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ABSTRACT

This manual describes two methods of assessing college students' conceptual structures in the interest of student evaluation. The focus is on the mental frameworks (conceptual structures) that enable students to remember and apply facts and theories. The guide offers two methods, the "ordered-tree" and the "fill-in-the-structure." An introduction discusses the general uses of the techniques, modes of assessment, and the measures that each offers. Section I describes the ordered tree technique including preparation of the stimuli, materials, administration, scoring (examples included), and interpretation of results. Section II describes the fill-in-the-structure method including preparation of the materials, administration (two figures from an ecology course included), scoring, and interpretation. A third section presents some considerations of similar and different aspects of the two techniques to assist instructors in selecting the best method for the situation. An appendix contains an example of scoring the fill-in-the-structure task with detailed explanation and eight references. A computer disk to aid in the analysis of the ordered-tree task has also been developed. (JB)

NATIONAL CENTER FOR
RESEARCH TO IMPROVE
POSTSECONDARY
TEACHING and LEARNING

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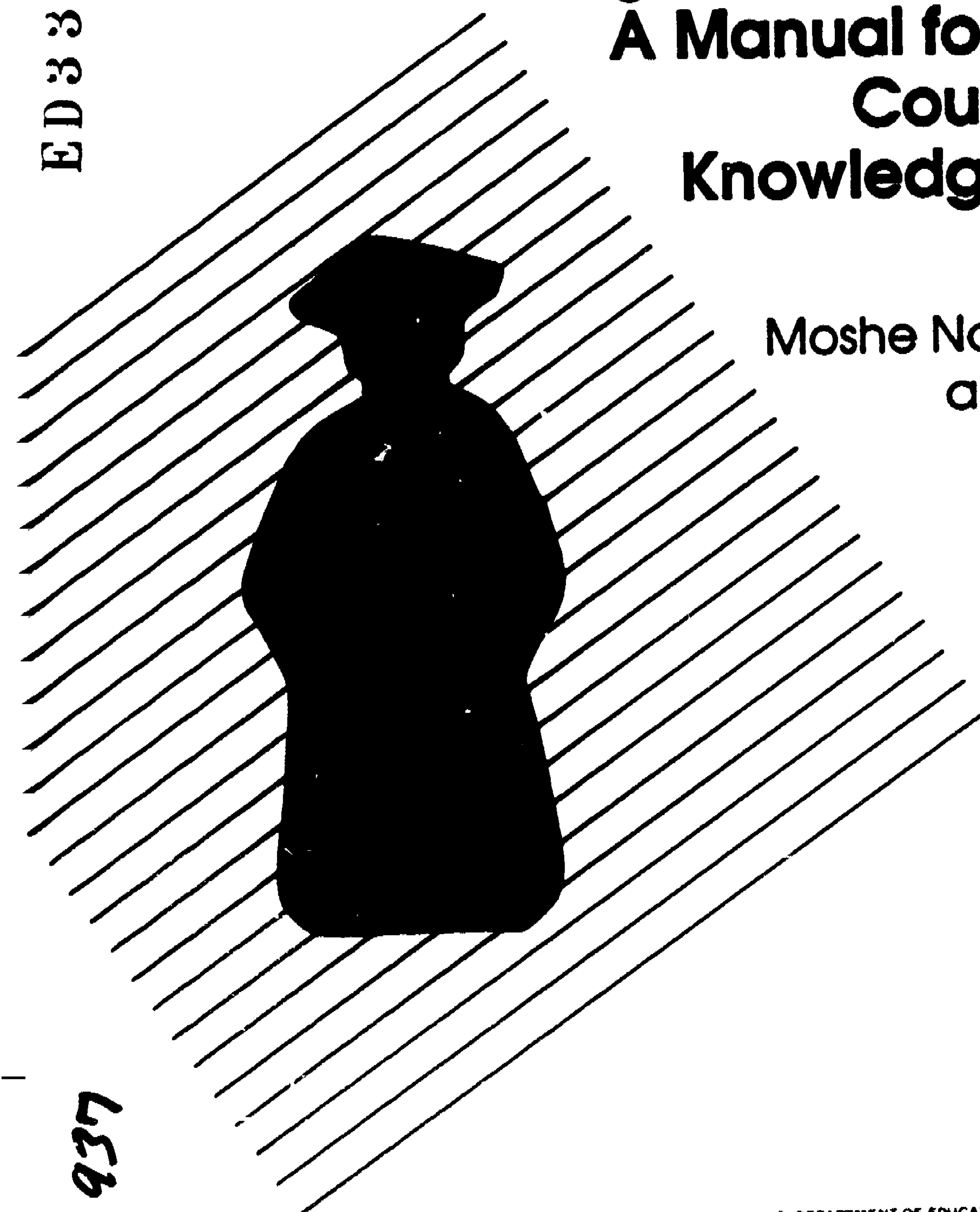
by
Moshe Naveh-Benjamine
and Yi-Guang Lin



FROM THE
PROGRAM ON
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OUTCOMES

Assessing Students' Organization of Concepts:
A Manual for Measuring Course-Specific Knowledge Structures

Developed by:

Moshe Naveh-Benjamin

and

Yi-Guang Lin

National Center for Research to Improve

Postsecondary Teaching and Learning

(NCRIPTAL)

The University of Michigan

Ann Arbor, Michigan

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CONTENTS

Attachment:

IBM PC disk for analyzing the ordered-tree task

INTRODUCTION

1. Purpose of the Manual

One of the major goals of college education is teaching the content of a discipline in such a way that students can see relationships among concepts and facts. You, as an instructor, hope that students will leave your courses with more than mere facts. You hope that they will develop a mental framework or conceptual structure that will enable them to remember and apply the facts and theories they have learned. And you hope this framework will establish a solid basis for continued learning. To help students develop such a conceptual structure you need to know what they already know and what they are gaining from your course, and what they take away at the end of the course.

This manual describes two methods of assessing conceptual structures. By "conceptual structure" or "knowledge structure" we mean a set of concepts that are or may be related to one another. Conceptual structures are the frameworks into which new phenomena and facts may be fitted.

Teachers have long recognized the importance of teaching students to look for relationships, but we seldom have had good ways of assessing the degree to which students learn appropriate conceptual relationships. The methods that follow are tools teachers and researchers can use to assess student learning of conceptual relationships.

While cognitive psychologists have developed other methods to assess concept development in laboratory experiments, few are adaptable to classroom situations (McKeachie, Pintrich, Lin, Smith & Sharma, 1990). The "ordered-tree" and "fill-in-the-structure" methods we describe in this manual have been successfully used in college and university classes.

