# Coding Scheme to observe variables in classroom

## 1. Learning Theories(Behaviourism, Cognitivism, Constructivism)

- An emphasis on producing observable and measurable outcomes in students [**behavioural objectives, task analysis, criterion-referenced assessment**]
- Pre-assessment of students to determine where instruction should begin [**learner analysis**]
- Emphasis on mastering early steps before progressing to more complex levels of performance [**sequencing of instructional presentation, mastery learning**]
- Use of reinforcement to impact performance [**tangible rewards, informative feedback**]
- Use of cues, shaping, and practice to ensure a strong stimulus-response association [**simple to complex sequencing of practice, use of prompts**][6]

- An Emphasis on the active involvement of the learner in the learning process [**learner control, metacognitive training (e.g., self-planning, monitoring, and revising techniques)**]
- Use of hierarchical analyses to identify and illustrate prerequisite relationships [**cognitive task analysis procedures]**
- Emphasis on structuring, organizing, and sequencing information to facilitate optimal processing [**use of cognitive strategies such as outlining, summaries, synthesizers, advance organizers, etc.]**
- Creation of learning environments that allow and encourage students to make connections with previously learned material [**recall of prerequisite skills, use of relevant examples, analogies**][6]

- An emphasis on the identification of the context in which the skills will be learned and subsequently applied **[anchoring learning in meaningful contexts].**
- An emphasis on learner control and the capability of the learner to manipulate information **[actively using what is learned].**
- The need for information to be presented in a variety of different ways [**revisiting content at different times, in rearranged contexts, for different purposes, and from different conceptual perspectives**].
- Supporting the use of problem-solving skills that allow learners to go “beyond the information given” [**developing pattern-recognition skills, presenting alternative ways of representing problems**].
- Assessment focused on transfer of knowledge and skills [**presenting new problems and situations that differ from the conditions of the initial instruction**].[6]

- If teacher is giving examples/analogies from day to day life or providing a truthful statement from real life it is both behaviourist and cognitivist approach
- If teacher is telling how to get better marks in exam this is seen as a method to push towards mastery learning and tangible rewards. Hence these situations should strictly classified as behaviourist approach.

- If teacher is giving analogies from a hypothetical situation or similar situation or a new situation not given in the book so that student has to use their imagination/cognitive abilities to apply the concept the teacher is teaching then it indicates dominant cognitivist/constructivist approach which makes it strongly distinct from behaviourism
- Another distinct approach teacher uses in cognitivism is that they provide alternate/negative/wrong answer to a question and ask students to verify the answer. Teaching  by prompting negative answer and then let student come up with correct answer based on intuition/prior knowledge/logic is kind of metacognitive training and hence dominant cognitivist approach.

- In constructivist learning, as mentioned on page 38, students engage in active cognitive processing, such as paying attention to relevant incoming information, mentally organizing incoming information into a coherent representation, and mentally integrating incoming information with existing knowledge (Mayer, 1999). In contrast, a focus on rote learning is consistent with the view of learning as knowledge acquisition, in which students seek to add new information to their memories (Mayer, 1999).

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- Constructivist learning (i.e., meaningful learning) requires that instruction go beyond the simple presentation of factual knowledge and that assessment tasks require more of students than simply recall or recognition of factual knowledge (Bransford, Brown, and Cocking, 1999; Lambert and McCombs, 1998; Marshall, 1996; Steffe and Gale, 1995).

## 2. Knowledge dimension

| MAJOR TYPES AND SUBTYPES | EXAMPLES |
|---|---|
| A. FACTUAL KNOWLDGE- The basic elements students must know to be acquainted with a discipline or solve problems in it | |
| A1. Knowledge of terminology | Technical vocabulary, musical symbols |
| A2. Knowledge of specific details and elements | Major natural resources, reliable sources of information |
| B. CONCEPTUAL KNOWLEDGE-The inter-relationships among the basic elements within a larger structure that enables them to function together | |
| B1. Knowledge of classifications and categories | Periods of geological time, forms of business ownership |
| B2. Knowledge of principles and generalizations | Pythagorean theorem, law of supply and demand |
| B3. Knowledge of theories, models, and structures | Theory of evolution, structure of Congress |
| C. PROCEDURAL KNOWLEDGE- How to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods | |
| C1. Knowledge of subject-specific skills and algorithms | Skills used in painting with watercolors, whole-number division algorithm |
| C2. Knowledge of subject-specific techniques and methods | Interviewing techniques, scientific method |
| C3. Knowledge of criteria for determining when to use appropriate procedures | Criteria used to determine when to apply a procedure involving Newton's second law, criteria used to judge the feasibility of using a particular method to estimate business costs |
| D. METACOGNITIVE KNOWLEDGE- Knowledge of cognition in general as well as awareness and knowledge of one's own cognition | |
| D1. Strategic knowledge | Knowledge of outlining as a means of capturing the structure of a unit of subject matter in a textbook, knowledge of the use of heuristics |
| D2. Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge | Knowledge of the types of tests particular teachers administer, knowledge of the cognitive demands of different tasks |
| D3. Self-knowledge | Knowledge that critiquing essays is a personal strength, whereas writing essays is a personal weakness; awareness of one's own knowled.ge level |

