COGNITIVE PROCESSES

1. Introduction

In 1956, Benjamin Bloom headed a group of educational psychologists who developed classification of levels of intellectual behavior important in learning. This became a taxonomy including three overlapping domains: the cognitive, psychomotor, and affective. **Cognitive learning** is demonstrated by knowledge recall and the intellectual skills: comprehending information, organizing ideas, analyzing and synthesizing data, applying knowledge, choosing among alternatives in problem solving, and evaluating ideas or actions. This domain on the acquisition and use of knowledge is predominant in the majority of courses. Bloom identified six levels within the cognitive domain, from the simple recall or recognition of facts, as the lowest level, through increasingly more complex and abstract mental levels, to the highest order, which is classified as evaluation. The six progressive stages of cognitive thinking are *knowledge (recall), comprehension, application, analysis, synthesis*, and *evaluation*. Initial work of Bloom was followed up with research that resulted in a list of Action Verbs representing intellectual activity on each respective level of the cognitive domain.

Krothwhol (1964) took the lead to produce a parallel taxonomy explaining the development of attitudes, principles, codes, and human values. **Affective learning** is demonstrated by behaviors indicating attitudes of awareness, interest, attention, concern, and responsibility, ability to listen and respond in interactions with others, and ability to demonstrate those attitudinal characteristics or values which are appropriate to the test situation and the field of study. This domain relates to emotions, attitudes, appreciations, and values, such as enjoying, conserving, respecting, and supporting. Five progressive stages constitute personal growth in the affective domain: receiving, responding, valuing, organization and characterization. Verbs applicable to the affective domain include accepts, attempts, challenges, defends, disputes, joins, judges, praises, questions, shares, supports, and volunteers.

Kibler et. al. (1970) completed the trilogy of taxonomies with the physical dimensions of behavior as it develops from gross to fine movements and nonverbal to verbal activities. **Psychomotor learning** is demonstrated by physical skills; coordination, dexterity, manipulation, grace, strength, speed; actions which demonstrate the fine motor skills such as use of precision instruments or tools, or actions which evidence gross motor skills such as the use of the body in dance or athletic performance. The categories here include: gross body movements, finely coordinated movements, nonverbal communication sets, and speech-related behaviors. Verbs applicable to the psychomotor domain include bend, grasp, handle, operate, reach, relax, shorten, stretch, write, differentiate (by touch), express (facially), perform (skillfully).

Together, these taxonomies for cognitive learning, social interaction, and physical development are the recognized building blocks for writing lesson plans, creating measurable learning objectives, and evaluating results.

Bloom's taxonomy has been revisited several times by educational psychologists and several variants of the original taxonomy were proposed. L.W. Anderson, D.R. Krathwohl and others presented a revision of Bloom's taxonomy of educational objectives in 2001 to reestablish the

relevance of the ideas in *Handbook* and to incorporate new knowledge and thought that has been produced since 1956. The revised framework is intended to broaden the typical set of educational objectives that promote 'retention' and 'transfer'. This framework consists of six cognitive processes (one that emphasizes retention and five that although they may facilitate retention, emphasize transfer). This note presents the taxonomy of cognitive processes as per this revised framework.

2. Cognitive Processes

2.1 Introduction

Cognitive processes are attention, perception, comprehension, calculation, judgment, storing in memory, reasoning, retrieval from memory, learning, planning, problem solving, self monitoring, and formation of speech. Cognitive learning is demonstrated by knowledge recall and the intellectual skills: comprehending information, organizing ideas, analyzing and synthesizing data, applying knowledge, choosing among alternatives in problem-solving and evaluating ideas or actions. This domain on the acquisition and use of knowledge is predominant in the majority of courses. As per the revised Bloom's taxonomy the taxonomy of cognitive processes involved in learning are *Remembering, Understanding, Applying, Analyzing, Evaluating* and *Creating*. There are several sub-processes associated with each one of these cognitive processes. These processes and sub-processes are presented in the following.

2.2 Remember

When the objective of instruction is to promote retention of the presented material in much the same form as it was taught, the relevant process category is *Remember*. Remembering involves retrieving relevant knowledge from long term memory. The two associative cognitive processes are *recognizing* and *recalling*.

To assess student learning in the simplest process category, the student is given a recognition or recall-task under conditions very similar to those in which he or she learned the material. Little, if any, extension beyond those conditions is expected. If, for example, a student has learned the symbols for different logical functions, then the test of remembering could involve requesting the student to match the logical functions given in one list with symbols given in a second list. The test for recall could involve asking the student to give the symbols for specified logical functions.

Remembering knowledge is essential for meaningful learning and problem solving as the knowledge is used in more complex tasks. When teachers focus on meaningful learning, however, remembering knowledge is integrated within the larger task of constructing new knowledge or solving new problems.