2. Uses of the Techniques

When students enroll in a course, we usually assume that they come with some prior knowledge. This level of knowledge at the beginning of a course, and especially the organization of that knowledge, is in many cases only assumed by the instructor. The students' initial knowledge can be accurate and relevant, reflecting what has been learned previously. More often it is inaccurate, reflecting, among other things, stereotypes prevailing in our society [see Box A]. Having information about students' initial knowledge should help you develop materials for the course, improve organization of the different topics, and stress the issues about which misconceptions or stereotypes exist. The techniques described in this manual are designed to help you assess students' knowledge and understanding. They can also help student diagnose the difficulties they may have in learning. Simply listening to a lecture or reading a textbook will not be sufficient for understanding. To become aware of the connections between concepts and facts students need to develop the same cognitive structure as that of the teacher or textbook author, presumably a structure representing the discipline.

Box A

We have used the techniques described here to assess students' initial knowledge at the beginning of a Psychology of Aging course. We asked the instructor to select 10 to 20 concepts that were important for students to understand in the course. This instructor chose concepts including "attachment," "intimacy," "encoding," "retrieval," and "mid-life crisis," among others. Students were then given this list of concepts and were asked to list them so that those most alike appeared together. The results of these student trials were then tabulated to provide a picture of the students' cognitive structures, the frameworks students use to understand and relate concepts.

When looking at students' organization at the beginning of the course, across all students in the class, we were able to identify organization based on three separate sources. First, these structures reflected some prior, general, common-language understanding of the relationships among the concepts. For example, "attachment" and "intimacy" tended to appear together, reflecting the fact that these two concepts are associated in everyday life.

Second, the initial structure also represented knowledge gained in previous psychology courses. This was illustrated by the frequency of the cluster containing "encoding" and "retrieval," two concepts that appear together in current psychology.

The third type of knowledge represented by the initial structure was misconceptions students have about the subject matter. Their belief in steep decline of abilities during middle age (a decline not supported by evidence) was indicated by the cluster containing the concepts "mid-life crisis" and "wear and tear."

A second type of information needed to improve teaching and evaluation is how students' knowledge structures develop throughout a course. Pre- and post-tests given in courses typically show that students learn knowledge and concepts. But in many cases they don't tell us about the way the organization of facts and concepts is developed. Measures revealing the development of student conceptual structures can help you adjust your teaching to students' current conceptual structures (e.g., by reviewing some of the materials and stressing some parts that seem poorly grasped) and develop explanations that bridge the gap between students current understanding and your goal.

Box B

In the Psychology of Aging course, students' structures in the middle of the course reflected both the relationships among concepts learned in the first half of the course and also some breakdown of misconceptions they had at the beginning of the course. For example, by the middle of the semester, fewer students thought that "mid-life crisis" was closely related to "wear and tear."

Finally, assessing students' knowledge at the end of the course could help you evaluate the course's outcomes in relation to your original objectives [see Box C].

Box C

In the Psychology of Aging course, mentioned above, the prior goal of the instructors was to stress both topical (biological, cognitive), and developmental (young, middle, and late adulthood) dimensions, yet students' structures at the end of the course revealed much more awareness of the topical than of the developmental dimension. In retrospect, although we intended to combine these two dimensions, in practice it proved difficult. For example, it was hard to discuss cognition in young adulthood without comparing young adulthood cognition to that of middle and old age. As a result, the course actually presented each topic independently of a given stage of development. Information about students' knowledge structures was useful to us as we tried, in the following semester, to better integrate the two perspectives.

Typically, we assess course outcomes by achievement tests, which measure knowledge of facts and concepts, but most tests provide little information about the students' organization of concepts and facts. The techniques described here will help you determine how those concepts are related to each other.

To summarize, the techniques suggested here can help you assess your students' knowledge organization at the beginning of a course (or a unit within the course), during the course, and at the end of the course. In addition, your students can analyze their own structures.

3. Modes of Assessment

The techniques described here, the "ordered-tree" and the "fill-in-the-structure," have been used in science, social science, humanities, and other courses by instructors and students in liberal art colleges, community colleges, comprehensive universities, and major research universities.

Both the "ordered tree" and the "fill-in-the-structure" methods can be administered to classes or to individuals for diagnosis of prior knowledge or evaluating achievement for a class or for an individual student. In-class administration should not take more than one class period for either of the techniques.

4. <u>Measures</u>

Both the "ordered tree" and the "fill-in-the-structure" techniques provide several measures of student organization of the material. For example, the ordered tree technique enables you to characterize a student's organization of the material in four ways:

a. The amount of organization the student has (reflected by the number of concepts that are grouped together consistently by the student).

b. The number of different hierarchical levels along which a student organizes the concepts.

c. The similarity of a student's organization to that of the instructor.

d. The direction of relationships between concepts as perceived by the student.

The fill-in-the structure technique enables you to characterize a student's organization of the materials in two ways:

a. The degree to which a student has an organization of general and specific concepts.

b. The departures of a student's organization from that of the instructor. Here, either global or specific departures can be assessed.

I. THE ORDERED-TREE TECHNIQUE

A. <u>Preparation of the Stimuli</u>

The ordered-tree technique is named for the tree-like form the analysis of results takes: basic concepts form the "trunk" and "branches" and detailed concepts make up the "leaves." To use this technique, follow these steps:

1. First, choose a set of concepts representing the subject-matter to be assessed. One way to develop your structure of the materials is by listing as many concepts as you can think of in the course (e.g., all animals names).

2. Then group the concepts into several categories (e.g, birds, fish, mammals).

3. Next, arrange the concepts in each category to reflect their relationships. For example, if one concept is an example of another one, they should be connected hierarchically where the first concept is below the second (e.g., a lion is an instance of mammals; a catfish is an instance of fish).

