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ABSTRACT

Advances in cognitive science have greatly increased our knowledge of how the human mind stores and uses information. That knowledge can be used to decompose curricular objectives so as to increase the specificity of instruction to a level of precision that should greatly enhance student writing. This article identifies some major types of cognitive structure and describes how they might be used in the process of decomposing curricular objectives. The two primary types of linguistic information are declarative (factual) and procedural. Declarative information can be subdivided into four basic types: concepts, facts, principles, and schemata. Procedural information includes process knowledge and conditional knowledge (or knowledge about when to use specific procedures). Both types of information are commonly stored in long-term memory in cognitive structures called "productions," which sometimes have associated terminology and symbols. This model for specifying the cognitive components of a given curricular objective is then applied to the objective of teaching students to read and interpret a bar graph. In laboratory tests, this process of decomposing curricular objectives has shown great promise for helping teachers to specify and plan instruction, and thereby to enhance student learning. (TE)

DECOMPOSING CURRICULAR OBJECTIVES TO INCREASE SPECIFICITY OF INSTRUCTION

by

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Since Mager (1975) popularized the notion of behavioral objectives, there has been a growing awareness of the need to increase the specificity of instructional goals so as to increase learning. This trend can be supported from many perspectives. Proponents of criterion referenced testing note that the more one specifies the information that is to be taught, the higher the probability that the information will be learned. For example, Popham (1978) asserts that increased specificity in educational objectives produces increased specificity in instruction which produces better learning. Specificity of instructional goals can also be defended from a pure information processing point of view. For example, Anderson (1983) notes that the more specific a goal, the less decision paths must be considered in its execution. That is, goal directed behavior is simply more efficient cognitively than behavior that is not goal directed because it involves less random stimuli to consider.

Although past attempts to identify criteria for writing curricular objectives have certainly aided in increasing the specificity of instruction, it is my contention that objectives can be made even more specific by decomposing them--breaking them apart--to disclose the various types of information therein contained. To understand the various types of information which might be contained in an objective, we must operate from a linguistically based model of information and how it is stored and used by the human mind. That is, since objectives are written in language form, one must understand the relationship between language and thought to identify the underlying types of cognitions embedded within objectives. Schank and Abelson (1977) note that historically within cognitive psychology the subjects of natural language processing, information storage and information utilization were considered separately. However, recently Quillian (1968), Anderson and Bower (1973), Rieger (1975), Norman and Rumelhart (1975) and many others have made it quite clear that language and most other cognitive processes are inextricably bound.

Trying to identify cognitive operations by analyzing language can be a difficult task, however, because language sometimes "hides" cognitions. That is Schank and Abelson (1977) have noted that language commonly includes implicit meanings and operations in the words used within an utterance. For example, embedded in the utterance " The pitcher threw the ball" is implicit information about:

a. a baseball game

b. the number and type of players on both sides

c. the presence of fans

d. and so on ...

So too can a curricular objective include implicit information not immediately apparent. For example, the curricular objective "Students will be able to summarize information contained in a 2-3 page passage from a social studies textbook," implies that students know:

a. the process of summarization

b. the major concepts and principles contained in the sample passage.

To make the information in curricular objectives more explicit, one must identify the different types of information and mental processes implied by the language used to phrase the objective. What, then, are the various types of information and mental processes that can be decomposed from a curricular objective by analyzing it linguistically?

TYPES OF INFORMATION

Most linguistically based models of information storage and utilization posit the existence of two primary types of information: 1) declarative and 2) procedural (Anderson, 1983; Sylwester, 1985). Declarative information is factual and somewhat "static" in nature. One might say that it contains who, what, where, when and why information. For example, in the sample curricular objective above, the concepts and principles contained in the sample social studies passage would be declarative in nature.

Procedural information is more dynamic in nature; it is information about how to perform specific cognitive operations. For example, in the sample curricular objective, the act of summarizing would involve procedural information.

These two basic types of information, declarative and procedural, can be further subdivided into more basic components which can be of use when decomposing curricular objectives.