[5]A TAXONOMY FOR LEARNING, TEACHING, AND ASSESSING
LORIN W. ANDERSON AND DAVID R. KRATHWOHL PETER W. AIRASIAN, KATHLEEN A. CRUIKSHANK, RICHARD E. MAYER, PAUL R. PINTRICH, JAMES RATHS, MERLIN C. WITTROCK

- We do not adhere to a simple behaviorist view that knowledge is best represented as an accumulation of associations between stimuli and responses (although some surely is) or merely a quantitative increase in bits of information (a hallmark of the empiricist tradition-see Case, 1998; Keil, 1998).
- Rather, our perspective reflects the idea that knowledge is organized and structured by the leaner in line with a rationalist-constructivist tradition. Reflecting recent cognitive and developmental psychological research (e.g., Case, 1998), however, we also do not adhere to the idea that knowledge is organized in "stages" or in system-wide logical structures as in traditional developmental stage models of thinking (e.g., Piagetian models)
- Our perspective is that knowledge is domain specific and contextualized. Our understanding of knowledge should reflect this domain specificity and the role that social experiences and context play in the construction and development of knowledge (Bereiter and Scardamalia, 1998; Bransford, Brown, and Cocking, 1999; Case, 1998; Keil, 1998; Mandler, 1998; Wellman and Gelman, 1998)
- For classification purposes, Factual knowledge may be distinguished from Conceptual knowledge by virtue of its very specificity; that is, Factual knowledge can be isolated as elements or bits of information that are believed to have some value in and of themselves.
- Sometimes it is difficult to distinguish knowledge of classifications and categories (Ba) from Factual knowledge (A). To complicate matters further, basic classifications and categories can be placed into larger, more comprehensive classifications and categories. In mathematics, for example, whole numbers, integers, and fractions can be placed into the category rational numbers. Each larger category moves us away from the concrete specifics and into the realm of the abstract
- I proposes the nature of the Factual and Conceptual knowledge dimension is dynamic rather then being static. In a year long course curriculum of Indian schools many chapters are linked and as chapters progresses the conceptual knowledge of one chapter becomes factual basis for the second chapter which makes it a Factual knowledge for the second chapter. For example, when a teacher is defining , “What is a mirror?” he/she can use the definition ,” A highly polished surface, such as a mirror, reflects most of the light falling on it.”(10th class NCERT Science Book, p160) now in the later part the chapter when they are teaching about topic “Magnification” they can use Concepts like, “Mirror” and “Spherical mirror” as factual knowledge rather than using them as conceptual knowledge.
- In the taxonomy[5] authors are only defining knowledge as a local dimension hence the definition of various kind of knowledge seems static in nature but in real classroom scenario(Indian education system) teacher uses previous conceptual knowledge as a factual knowledge to build/teach the next conceptual knowledge. This justifies dynamic interaction between Factual and Conceptual knowledge on global scale.
- Whereas Factual knowledge and Conceptual knowledge represent the "what" of knowledge, procedural knowledge concerns the "how." In other words, Procedural knowledge reflects knowledge of different "processes," whereas Factual knowledge and Conceptual knowledge deal with what might be termed "products." It is important to note that Procedural knowledge represents only the knowledge of these procedures;
- Subtype Bc(KNOWLEDGE OF THEORIES, MODELS, AND STRUCTURES) includes knowledge of the different paradigms, epistemologies, theories, and models that different disciplines use to describe, understand, explain, and predict phenomena.
- In contrast to Metacognitive knowledge (which includes knowledge of more general strategies that cut across subject matters or academic disciplines), Procedural knowledge is specific or germane to particular subject matters or academic disciplines. Accordingly, we reserve the term Procedural knowledge for the knowledge of skills, algorithms, techniques, and methods that are subject specific or discipline specific. In mathematics, for example, there are algorithms for performing long division, solving quadratic equations, and establishing the congruence of triangles.
- Although the concern here is with Procedural knowledge, the result of using Procedural knowledge is often Factual knowledge or Conceptual knowledge. For example, the algorithm for the addition of whole numbers that we use to add 2 and 2 is Procedural knowledge; the answer 4 is simply Factual knowledge. Once again, the emphasis here is on the student's knowledge of the procedure rather· than on his or her ability to use it.
- Strategic knowledge is knowledge of the general strategies for learning, thinking, and problem solving. The strategies in this subtype can be used across many different tasks and subject matters, rather than being most useful for one particular type of task in one specific subject area (e.g., solving a quadratic equation or applying Ohm's law)
- This subtype, Da, includes knowledge of the variety of strategies that students might use which can be grouped into three general categories: rehearsal, elaboration, and organizational (Weinstein and Mayer, 1986). Rehearsal strategies involve repeating words or terms to be recalled over and over to oneself; elaboration strategies include the use of various mnemonics for memory tasks as well as techniques such as summarizing, paraphrasing, and selecting the main idea from texts. Organizational strategies include various forms of outlining, drawing "cognitive maps" or concept mapping, and note taking; students transform the material from one form to another.
- students can have knowledge of various metacognitive strategies that are useful in planning, monitoring, and regulating their cognition. Students can eventually use these strategies to plan their cognition (e.g., set subgoals), monitor their cognition (e.g., ask themselves questions as they read a piece of text, check their answer to a math problem), and regulate their cognition (e.g., re-read something they don't understand, go back and "repair'' their calculating mistake in a math problem)
- Da, includes general strategies for problem solving and thinking (Baron, 1994; Nickerson, Perkins, and Smith, 1985; Sternberg, 1985). These strategies represent the various general heuristics students can use to solve problems, particularly ill-defined problems that have no definitive solution method. Examples of heuristics are means-ends analysis and working backward from the desired goal state. In addition to problem-solving strategies, there are general strategies for deductive and inductive thinking, including evaluating the validity of different logical statements, avoiding circularity in arguments, making appropriate inferences from different sources of data, and drawing on appropriate samples to make inferences (i.e., avoiding the availability heuristic-making decisions from convenient instead of representative symbols).
- Da. KNOWLEDGE ABOUT COGNITIVE TASKS, INCLUDING CDNTEXTUAL AND CONDITIONAL KNOWLEDGE-Students also need to develop the conditional knowledge for these general cognitive strategies; in other words, they need to develop some knowledge about the when and why of using these strategies appropriately (Paris, Lipson, and Wixson, 1983). Conditional knowledge refers to knowledge of the situations in which students may use Metacognitive knowledge. In contrast, Procedural knowledge refers to knowledge of the situations in which students may use subject-specific skills, algorithms, techniques, and methods. Certain general learning and thinking strategies are better suited to different tasks. For example, if one confronts a novel problem that is ill defined, then general problem-solving heuristics may be useful. In contrast, if one confronts a physics problem about the second law of thermodynamics, then more specific Procedural knowledge is more useful and adaptive. An important aspect of learning about strategies is the conditional knowledge of when and why to use them appropriately.