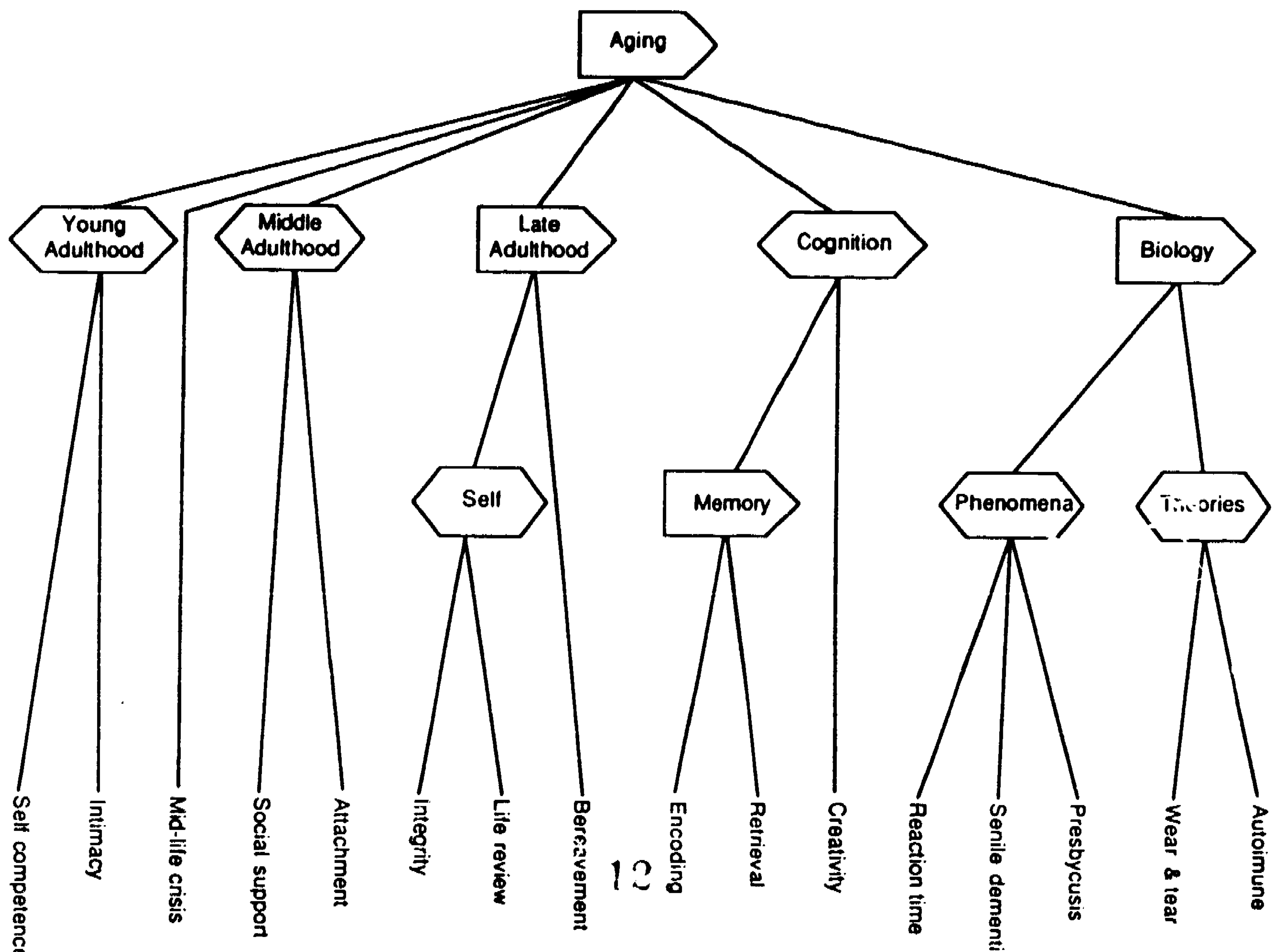
4. After you have organized each category, put all the groups together under the top of the hierarchy, which includes the course title. You can make any changes now, until the structure is compatible with your view of teaching the course. This is the instructor's structure (see Figure 1 for an example for a Psychology of Aging course).

5. At the end of this process you should have a structure with <u>16 to 20 concepts at the lowest level</u>. These will be the concepts given to the students as part of their task, as described below.

These concepts should represent major content areas in the course (or unit of instruction), with a few concepts from each area. The concepts should be from different levels of generality. These concepts will probably reflect materials from lectures, the textbook, or both. Your final structure should have at least two related concepts in each group or "chunk" and the various branches of the structure should not be connected at the lowest levels.

Note that the final list given to students does <u>not</u> include major abstract concepts. In the example from the Psychology of Aging course, "stages of the life cycle," a major focus of the course, is in the middle of the structure with the terms "young adulthood," "middle adulthood," etc.

Figure 1 Instructor's Knowledge structure: Psychology of Aging course



The final list given to students includes issues/tasks associated with each stage.

Another way to create the structure is by using an empirical approach. After choosing the concepts, you can actually perform the ordered-tree task described below. Analyzing your results will provide you with your structure of the materials.

B. Materials for the Task

Prepare a booklet for each student. This booklet should include four or more pages. Each page will have the same set of concepts (an even number between 14 and 24, as required by the computer program that analyzes the results) that are at the lowest levels in the instructor's structure. The concepts should appear in rows and columns in no specific order. For example, for 16 concepts you might arrange them in 4 rows and 4 columns. The order of the concepts in each page should be different to prevent students from simply repeating the same order on each trial.

On the right side of each page should be vertical blanks corresponding to the number of concepts that appear in the rows and columns. In Figure 2 you can see an example of the four pages taken from a Psychology of Aging course.

The first and fourth pages should instruct the students to begin with any word they may choose (uncued trials). On the second page, choose any word you wish (perhaps randomly) and ask the student to begin with that word. For the third page, choose another word as the beginning word. Thus, the second and third trials are "cued" trials.

C. Administration

1. Ask students to arrange the concepts in a vertical order so that concepts closely related in terms of their meaning in the course appear close to each other. In the first trial students start with any one of the concepts (an uncued trial). Our experience shows that students usually need between 5 and 8 minutes to perform the task. It is important to stress that they use every concept, and each only once.

2. When the students have completed the first page, lecture, or assign some other activity, for a few minutes (4-6), then ask them to fill out the second page of the booklet under the same instructions,

Figure 2 Examples of cued and uncued trials

Page 1 - Uncued Trial

<u>Ordered tree task</u>

Please arrange the following concepts on the space provided starting with the first space, so that concepts that are closely related in terms of their meaning in the course Psychology 459 will be close to each other. You may start with any concept of the 16 given. <u>Be sure to use all 16 concepts</u>.