Recognizing involves retrieving relevant knowledge from long-term memory in order to compare it with presented information. In recognizing, the student searches long-term memory for a piece of information that is identical or extremely similar to the presented information. Three main methods of presenting a recognition task for the purpose of assessment are verification, matching, and forced choice.

Recalling (retrieving) involves retrieving relevant knowledge from long-term memory when given a prompt to do so. The prompt is often a question. In recalling, a student searches a long-term memory for a piece off information and brings that piece of information to working memory where it can be processed. Assessment tasks for recalling can vary in the number of cues that students are provided. With low cueing, the student is not given any hints or related information. With heavy cueing, the student is given several hints. Assessment tasks for recalling can also vary in amount of embedding, or the extent to which the items are placed within a larger meaningful context. With low embedding, the recall task is presented as a single, isolated event. With heavy embedding, the recall task is included within the context of a larger problem.

2.3 Understand

Students are said to **Understand** when they are able to construct meaning from instructional messages, including oral, written, graphic communications, however, they are presented to students: during lectures, in books or on computer monitors. Examples of instructional messages also include laboratory demonstrations, observations during field trips and role playing sessions, results of computer simulations, as well as numerous verbal, pictorial, and symbolic representations on paper. Students understand when they build connections between the new knowledge to be gained and their prior knowledge. More specifically, the incoming knowledge is integrated with existing schemas and cognitive framework. Since concepts are building blocks for these schemas and frameworks, conceptual knowledge provides a basis of understanding. Cognitive processes in this category of *Understanding* include *interpreting, exemplifying, classifying, summarizing , inferring, comparing,* and *explaining*.

Interpreting occurs when a student is able to convert information from one representational form to another. Interpreting may involve converting words to words (paraphrasing), pictures to words, words to pictures, numbers to words, words to numbers, and the like. Alternative terms for interpreting are *translating, paraphrasing, representing* and *clarifying*.

Exemplifying occurs when a student gives a specific example or instance of a general concept or principle. Exemplifying involves identifying the defining features of the general concept or principle and using these features to select or construct a specific instance. Alternative terms are *illustrating* and *instantiating*.

Classifying occurs when a student recognizes that something belongs to a certain category (concept or principle). Classifying involves detecting relevant features or patterns that fit both the specific instance and concept or principle. Classifying is complementary process to exemplifying. Alternative terms for classifying are *categorizing* and *subsuming*.

Summarizing occurs when a student suggests a single statement that represents presented information or abstracts a general theme. Summarizing involves constructing a representation of information, such as the meaning of a scene in a play, and abstracting a summary from it, such as determining a theme or main points. Alternate terms are *generalizing* and *abstracting*.

Inferring involves finding a pattern within a series of examples or instances. Inferring occurs when a student is able to abstract a concept or principle that accounts for a set of examples or instances by encoding the relevant features or each instance and, most important, by noting

relationships among them. A student is able to distinguish a pattern in the series of numbers 1, 2, 3, 5, 8, 13, 21, . . The process of inferring involves making comparisons among instances within the context of the entire set. A related process is using the pattern to create a new instance (e.g., the next number on the series is 34, the sum of 21 and 13). This is an example of *executing*, which is a cognitive process associated with *Apply*. *Inferring* and *executing* are often used to together on cognitive tasks.

Comparing involves detecting similarities and differences between two or more objects, events, ideas, problems, or situation, such as determining how a well known event (e.g., recent separate Teleganana state issue) is like or unlike a less familiar event (e.g., creation of States on linguistic basis). Comparing includes finding one-to-one correspondences between elements and patterns in one object, event, or idea and those in another object, event or idea. When used in conjunction with *inferring* (e.g., first, abstracting a rule form the more familiar situation) and *implementing* (e.g., second, applying the rule to the less familiar situation), *comparing* can contribute to reasoning by analogy. Alternative terms are *contrasting*, *matching*, and *mapping*.

Explaining occurs when a student is able to construct and use a cause-and-effect model of a system. The model may be derived from formal theory (as is often the case in the natural sciences) or may be grounded in research or experience (as is often the case in social sciences and humanities). A complete explanation involves constructing a cause-and-effect model, including each major part in a system or each major event in the chain, and using the model to determine how a change in one part of the system or one "link" in chain affects a change in another part. An alternate term of explaining is *constructing a model*.

