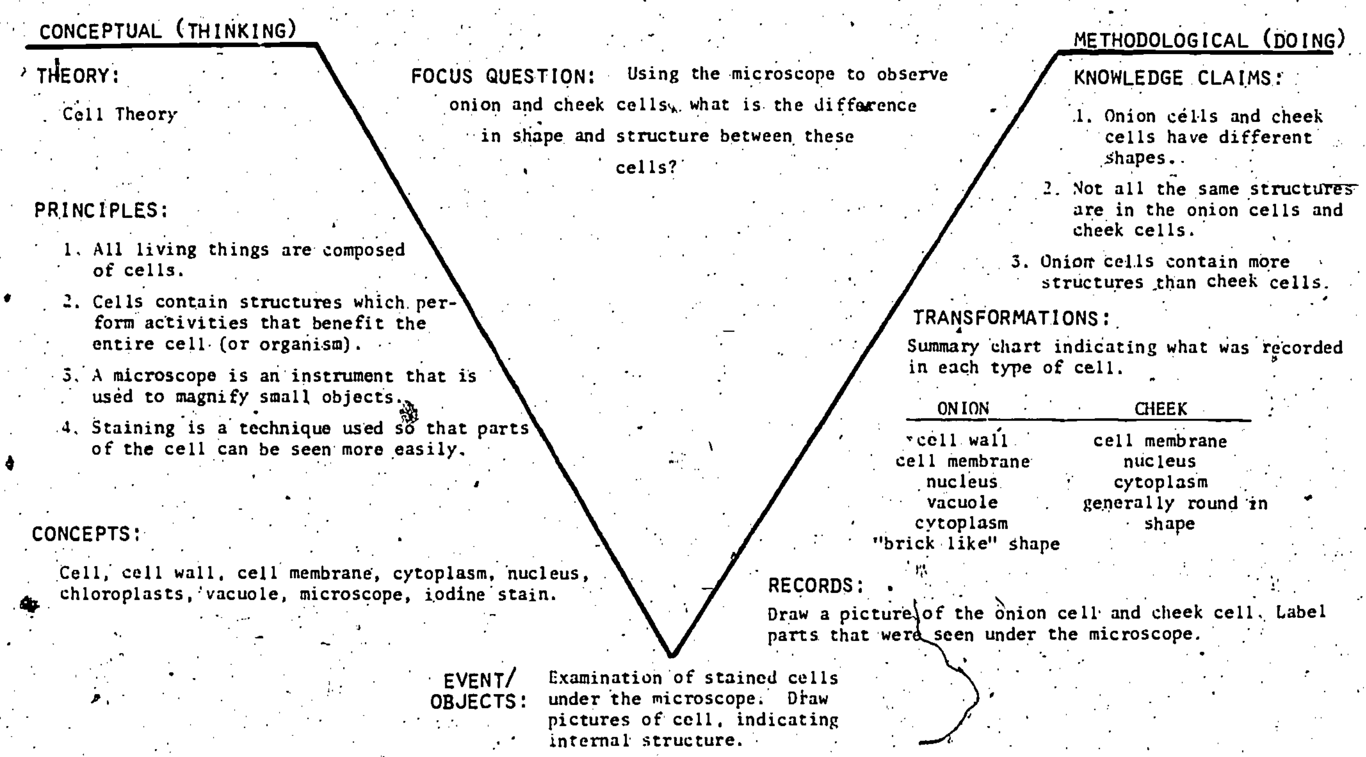
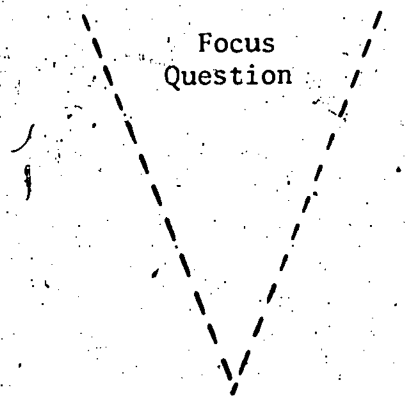


Figure 13. Sample "V" #2, produced from a "classic" junior high biological science laboratory exercise.

CONCEPTUAL/METHODOLOGICAL SIDES

In our work with junior high students, we have found it helpful to use these two terms in coordination with two other terms that the students are more familiar with. We can talk of the conceptual side as the <u>thinking</u> side, and the methodological side as the <u>doing</u> side. Whether the teacher wants to use the "five dollar" words or the more common terms, or both, is left as an individual choice.

FOCUS QUESTION



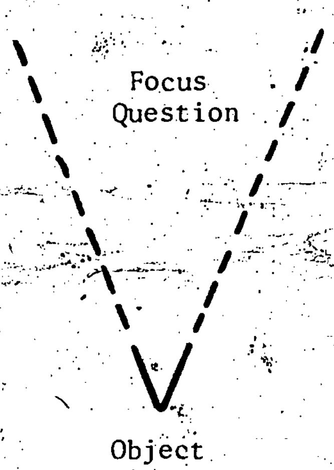
The promotion of conceptual change is fostered by the development of good questions. A good question is one that leads to an examination of objects and events, theory and concepts, so that new knowledge is constructed. Thus, a good focus question will arise from the examination of the concepts that a student has, will steer the methodology (right-hand side), and will eventually lead up through the knowledge claim. New knowledge claims enhance the meanings of the concepts, principles, and theories. As each knowledge claim is collected, it can lead to a refinement of the concepts used to form that knowledge claim. But what is the function of the focus question in all of this? The focus question indicates the kind of knowledge claim that will be made, what concepts and principles need to operate in the inquiry, and should suggest the major event that will be examined and recorded. In our example of the difference between onion and cheek cells, the focus question indicates clearly what concepts are being used (cell, difference, structure, shape, onion, and cheek), and the major event of that inquiry (looking at these cells with the microscope).

Of course, there are several kinds of questions that can be asked as a focus question. In some laboratory exercises, the questions only asks for a "what", for instance, "What is the difference in structure between onion cells and cheek cells?" In these cases, a simple identification of something is required. To ask, by contrast, "How is the structure of a cell related to its function?" requires a different operation. In this case, the question asks for some kind of description, not an identification.

Another kind of question that is sometimes asked in the laboratory exercise is a "why" question. The function of this kind of question is to focus on not an identification or a description but an explanation.

In this case, more than any other, a theory or some theory-bound principle must be used as a conceptual ingredient of the left-hand side. For instance, to ask, "Why are onion cells different than cheek cells?" or "Why do the hot washers give up heat to the water?" requires that we bring to the knowledge claim some explanation that is consistent with the theory that is identified on the upper left-hand side.

From this, we can summarize two functions of a good focus question. First, it focuses upon the concepts, principles, theory, and event that will be used in the construction of a knowledge claim. Secondly, it focuses upon the kind of knowledge claim that is to be made as we ask "what," "how," or "why."



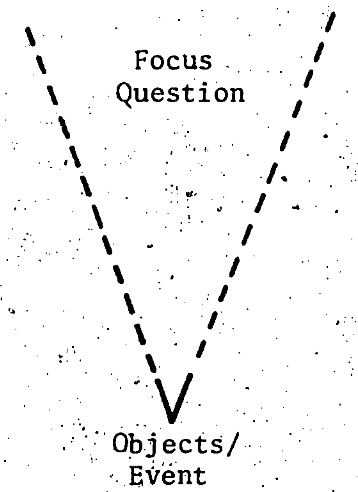
OBJECT

"Object" is one of the terms that is defined in a specific way when using the "V". Closely related to the "event," the objects are the things in the inquiry that allow the event to occur. In the examples given previously, the objects are the microscope, the cheek and onion cells, the calorimeter, the thermometer, and the water in the calorimeter.

We can also distinguish the <u>key</u> object of the inquiry from objects that are relevant, but less central to our focus question. The key objects of the cell experiment are the onion and cheek cells. The microscope is an object we need to perform our observations and to make our records.

We will return to a consideration of objects in two places further on in this handbook. When we consider the "event" of an inquiry, the objects will be distinguished from the "event." Also, when "concept" is discussed and defined, the distinction between "concept" and "object" will be examined.

EVENT



Even though we can talk about future "events," an occurrence is not an actual event until it happens or unfolds and we can take a record of it. Thus, we can conceptualize about and plan for our next birthday or an experiment to be done, but it is not an event until it begins to occur.

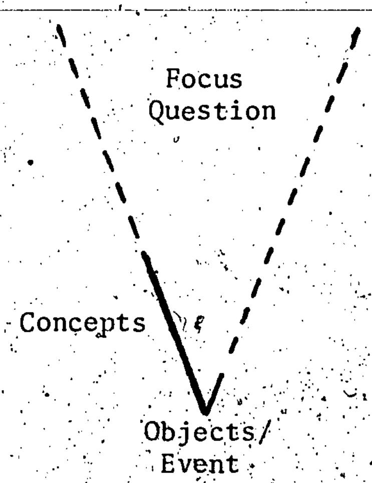
Events and objects are related in that objects are always involved in an event, and may even be the event itself (for instance, examining tree rings to determine the tree's age). Look back over the procedures from the laboratory exercises you have taught. What was going to occur? This is the major event. What was there so that the event could occur? These are generally the objects.

In the two laboratory exercises given as examples, the major event appears at the bottom of the "V" for each. In the lab involving onion and cheek cells, the major event is to look at stained mounts of these cells under the microscope; for the lab involving heat loss, the major event is the plunging of the hot washers into the calorimeter and recording the temperature change.

Events can either be made to happen (as in the two examples above), or the event may be occurring and we, at some time, come upon it. In either case, the event is the thing that we take a record of. This will be examined a little further on.

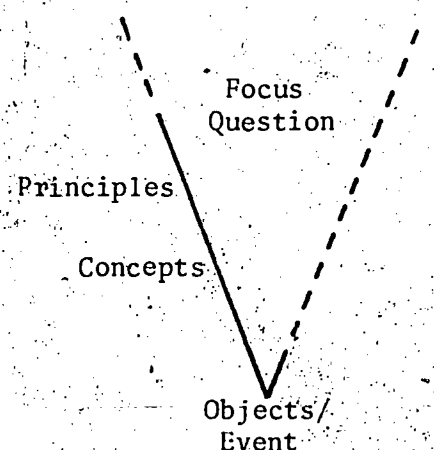
CONCEPTS

To understand the conceptual, left-hand side of the "V", it is imperative that the student and teacher understand what a concept is. Concepts refer to regularities in events or objects. For example, the concept of "cell" which is used in the experiment with onion and cheek cells has certain regularities that distinguishes it from other objects.