Reaction Time	Integrity	Senile Dementia	1.______
Bereavement	Creativity	Presbycusis	2.______
Mid-Life Crisis	Self Competence	Retrieval	3.______
Life Review	Encoding	Autoimmune	4.______
Intimacy	Social Supports	Attachment	5.______
		Wear and Tear	6.______
			7.______
			8.______
			9.______
			10.______
			11.______
			12.______
			13.______
			14.______
			15.______
			16.______

Page 2 - Cued Trial

<u>Ordered tree task - Continuation</u>

Please arrange the following concepts on the space provided starting with the concept <u>autoimmune</u>, so that concepts that are closely related in terms of their meaning in the course Psychology 459 will be close to each other. <u>Be sure to use all 16 concepts</u>.

Retrieval	Mid-Life Crisis	Social Support	1. <u>Autoimmune</u> ______
Intimacy	Encoding	Autoimmune	2.______
Senile Dementia	Self Competence	Reaction Time	3.______
Bereavement	Life Review	Integrity	4.______
Attachment	Presbycusis	Wear and Tear	5.______
Creativity			6.______
			7.______
			8.______
			9.______
			10.______
			11.______
			12.______
			13.______
			14.______
			15.______
			16.______

Page 3 - Cued Trial

<u>Ordered tree task - Continuation</u>

Please arrange the following concepts on the space provided starting with the concept <u>mid-life crisis</u>, so that concepts that are closely related in terms of their meaning in the course Psychology 459 will be close to each other. <u>Be sure to use all 16 concepts</u>.

Integrity	Mid-Life Crisis	Life Review	1. <u>Mid-Life Crisis</u> ______
Encoding	Senile Dementia	Presbycusis	2.______
Intimacy	Social Supports	Wear and Tear	3.______
Bereavement	Retrieval	Attachment	4.______
Autoimmune	Self Competence	Reaction Time	5.______
Creativity			6.______
			7.______
			8.______
			9.______
			10.______
			11.______
			12.______
			13.______
			14.______
			15.______
			16.______

Page 4 - Uncued Trial

<u>Ordered tree task - Continuation</u>

Please arrange the following concepts on the space provided starting with the first space, so that concepts that are closely related in terms of their meaning in the course Psychology 459 will be close to each other. You may start with any concept of the 16 given. <u>Be sure to use all 16 concepts</u>.

Presbycusis	Attachment	Mid-Life Crisis	1.______
Encoding	Reaction Time	Bereavement	2.______
Intimacy	Social Supports	Wear and Tear	3.______
Autoimmune	Self Competence	Integrity	4.______
Life Review	Retrieval	Senile Dementia	5.______
Creativity			6.______
			7.______
			8.______
			9.______
			10.______
			11.______
			12.______
			13.______
			14.______
			15.______
			16.______

this time starting with a specified concept (cued trial). They should be given about the same time to complete the task as they were given for the first page.

3. After a few more minutes of activity unrelated to the ordered-tree, have the students turn to the third page and ask them to perform the same task as described above, this time starting with a different concept.

4. After another interval of unrelated activity, students should turn to the fourth page and be asked to relate the concepts, this time starting with any concept they wish (uncued trial).

It should be noted that repeating the procedure four times is reasonable when using this number of concepts. In some of our studies we created structures based on three or five trials. Three trials showed much less structure in comparison to the four-trials case, whereas five trials added little. As a result, we recommend using at least four trials. If there is enough time, more trials can be used (while alternating between cued and uncued ones). Figure 2 presents an example of cued and uncued trials.

D. Scoring

The four trials (or more, depending on how many you actually use) for each student are coded using an IBM-PC computer program that will summarize a student's responses in both a formal expression representing a tree structure for that student, and a graphic representation of this student's knowledge structure. As an example, Figure 3 shows the four strings produced by a student in a Psychology of Aging course, with the resulting computer output. Information in parentheses indicates chunk, concepts that consistently appear together in the student's strings. (For information about how the program works and the assumptions underlying it, see Box D and the article by Reitman & Rueter, 1980). The instructions about using this program are in the file READ ME.TEXT on the disk.

Figure 3. An example of a student's trials and resulting computer expression and structure.