2.4 Apply

Apply involves using procedures to perform exercises or solve problems. Thus, apply is closely linked with *Procedural Knowledge.* An exercise is a task for which the student already knows the proper procedure to use, so the student has developed a fairly routinized approach to it. A problem is a task for which the student initially does not know what procedure to use, so the student must locate a procedure to solve the problem. The apply category consists of two cognitive processes: *executing* – when the task is an exercise (familiar) – and *implementing* – when the task is a problem (unfamiliar). In contrast to *executing*, *implementing* requires some degree of *understanding* of the problem as well as of the solution procedure. In case of *implementing*, to understand *conceptual knowledge* is a prerequisite to being able to apply *procedural knowledge*.

In **executing**, a student routinely carries out a procedure when confronted with a familiar task (exercise). The familiarity of the situation often provides sufficient clues to guide the choice of the appropriate procedure to use. Executing is more frequently associated with the use of *skills* and *algorithms* than with the *techniques* and *methods*. Skills and algorithms have two qualities that make them particularly amenable to executing. First, they consist of a sequence of steps that are generally followed in a *fixed order*. Second when the steps are performed correctly, the end result is predetermined answer. An alternative term for *executing* is *carrying out*.

Implementing occurs when a student selects and uses a procedure to perform an unfamiliar task. Because selection is required, student must possess an understanding of the type of problem encountered as well as the range of procedures that are available. Thus, implementing is used in conjunction with other cognitive process categories, such as *Understand* and *Create*.

Because the student is faced with an unfamiliar problem, he or she does not immediately know which of the available procedures to use. Furthermore, no single procedure may be a "perfect fit" for the problem; some modifications to the procedures may be needed. Implementing is more frequently associated with the use of techniques and methods than with skills and algorithms. Techniques and methods have two qualities that make them particularly amenable to implementing. First, the procedure may be more like a "flow chart", than fixed sequence; that is procedure may have "decision points" built into it. Second, there often is no single, fixed answer that is expected when the procedure is applied correctly. The notion of no single, fixed answer is especially applicable to objectives that call for applying *conceptual knowledge* such as theories, models, and structures where no procedures have been developed for the application. An alternative term for *implementing* is *using*.

2.5 Analyze

Analyze involves breaking material into its constituent parts and determining how the parts are related to one another and to an overall structure. This process category includes the cognitive processes of *differentiating* (determining the relevant and important pieces of a message), *organizing* (determining the ways in which the pieces of message are organized), and *attributing* (determining the underlying purpose of the message). Learning to analyze may be as an end itself. Educationally it is considered as an extension of *Understanding* or as a prelude to *Evaluating* and *Creating*. A teacher may wish to develop in his/her students the ability to:

- Distinguish fact from opinion (or reality from fantasy)
- Connect conclusions with supporting statements
- Distinguish relevant from extraneous material
- Determine how ideas are related to one another
- Ascertain the unstated assumptions involved in what is said
- Find evidence in support of the author's purposes

The processes of Understanding, Analyzing and Evaluating are interrelated and often used iteratively in performing cognitive tasks. At the same time, however, it is important to maintain them as separate process categories. A person who understands a communication may not be able to analyze it well. Similarly, someone who is skillful in analyzing a communication may evaluate it poorly.

Differentiating involves distinguishing the parts of a whole structure in terms of their relevance or importance. *Differentiating* occurs when a student discriminates relevant from irrelevant information, important from important from unimportant, and then attends to relevant and important information. *Differentiating* differs from *comparing* in using the larger context to determine what is relevant and important. In comparing all factors are equal irrespective their

relevance and importance. Alternate terms for *differentiating* are *discriminating*, *selecting*, *distinguishing*, and *focusing*.

Organizing involves identifying the elements of a communication or situation and recognizing how they fit together into a coherent structure. In organizing, a student builds systematic and coherent connections among the pieces to presented information. *Organizing* usually occurs in conjunction with *differentiating*. The student first identifies the relevant or important elements and then determines the overall structure within which the elements fit. *Organizing* can also occur in conjunction with *attributing*, in which the focus is on determining the author's intention or point of view. Alternative terms for *organizing* are *structuring*, *integrating*, *finding coherence*, *outlining*, and *parsing*.

Attributing occurs when a student is able to ascertain the point of view, biases, values, or intention underlying communications. *Attributing* involves a process of deconstruction, in which a student determines the intentions of the author of the presented material. In contrast to interpreting, in which the student seeks to *Understand* the meaning of the present material, *attributing* involves extension beyond basic *understanding* to infer the intention or point of view underlying the presented material. An alternative term is *deconstructing*.

2.6 Evaluate

Evaluate is defined as making judgments based on criteria and standards. The criteria most often used are quality, effectiveness, efficiency, and consistency. They may be determined by the student or others. The standards may be quantitative or qualitative. *Evaluating* includes the cognitive processes of *checking* (judgments about internal consistency) and *critiquing* (judgments based on external criteria). However, all judgments are evaluative. Most cognitive processes, in fact, require some form of judgment. What most clearly differentiates Evaluate from other judgments made by students is the use of standards of performance with clearly defined criteria. Is this machine or software working as efficiently as it should be? Is this method the best way to achieve the goal? Is this approach the most cost effective than other approaches?