Not all onion cells are identical and not all types of cells look alike. But there are enough common features or regularities among all kinds of cells so that the concept "cell" can be used for a number of examples. In biology, the use of the term "typical cell" points up all the regularities that can be found generally in cells. In the experiment on heat loss, "calorimeter" is a concept used to designate the the instrument that will be used to measure the heat loss by the hot washers. For junior high school, the calorimeter used is a very simple one, being made of one styrofoam cup inside another, a top, and a thermometer. This is much different than the more sophisticated calorimeters used in formal science laboratories, but the simple calorimeter shares enough regularities with the sophisticated type to warrant that name of "calorimeter."

The final point to consider about concepts is how they are denoted. Language provides signs and symbols to designate the concepts. Simply, the sign or symbol of a concept is its name. Explore some of the kinds of symbols and signs that students use in science class and examine the regularities that those signs and symbols denote. You may also want to return to the consideration of meaning which was discussed in Activity #5 on page II-10.



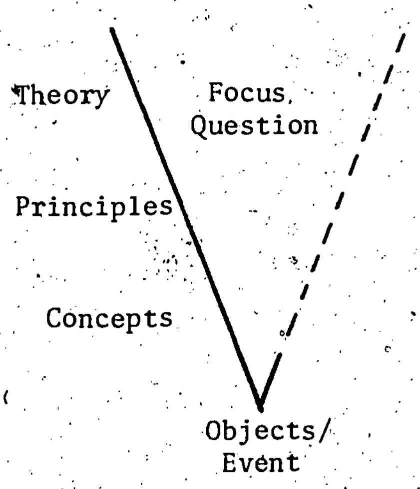
PRINCIPLES

Principles fit right above concepts on the left-hand side of the "V". A principle is a conceptual or methodological rule which guides the inquiry. Conceptual principles may find their source from knowledge claims of some previous research. There have been several examples identified in this handbook: Heat is a form of energy, Carbon dioxide is given off during fermentation; and, As the temperature increases, the rate of fermentation also increases. Each of these were constructed as a result of performing an empirical study.

Conceptual principles come also from theories. Theories contain principles, as propositions, which state the relationships among the concepts that the theory attempts to relate. An illustration of this relationship among concepts, principles, and theory will be discussed below in the section on "Theory."

There are also methodological principles which, as the name suggests, guide us primarily on the right-hand side of the "V". To state that a thermometer measures the average speed of molecules in a substance is a methodological principle derived from a theory guiding the use of that instrument. In the activities reported previously, try to pick out those principles that are methodological and those that are conceptual.

THEORY



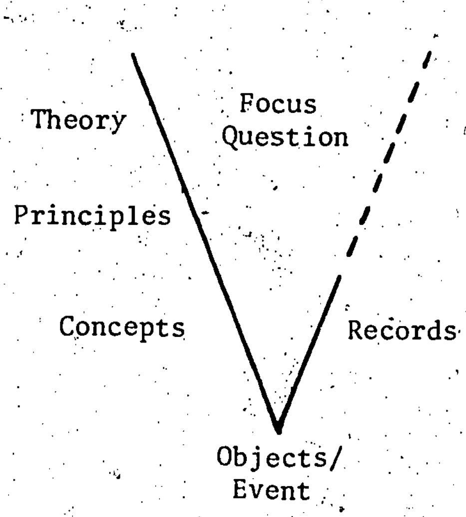
Theories are statements, developed by people, which attempt to explain and predict the interactions among concepts, events, and knowledge claims. Theories are labels, but these labels are not the theories themselves. The theory encompasses the relationships among the principles and concepts of that theory.

Perhaps the best way to illustrate how theories work is to provide an example of theory and its relationship to concepts and principles.

Expansion is a concept that denotes the regularity of a substance increasing in volume which is caused by some agent. The caloric theory of heat stated that heat, since it was a "fluid," infused into the substance causing the increase in volume. This illustrates the relationship among the theory (caloric theory), its propositions (heat is a fluid which moves from hotter objects to colder objects), and the concept (expansion). But the caloric theory could not explain all the phenomena associated with heat and heat transfer. Friction, for instance, did not easily fit into the caloric model of heat.

Another theory, the kinetic theory of matter, replaced the older theory, and stated different principles and different relationships among concepts that more adequately explained the phenomena of heat. The kinetic theory stated that heat was not a substance that moved from one body to another, but was the result of molecular motion within a substance. Thus, the heat energy in a substance was directly related to the molecular motion within that substance. The concept of expansion was explained in terms of the molecular motion. As more heat was added to a substance, the space between the molecules increased. This increase caused the increase of volume of the substance, that is, expansion.

In many instances in a junior high science class, the theory that stands behind the subject matter may not be evident to you or the students. Therefore, there will be times when you will not be able to fill in this part of the "V". However, it is important that students realize that some theory does indeed operate in the explanation of events and the prediction of new knowledge.

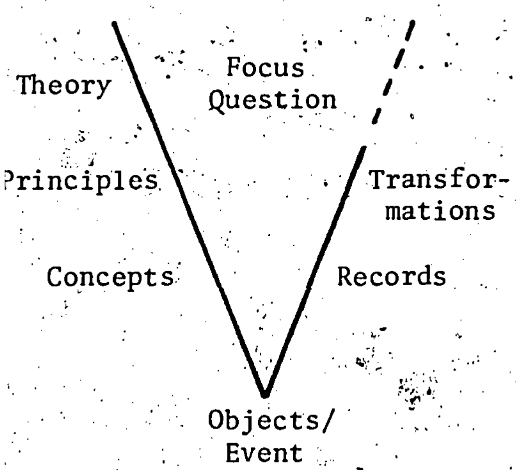


RECORDS

In order to be a record, we must take our sense perceptions of objects and events and produce them into a relatively permanent form which can be conveyed to others. The record may take the form of a written document, a photograph, or a tape recording. The records of the onion and cheek cells laboratory exercise are the diagrams that the students prepared. In the heat loss experiment, the students were instructed to record the temperature of the water in the calorimeter before and after the hot washers were plunged into the water. Other records about the mass of the water and calorimeter were also included.

It is important to realize that a record is made about the events and objects, not about concepts. We can take a record of a thermometer reading, or draw a cell, but we cannot make a record of the concepts of "temperature" or "cell."

TRANSFORMATIONS

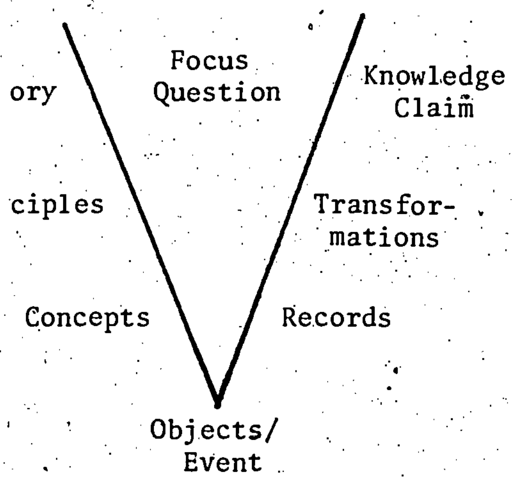


As you probably realize from the two examples given, making records of events and objects does not complete a scientific inquiry. In science, these records are often reorganized or rearranged into a more manageable form. When this is done, a transformation is performed. The type of knowledge claim determines the type of transformation needed.

The difference between records and transformations are often subtle. Generally, a record can be made of some sense perception, such as reading the temperature on a thermometer. A transformation requires some type of manipulation of several of these sense perceptions, such as computing the difference between the temperature before and after the hot washers are plunged into the water.

Transformations can take many forms, and may involve several steps. The most common in science and in science classes include graphs, simple differences, charts, statistics, or any comparison of two or more records. You might want to discuss this further with your students, indicating or soliciting from them examples of records and transformations found in the work that they have done. Examples could come from everyday experiences or from previous laboratory work.

KNOWLEDGE CLAIMS



There are two things that knowledge claims do. First, they are the answers to the focus questions that were asked at the start, and as such, provide information. Second, they can suggest new questions that can lead to new investigations.

Knowledge claims come from the inquiry that has lead to those knowledge claims. They must be consistent with the focus question, concepts, principles, objects, events, records, and transformations that preceded its construction. In our example of the onion and cheek cells, the cheek cells were claimed not to possess vacuoles. This was done because the observer, using the microscope, did not or could not detect vacuoles in those cheek cells. To state the claim that cheek cells, or animal cells in general, have vacuoles requires still another inquiry, using perhaps different representatives of animal cells or a stronger microscope. It is this activity -- realizing the limitation upon the knowledge claim made -- that spawns new questions and further investigations.

To familiarize yourself further with the structure and function of the knowledge "V", take a look at several of your own laboratory exercises and "lay them on the 'V'." It is only through this activity that you can fully comprehend the simplicity and power of this device both as a pre-teaching tool and a teaching tool.

USE OF THE "V" AS A PRE-TEACHING, TEACHING, AND LEARNING TOOL

The versatility of the knowledge "V" becomes evident as the range of possibilities for its use are examined. In our work with the "V" we have identified three different areas for its use: it is a pre-teaching, teaching, and learning tool.

As a pre-teaching tool, the "V" provides a strategy to analyze laboratory exercises prior to introducing them to the students. The teacher can take an existing experiment, and, using the "V", determine if that exercise is structured in such a way that it can facilitate meaningful learning. That is, the "V" allows the teacher to assess what concepts the students must know before beginning the experiment in order to make sense of the experience. Further, the "V" can be used as a device to construct individually-designed laboratory exercises for classes.

If it is kept in mind that the "V" is primarily a strategy for analysis, by asking certain questions, the teacher can analyze a laboratory work. In a manner of speaking, the teacher "unpacks" the work to examine its constituent parts. As the teacher unpacks the experiment, the "V" is used to answer a number of questions about the structure of the work. For these questions, you might want to examine the criteria, both general and specific, that are presented in "Assessment of Student-Constructed 'V's'" on pages V-12 through V-17 in this handbook.

As a teaching tool, the "V" fits nicely into what is traditionally known as the laboratory discussion. It can precede the actual laboratory experiment, where the left-hand, conceptual, side might be completed as a form of summary to re-cap what the student already knows about the task at hand. Indicating what kinds of records and transformations that will be made could facilitate the smooth movement of the lesson so that as little time as possible is expended with methodological problems.

The "V" also has versatility as a guide during the experiment. A partially filled "V" in front of the student during the actual running of the lab and record collection can give the student a short-hand approach for determining what to do next.

And finally, the "V" has worth as a summary technique after the experiment has been completed. As such, the student can see where his/her knowledge claim came from, what basis it had in the concepts that occupy the left-hand side, and the methodology on the right-hand side. As a summary device the "V" can be discussed as a whole class activity, where different groups of students compare results and knowledge claims, and attempt to discuss any discrepancies in the results.

Many teachers require written laboratory reports from the students. These reports usually summarize the experiment and also indicate certain inferences that follow from the work done in the experiment. The "V" can represent the short-hand form of that report, or the teacher can opt to have students prepare "V's" as the outline for an extended laboratory write-up.