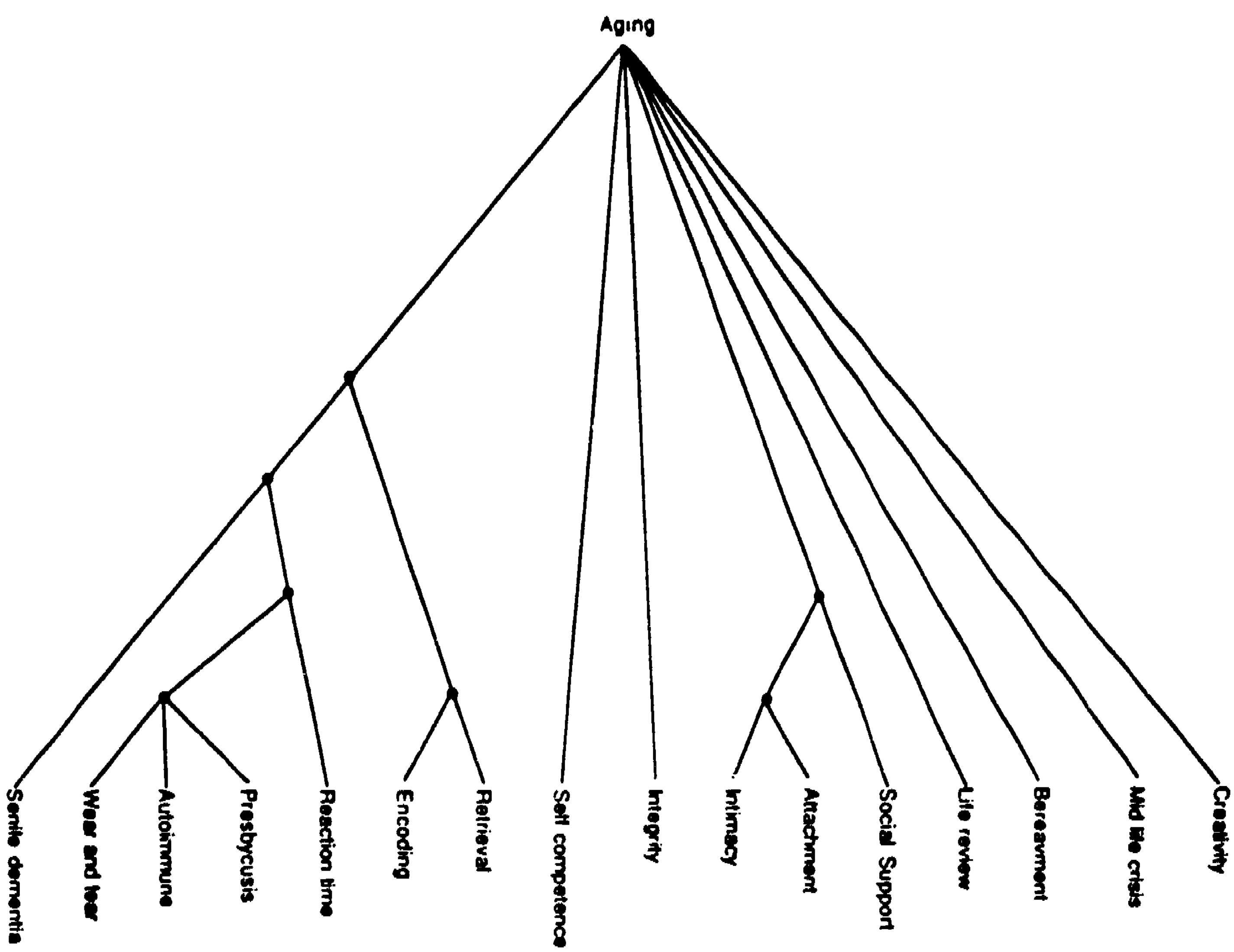
Student's Trials

1. sen wea aut pre rea enc ret sel ing int att soc lif ber mid cre
2. cre ing sel lif enc ret sen rea wea aut pre soc att int ber mid
3. sen enc ret rea wea aut pre sel ing cre lif att int soc ber mid
4. int att soc ber lif sel cre ing mid rea wea aut pre sen enc ret

Computer Expression

(<<sen<[wea aut pre] rea>>[enc ret]> sel ing<<int att> soc> lif ber mid cre)

Computer Structure



Box D

The program is based on a theory of mental organization that assumes that single concepts or sets of concepts are mentally organized into a hierarchy whose lowest level terminal nodes represent single concepts and higher-level nodes represent more abstract categories or concepts. The technique capitalizes on people's tendency to list all items in one chunk of information before moving on to the next chunk. From a set of cued and uncued trials, the algorithm efficiently finds the set of all chunks for each subject and represents this set as an ordered-tree that represents a student's knowledge structure from a course.

For each student, four measures are provided by the computer program.

1. Amount of organization: This measure, Possible Recall Orders (PRO)[1], provides information about the amount of organization in a student's structure. If the order in which a student writes the concepts in each trial is completely different, it indicates a small amount of organization of the materials, since he or she relates different concepts to each other in each trial. However, if a student uses a consistent order of concepts across trials, it indicates a high degree of organization.

The computer program accompanying this manual computes the amount of organization for each student's responses. Note that a large number of Possible Recall Orders (PRO) indicates little organization, and a small PRO indicates high organization, i.e. the students group concepts together consistently. The range of PRO scores varies according to the number of concepts used. For example, for 14 concepts the range is from 0 (very organized structure) to 36 (unorganized structure); for 16 concepts PRO scores range from 0 to 44; for 18 concepts from 0 to 52 and for 20 concepts from 0 to 61.

2. Depth: Another measure shown by the "ordered tree" is the average hierarchical depth[2] (Average number of levels in each chunk). Larger average depths indicate more structure and differentiation among concepts in terms of their hierarchical position. A depth measure of 1.0 indicates no depth at all. The chunks "Dogs-Wolves, Cats-Tigers, Rattlesnake-Cooperhead," would represent three levels (1-dogs, etc; 2-mannals; 3-animals), resulting in a depth measure of 3.0. The chunk, "Cat-Catnip," has only one level resulting in a depth measure of 1.0. The higher the depth value, the more elaborate is the structure. Use the computer program to compute a depth measure for each subject.

3. Similarity: This measure provides an index of similarity between a student's structure and that of the instructor (or between any two students' structures). Generally, the greater the number of chunks a student's structure shares with that of the instructor, the greater the index of similarity (see McKeithen, Reitman, Rueter, & Hirtle, 1981 for details). A high value on this

[1] PRO is the natural logarithm (base 2) of the number of different written orders that could contain its chunks.

[2] Depth is defined as "the average number of nodes between root and terminal items."

measure indicates similarity in a student's cognitive structure to the structure of the instructor, or the degree to which the student has learned what the teacher taught. This measure ranges from 0.0 (no similarity) to 1.0 (structure identical to the instructor's). Again, to obtain this measure, use the computer program.

4. Directionality: A cluster of concepts can be non-directional, bidirectional, or unidirectional. A non-directional cluster [indicated by parentheses ( )] in the structure obtained by the computer, is one in which three or more concepts occur together consistently, but in no consistent order; a bidirectional cluster (indicated by arrow brackets < >) is one in which the concepts in the cluster are consistently ordered but the student may start from either end of the cluster; a unidirectional cluster (indicated by square brackets [ ]) is one in which the cluster is consistently written by the student in one order. Thus, the directionality measure seems to indicate the direction of relationships between concepts as perceived by the student. A concept that is first accessed in a cluster may be more salient or more accessible in memory than those coming later, or may precede the others chronologically, as in the chunk "Stone age - Iron age".

E. Interpretation of the Results

Students who have high scores on all the measures have appropriate conceptual structures. Those who have a large amount of organization and depth but a low similarity index, may organize the materials studied, but their organization does not fit the instructor's. These students are likely to misinterpret the instructor's explanations and to distort facts to make them fit their own structure. They will need opportunities to see how their misconceptions lead to errors and opportunities to develop more realistic structures. Students with both little organization and low similarity need to work on learning the materials in the course, on looking for relationships between concepts, and on developing a general tendency towards integrative, conceptual learning.

II. THE FILL-IN-THE-STRUCTURE TECHNIQUE

In the "fill-in-the-structure" technique the instructor's structure is presented with some concepts omitted. The student's task is to fill in the blanks.

A. Preparation of the Materials

As a first step, the instructor should come up with a hierarchical representation of the subject-matter domain to be taught to the students. This means, as in the "ordered tree" technique, graphic representation of major concepts and the relationships among them. An example of such a representation from an ecology course appears in Figure 4. The number of concepts to be used is limited only by the time it will take the students to do the task. We have used structures with 30 to 55 concepts.

The next step involves taking out some of the concepts, leaving their spaces blank. These concepts are then placed at the bottom of the page intermixed with concepts not used in the structure (distractors). We have used between 10% and 20% distractor concepts. Usually we recommend that no more than 50% of the concepts be taken out of the structure. In addition, you should try to take out about the same percentage of concepts from each level of the hierarchy.

