DOCUMENT RESUME

ED 314 734 CS 009 913

AUTHOR Lloyd, Carol V.
TITLE How Ideas Are Elaborated in One Topic across Three Biology Textbooks.
PUB DATE 90
NOTE 29p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Audience Awareness; Biology; *Content Area Reading; High Schools; *Science Instruction; Scientific Concepts; *Textbook Content; *Textbook Evaluation; Textbook Research
IDENTIFIERS Concept Identification; *Concepts in Science; Conceptual Analysis; *Elaboration; Ideas; Text Factors

ABSTRACT

A study examined text-based scientific concepts and described how those concepts were elaborated in three high school biology textbooks. The three textbooks were aimed at different student audiences: non-college bound students, special education students, and high school students at all levels. A concept analysis was established for each text, and then the extent to which the concepts were elaborated was determined. Results indicated that the textbook designed for the least able students presented the least amount of information. Results also indicated that the other texts presented similar amounts of information and elaborated many of the concepts, but to different degrees. (Three figures and two tables of data are included; 40 references are attached.) (RS)

How Ideas are Elaborated in one Topic Across Three Biology Textbooks[1]

Carol V. Lloyd

As a society, our conception of literacy is in a state of transition. Harste & Mikulecky (1984) suggest that as the demands of society have changed, so must our understanding of literacy. They suggest that literacy must be concerned with the function of print within the context of a society that requires knowledgeable and thoughtful citizens.

One of those societal demands is the need to be scientifically literate. As members of a highly technological society, we need to understand how science impacts our everyday lives. However, studies concerned with science achievement have consistently shown that students have not learned much science (Hueftle, Rakow, & Welch, 1983; National Assessment of Educational Progress, 1978; National Science Foundation & Department of Education, 1980). In fact over the years, the level of science achievement has shown a downward trend (Anderson & Smith, 1986).

Given the nature of school achievement in science, it is not surprising that adults also lack a basic understanding of scientific concepts (Miller, 1989). Miller's study reveals a scientifically literate adult population of only 5 to 7 percent. Yet knowledge of these ideas is necessary to make decisions in

[1]This paper is based on a presentation by C.V. Lloyd & J.N. Mitchell (1987) at the 37th Annual Meeting of the National Reading Conference.

our society. Issues of current concern such as acid rain, the greenhouse effect, and "Star Wars" emphasize the importance of these understandings.

Current definitions of scientific literacy emphasize both basic knowledge of science content and the application of that knowledge to personal and societal needs (Harms & Yager, 1981; Mitman, Mergendoller, Marchman, & Packer, 1987). In contrast, most existing curriculum focuses on science content. This is evidenced by both classroom instruction and textbook content (Stake & Easley, 1978; Harms & Yager, 1981).

However, though the components of relevance and context represented by the application of scientific ideas are certainly important within a framework of scientific literacy, it is obvious from the above cited studies that the nature of science education in our society has not facilitated the acquisition of the basic knowledge to use within these contexts.

Textbooks in Science Education

Why haven't students learned the content of science? One way to answer that question is to ascertain the source of most of this information. From studies investigating instruction in science classrooms, research has found that textbooks have played a major role (Barber & Tomera, 1985; Harms & Yager, 1981; Koballa, 1985; Stake and &Easley, 1978). In fact, an overwhelming 90 to

95 percent of 12,000 science teachers surveyed reported that textbooks were used 90 percent of the time for curriculum and instruction (Yager, 1983).

Given the dominant role of science textbooks in science education, it seems essential to describe the nature of these texts. Meyer, Crummey, and Greer (1988) described four elementary science textbooks using Anderson and Armbruster's (1984) criteria of considerateness. In addition, they added content factors to their evaluation. Specifically, they identified the topics presented, described how they were presented, and described the activities outlined in the texts. Typically, these four textbooks were considerate. However, what this study did not do, and what the construct of considerateness does not address, is how the information presented in text is elaborated. Ascertaining whether the content reflects purposes and main ideas or contains extraneous information is necessary, but not sufficient in identifying factors that may contribute to the comprehensibility of text and subsequent retrieval of text-based information.