Throughout this entire handbook, there have been two themes that have been developed about the "V" and its relation to education. First, than the "V" is a means of unpacking an inquiry, and is therefore a method of analysis. Second, the "V" provides a piece of knowledge about knowledge creation. If these two aspects of the "V" are kept in mind, then the use of the "V" as a learning tool becomes apparent. By providing a means of analysis, the "V" separates and identifies the major concepts and principles that are used to sort out and create the knowledge. This identification of what is required to make sense of the experiment provides the means by which the students can indicate what concepts they already know, how those concepts are related to each other, and how this linking of existing concepts can bring about new knowledge and new concepts. This is tightly consistent with the theory of learning developed in Sections I and II in this handbook. Thus, the "V", along with concept mapping, can provide strategies for meaningful learning.

However, the versatility of the "V" does not stop there. In essence, as we teach the "V", not only are we teaching for meaningful learning of concepts, but also teaching for the meaningful learning of how knowledge is made. While it is important for students to learn what the accumulated knowledge of science is, another type of learning is going on as the student uses these strategies -- that is, how science is constructed. Students learn what counts as a concept, how theories work in providing explanation, how concepts change over time, what are the intellectual commitments for record-making and transformations, and the limits of the constructed knowledge of the sciences. They come to realize that knowledge is the product of inquiry. And that inquiry comes about as a result of the interaction of the conceptual structure we possess and the methodologies we choose in the task of building that knowledge.

SUGGESTIONS FOR INTRODUCING THE KNOWLEDGE "V"

Given all this introductory material on the "V", it is also necessary to discuss some practical aspects of introducing the "V" into the classroom. These ideas are presented to facilitate the smooth introduction of the "V", and also provide options for you who will ultimately make the decision of what is best for your students.

1. Do not present the "V" and its accompanying terms out of context. That is, don't just teach the terms abstractly. The "V" should be introduced with respect to a laboratory exercise done, a demonstration completed, or some other relevant material.
2. Don't worry about the structure of the "V" immediately. As you and the class perform laboratory exercises, get them used to using the terms of the "V" -- "What is the record of this experiment?", "What is the focus question?", etc.
3. When the time is appropriate, and the students have a good understanding of the meanings of each of the terms, the structure of the "V" can be introduced. In some classes, you might want to complete some of the "V" for the students, having them finish the "V" as a result of having completed the laboratory exercise. In some other classes, you might want the students to complete the entire "V". That will be up to you.
4. As the students become more familiar with the "V", you might want them complete the left-hand side as a pre-lab and/or homework assignment.
5. Large poster boards of completed "V's" could be placed up around the classroom; a list of the theories and major principles used in class could be put on a bulletin board; also, concept maps could enhance the conceptual nature of the program. Not only will this give students handy reference sources, but will also reinforce the notion of conceptual teaching and learning.

INTEGRATION OF CONCEPT MAPPING AND THE KNOWLEDGE "V"

The final part of the knowledge "V" section relates the two strategies discussed in this handbook -- concept mapping and the "V". It has already been suggested that the left-hand, conceptual, side of the "V" can be represented by a concept map. The concept map has the purpose to conceptually guide initial and further inquiries through the formation of good focus questions.

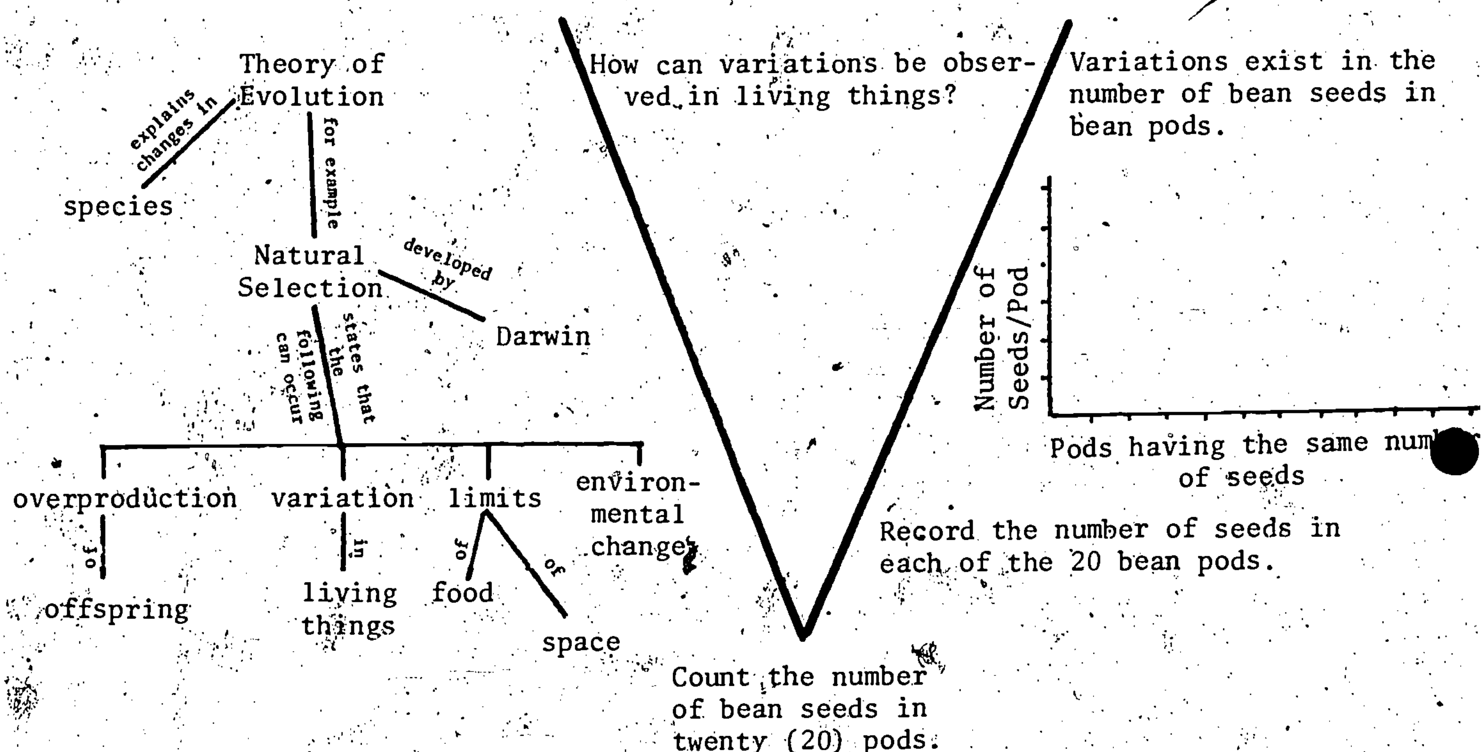


Figure 15: Integration of Concept Mapping and the Knowledge "V". Exercise is adapted from Kaskel, et al. (1977) Life Science: A Learning Strategy for the Laboratory, pp. 31-34.

Using the concept map and "V" above, the question could establish the relationship between two concepts that are represented horizontally on the map, e.g. between "limits of food" and "environmental change." Or the question could ask whether one concept is subordinate to another, such as, "What kinds of limits are imposed on organisms in an environment?" Or, as in the example above, whether a concept can be demonstrated. The focus question then sets the stage for the inquiry and provides the key for meaningful learning. As each focus question is answered, the conceptual structure of that part of the discipline grows for the student, and his/her knowledge becomes more complete and more complex.

In the next and final section, issues of evaluation are discussed. Given the psychological and nature of knowledge orientation of this approach, the evaluative instruments are somewhat different than what is usually used in science classes. Clear criteria for assessing students' ability to use concept mapping and the knowledge "V" has been devised to assist the teacher in determining how proficient the students are in each of these areas.

V. EVALUATION

ASSESSMENT OF STUDENT-CONSTRUCTED CONCEPT MAPS

EVALUATION OF KNOWLEDGE "V" - IDENTIFICATION, DEFINITIONS, AND EXAMPLES OF TERMS

ASSESSMENT OF STUDENT-CONSTRUCTED "V'S"

USING THE "V" IN SEQUENCE

INTEGRATION OF THE "V" AND CONCEPT MAPPING

CONCEPTUAL QUESTIONS: USE OF THE "V" AND CONCEPT MAPPING

Materials for evaluating concept maps and "V's" have been devised that are consistent with the information and background given in this handbook. Although these materials have been divided into various parts in this section, they actually work together to give the teacher a broad spectrum of ways of seeing how well students are performing with the various strategies.

Before each evaluation method is given, a description of what that method is intended to do is discussed. These objectives should be kept in mind as the teacher both reads the methods and uses them in the classroom.

ASSESSMENT OF STUDENT-CONSTRUCTED CONCEPT MAPS

Several features that characterize concept maps have already been discussed in Section III: they are two-dimensional, they proceed from general to specific, they show the relationships among concepts, and they illustrate some hierarchy among the concepts. Given these features, it is not difficult to develop some forms for assessing the concept maps that students complete.

Two forms for assessing concept maps are provided on the next few pages. The first form (A) is designed to give a "large field of view," providing the teacher with a quick overview of maps. The second form (B) provides a more comprehensive scaling of the features of a concept map, including some features not already mentioned. Of course, the second form requires a greater amount of time to use properly, but this is weighed against the advantage of thoroughness. Further, the more comprehensive form indicates weaknesses in the maps, and can thus suggest future instructional needs.

GENERAL OVERVIEW FOR STUDENT-CONSTRUCTED CONCEPT MAPS (FORM A)

	YES	NO	NEEDS WORK
1. Are relationships between concepts indicated on line and are they content correct, that is valid?	( )	( )	( )
2. Are the concepts arranged from general to specific? (Look for the most inclusive concept at the top; examples at the bottom.)	( )	( )	( )
3. Are the concepts linked? (Look for lines between the concepts. The relationship between concepts should be indicated. That is, something should be written on the lines.)	( )	( )	( )
4. Is the map hierarchical? (Look for more inclusive concepts connected to two or more lower or subordinate concepts.)	( )	( )	( )

Figure 16. General Overview for Quick Scoring of Student-Constructed Concept Maps.

COMPREHENSIVE FORM FOR ASSESSING STUDENT-CONSTRUCTED CONCEPT MAPS (FORM B)

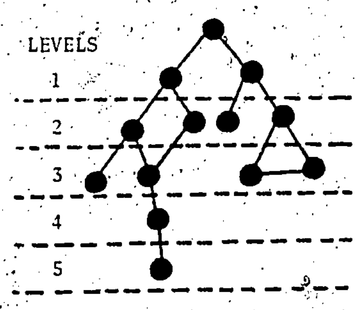
In this form, the features of a concept map are expanded. These additional features reflect a more complete view of concept maps that students develop. They should be used only after the students have had enough exposure to the strategy, and feel confident to expand the strategy.

Ignore all parts of the map for relationships criterion if no relationships are <u>explicitly identified</u> by proper labeling of the connecting line.