B. Administration

1. Students receive the hierarchical graphic representation of course materials in which some of the concepts are missing. (See Figure 5 for an example in the ecology course). These concepts appear at the bottom of the page intermixed with distractor concepts.

2. The students' task is to fill in the concepts in the appropriate position in the structure while <u>recording down the order in which they are using the concepts</u>. The students will usually need between 15 and 25 minutes to complete this task, depending on the number of missing concepts.

Figure 4 Instructor's Knowledge Structure: Ecology Course

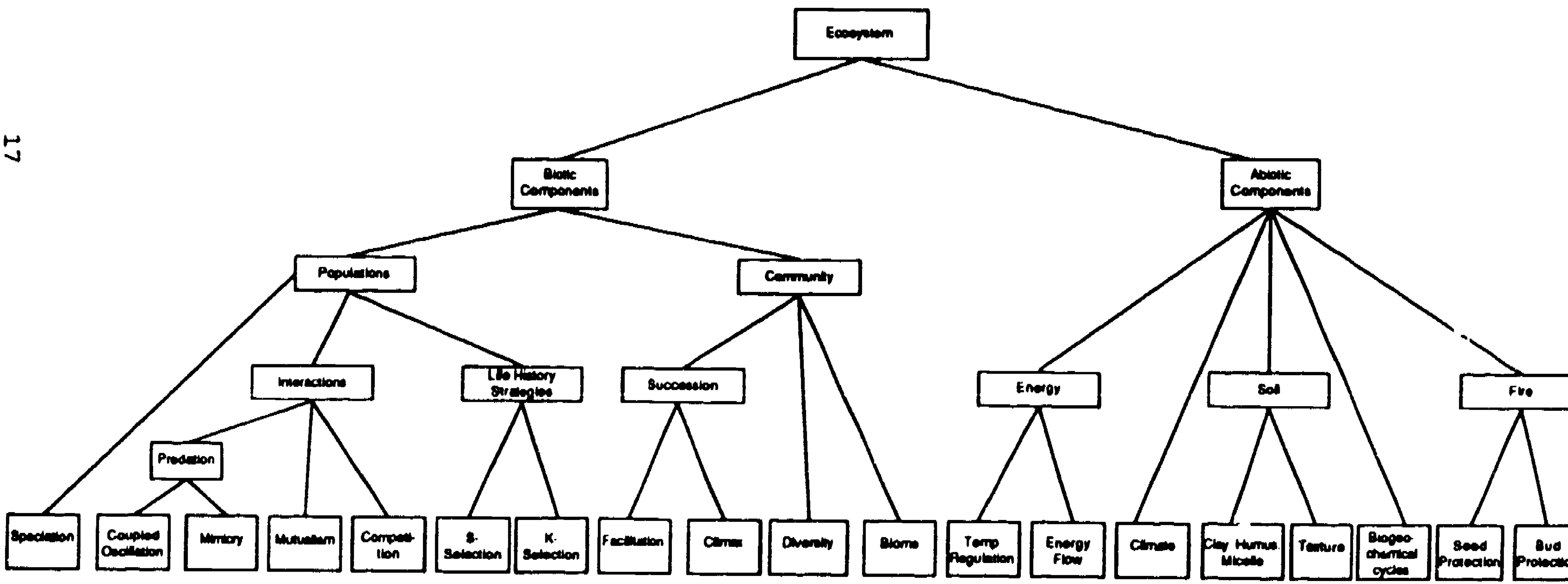
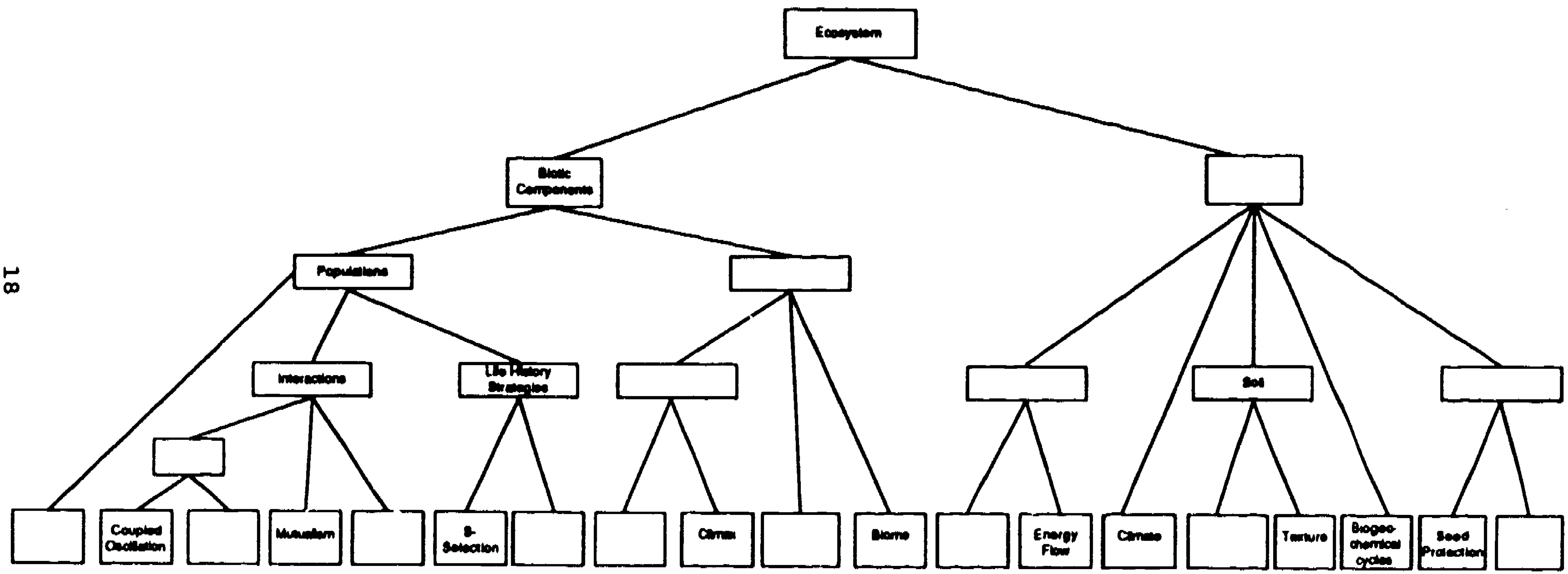


Figure 5 Fill-in-the-structure in Ecology course



Disruptive
Energy
Diversity
Predation
Fire
Genetic Drift
Inheritance of Traits
Batesian
Succession
Temperature Regulation
Recombination
Community
Abiotic Components
Range Division

Texture
Mimicry
Speciation
Bud Protection
Clay-Humus Micelle
Law of Tolerance
Competition
Genetic Variability
Hemicryptophyte
Facilitation
Selction Pressures
K-Selection
CAM Photosynthesis

C. Scoring

Several measures can be obtained for each student. These measures include:

1. The total number (or percentage) of correct responses. This indicates the concepts that were correctly filled in, according to the instructor's structure. This measure provides an overall similarity index of a student's cognitive structure to that of the instructor.