The purpose of content area textbooks is to provide new information to the reader (Anderson & Armbruster, 1984; Spiro & Taylor, 1987). Yet both elementary science texts (Elliott, Nagel, & Woodward, 1986) and college biology texts (Blystone, 1987) have been criticized for their surface level presentation of ideas because this type of presentation neglects to elaborate ideas. In addition, Lloyd and Mitchell (1989) have questioned how much students might learn from content books with large numbers of concepts. This lack of elaboration and large concept load creates a learning situation requiring students to memorize information without developing in-depth understandings.

One important psychological process that affects reading comprehension is the process of elaboration. Elaboration is the embellishment of ideas, either by the learner/reader, or by the text. The potential impact of elaboration is at least twofold. First, elaborations can affect one's memory of information at either the encoding or retrieval stage (Anderson, 1980; Reder, 1980). Second, elaborations can add to the meaningfulness of an idea by making concepts relevant or nonarbitrary (Bransford, 1979).

Though elaborations of ideas within a text has the potential for a significant impact on a reader's comprehension, existing methods of text analysis do not specifically address this issue.

Elaborations as a mechanism for affecting memory can be illustrated in the following example. Suppose a reader encountered the statement "Joanne was worried because she had forgotten her homework again". In addition to storing a representation of this idea in memory, the reader may elaborate the statement by adding information such as Joanne often forgets her homework, and the teacher will punish Joanne for forgetting her homework. These elaborations are generated by the reader as he applies his prior knowledge to this information. Now suppose that at some later time the reader is asked to recall the original statement, but for some reason is unable to. First, the elaborations could aid memory by providing additional routes of retrieval to the target idea. Second, the reader might remember the elaborations only, and use these to infer what cannot be remembered. In other words, "elaborations increase the redundancy with which information is encoded in memory" (Anderson, 1980, p. 194).

Experimental evidence supports this mechanism. In a study providing various types of background knowledge to students before reading about a fictitious tribe, Brown, Smiley, Day, Townsend, and Lawton (1977) found evidence of elaboration and its effects. After reading about the fictitious tribe, subjects in the experimental groups recalled more information about the passage and provided more elaborations than did a control group. Elaborations were consistent with the background information they had received. In other words, these subjects used their new background to embellish the story they later read, and these embellishments facilitated their memory of the story. (For a review of other studies supporting this notion, see Reder, 1980).

The second way in which elaborations may affect comprehension, by affecting the perceived relevance or nonarbitrary nature of a concept, is described in the following way. In an experiment by Stein, Morris, and Bransford (1978), subjects were given one of two target paragraphs. Each paragraph briefly described the praise or criticism received by each of several men with varying characteristics, and a general statement of causality for such evaluations. Other groups of subjects were given one of two additional paragraphs. These paragraphs provided elaborative information about each of the men. One paragraph contained conceptually related elaborations, while the other had seemingly arbitrary elaborations. The group who recalled the greatest amount of information was the group who received two paragraphs that contained related information and whose introductory paragraph included conceptually related information. This first paragraph provided information which made the concepts in the subsequent paragraph relevant and nonarbitrary.

Other elaborations may be in the form of examples. College students who were presented a basic text about seven psychological defense mechanisms with two one-sentence examples for each of these remembered these mechanisms significantly better than those who read only the basic text (Pollchik, 1975 in Bransford, 1979).

Results from basic research in learning and memory have shown that elaborations, whether presented in text or generated by learners, have a facilitative effect on memory and retrieval. A direct transfer from these studies to texts used for the purpose of learning in schools, however, cannot be made since the texts used in these studies and the learning requirements lacked ecological validity.

Considering the low level of scientific knowledge of students and adults, the dependence on science textbooks in schools, and the facilitative power of elaborations in the learning process, it follows that the study of elaborations of textbooks is important. Therefore, the purpose of this analysis is to identify the text-based concepts and to describe how these concepts are elaborated.