Checking involves testing for internal inconsistencies or fallacies in operation or a product. For example, *checking* occurs when a student tests whether or not a conclusion follows from its premises, whether data support or disconfirm a hypothesis, or whether presented material contains parts that contradict one another. When combined with *planning* (a cognitive process in the category *Create*) and *implementing* (a cognitive process in the category *Apply*), checking involves determining how well the plan is working. Alternative terms for *checking* are testing, detecting, monitoring, and coordinating.

Critiquing involves judging a product or operation based on externally imposed criteria and standards. *Critiquing* lies at the core of what has been called critical thinking. An example of *critiquing* is judging the merits of a particular solution to the problem of acid rain in terms of likely effectiveness and its associated costs. An alternate term is judging.

2.7 Create

Create involves putting elements together to form a coherent or functional whole. Objectives classified as *Create* have students make a new product by mentally reorganizing some elements or parts into a pattern or structure not clearly present before. Although Create requires creative thinking on the part of the student, this is not completely free creative expression unconstrained by the demands of the learning task or situations. To some persons, creativity is the production of unusual products, often as a result of some special skills. Create, as used here, although includes objectives that call for unique production, also refers to objectives calling for production that all students can and will do. If nothing else, in meeting these objectives, many students will create in the sense of producing their own synthesis of information or materials to form a new whole, as in a circuit, a software unit, a mechanism, a structure, and so on.

Although the process categories of *Understand*, *Apply*, and *Analyze* may involve detecting relationships among presented elements, *Create* is different because it also involves the construction of an original product. Unlike create, the other categories involve working with a given set of elements that are part of a given whole; that is, they are part of larger structure the student is trying to understand. In create, on the other hand, the student must draw upon elements from many sources and put them together into a novel structure or pattern relative to his or her own prior knowledge. Create results in a new product, that is, something that can be observed and that is more than the student's beginning materials. A task that requires Create is likely to require aspects of each of the earlier cognitive process categories to some extent, but not necessarily in a specific order.

The creative process can be broken into three phases: problem representation, in which a student attempts to understand the task and generate possible solutions; solution planning, in which a student examines the possibilities and devices a workable plan; and solution execution, in which a student successfully carries out the plan. Thus the creative process can be thought of as starting the divergent phase in which a variety of possible solutions are considered as the student attempts to understand the task (*generating*). This is followed by a convergent phase, in which the student devises a solution method and turns it into a plan of action (*planning*). Finally, the plan is executed as the student constructs the solution (*producing*). It is not surprising, then that the *Create* is associated with three cognitive processes: *generating*, *planning*, and *producing*.

Generating involves representing the problem and arriving at alternatives or hypotheses that meet certain criteria. Often, the way a problem is initially represented suggests possible solutions; however, redefining or coming up with new representation of the problem may suggest different solutions. When generating transcends the boundaries or constraints or prior knowledge and existing theories, it involves divergent thinking and forma the core of what is called creative thinking.

Generating is used in a restricted sense here. Understand also requires generative processes, which were included in translating, exemplifying, summarizing, inferring, classifying, comparing, and explaining. However, the goal of Understand is most often convergent (that is, to arrive at a single meaning). In contrast, the goal of generating within Create is divergent (that is to arrive at various possibilities). An alternative term for generating is hypothesizing.

Planning involves devising a solution method that meets a problem's criteria, that is, developing a plan for solving the problem. *Planning* stops short of carrying out the steps to create the actual solution for a given problem. In *planning*, a student may establish sub goals, or break a task into subtasks to be performed when solving the problem. An alternative term is *designing*.

Producing involves carrying out a plan for solving a given problem that meets certain specifications. Objectives within the category *Create* may or may not include originality or uniqueness as of the specifications. So it is with producing objectives. *Producing* can require the coordination of the four types of knowledge. An alternative term is *constructing*.

3. Summary

The analysis of cognitive processes presented here has implications for both teaching and assessing. On the teaching side, two of the cognitive processes help to promote *retention* of learning, whereas 17 of them help to foster transfer of learning. Thus, when the goal of instruction is to promote *transfer*, objectives should include the cognitive processes associated with *Understand, Apply, Analyze, Evaluate* and *Create*.

On the assessment side, the analysis of cognitive processes is intended to help broaden their assessment of learning. When the goal of instruction is to promote transfer, assessment tasks should tap cognitive processes that go beyond remembering.

References

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