2. The number of concepts that were placed correctly at each level of the hierarchy. These measures provide information about the similarity between each level of a student's structure (from the upper, more general, to the lower, more specific) and that of the instructor.

3. The order in which the concepts were filled in. This describes how students access the structure. For each level of the hierarchy add the number of the orders the students listed when filling in the blanks. Divide this sum by the number of blanks filled in. Smaller average orderings at lower levels of the hierarchy imply that students access their structure in a bottom-up fashion (from the specific to the more general concepts). In contrast, smaller average orderings at the upper levels of the hierarchy imply that students access their structure in a top-down fashion (from the general to the specific).

4. A final group of measures can be obtained by looking at the type of errors that students committed. For instance, two students could misplace the same number of concepts but at different places in the structure.

   a. One type of analysis of types of errors, looks at the degree of misplacement. For example, you can compute a measure of distance between the blank in which a concept was placed and the blank where it should have been placed, moving along the shortest path which connects these places, and then average these distances across all errors made by a student. A high value on this measure indicates significant deviations from the instructor's organization. See the Appendix for an example of the scoring method.

   b. Another type of analysis looks at whether misplacements occurred within the same chunk or between chunks. Total the errors within chunks and the errors between chunks. Errors within a chunk may indicate some similarity to the instructor's structure. while errors between chunks indicate some major structural differences.

   c. Similarly, errors can occur within the same hierarchical level or between different levels. Total the errors within levels and the errors between levels. Errors within the same level indicate some similarity to the instructor's structure in terms of the hierarchical relationships, while errors between levels indicate hierarchical dissimilarity.

d. Finally, analyses of errors can be done to assess relationships between concepts. For example, all sets of "parent-child"* relationships (e.g., the related concepts "Memory" [higher-level] and "Retrieval" [lower-level] in Figure 1) in the instructor's structure could be scanned to reveal their placement in a student's structure. For example, a parent and a child that were both misplaced by a student but that kept their hierarchical relationships intact, indicate knowledge about these relationships. Alternatively, a parent and a child that were both misplaced by a student and placed as "siblings", may indicate that a student has information about their being related but does not know the type of relationships between them. Finally, a parent and a child that were misplaced in different parts of the structure may indicate that the subject does not know that they are related.

An example of how to calculate these measures of performance appears in the Appendix.

The analysis can also be used on specific parts of the structure if a particular topic represented in the structure is of interest. As you can see, there are various options for scoring in this task, and you may think of others that are of interest to you. Analyzing their own structures can be a useful learning experience for students.

D. Interpretation of the Results

A student with a small percentage of correct responses needs to work on gaining a better understanding of the concepts and their relationships. If more errors occur at the upper level of the structure, the student needs to focus on overall organization. If, however, errors primarily occur at the lower levels, students need to focus on basic definitions and examples and the relationships between these concepts and more general ones.

If many errors occur between hierarchical levels, you can help students by reviewing the hierarchical relationships between the concepts. Errors in specific parent-child or sibling relationships can be corrected by reviewing the correct relationships between the relevant pairs of concepts.

Small group discussions in which students compare their structures can be useful in helping students to develop more accurate and complete structures.

*Parent = higher level; Child = lower level

III. CHOOSING THE RIGHT TECHNIQUE

To help you choose which technique to use, we present some considerations of similar and different aspects of the ordered-tree and fill-in-the-structure techniques.

A. Similarities:

1. Both techniques use the notion of a knowledge structure represented as a group of concepts interrelated in an hierarchical fashion.

2. Both provide several manifestations and indicators of a student's structure.

B. Differences:

1. The ordered-tree indirectly infers structure, because we infer the student's structure indirectly from his or her orderings of the concepts. The student might not necessarily be aware of the hierarchical nature of the relationships. The fill-in-the-structure, however, is a direct technique where the student is aware of the hierarchical representation of the materials.

2. The ordered-tree technique is less flexible in that it results in strict hierarchical relationships. The fill-in-the-structure technique allows deviations from hierarchical relationships (e.g., two parent concepts can be both related to a mutual child).

3. The ordered-tree takes longer to complete.

4. In the ordered-tree, the subject is less constrained by the type of relationships he or she may show, while in the fill-in-the-structure, the subject's responses are constrained by the graphic representation, which includes some predetermined relations.

C. Order of Administering the Two Techniques:

Both tasks can be administered to the same class, although it is better to perform the ordered-tree first to minimize the practice effects from one task to the other. There is little information in the ordered-tree task to serve as cues for the fill-in-the-structure task. Using the fill-in-the structure task first, however, could reveal to the students parts of the instructor's structure, hence affecting the order in which they list the concepts in the ordered tree task.

We have established the reliability and validity for these measures in several research studies (Naveh-Benjamin, McKeachie, Lin, & Tucker, 1986;

Naveh-Benjamin, McKeachie, & Lin, 1987, 1989; Naveh-Benjamin, Lin, & McKeachie, 1989). The various measures extracted from both techniques were shown to be related to course performance and to develop substantially throughout various courses. Although they have been used successfully in a variety of courses, the sort of hierarchical structure which these techniques measure is probably more clearly represented in science courses than in humanities courses (Donald, 1986).