Publishers develop content area textbooks for different student audiences, and teachers often select their textbooks based on a perceived match between the intended audience and their students. Therefore, in an effort to generalize the results of this analysis, three science books were selected which were identified by their publishers as intended for three different student populations. Sections from each text which addressed the same topics were used in this analysis.

Method

Three high school biology books were selected which were designed by their publishers for different student populations. Textbook

I is intended for non-college bound students with average ability but below grade level success. Textbook II is intended for students with average ability and low achievement who are identified as special education students. Textbook III is written for high school students at all levels. (See Table 1).

Analysis

Two procedures were developed to analyze the text in a way that would accomplish the purpose of the analysis, and to compare the nature of the concepts in these three textbooks. The first was a concept analysis, the second was an identification of elaborations.

Concepts. The term "concept" is used in many ways in educational and psychological literature. Some definitions focus on common attributes of objects or events which result in their belonging to the same category, and the labelling of that concept with a word (Frayer, Fredrick, & Klausmeier, 1969; Tennyson & Park, 1980). This definition is operationalized in content reading books by focusing on words or phrases as labels for concepts (e.g., Estes & Vaughan, 1985).

Others have discussed concepts as an idea in relationship to others (Anderson, 1980). Operationalizing concepts in this case often requires phrases or sentences which create a context for those ideas by relating them to others. In another content area reading book, concepts are presented as sentences which maintain the integrity of those relationships (Vacca, 1981). An example of such a concept from biology is "The respiratory system of living things is responsible for the exchange of gases" (p. 36). Though one could easily argue that this sentence contains <u>many</u> concepts, the set of relationships represented by this sentence is also a concept. To examine each contributing concept separately would alter the nature of this idea.

These two ways of operationalizing concepts do not seem in conflict. Concepts represented by single words or phrases have implicit relationships, with those words or phrases often representing complex ideas. And, concepts represented by more linguistic information such as a sentence may not have a single word to represent the idea.

In the following analysis, therefore, concepts were represented by single words, phrases, or sentences. The criteria used to determine the representation of concepts was how to best maintain the integrity of the concept, as illustrated in the example above about the respiratory system. Sometimes authors use analogies as similar sets of information to help convey ideas (Tierney & Cunningham, 1984). In this analysis, an analogy was treated as a concept, thereby maintaining its integrity. The analysis was carried out on the running text only.

Concept Analysis. Before it was possible to determine the extent to which ideas were elaborated, the concepts needed to be identified. To accomplish this task, a concept analysis was constructed for each text through the following steps.

First, a text was read for its gist and overall organization of ideas. During this reading, certain statements in the text seemed different than others in that they encompassed many ideas. Therefore, as the second step, these presentations of very broad and interrelated ideas were identified and labeled as principles (Gagne, 1965). Since the individual ideas contained in these principles were often more fully described within the remainder of the text, they were not included at this time in the concept of analysis. The purpose of these principles seemed to be similar to that of an advance organizer (Ausubel, 1968) - to provide a context and overview at a high level of conceptual organization.

The third step was to re-read the text to identify and organize major categories of ideas. These categories represented the most general level of ideas, and thus were the concepts that were to subsume the remaining ideas. The labels for these categories were taken from the text when they were explicitly stated. When there was not an explicit label, one was inferred. The following example from the Prentice-Hall text demonstrates both explicit and implicit categories. "For photosynthesis to take place, a plant must have three things: raw materials, an energy source, and a catalyst" (p. 262). "Requirements" became an inferred label for a general category, while "raw materials", "energy source", and "catalyst" became explicit labels for the concepts immediately subsumed by requirements." (See Figure 2).

The physical arrangement of these concepts was a combination structured overview (hierarchy) and flow chart. Descriptive information fit well into a hierarchy, but the process-related ideas were not hierarchical. Rather, their relationships could be described as chains of cause-effect relationships, and were connected with arrows.

Next, the remaining ideas were added to the developing concept analysis. When some of these ideas did not fit into the existing categories, categories were either revised or new ones identified.