RELATIONSHIPS: One point is given for each relationship between two concepts provided the relationship is content correct and explicitly stated. No additional credit is awarded for duplication of the same relationship on the concept map.

HIERARCHY: Points are awarded depending on the degree of hierarchy in the concept map. The number of points given for hierarchy depends upon the number of levels that are identified in the constructed map. Use the map to the right for illustration.

One point is given for at least one correct relationship per level, up until two levels beyond the last branching if the map remains linear.



BRANCHING: The branching of the concept map refers to the level of degree of differentiation among the concepts that are illustrated in the hierarchy. That is, it attempts to rate the degree that specific concepts are connected to more general or inclusive concepts. That rating is as follows:

One point for the first branching where two or more concepts are connected to the concept above.

Three points for any subsequent branching where there is an example of two or more concepts connected to a concept above. The illustrated map above would receive a score of seven; 1 point for Level 1, and three points each for Levels 2 and 3. Note that since no branching occurs in Levels 4 and 5, no further points are awarded for this criterion.

GENERAL TO SPECIFIC: The concept map receives an additional rating for illustrating a general to specific pattern. Whether one concept is more general than the ones below it depends upon the line which connects the two concepts. If no general to specific relationships exist, or less than 10% of the relationships are general to specific, the map receives a score of zero.

If 10 - 29%	are correct	=	1 point
30 - 49%	"	=	2 points
50 - 69%	"	=	3 "
70 - 89%	"	=	4 "
90 - 100%	"	=	5 "

CROSS LINKS: Interratedness in a student's concept map indicates an integration of concepts, and is depicted as cross links on the concept map. Cross links show a relationship between concepts on one branch of the hierarchy with concepts on another branch. Notice the two examples of cross links in the illustration above. A rating of one point is given for each cross link showing the integration among concepts. No additional points are awarded for duplication of the same cross link, that is, showing the same integration of concepts.

Figure 17. Comprehensive From for Assessment of Student-Constructed Concept Maps.

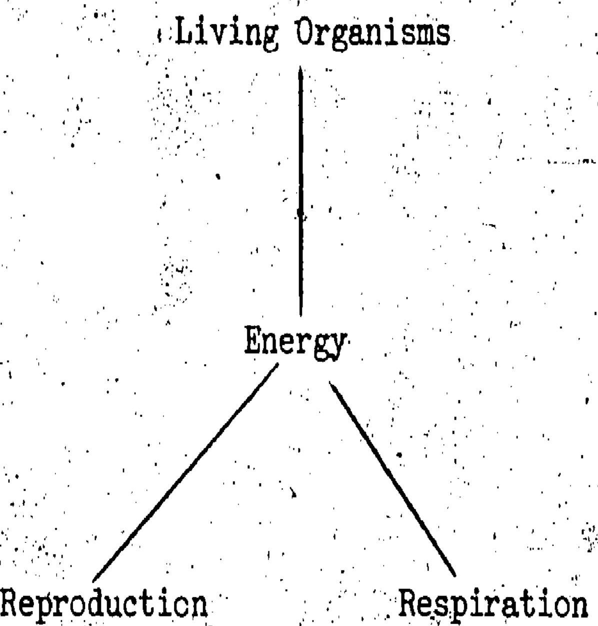
SAMPLES OF STUDENT-CONSTRUCTED CONCEPT MAPS WITH ANNOTATED ASSESSMENTS

The next three pages show examples of concepts maps that students have made during the evaluation phase of our "Learning How to Learn Project." These examples were solicited from seventh grade students during clinical interviews. The interviewees were given a paragraph reading that was based on material that they already had in class. After reading the paragraph, the students were asked to construct concept maps of the reading. The reading used for the sample of students whose maps appear in the following pages is presented below.

In addition to the reconstructed concept maps, an annotated rating, based on the comprehensive scale on page V-4 has been included in order to familiarize the teacher with how this type of rating technique can be used.

> Living things all need energy. Plants and animals use energy for life activities. Some life activities that both plants and animals have are growth, reproduction, respiration, and transport of materials. A life activity found only in green plants is the production of food. Animals cannot produce their own food, so they need the life activity of locomotion to find food.

Figure 18. Sample Paragraph for Clinical Interviews used in the Evaluation of students' Concept Mapping Approaches.



RATING:

Relationships	0	(Student has not identified any connections among the concepts. Since these connections have not been explicitly made, no credit is given for the other criteria as well.)
Hierarchy	0	
Branching	0	
General to Specific	0	
Cross Links	0	

Figure 19A. Student-Constructed Concept Map #1. This map is included to illustrate the importance of the connections among the concepts. Without these connections, no other criterion can be determined, and thus, the map receives a total score of zero.

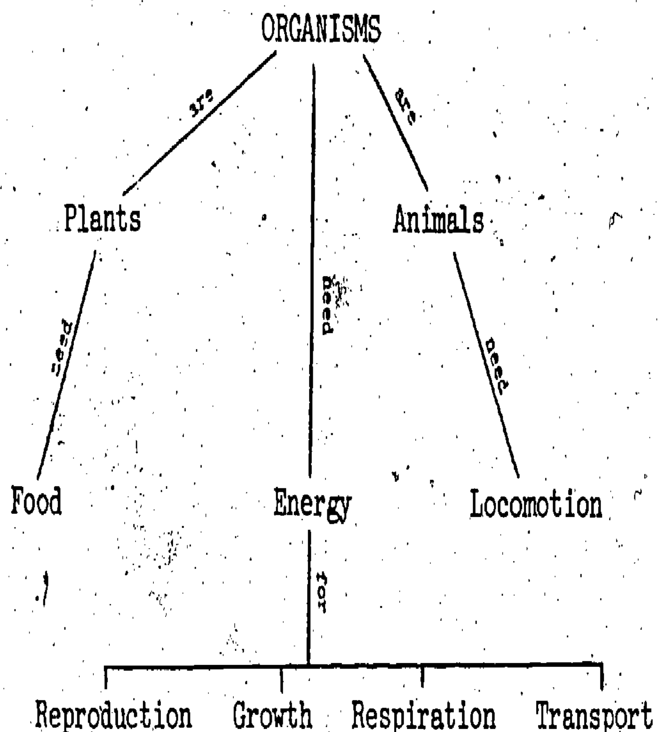


Figure 19B. Student-Constructed Concept Map #2.

RATING:

Relationships	9	(Student has identified nine connections among the concepts represented on the map, and all of these are content correct.)
Hierarchy	2	(Student has identified two levels of hierarchy: from ORGANISMS to PLANTS and ANIMALS and ENERGY; and from ENERGY to REPRODUCTION, GROWTH, etc. One point for Level 1, one point for Level 2, for a total of two points.)
Branching	4	(Student has branched the concepts at the two levels of hierarchy. One point for Level 1, three points for Level 2, for a total of four points.)
General to Specific	5	(All of the concepts and their levels illustrate the general to specific rule, resulting in five points.)
Cross Links	0	(No cross links are indicated on the concept map.)

V-7

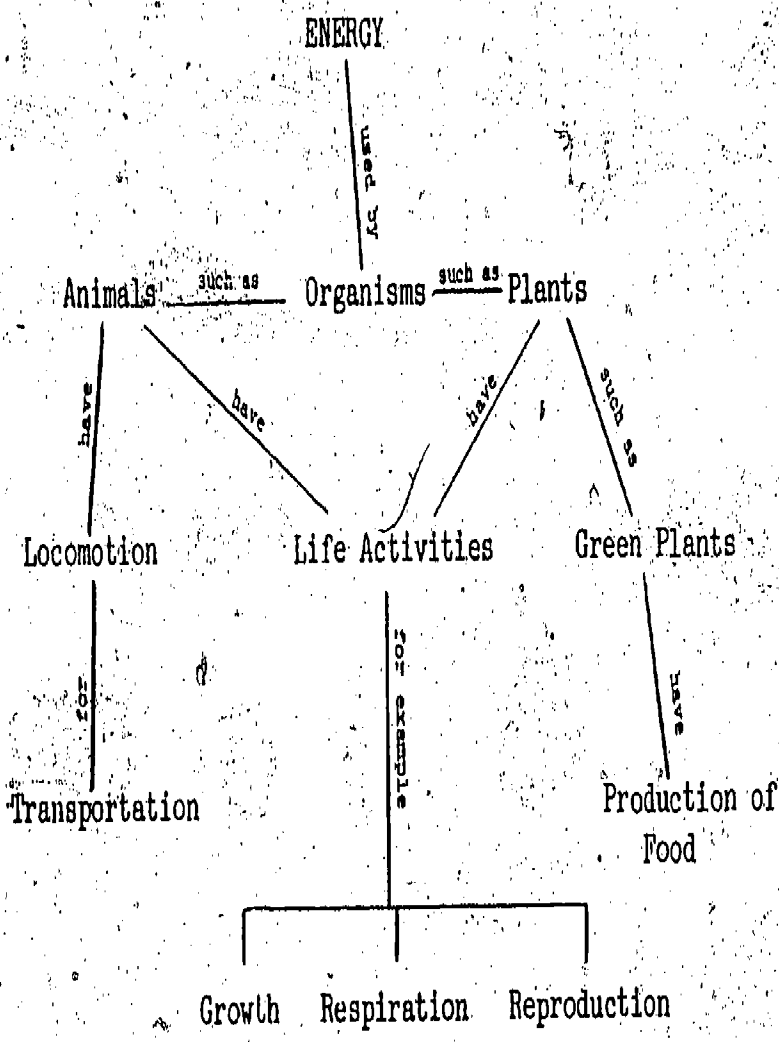


Figure 19C. Student-Constructed Concept Map #3.

RATING:

Relationships	11	(Student has identified eleven connections among the concepts represented on the map. The connection of LOCOMOTION "for" TRANSPORTATION represents a misconception and thus is not computed in the total.)
Hierarchy	3	(Three levels of hierarchy are identified.)
Branching	7	(No branching at Level 1. Branching is represented at Levels 2, 3, and 4. One point for Level 2, three points each for Levels 3 and 4, for a total of seven points.)
General to Specific	5	(All but the misconception mentioned above show the general to specific rule. This is greater than the 90% level, thus the map is awarded five points.)
Cross Links	1	(One cross link, showing the integration of concepts is represented: ANIMALS-ORGANISMS-PLANTS-LIFE ACTIVITIES.)

V-8

EVALUATION OF THE KNOWLEDGE "V" - IDENTIFICATION, DEFINITIONS, AND EXAMPLES OF TERMS

This aspect of the evaluation of the implementation of the "Learning How to Learn Program" in your classroom is a simple, straightforward pencil-paper format. Its objective is to determine if students can identify the parts of the "V," define each of these terms in their own words, and, given an example of a laboratory exercise, identify an example of "record," "concept," "knowledge claim," etc. in a laboratory exercise. The format is given on the next two pages.