Declarative Information

Declarative information can be subdivided into four basic types: 1) concepts, 2) facts, 3) principles and 4) schemata. Concepts are cognitive structures that are usually represented by a single word within a society. Klausmeier (1985) notes, that a concept consists of a person's organized information about one or more entities--objects, events or ideas -- that enable the individual to discriminate the particular entity or class of entities and also to relate it to other entities and classes of entities. For example, such labels as people, sports, and punctuation represent concepts. Common types of concepts include animate entities (e.g. dog) places (e.g. London) things (e.g. a hammer) and events (e.g. a carnival). Facts are statements of relationships between or among concepts. Linguistically facts are commonly communicated as proposition--"conceptual structures that are the minimal bearers of truth." (van Dijk, 1980, p. 207). It follows that people and sports are concepts but are not information that can be examined for truth or falsity. However, "People like sports," is a proposition because we can ask whether it is true or false. Facts, then, are propositions important to a given content area. For example, "that President John F. Kennedy set a goal in the early 1960's to have a manned flight to the moon by the end of the decade," might be considers an important fact within a social studies class.

Like facts, principles, are stated in propositional form. However, principles assert information which can be exemplified whereas facts do not. For example, "My car is blue" is a fact but it is not a principle because examples can not be provided. There can be only one instance of the proposition "My car is blue". Principles are very important in an educational sense because they help to organize information within a discipline. Katz (1976) identified four types of principles important to various content areas: 1) cause/effect, 2) correlational, 3) probability and 4) axiomatic. Cause and effect principles articulate relationships that have an underlying "if-then" meaning, as in the proposition "Tuberculosis is caused by the organism myobacterim tuberculosis", or "One effect of morphine is to produce strep" (Katz, p.14). Correlational principles express a relationship in which an increase in one state or event is predictably related to an increase or decrease in another state or event. For example, "The increase in lung cancer among women is proportional to the number of the women who smoke," and "The longer it stays below zero in the winter, the fewer pine beetles we have in the spring," are examples of correlational principles. Probability principles are those which indicate the likelihood of occurrence of a state or event. For example, "The probability of giving birth to a boy during any one pregnancy is .52," and "There is a 60% chance of rain today" are probability principles. Axiomatic principles are the largest class of principles. They represent commonly held fundamentals, laws or rules (states or events held to be true) within a content area. For example, "All people are created equal" is an axiomatic principle within most democratic societies.

Schemata represent the last general category of declarative information. Rumelhart (1975) describes schemata as "packages" of information stored in long term memory. A commonly used example of a schema (the singular of schemata) is that knowledge associated with going to a restaurant. That is, people in our culture have an internalized restaurant schema that includes knowledge or expectations about reading a menu, ordering food, waiting for it to come, eating with an array of utensils and paying the bill. Theorists and researchers in artificial intelligence (Schank and Abelson, 1977) subdivide the broad notion of schemata into a number distinct types whereas psycholinguists commonly do not make fine distinctions as to different categories or types of schemata. For the purpose of decomposing curricular objectives a more detailed perspective is very useful. There are at least four general types of schemata useful for decomposing curricular objectives : 1) time lines, 2) problems and solutions, 3) causal networks, and 4) episodes.

Time lines are one of the simplest types of schema. They include a listing of events that occurred in a given sequence. For example, history classes and period literature classes commonly involve information that can be organized in a time line schemata. Problem/solution schemata include a problem and acceptable solutions. For example, in an class on auto-mechanics a teacher might stress information which includes a common problem (e.g. an engine won't start) and possible solutions (e.g. no gas is getting to the carburetor, no charge is getting to the distributor, and so on). Casual networks are a third type of schema. According to Schank and Abelson (1977) they are comprised of chains of casually related states and events. For example, one could organize information about the causes of World War II as a casual network schema. Episodes are a fourth type of schema. They might be likened to what Stein and Glenn (1978) refer to as a story grammar. An episode commonly contains characters, a setting, (time, location), an initiating event, a reaction and a conclusion. For example, one might store the fact that Watergate occurred at a particular time and place, involving high ranking officials in the U.S. government, spawned a lengthy inquiry into undercover political operations and concluded with the resignation of the president, as an episode.

Declarative information, then, involves concepts, facts, principles and schemata each of which are important to identify within curricular objectives. So too is the procedural information within curricular objectives.