Sometimes information was presented in the text which was related tangentially rather than directly to the process of photosynthesis. For example, the Prentice-Hall text presented an elaborate explanation of carbohydrates. Though carbohydrate is a class of products of photosynthesis, an explanation of the nature of this product is not directly related to the process being presented. Therefore, this type of information was identified as ancillary to the main concept and not included in the main body of the concept analysis.

Identification of Elaborations. The three uppermost levels of concepts were the points of reference in the description of concept elaboration. Since these are the most general ideas in the text, they are likely to be the most important in understanding photosynthesis. Thus, the research question of How are concepts in this text elaborated became How are the major concepts elaborated? The following methodology was developed to address this issue.

First, the three uppermost levels of ideas from each of the three concept analyses were integrated into one chart (see Table 2). This would permit a description of concepts and concept elaboration within a text, and a comparison of these two factors across texts. Four major concepts were identified across the three texts. They were 1) the requirements, 2) the process, 3) the products, and 4) the by-products of photosynthesis. The coordinate and subordinate concepts related to each are noted in Table 1.

Next, these most general levels were evaluated for the following variables for each text: 1) presence or absence of the word representing that concept, 2) number of ideas presented which provided supporting information for each concept (the number of elaborations), 3) number of ideas related to these concepts but identified as ancillary to the general idea of photosynthesis, and 4) indication of the presence of an analogy used to explain an idea. The analogy was counted as one elaboration.

To address variable number 2 above, the number of elaborations, ideas which were subsumed by each concept depicted in Figures 1-3 were identified. Next, they were placed on separate figures which indicated their relationships to these uppermost ideas.

It should be noted that the number of elaborations indicated at each level of concept in Table 2 is not cumulative, but represents the number of related ideas at that level only. For example, Textbook II had two elaborations about pigments in general, plus two addressing their location and nine addressing chlorophyll.

Results

Concept Analysis. Figures 1-3 illustrate how the three uppermost levels of ideas about photosynthesis are represented by each text. Some concepts, though present in different texts, are organized differently across texts. (This condition should be neither surprising nor problematic). For example, though all texts discuss the requirements of photosynthesis, each has its own way of organizing the subordinate concepts it subsumes.

From these figures, it is obvious that Textbook I, which was designed for the lowest level of student, also presents the least amount of information. Textbooks II and III present a similar number of ideas. The main differences between these two books are their different organizational plans and the choice of ideas to elaborate more fully.

Elaborations. Table 2 shows the quantity of elaborations of concepts for the three uppermost levels of ideas. These elaborations reflect not only the information depicted in Figures 1-3, but also the information in the text related to each of these levels of ideas.

What becomes more obvious from this table is the lack of any depth of coverage of any of the ideas in Text I. What is also obvious are the topics that have been omitted.

Both Texts II and III elaborate many of their concepts, but to different degrees. For example, Text III has developed the concept of chlorophyll through 19 related ideas, while Text II has used 9. However, in their discussion of raw materials required for photosynthesis, Text II presents more related information about carbon dioxide, water, and minerals than does

Text III. Other differences can also be seen in this table.

Other Variables in Texts. Aside from providing a vehicle for identifying concepts, their relationships, and their elaborations, the concept analyses also permit a detailed look at other variables within these texts.

One of these variables is that of incorrect information. In the three textbooks examined, only Textbook II was found to contain misinformation. First, it misidentifies minerals as one class of the raw materials necessary for photosynthesis. Though minerals can impact the proces of photosynthesis, they are not raw materials (Rost, Barbour, Thornton, Weier, & Stocking, 1984). Another error is in its examples of catalysts. It misidentifies chlorophyll as a catalyst in photosynthesis, and heat as a catalyst in an analogy for photosynthesis.