You will notice that page V-11 contains two laboratory exercises. These are examples that we have used in our research. For a test that you would devise, one example from work previously done by your students should be used.

NAME: ______________________ DATE: __________ SCHOOL: __________

DEFINITIONS AND EXAMPLES OF THE TERMS OF THE "V"

Instructions: Below is an outline of the "V" that we have been using in class. As you know, there are nine terms that are used with the "V". In each of the spaces with a double line (═══), fill in the proper term, and write the definitions of that term in the space designated by the single line (___).

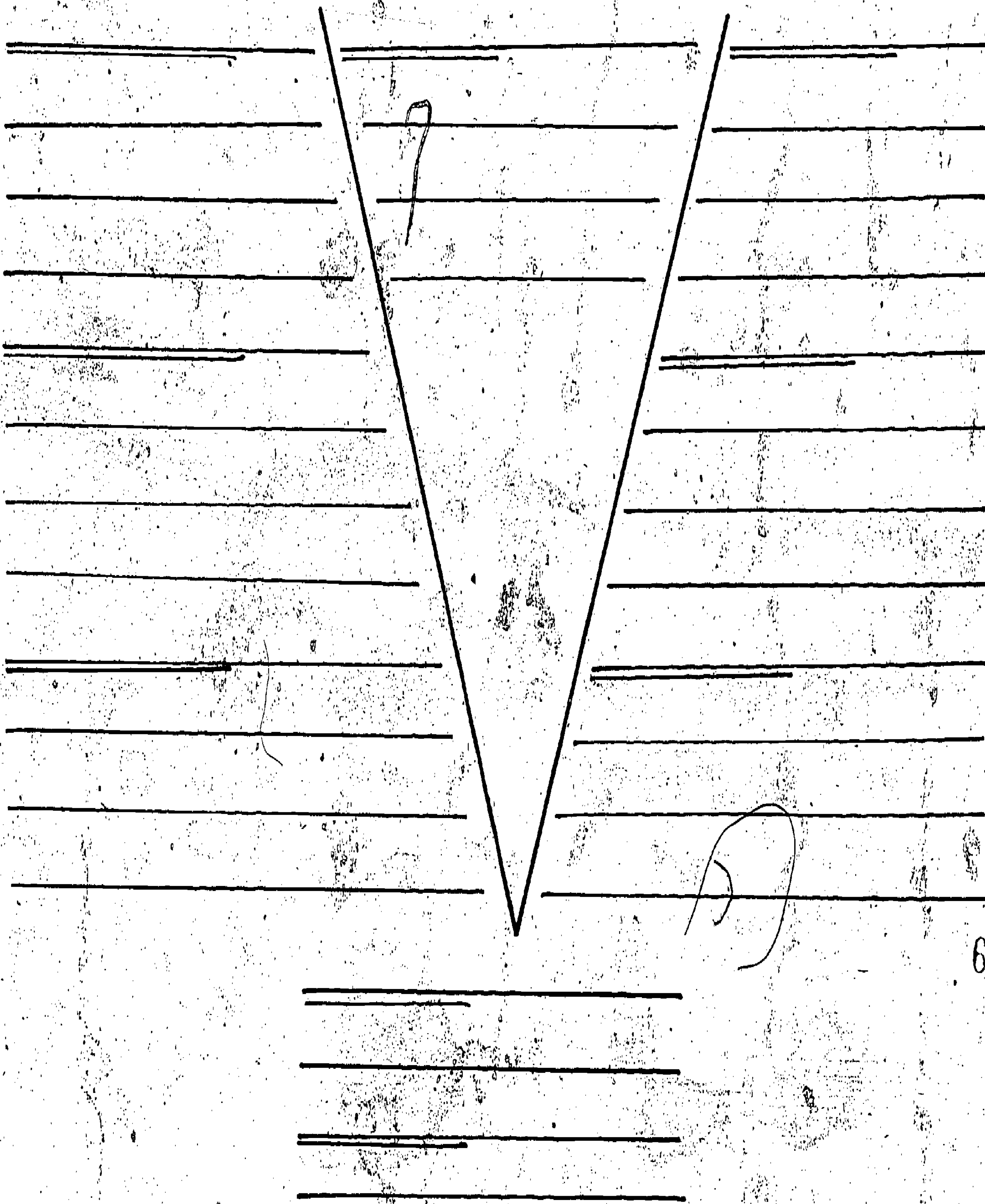


Figure 20A. Assessment of students' understanding of the terms and definitions of the Knowledge "V".

V-10

Instructions: Below is an example of a simple laboratory exercise that is similar to one you have done already in class. Read through the exercise carefully, and then identify which part of the laboratory exercise is an example of each of the terms around the "V".

PROBLEM: Do variations exist in the number of seeds in bean pods?

BACKGROUND: Are there two people in your class who look alike? Even if identical twins are present, the answer to this question will always be that no two people are exactly alike. Natural selection states that all living things show some differences when compared to each other. Scientists have made the statement that there is much variation even among living things that are closely related. Sometimes the variation can be helpful to living things and may give them an advantage over others.

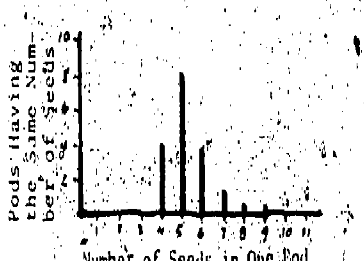
MATERIALS: Fresh bean pods (green or string beans).

PROCEDURE:

1. Open twenty bean pods.
2. Count the number of bean seeds that you find in each. Count all sizes even if they are small.
3. Write down your results below using the mark (/) to show the number of pods having those number of seeds listed. Then prepare a bar graph of your results.

NUMBER OF SEEDS IN ONE POD

	1	2	3	4	5	6	7	8	9	10	11
Pods Having Same Number of Seeds				////	//// ////	////	//	/	/		



CONCLUSIONS: Based on the results, variations in the number of seeds in bean plants does exist. The number of seeds could be useful to the organism because it gives them an advantage over other organisms of the same species.

Figure 20B. Two examples of laboratory exercises used to determine whether students can identify examples of terms of the Knowledge "V".

INSTRUCTIONS: Below is an example of a laboratory exercise, that is similar to one that you have already completed in class. Read through the exercise carefully. Then, identify by underlining or circling that part of the exercise that corresponds to each of the terms around the "V". Label these parts using the terms of the "V".

FIND OUT: How much heat is lost by hot iron washers when they are placed in water?

BACKGROUND: The kinetic molecular model states that the amount of heat energy in a substance is related to the kinetic energy of the molecules and the number of molecules in that substance. As heat is given off by a substance, the molecules in that substance move more slowly. As heat is added to a substance, the molecules move more quickly. When two substances of different temperatures are brought near each other or are mixed, heat from the warmer substance is given off to the cooler substance until both substances reach the same temperature. The amount of heat lost by the warmer substance is equal to the amount of heat gained by the cooler substance.

A thermometer is an instrument that measures the average speed of the molecules in a substance. To measure the amount of heat, a person can use a calorimeter. Basically, a calorimeter is nothing more than an insulated container with a thermometer fitted into it. The name "calorimeter" comes from the fact that heat is measured in calories -- a calorie being the amount of heat that will raise the temperature of one gram of water one degree Celsius.

MATERIALS: cardboard, Celsius thermometer, ring stand and ring, set of known masses, styrofoam cups, wire gauze, iron washers, balance, beaker, string, tongs, bunsen burner, matches.

PROCEDURE:

1. Make a simple calorimater by placing one styrofoam cup inside another. Make a lid from a piece of cardboard. Punch a hole in the lid and place the thermometer in the hole.
2. Using the balance, find the mass of the entire calorimeter, including the thermometer. Write this mass (M_1) in the space below.
3. Half fill the calorimeter with water. Find the mass of the calorimeter with the water in it. Write the mass of the calorimeter and water (M_2) in the space below.
4. Measure the temperature of the water inside the calorimeter. Write this temperature as the initial temperature of the water (T_1) in the space below.
5. Tie about ten iron washers together with a piece of string. Set a beaker of water over the bunsen burner. When the water boils, place the washers in the water. Leave them in the water for several minutes. Then, using the tongs, quickly remove the washwers from the beaker and place them in the calorimeter. Observe and write down the highest temperature reached on the thermometer in the calorimeter. Write this temperature (T_2) in the space below.

OBSERVATIONS AND DATA:

M_1 = 120 grams T_1 = 24 °C

M_2 = 210 grams T_2 = 27 °C

Compute the following:

Mass of the water ($M_2 - M_1$) = 90 grams

Change in Temperature ($T_2 - T_1$) = 3 °C

Calories Gained by the Water $[(M_2 - M_1) \times (T_2 - T_1)]$ = 270 calories

CONCLUSIONS: The washers lost heat to the water. Since the water gained 270-calories of heat, the washers must have lost an equal amount of heat (270-calories).

V-11

ASSESSMENT OF STUDENT-CONSTRUCTED "V's"

Although the title indicates that this evaluation method is intended for use in assessing student-constructed "V's", it is important to remember that the "V" is also a pre-teaching tool, and thus has applicability there as well.

The objective of this part of the evaluation is to determine how good are the "V's" that students prepare. The first form of the evaluation gives an overall picture of the "V" and attempts to locate large holes in the students' work. In other words, it gives the teacher a large field of view so that a more general picture can be determined. The second form is more comprehensive. Its function is to give the teacher a closer look at each of the parts of the "V" and to assess the students' performances at developing a focus question, at recognizing the major event, at checking the records and transformations, etc. For each of these parts of the "V" a range of scores can be assigned. The range is constructed from zero (0) which indicates that there has been nothing written for that part of the "V", through an optimal score for that part. This form can function in two ways. First, it can help track the progress of a student over time in each part of the "V". The "Progress Sheet" on page V-17 can be used to follow individual student progress to see where major difficulties still stand out, and where the teacher should concentrate in subsequent work with individual students. Second, the total of all the parts of the "V" can be used to provide a single mark for laboratory exercises. This mark is represented at the bottom of the "Progress Sheet."

GENERAL OVERVIEW OF STUDENT-CONSTRUCTED "V's" (FORM A)

This checklist gives the teacher a general assessment technique for evaluating student-constructed "V's". As the students and the teacher gain more proficiency with the range and use of the "V", the teacher will probably want to use Form B on the next page. However, this form will serve the purpose of initial assessment.

Figure 21. General Assessment of Student-Constructed "V's".