Procedural Information

Procedural information includes process knowledge and conditional knowledge. Processes commonly involve "steps" which are either ordered or unordered. For example, the process for reading a bar graph would involve a relatively unordered set of steps. One step might be to determine which axis relates to the nominal variable and which axis relates to the interval or ratio variable. Another step might be to determine the magnitude of each of the nominal variables included in the graph. A final step might be to compare the different values of the nominal variable relative to their magnitude. Although there is certainly a general order to the steps in the process it is not a rigid one (i.e. the steps can be performed in a variety of orders). The process for performing long division, on the other hand, has a rather rigid order to the steps involved. One must first determine how many times the divisor goes into the leftmost digits of the dividend which constitute a number larger than the divisor. Next the number of times the divisor goes into those identified numbers must be entered above the rightmost digit of that number and so on. A process that has a very rigid set of steps is commonly referred to as an algorithm. A process which has loosely ordered steps or no order at all is sometimes referred to as a set of heuristics.

Processes can be very short or quite long consisting of many sub-processes. A useful metaphor is that process knowledge is like a computer program (Lewis and Greene, 1982). Some programs are very simple and contain only a few steps. Others are quite complex and contain sub-routines nested within sub-routines. So too can processes be relatively simple containing a few steps, or quite complex, contain sub-processes within sub-processes.

Along with knowledge of process, procedural knowledge also includes knowing when the process should be used or "conditional knowledge." For example, along with knowledge of the process for performing long division, one should have an understanding of the situations in which it is useful (e.g. in certain types of problems and not in others.) Along with the process knowledge of how to summarize, one should also know when summarizing is important and when it is not.

Procedural knowledge, then, is comprised of both process knowledge and conditional knowledge or knowledge about when to use specific processes.

The Interaction of Declarative and Procedural Knowledge

Although declarative and procedural knowledge have been discussed separately above because it is useful to identify both types within curricular objectives, they are not separated in long term memory. In fact, procedural knowledge is highly dependent on declarative knowledge. Theorists in artificial intelligence (Anderson, 1983; Newell and Simon, 1972) represent the interaction of declarative and procedural knowledge as "productions"--if/then structures in the mind. For example, consider the following example.

IF: 1. it is snowing,

2. the time is before 9:00 a.m. on a work day,

3. the snow accumulation is six inches or more, and,

4. the car is in the garage.

THEN: I shovel the driveway.

The process in this production is that of shoveling the driveway. The conditional knowledge is represented in statements 1, 2, 3 and 4. Together these make up the procedural information. Yet, contained within that procedural information is such declarative information as the schema for "snowing," the schema for a "work day," the concept of "six inches" and so on. Hence, this production contains both declarative and procedural information integrated in a unified whole called a production.

Labels for Declarative and Procedural Information

The final consideration one must make when decomposing a curriculum objective is the label or labels used to represent the declarative and procedures information. In general, this involves the correct "language" within a content area for the declarative and procedural knowledge contained within a curricular objective. For example, if an objective requires that students know particular content area concepts, is it also important that they know the correct labels or names for those concepts. If a curricular objective involves a specific process, is it important that students know the label or name for that process? Those who take a linguistic perspective of human knowledge would argue that use of correct labels should always be considered import. nt. For example, Condon (1968) notes that when we know the name for a piece of information we are better able to identify the distinctions which are important to that information.

Another type of label that is important to declarative and procedural information is the symbolic representation for the information. The field of semiotics (Eco, 1976) has highlighted the importance of symbols in the understanding of both declarative and procedural information. By symbol is meant any graphic or pictographic representation for information. For example, information commonly associated with the concept <u>first aid</u> is frequently associated with the symbol +; the process of long division is commonly associated with the symbol ÷. Actually symbols commonly represent productions which, as we have seen, are combinations of declarative and procedural. The symbol + includes both declarative and procedural information (e.g. principles about health care, procedures for treating specific types of wounds); so too does the symbol ÷ (e.g., the principle of commutativity, the procedure for carrying).

In summary, information which can be found in curricular objectives can be subdivided into declarative and procedural knowledge. Declarative knowledge is factual in nature and includes concepts, facts, principle and schemata. Procedural knowledge includes process knowledge and the conditions under which processes should be used. Both types of information are commonly stored in long term memory in cognitive structure called productions which sometimes have associated terminology and symbols. This breakdown or description of different types of knowledge can be used to decompose curricular objectives to increase the specificity of instruction.