- Another important aspect of conditional knowledge is the local situational and general social, conventional, and cultural norms for using different strategies. For example, a teacher may encourage the use of a certain strategy for monitoring reading comprehension. A student who knows that strategy is better able to meet the demands of this teacher 's classroom. In the same manner, different cultures and subcultures may have norms for the use of different strategies and ways of thinking about problems. Again, knowing these norms can help students adapt to the demands of the culture in terms of solving the problem
- Along with knowledge of different strategies and cognitive tasks, Flavell (1979) proposed that self-knowledge was an important component of metacognition. In his model self-knowledge includes knowledge of one's strengths and weaknesses in relation to cognition and learning. For example, students who know they generally do better on multiple-choice tests than on essay tests have some self-knowledge about their test-taking skills.
- A consensus has emerged, however, around general social cognitive models of motivation that propose three sets of motivational beliefs (Pintrich and Schunk, 1996). Because these beliefs are social cognitive in nature, they fit into a taxonomy of knowledge. The first set consists of self-efficacy beliefs, that is, students' judgments of their capability to accomplish a specific task. The second set includes beliefs about the goals or reasons students have for pursuing a specific task (e.g., learning vs. getting a good grade}. The third set contains value and interest beliefs, which represent students' perceptions of their personal interest (liking) for a task as well as their judgments of how important and useful the task is to them
- It is difficult to assess Metacognitive knowledge using simple paper-and pencil measures (Pintrich, Wolter, and Baxter, in press). Consequently, objectives that relate to Metacognitive knowledge may be best assessed in the context of classroom activities and discussions of various strategies