	Yes	No	Needs Work
1. Does the focus question attempt to relate two or more concepts?	[ ]	[ ]	[ ]
2. Does the focus question relate to what going to occur in the laboratory exercise?	[ ]	[ ]	[ ]
3. Has the student properly identified the major event?	[ ]	[ ]	[ ]
4. Are relevant concept identified?	[ ]	[ ]	[ ]
5. Have relevant principles and theory been identified?	[ ]	[ ]	[ ]
6. Has the student made adequate records and transformations?	[ ]	[ ]	[ ]
7. Is the knowledge claim clear, complete, and consistent with the focus question?	[ ]	[ ]	[ ]

COMPREHENSIVE FORM FOR ASSESSING STUDENT-CONSTRUCTED "V's"

Focus Question:

0 - no focus question is identified.

1 - a question is identified, but does not focus upon the objects and the major event OR the conceptual side of the "V".

2 - a focus question is identified; includes concepts, but does not suggest objects or the major event OR the wrong objects and event are identified in relation to the rest of the laboratory exercise.

3 - a clear focus question is identified; includes concepts to be used and suggests the major event and accompanying objects.

Objects/Event:

0 - no objects or event is identified.

1 - the major event OR the objects are identified and is consistent with the focus question, OR an event and objects are identified, but are inconsistent with the focus question.

2 - the major event with accompanying objects is identified, and is consistent with the focus question.

3 - same as above, but also suggests what records will be taken.

Theory, Principles, and Concepts:

0 - no conceptual side is identified.

1 - a few concepts are identified, but without principles and theory, or a principle written is the knowledge claim sought in the laboratory exercise.

2 - concepts and at least one type of principle (conceptual or methodological) OR concepts and a relevant theory is identified.

3 - concepts and two types of principles are identified, OR concepts, one type of principle, and a relevant theory are identified.

4 - concepts, two types of principles, and a relevant theory are identified.

Records/Transformations:

0 - no records or transformations are identified.

1 - records are identified, but are inconsistent with the focus question or the major event.

2 - records OR transformations are identified, but not both.

3 - records are identified for the major event; transformations are inconsistent with the intent of the focus question.

4 - records are identified for the major event; transformations are consistent with the focus question and the grade level and ability of the student.

Knowledge Claim:

0 - no knowledge claim is identified.

1 - a claim that is unrelated to the left-hand side of the "V".

2 - a knowledge claim that includes a concept that is used in an improper context OR any generalization that is inconsistent with the records and transformations.

3 - a knowledge claim that includes the concepts from the focus question and is derived from the records and transformations.

4 - same as above, but the knowledge claim leads to a new focus question.

Below and on the next page are three examples of "V's" for the same laboratory exercise involving heat loss and heat gain. Each "V" is completed and annotated to indicate what mark that part of the "V" would receive based on the criteria on page V-14. The mark for that section appears in parentheses at the start of each annotation.

On page V-17 these three sample "V's" are recorded on the "Student Progress Sheet."

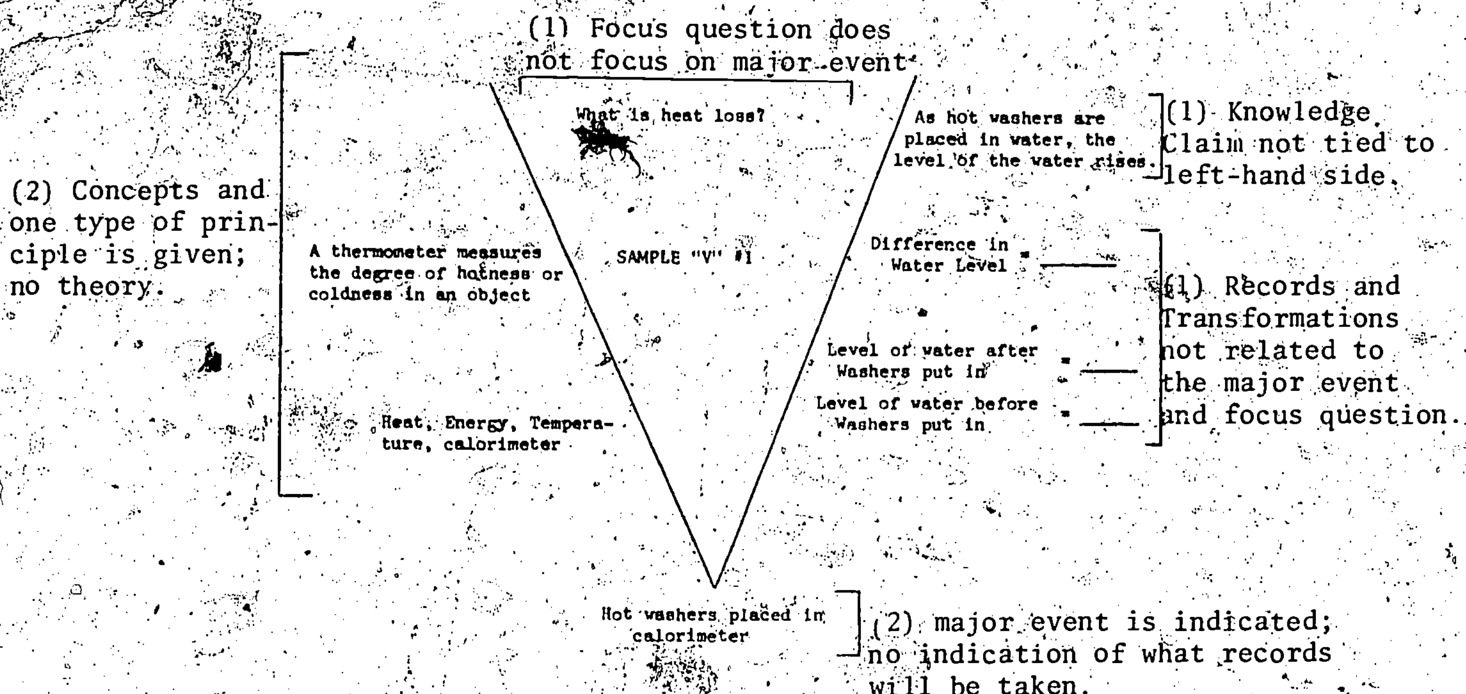


Figure 22A. Sample V#1 with Annotated Evaluative Rating for a total of seven points out of a possible eighteen.

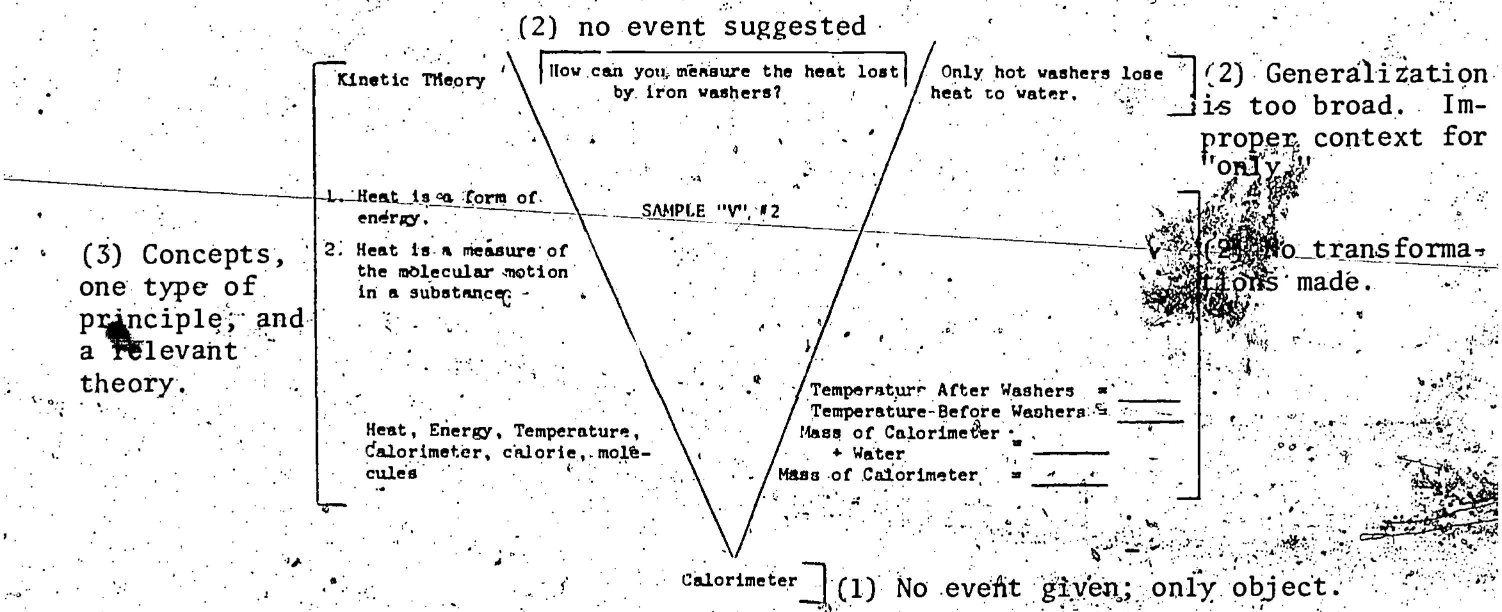


Figure 22B. Sample "V" #2 with a total score of ten out of a possible eighteen.

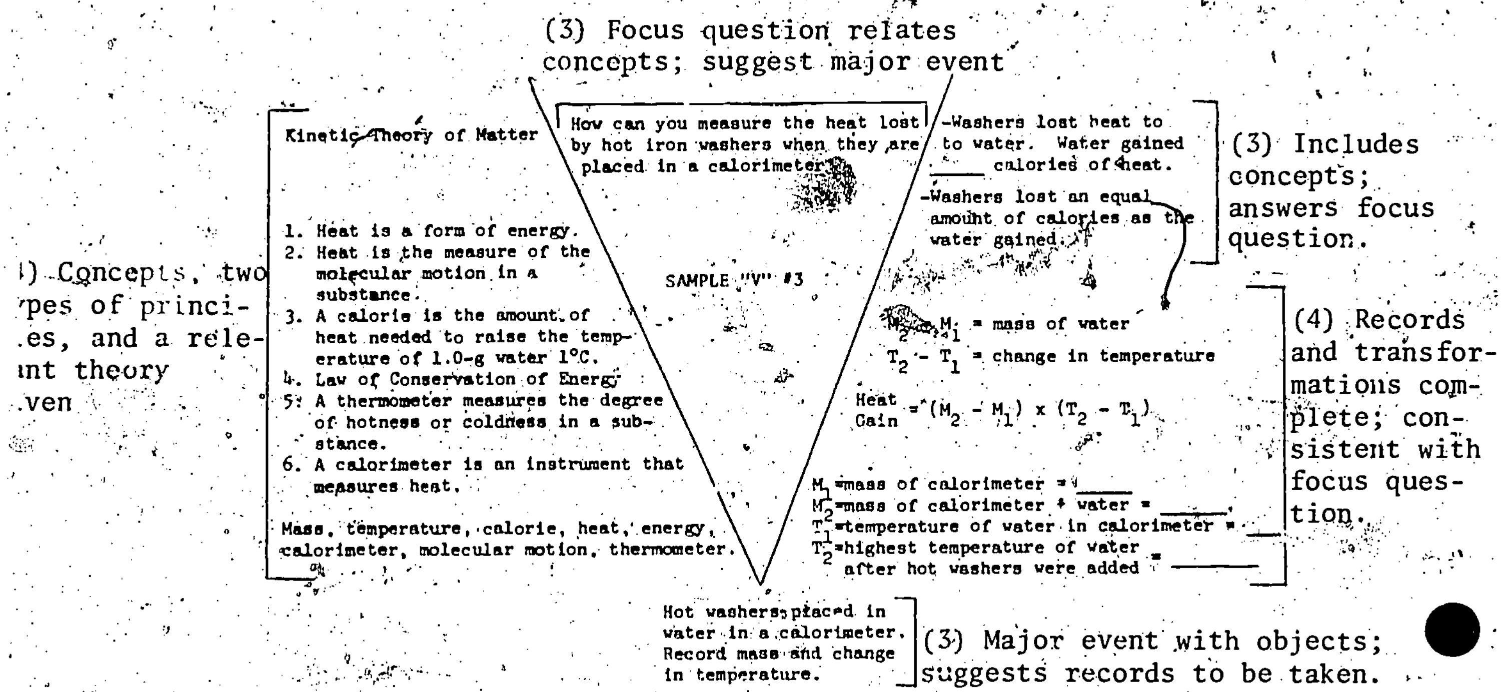


Figure 22C. Sample "V" #3 with a total score of seventeen out of a possible eighteen.