DECOMPOSING A CURRICULAR OBJECTIVE

The model described above can be used to decompose curricular objectives so as to specify the important cognitive components of the objective. That is, the following types of information can be extracted from curricular objectives to help specify their intent:

1) the important declarative information necessary to complete the objective
2) the cognitive processes necessary to complete the objective
3) the conditions under which the cognitive processes should be used
4) the important terms and symbol(s) associated with the objective

To illustrate consider the following curricular objective:

Students will be able to read and interpret a bar graph.

To identify the different types of declarative and procedural information described above, it is useful to ask the following seven "decomposition" questions relative to the objective:

1. What are the important concepts necessary to complete the objective?
2. What are the important facts necessary to complete the objective?
3. What are the important principles necessary to complete the objective?
4. What are the important schemata necessary to complete the objective?
5. What are the important processes necessary to complete the objective and what are the steps or heuristics in those processes?
6. What are the important conditions under which the processes should be used?
7. What are the important terms or symbols associated with the curricular objective?

I should note that asking and answering these seven questions is meant only as a tool to aid instruction. One need only go into as much depth as is necessary to make explicit the important information in the object which should be the subject of instruction. That is, one does not have to identify all concepts, principles, etc. within the objective, only those that might be unknown to students and will, consequently, require attention on the part of the teacher. For example, to complete the objective above students would certainly need to know the principle that "Height on the vertical axis represents quantity on the continuous variable." However, in many grades the teacher could assume that students know this principle although they might not be able to articulate it in the manner above. Consequently, the principle would not be identified in question #3 as a possible candidate for instruction. As stated above, the decomposition questions are meant to help teachers identify the important cognitive components for which instruction might be provided; they are not meant to provide a comprehensive analysis of all cognitive components necessary for the completion of an objective. Consequently teachers might answer the decomposition questions differently for their respective groups of students. Variations in answers among teachers should, then, reflect the differences in the knowledge bases of their students.

For a given grade level and content area a teacher might generate the following answers to the decomposition questions for the sample objective:

1. The following concepts are necessary:
   - horizontal and vertical axes.
   - nominal variables
   - continuous variables
2. No facts are necessary
3. No principles are necessary
4. No schemata are necessary

5. A specific process is necessary
6. No important conditions are necessary for using the process
7. The following terms are important: nominal variable, continuous variable.

Once the general cognitive components of a curricular objective are identified, then the details of those components should also be identified. To do this a teacher would have to answer such questions as:

- What are the specific aspects of horizontal and vertical axis that my students should know?
- What are the specific aspects of continuous variables that are important?
- What are the specific aspects of nominal variables that are important?
- What are the steps in a process that can be used to read a bar graph?
- Should the steps be ordered or presented as heuristics?

Of course, these questions will also be answered differently by teachers at different grade levels with different student groups.

Regardless of these differences, the process of articulating the cognitive components of a curricular objective can be used to increase specificity of instruction. Armed with such knowledge a teacher can tailor instruction to the demands of the objective and the needs of students. For example, based on the answers described above, a teacher might spend a great deal of time developing the concepts of horizontal axes, vertical axes and the concepts of nominal variables and continuous variables. The teacher might then present a set of steps in heuristic form for reading a bar graph and model their use. Over time the teacher would provide guided and independent practice in the process allowing students to shape it to their own personal needs and style.

SUMMARY

Advances in cognitive science have greatly increased our knowledge of how the human mind stores and utilizes information. That knowledge can be used to decompose curricular objectives so as to increase the specificity of instruction to a level of precision which should greatly enhance student learning. In this article I have attempted to identify some major types of cognitive structures and describe how they might be used in the process of decomposing curricular objectives. The process of decomposing curricular objectives is now being field tested at the Mid-continent Regional Educational Laboratory with teachers at all levels (K-12). Although summative findings are not complete, formative results indicate that: 1) teachers can quite easily decompose the curricular objectives pertinent to their content area and/or grade level, and 2) the process is of great benefit to specifying and planning instruction and, consequently, to student learning.

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