Another interesting variable to consider is nature of the information contained in the elaborations. For example, elaborations about carbon dioxide in Text I were about its source and how it entered the leaf. Text III also gave its source, but then told what it was used to produce in the leaf. Both of these texts contained two ideas (elaborations) in their discussion of carbon dioxide. In contrast, Text II included seven ideas about carbon dioxide. However, three of these ideas were details about the amount of carbon dioxide in the air, describing its percentage and weight. One might question how important these details are to understanding the role of carbon dioxide in photosynthesis. This text failed to explain how this gas entered the plant.

Conclusions and Implications

As students are expected to learn information from text, it is important to ascertain the nature of that text with special consideration for how it facilitates learning. Analyzing the nature of the concepts for the number and quality of their elaborations provides one means of describing such text. Text which is written with a greater number of elaborations that are relevant to its main purpose provides a rich source of information to be learned. From a cognitive perspective, these elaborations provide more complex connections of ideas which can facilitate learning and retrieval.

Some have suggested that only ideas at the "highest" levels of such an analysis should be taught because these ideas/words are the important ones (Anders & Bos, 1984). However, the issue addressed by a concept analysis is not a question of important idea versus detail, but rather <u>how</u> the details provide meaningful elaborations of higher level concepts. Without these elaborations, texts seem to list ideas instead of promoting the relationships which facilitate concept development (Blystone, 1987; Elliott, Nagel, & Woodward, 1986).

Unelaborated ideas become problematic in the learning process because they increase the content density of a text. The content density of a passage is determined by the number of "self-contained or unelaborated propositions" (Amiran & Jones, 1982, p. 23). Ideas which are not elaborated must, to increase the probability of memory and retrieval, require the reader to interrelate these ideas (Amiran & Jones, 1982), or to relate them to prior knowledge on his own.

It is interesting to note that of the three texts analyzed in this study, the one written specifically for the least able reader (Text I) is the text with the least amount of elaborations. It would seem that one characteristic of the less able reader is his reduced likelihood of using various means of processing which may facilitate learning, including spontaneously elaborating ideas from text. Though it is not suggested that these readers be provided with the same text as students who are more advanced in their knowledge of content and their facility with text, perhaps these students should be provided with more elaborate text. In fact, what may be appropriate is text with <u>more</u> elaborations for each idea presented, but perhaps a fewer number of total ideas.

The texts described in this paper represent textbooks from one domain, biology, that are used in secondary classrooms. This analysis provides a description of these texts within the cognitive framework of elaborations. The next research questions emanating from this analysis and from the basic research reviewed at the beginning of this paper must ask about how students comprehend such ecologically valid texts which differ in the way they elaborate concepts, and how these texts affect learning for different types of readers.

REFERENCES

Amiran, M.R., & Jones, B.F. (1982). Toward a new definition of readability. Educational Psychologist, 17(1), 13-30.

Anders, P. L., & Bos, C.S. (1984). In the beginning: Vocabulary instruction in content classrooms. Topics in Learning Disabilities, 3(4), 53-65.

Anderson, J.R. (1980). Cognitive psychology and its implications. San Francisco: W.H. Freeman & Co.

Anderson, C.W., & Smith, E.L. (1986). Teaching science, Research Series No. 168. East Lansing, MI: Institute for Research on Teaching, Michigan State University.

Anderson, T.H., & Armbruster, B.B. (1984). Content area textbooks. In R.C. Anderson, J. Osborn, & R.J. Tierney (Eds.), Learning to read in American schools: Basal readers and content texts. Hillsdale, NJ: Lawrence Erlbaum Assoc.

Ausubel, d.P. (1968). Educational psychology: A cognitive view. New York: Holt, Rinehart, and Winston.

Barber, B.H., & Tomera, A.N. (1985). Is ecology being taught in general biology classrooms:--A survey of Illinois teachers. School Science and Mathematics, 85(4).

Blystone, R.V. (1987). College introductory biology textbooks. The American Biology Teacher, 49(7), 418-425.

Bransford, J.D. (1979). Human cognition: Learning, understanding and remembering. Belmont, CA: Wadsworth Publishing Co.