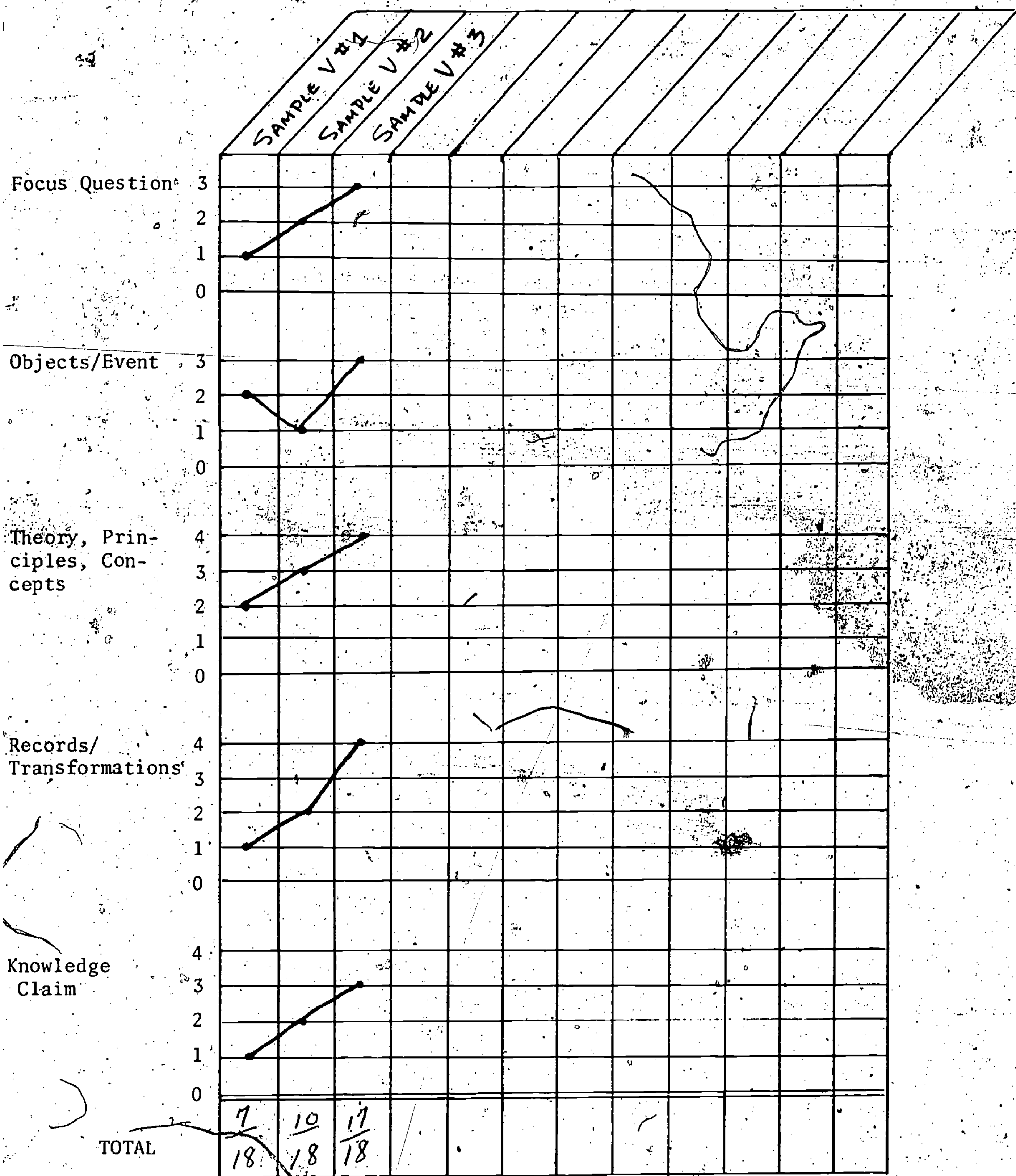
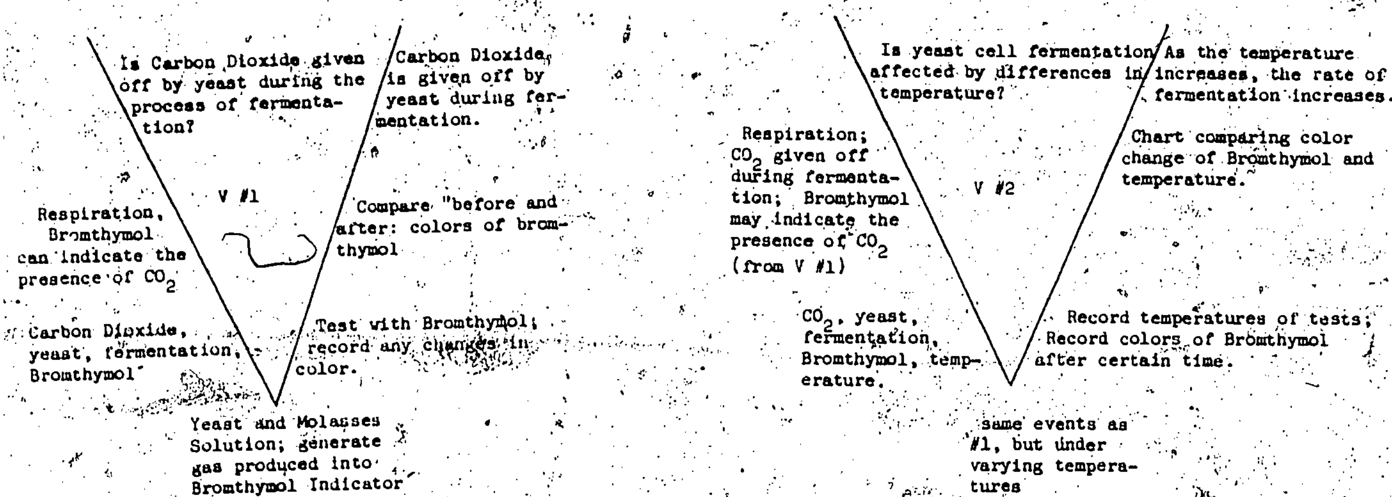


Figure 23. The Student Progress Sheet. The purpose of this sheet is to provide the teacher with a quick visual overview of individual student progress in relation to the parts of the "V". The total score at the bottom provides a single defensible rating for the student's laboratory exercise.

USING THE "V" IN SEQUENCE

This part of the evaluation attempts to determine if the knowledge claims from previous experiments can operate as conceptual principles in subsequent experiments. In "V" #1 below, the student reaches the claim that carbon dioxide is given off during fermentation. Knowing that, the student can use that information as conceptual principles for determining other knowledge claims about yeast fermentation. In "V" #3 the student takes the knowledge claims from the previous two experiments and uses them as conceptual principles for the new focus question. Each "V" can be evaluated on the basis of the criteria already identified on page V-14 in this handbook. The teacher should, however, concentrate on whether these previous knowledge claims are being used as conceptual principles in the subsequent experiments.



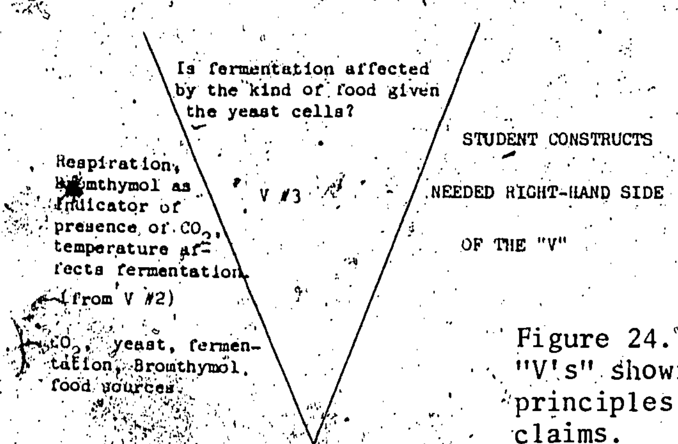


Figure 24. Sequences of Laboratory "V's" showing construction of principles from previous knowledge claims.

INTEGRATION OF THE "V" AND CONCEPT MAPPING

At this stage of the evaluation of the introduction of these strategies into the classroom, the student should have a firm grasp of both techniques. What time is appropriate to integrate concept mapping and the "V" depends upon a number of conditions: ability of the students, pacing of the class work, and how intense the exposure to these strategies has been previous to this time. However, when the teacher feels that the students are ready, the integration can begin.

In our studies, one teacher eased into this integration by having students construct small concept maps for the "background" information of an experiment. This exercise was given for homework or in the pre-lab discussion. After the experiment was completed, the students proceeded to construct the "V" for the exercise. After a few trials with this method, the students were asked to take this preliminary concept map and make it the left-hand side of the "V".

Evaluation of the integration of both concept mapping and the "V" involves taking certain aspects of the assessment techniques already mentioned in this handbook. Here then are some general guidelines as suggestions for implementing the integration:

1. When assessing a student's "V" delete "Theory, Principles, and Concepts" from the criteria for evaluating the "V" (page V-14).
2. Substitute either the general format for assessing concept maps (Form A), or the more comprehensive (Form (B). It is recommended that the more general form be used at first, and then switch to the more comprehensive form as students become more familiar with the integration.
3. If the students have already come this far with these strategies, it is not recommended that the teacher use Form A for assessing the "V". Form A is too general to provide the kind of specificity that Form B provides.