A. FACTUAL KNOWLEDGE

a) KNOWLEDGE OF TERMINOLOGY

Examples of knowledge of terminology

i. Knowledge of the alphabet
ii. Knowledge of scientific terms (e.g., labels for parts of a cell, names for sub-atomic particles)
iii. Knowledge of the vocabulary of painting
iv. Knowledge of important accounting terms
v. Knowledge of the standard representational symbols on maps and charts
vi. Knowledge of the symbols used to indicate the correct pronunciation of words

b) KNOWLEDGE OF SPECIFIC DETAILS AND ELEMENTS

Examples of knowledge of specific details and elements

i. Knowledge of major facts about particular cultures and societies
ii. Knowledge of practical facts important to health, citizenship, and other human needs and concerns
iii. Knowledge of the more significant names, places, and events in the news
iv. Knowledge of the reputation of a given author for presenting and interpreting facts on governmental problems
v. Knowledge of major products and exports of countries
vi. Knowledge of reliable sources of information for wise purchasing

B. CONCEPTUAL KNOWLEDGE

a) KNOWLEDGE OF CLASSIFICATIONS AND CATEGORIES

Examples of knowledge of classifications and categories

i. Knowledge of the variety of types of literature
ii. Knowledge of the various forms of business ownership
iii. Knowledge of the parts of sentences (e.g., nouns, verbs, adjectives)
iv. Knowledge of different kinds of psychological problems
v. Knowledge of the different periods of geologic time

b) KNOWLEDGE OF PRINCIPLES AND GENERALIZATIONS

Examples of knowledge of principles and generalizations

i. Knowledge of major generalizations about particular cultures
ii. Knowledge of the fundamental laws of physics
iii. Knowledge of the principles of chemistry that are relevant to life processes and health
iv. Knowledge of the implications of American foreign trade policies for the international economy and international good will
v. Knowledge of the major principles involved in learning
vi. Knowledge of the principles of federalism
vii. Knowledge of the principles that govern rudimentary arithmetic operations (e.g., the commutative principle, the associative principle)

c) KNOWLEDGE OF THEORIES, MODELS, AND STRUCTURES

Examples of knowledge of theories &, models, and structures

i. Knowledge of the interrelationships among chemical principles as the basis for chemical theories
ii. Knowledge of the overall structure of Congress (i.e., organization, functions)
iii. Knowledge of the basic structural organization of the local city government
iv. Knowledge of a relatively complete formulation of the theory of evolution
v. Knowledge of the theory of plate tectonics
vi. Knowledge of genetic models (e.g., DNA)

C. PROCEDURAL KNOWLEDGE

a) KNOWLEDGE OF SUBJECT SPECIFIC SKILLS AND ALGORITHMS

Examples of knowledge of subject-specific skills and algorithms

i. Knowledge of the skills used in painting with watercolors
ii. Knowledge of the skills used to determine word meaning based on structural analysis
iii. Knowledge of the various algorithms for solving quadratic equations
iv. Knowledge of the skills involved in performing the high jump

b) KNOWLEDGE OF SUBJECT SPECIFIC TECHNIQUES AND METHODS

Examples of knowledge of subject-specific techniques and methods

i. Knowledge of research methods relevant to the social sciences
ii. Knowledge of the techniques used by scientists in seeking solutions to problems
iii. Knowledge of the methods for evaluating health concepts
iv. Knowledge of various methods of literary criticisrn

c) KNOWLEDGE OF CRITERIA FOR DETERMINING WHEN TO USE APPROPRIATE PROCEDURES

Examples of knowledge of criteria for determining when to use appropriate procedures

i. Knowledge of the criteria for determining which of several types of essays to write (e.g., expository, persuasive)
ii. Knowledge of the criteria for determining which method to use in solving algebraic equations
iii. Knowledge of the criteria for determining which statistical procedure to use with data collected in a particular experiment
iv. Knowledge of the criteria for determining which technique to apply to create a desired effect in a particular watercolor painting

## D. METACOGNITIVE KNOWLEDGE

### a) STRATEGIC KNOWLEDGE

Examples of strategic knowledge

i. Knowledge that rehearsal of information is one way to retain the information
ii. Knowledge of various mnemonic strategies for memory (e.g., the use of acronyms such as Roy G Biv for the colors of the spectrum.)
iii. Knowledge of various elaboration strategies such as paraphrasing and summarizing
iv. Knowledge of various organizational strategies such as outlining or diagramming ·
v. Knowledge of planning strategies such as setting goals for reading
vi. Knowledge of comprehension-monitoring strategies such as self-testing or self-questioning
vii. Knowledge of means-ends analysis as a heuristic for solving an ill-defined problem
viii. Knowledge of the availability heuristic and the problems of failing to sample in an unbiased manner