APPENDIX

An example of scoring the Fill-in-the-structure task

This example refers to the performance of a hypothetical student in a Learning to Learn course, where the student's responses are compared with those of the instructor. The structures of both appear on Figure 6.

a. Total number of correct responses (percentage correct):

7 of 16 = 43.75%

b. Number of concepts placed correctly at each level of the structure:

Level 1 - 2 of 3 = 66.7%

Level 2 - 2 of 2 = 100.0%

Level 3 - 1 of 3 = 33.3%

Level 4 - 2 of 8 = 25.0%

It can be noted that this student had fairly accurate organization of higher levels of the structure (major concepts) but not as much organization of lower levels of the structure.

c. Order:

Average at Level 1 [1+2+3=6] 6 / 3 = 2.0

Average at Level 2 [4+5=9] 9 / 2 = 4.5

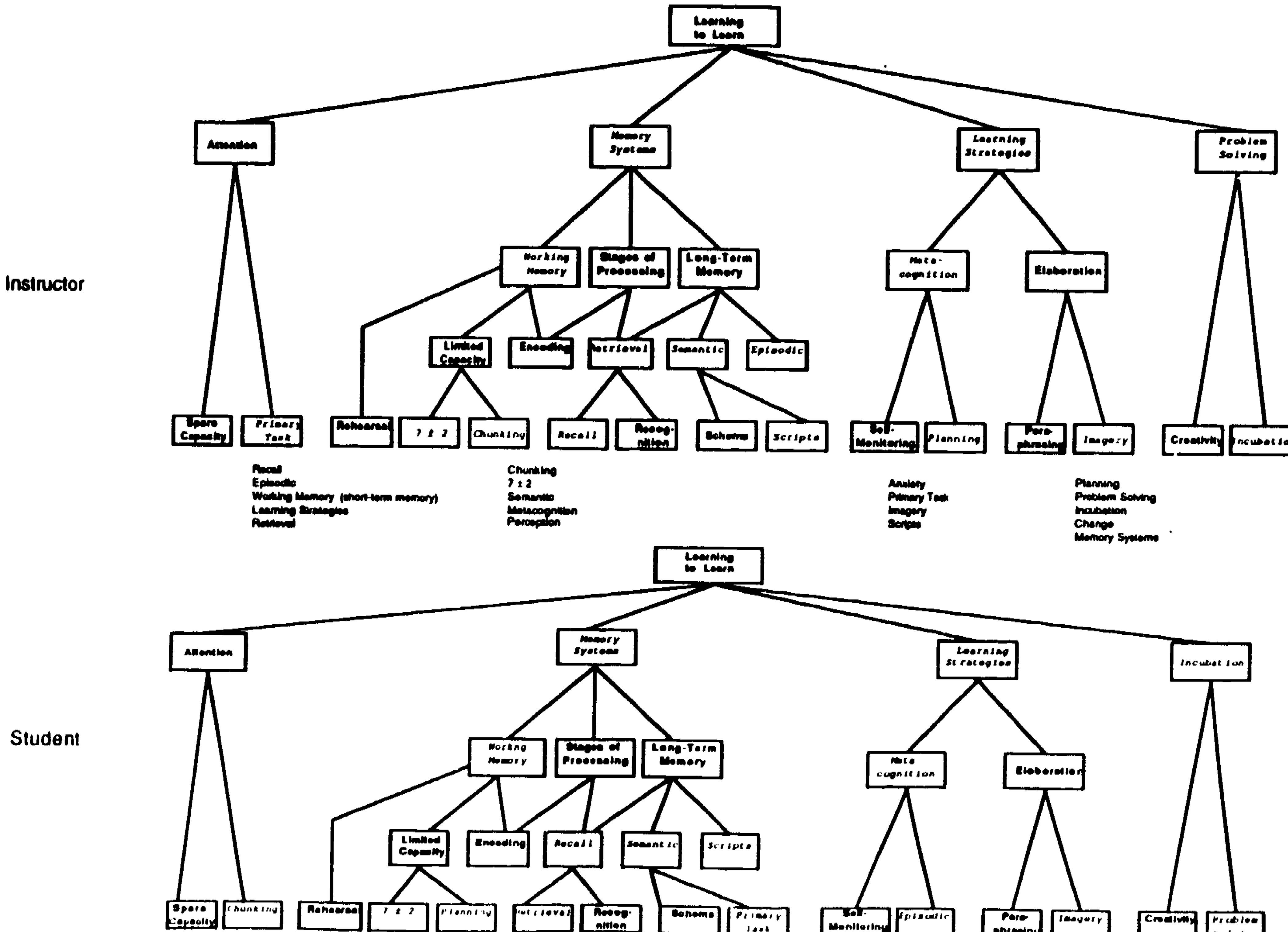
Average at Level 3 [6+7+8=21] 21 / 3 = 7.0

Average at Level 4 [9+10+11+12+13+15+16+14=100]

100 / 8 = 12.5

Note that this student, in filling in the structure, completed it in a top-down direction. The average order is the lowest for the upper level of the structure and it gradually increases as we get to the lower levels.

Figure 6 The Instructor's and Student's Structures: Learning to Learn course



d. Types of Error:

(1) Degree of misplacement.

For each error we compute the shortest distance between the expected placement (according to the instructor's structure) and the one obtained by the student. Then we average these distances across all the misplaced concepts.

For example, "chunking" was misplaced by a distance of 6 (going from its observed placement through, "attention," "learning to learn," "memory systems," "working memory," and "limited capacity," to its correct placement).

We can calculate the distance for all concepts misplaced in the same way.

chunking = 6

primary task = 6

recall = 1

episodic = 6

scripts = 3

incubation = 1

planning = 6

problem solving = 1

retrieval = 1

The average misplacement distance is 31 / 9 = 3.44

(2) Misplacement within and between chunks.

For convenience, let us consider as chunks the four major branches in the instructor's tree.

# of within-chunk errors = 5

# of between-chunk errors = 4

In this case there were about same number of between-chunks and within-chunks misplacements.

(3) Misplacements within and between levels.

# of within-level errors = 3

# of between-level errors = 6

This student shows twice as many between-level misplacements, possibly indicating confusion between general and specific concepts, especially in levels 3 and 4, where most error occurred.

(4) Errors in relationships between concepts.

Following is an example of an analysis of parent-child errors.

There were six such relationships in the instructor's structure to fill in (e.g., learning strategies-metacognition).

* Of those, two were correct in the student structure. In other words, both parent and child were placed in their appropriate positions. (e.g, memory systems-working memory).

* Of the four parent-child relationships that did not hold, two were reversed (the child became the parent and vice versa, e.g., recall-retrieval).

One set was placed as siblings (semantic-scripts).

One set drifted apart altogether (metacognition-planning).

It may be noted that in three of the four errors of this type, the association between the pair members was kept (they still were put close to each other). However, what has been missed is their hierarchical relationships. This means that this student could not identify the correct relationships between the concepts, implying some loss of their hierarchical organization.

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Attachment

IBM PC disk for analyzing the ordered-tree task.

If you have any questions about the use of these techniques in your own classes, please write to: NCRIPTAL, 2400 SEB, University of Michigan, Ann Arbor, Michigan 48109.

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