CONCEPTUAL QUESTIONS: USE OF THE "V" AND CONCEPT MAPPING

As in the previous section, the student should be completely familiar with the strategies of concept mapping and the Knowledge "V". This section of the handbook attempts to suggest techniques that can be used to determine if the strategies have had any effect on meaningful learning (Section II).

How students learn is affected to some degree by the kinds of questions which they anticipate on tests and quizzes. If the students are asked only questions that require rote memorization, and if they have experienced success by learning that way, then there will be less incentive for them to learn in a meaningful fashion.

The technique that we advocate involves the construction of what can be called "conceptual questions." There are not what some may think of as "thought questions" or "brain teasers." Answering a conceptual question requires that students employ meaningfully learned concepts, facilitated through the use of the strategies of concept mapping and the Knowledge "V".

Although it is highly improbable to devise questions that totally eliminate the rote mode of learning, it is possible and desirable to devise questions that minimize this factor and which are more conducive to being answered by the student who has learned meaningfully. These kinds of questions can also be used in a variety of situations, including review sessions, independent study, as well as test construction by the teacher.

Two examples of conceptual questions which were used in our research are described in the next few pages. Both involved a description of an experimental event which paralleled one that the students had previously done in class, and which contained concepts that the learners had already encountered. The first example illustrates how a laboratory exercise already completed can pave the way for the construction of a conceptual question. The second example relies on a different conceptual system (atomic theory, in this case) to offer an explanation for an event usually associated with electricity. Following the description of each example, the method for evaluation of the questions is given.

CONSTRUCTING CONCEPTUAL QUESTIONS: EXAMPLE #1 (THE WINEBOTTLE)

The following is a method for constructing conceptual questions. This first example will be used to illustrate each step of the method.

1. Select an experimental event that the students have been exposed to, and construct a concept map for the left-hand side of the "V" if one has not already been constructed. (See Figure 25 below.)

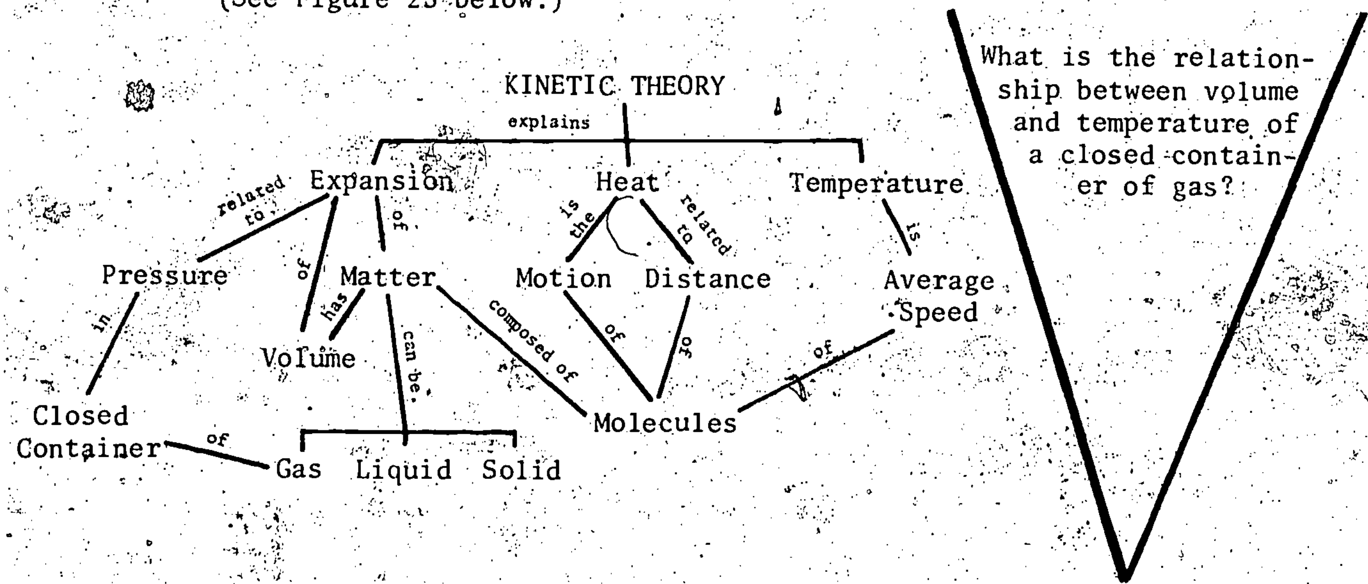


Figure 25: Incomplete "V" with Concept Map for purposes of constructing conceptual questions.

Flask with thermometer and tube with water droplet inside. Heat in bath of hot water. Record changes in temperature and height of water droplet.

2. Select another experimental event for which the same concepts would be relevant. In this example, the event was a capped winebottle that had been moved from the refrigerator to a sunny windowsill.

3. Construct a conceptual answer to the question to anticipate the kinds of conceptual links that the students might offer in their explanations. "Dissect" that explanation, picking out those

sentences which indicate a link between or among concepts. For instance, your anticipated explanation might include such sentences as:

EXPANSION IS DUE TO AN INCREASE IN THE DISTANCE BETWEEN MOLECULES,

HEAT IS DIRECTLY RELATED TO THE AMOUNT OF MOTION OF THE MOLECULES IN A SUBSTANCE, or

THE PRESSURE OF A GAS INSIDE A CLOSED CONTAINER INCREASES AS THAT GAS IS HEATED.

4. In addition to the correct conceptual connections that should be anticipated, the teacher should also prepare a list of misconceptions, commonly held by students.

   AS HEAT IS ADDED TO A SUBSTANCE, THE MOLECULES EXPAND,

   TEMPERATURE AND HEAT MEASURE THE SAME THING, or

   GASES ARE HOTTER THAN SOLIDS.

5. The actual test question should include four elements consistent with the information above: a clear focus question, a major event, some record of that event, and the concepts necessary to sort out the event and answer the question. Below is an example of a conceptual question used in our research. Please notice that all of the necessary elements are present.

DIRECTIONS: Read the paragraph below very carefully, and then do the the following:

-construct a concept map which includes the following concepts: kinetic theory, heat, temperature, gas, molecules, volume, pressure, and expansion.

-using that concept map as a guide, and including as many of the concepts into your answer as you can, explain why the cork popped out of the bottle.

An empty wine bottle is left in the refrigerator overnight. In the morning it is taken out. A cork is stuck in the mouth of the bottle, and the bottle is left on the windowsill where the warm rays of the Sun can hit it. Several minutes later, the cork pops right out of the bottle.

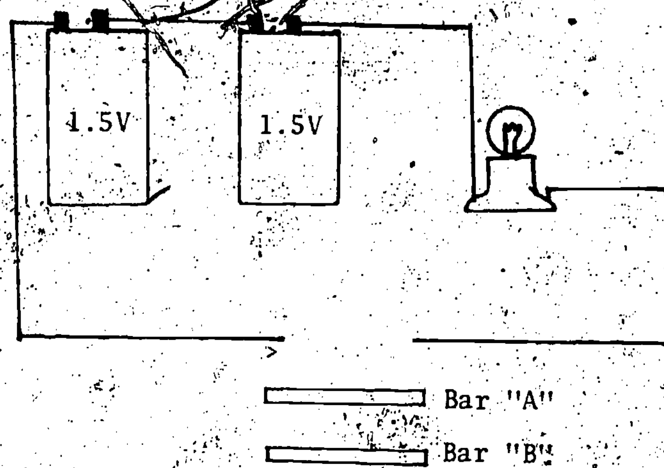
6. Several variations of this kind of question is, of course, possible, but the major elements mentioned already should be included. You may, for instance, decide that you do not want your students to construct a concept map as part of the answer. Although the constructed concept map may be helpful in indicating areas where misconceptions exist, our research seems to demonstrate that the making of a concept map is not necessarily imperative to answering the question.*

7. One final feature that our research has shown to be important should be considered. In our attempts to construct conceptual questions, it has been found that the list of concepts must include one superordinate concept under which all the others can be subsumed. In the example given above, that superordinate concept was "kinetic theory." In the next example, it is the "atomic theory," implied because of the presence of the concepts "electron" and "proton."

CONSTRUCTION CONCEPTUAL QUESTIONS: EXAMPLE #2 (ELECTRICITY)

Using the method described in this section, another example of conceptual questions was designed during our research. Again, the major elements are present: a clear focus question, a major event, some record of that event, and the concepts necessary for the student to answer the question. On the next page the question that was given to the students is provided.

*This is consistent with our thesis that concept mapping is a heuristic device, needed only to facilitate meaningful learning. Once the meaningful learning has occurred, the construction, or re-construction, of a concept map may not be necessary.



The apparatus shown in the figure above was set up by a science teacher. Bar "A" and Bar "B" are exactly the same size, but are composed of different materials. When Bar "A" is use to complete the circuit, the bulb lights up very dimly. When Bar "B" is used to complete the circuit, the bulb lights up brightly.

QUESTION: What must be happening inside Bar "A" that is different than what is happening inside Bar "B"? Use as many of the following concepts as you can to answer this question, or include any other concepts that you feel necessary to answer the question. The concepts include: attraction, conductor, charge, electron, insulator, resistance, proton.

REFERENCES

Ausubel, David P., Novak, J.D., and Hanesian, H. *Educational Psychology: A Cognitive View.* 2nd Edition. New York: Holt, Rinehart and Winston, 1978.

Gowin, D. Bob. "Educating," 1979. (Unpublished manuscript).

Heimler, Charles H. and J. David Lockard. *Focus on Life Science.* Columbus, OH: Charles E. Merrill Publishing Company, 1977.

Meyer, R.E. *Thinking and Problem Solving: An Introduction to Human Cognition and Learning.* Glenville, IL: Scott, Foresman and Company, 197

Moreira, Marco A. "Concept Maps as Tools for Teaching." *Journal of College Teaching,* vol. 8, no. 5, 1979, pp. 283-286.

Novak, Joseph D. *A Theory of Education,* Ithaca, NY: Cornell University Press, 1977.

Novak, Joseph D. "Applying Psychology and Philosophy to Improvement of Laboratory Teaching." *The American Biology Teacher,* vol. 41, no. 8, November, 1979, pp. 466-470.

Novak, Joseph D. "Learning Theory Applied to the Biology Classroom." *The American Biology Teacher,* vol. 42, no. 5, May, 1980, pp. 280-285.

Novak, Joseph D. "Biology Teaching Practices Based on Application of Learning Psychology and Philosophy of Science." *The American Biology Teacher* (in press), 1980.

Novak, Joseph D. "Progress in Application of Learning Theory." *Theory into Practice,* vol. 19, no. 1, Winter, 1980, pp. 58-65.

Novak, Joseph D. "Effective Science Instruction: The Achievement of Shared Meaning." submitted to *Australian Science Teachers Journal.*