Brown, A.L., Smiley, S.S., Day, J.D., Townsend, M.A.R., & Lawton, S.C. (1977). Intrusion of a thematic idea in children's comprehension and retention of stories. Child Development, 48, 454-466.

Elliott, D., Nagel, K., & Woodward, A. (1986). Scientific literacy in elementary school science textbook programmes. Journal of Curriculum Studies, 19(1), 73-76.

Estes, T.H., & Vaughan, J.L. (1985). Reading and learning in the content classroom. Boston: Allyn and Bacon.

Frayer, D.A., Fredrick, W.C., & Klausmeier, H.J. (1969). A schema for testing the level of concept mastery. (working paper No. 16.) Madison, WI: Wisconsin Research and Development Center for Cognitive Learning.

Gagne, R.M. (1965). Conditions of learning. New York: Holt, Rinehart, & Winston.

Goodman, H.D., Emmel, T.C., Graham, L.E., Slowiczek, F.M., & Schechter, Y. (1986). Biology. Orlando: Harcourt, Brace, Jovanovich.

Harms, N.C., & Yager, R.E. (1981). What research says to the science teacher. Washington, D.C.: National Science Teachers Association.

Harste, J.C., & Mikulecky, L.J. (1984). The context of literacy in our society. In A.C. Purves & O. Niles (Eds.), Becoming readers in a complex society, 83rd Yearbook of the National Society for the Study of Education. Chicago: University of Chicago Press.

Hueftle, S.J., Rakow, S.J., & Welch, W.W. (1983). Images of science: A summary of results from the 1981-82 National Assessment in Science. Minneapolis: University of Minnesota, Minnesota Research and Evaluation Center.

Koballa, T.R., Jr. (1985). Goals of science education. In D. Holdzkom & P.B. Lutz, (Eds.), Research within reach: Science education, (pp. 25-39). Washington, DC: National Science Teachers Association.

Lloyd, C.V., & Mitchell, J.N. (1989). Coping with too many concepts in science texts. Journal of Reading, 32(6), 542-545.

Meyer, L.A., Crummey, L., & Greer, E.A., (1988). Elementary science textbooks: Their contents, text characteristics, and comprehensibility. Journal of Research in Science Teaching, 25(6), 435-463.

Miller, J.D. (1989). Scientific literacy. Paper presented to the 1989 Annual Meeting of the American Association of the Advancement of Science, San Francisco, CA.

Mitman, A.L., Mergendoller, J.R., Marchman, V.A., & Packer, M.J. (1987). Instruction addressing the components of scientific literacy and its relation to student outcomes. American Educational Research Journal, 24(4), 611-633.

National Assessment of Educational Progress (1978). Three national assessments of science: Changes in achievement, 1967-77 (Report #08-S-00). Denver: Education Commission of the States.

National Science Foundation & Department of Education (1980). Science and engineering for the 1980's and beyond. Washington, DC: U.S. Government Printing Office.

Reder, L.M. (1980). The role of elaboration in the comprehension and retention of prose: A critical review. Review of Educational Research, 50, 5-53.

Rost, T.L., Barbour, M.G., Thornton, R.M., Weier, T.E., Stocking, C.R. (1984). Botany: A brief introduction to plant biology (2nd Edition). New York: John Wiley & Sons.

Spiro, R.J., & Taylor, B.M. (1987). On investigating children's transition from narrative to expository discourse: The multidimensional nature of psychological text classification. In R.J. Tierney, P.L. Anders, & J.N., Mitchell (Eds.), Understanding readers' understanding: Theory and practice, (pp. 77-93). Hillsdale, NJ: Lawrence Erlbaum Associates.

Stake, R.E., & Easley, J.A. (1978). Case studies in science education. Urbana: Center for Instructional Research and Curriculum Evaluation, University of Illinois.

Stein, B.S., Morris, C.D., & Bransford, J.D. (1978). Constraints on effective elaboration. Journal of Verbal Learning and Verbal Behavior, 17, 707-714.

Tennyson, R.D., & Park, O.C. (1980). The teaching of concepts: A review of instructional design research literature. Review of Educational Research, 50, 55-70.

Tierney, R.J., & Cunningham, J.W. (1984). Research on teaching reading comprehension. In P.D. Pearson (Ed.), Handbook of reading research. New York: Longman.

Vacca, R.T. (1981). Content area reading. Boston: Little, Brown & Co.

Watkins, P.M., Chang-Van Horn, D. & Kron, Jr., H.E. (1987). Biology for living. New York: Globe Book Company.

Wong, H.K., & Dolmatz, M.S. (1983). Biology: The key ideas. Englewood Cliffs: Prentice Hall.

Yager, R.E. (1983). The importance of terminology in teaching K-12 science. Journal of Research in Science Teaching, 20, 577-588.

Table 1

Text Information

Book/Publisher	Stated Readability	Intended Audience
I Biology for Living/Globe	6-7	High school, below grade level and average ability, non-college bound
II Biology: The Key Ideas/ Prentice Hall	7-8	High school, below grade level and average ability, special ed
III Biology/Harcourt, Brace, Jovanovich	None Provided	High school, all levels

Table 2

Quantity of Elaborations of Concepts

CONCEPTS Text:	I	II	III
(Requirements of Photosynthesis)			
Light	+ 1	+ 14	+ 5 (8)
Pigments	-	+ 2	+ 1
location: chloroplasts	+ 1	+ 2	+ 9
chlorophyll	+ 1	+ 9	+ 19
xanthophylls	-	-	+ 5
carotenes	-	-	+ 5
Raw materials	-	+ 1	+ 1
carbon dioxide	+ 2	+ 7	+ 2
water	+ 2	+ 5	+ 2
minerals	-	+ 2	-
Process (of photosysnthesis)	+ 1	+ 2	+ 1
General Equation	4	+ 6a(3)	+ 2
Factors affecting rate	-	-	+ 14
Light reaction	-	+ 10(2a)	+ 20a
Dark reaction	-	+ 10	+ 28 (3)
Product(s) (of photosynthesis)			
Carbohydrates	-	+ 26(6)	-
glucose	-	+ (above)	+ 5 (4)
sugar	+ 3	+ (above)	+ (above)
By-Product(s) (of photosynthesis)	-	+ 1 (2a)	+ 1
oxygen	+ 1	+ 6 (7)	+ 4
water	-	-	+ 1

Key:

+ indicates that the term listed on the table occurred in the text. The number indicates how many ideas (elaborations) were subordinate to that concept.
- indicates that the term was not used in that text.
(#) indicates number of ideas presented that were considered ancillary to photosynthesis.
a indicates that an analogy was used (counted as 1 elaboration)

Figure 1
General Hierarchy: Textbook I

Photosynthesis

- Definition
- Requirements
  - light
  - water
  - carbon dioxide
  - chlorophyll
- Process
- Products
  - sugar
  - oxygen

Figure 2
General Hierarchy: Textbook II

Photosynthesis

- **Definition**
- **Requirements**
  - Raw Materials
    - carbon dioxide
    - water
    - minerals
  - Energy Source
    - solar energy
  - Catalyst
    - definition
    - analogy
    - chlorophyll
- **Location**
  - in chloroplasts
- **Process**
  - analogy
  - summary
  - 2 steps:
  - light reaction
  - dark reaction
- **Products**
  - carbohydrates
- **By-Product**
  - oxygen

Figure 3
General Hierarchy: Textbook III

Photosynthesis

- <u>Definition</u>
- <u>Requirements</u>
  - <u>Light</u>
  - Plant <u>Pigments</u>
    - definition/ function
    - classes
      - chlorophyll
      - xanthophylls
      - carotenes
    - location
      - chloroplasts
  - Raw <u>Materials</u>
    - carbon dioxide
    - water
  - <u>Enzymes</u>
- <u>Process</u>
  - summary
  - factors affecting rate
  - 2 phases:
    - light reaction
    - dark reaction
- <u>Product</u>
  - glucose
- <u>By-Products</u>
  - oxygen
  - water