### b) KNOWLEDGE ABOUT COGNITIVE TASKS, INCLUDING CDNTEXTUAL AND CONDITIONAL KNOWLEDGE

Examples of knowledge about cognitive tasks, including contextual and conditional knowledge

i. Knowledge that recall tasks (i.e., short-answer items) generally make more demands on the individual's memory system than recognition tasks (i.e., multiple-choice items)
ii. Knowledge that a primary source book may be more difficult to understand than a general textbook or popular book
iii. Knowledge that a simple memorization task (e.g., remembering a phone number) may require only rehearsal
iv. Knowledge that elaboration strategies like summarizing and paraphrasing can result in deeper levels of comprehension
v. Knowledge that general problem-solving heuristics may be most useful when the individual lad<s relevant subject- or task-specific knowledge or in the absence of specific Procedural knowledge
vi. Knowledge of the local and general social, conventional, and cultural norms for how, when, and why to use different strategies

### c) SELF KNOWLEDGE

Examples of self-knowledge

i. Knowledge that one is knowledgeable in some areas but not in others
ii. Knowledge that one tends to rely on one type of "cognitive tool" (strategy) in certain situations
iii. Knowledge of one's capabilities to perform a particular task that are accurate, not inflated (e.g., overconfident)
iv. Knowledge of one's goals for performing a task
v. Knowledge of one's personal interest in a task
vi. Knowledge of one's judgments about the relative utility value of a task

- The use of examples and nonexamples (a recognized approach to teaching Conceptual knowledge).

# 3. Cognitive Processes dimension

| Dimension | Indicators | Meaning and words with high attention | Interactive text data example |
| --- | --- | --- | --- |
| Cognitive level | Remembering | Refers to extract relevant knowledge from long-term memory<br>Recognising, Listing, Describing, Identifying, Retrieving, Naming, Locating, Finding, Bullet pointing, Highlighting, Bookmarking, Social networking, Social bookmarking, Favouriting/local bookmarking, Searching, Googling | "What is the concept of the public domain?"<br>("New media is a relative concept, it is a new form of media that has developed after traditional media such as newspapers, radio, and television, including online media. . .") |
| | Understanding | Refers to constructing meaning from teaching information disseminated verbally, written, or graphically<br>Interpreting, Summarising, Inferring, Paraphrasing, Classifying, Comparing, Explaining, Exemplifying, Advanced searches, Boolean searches, Blog journalling, Twittering, Categorising and tagging, Commenting, Annotating, Subscribing | ("How should we understand the 'propagation system' in the definition?")<br>("I understand that the throttle represents the social demand for information, and the brake represents the bottom line of laws and regulations") |
| | Applying | Refers to the execution or use of a certain procedure in a given situation, including execution and implementation.<br>Implementing, carrying out, using, executing, running, loading, playing, operating, hacking, uploading, sharing, editing | ("How to better apply new media to education and teaching?")<br>("Use the short video platform for promotion. If the economy can support it, it will find influential people to promote it, and effectively spread a new media technology or product") |
| | Analyzing | Refers to the decomposing of a material into its constituent parts and determining the relationship between the constituent parts to form an overall structure.<br>Comparing, Organising, Deconstructing, Attributing, Outlining, Finding, Structuring, Integrating, Mashing, Linking, Reverse-engineering, Cracking and Mind-mapping. | ("What is the difference between perceived usefulness and perceived ease of use?")<br>("The main difference between new media and traditional media is interactivity. . .") |
| | Evaluating | Refers to making judgments based on certain standards, including verification and judgment.<br>Checking, Hypothesising, Critiquing, Experimenting, Judging, Testing, Detecting, Monitoring, (Blog/vlog) commenting, Reviewing, Posting, Moderating, Collaborating, Networking, Reflecting, (Alpha & beta) testing, validating. | ("Many people on the Internet have online violence. How should each of us view this phenomenon?")<br>("How to view Tesla's 'rights protection'? Many car owners say that they are more concerned about the eyes of others. It is said that the behavior of female Tesla owners has affected their car experience, but the car is still good") |
| | Creating | Refers to the reorganization of various elements to form a consistent or functional whole or the reorganization of elements into a new model or structure.<br>Designing, Constructing, Planning, Inventing, Devising, Making, Programming, Filming, Animating, Blogging, Video blogging, Mixing, Remixing, Wiki-ing, Publishing, Videocasting, Podcasting, Directing/producing, Building or compiling mash-ups | ("In the electronic age, will people face the danger of being "replaced" by electronic products?")<br>("New media will integrate different media, allowing people to obtain new information through the combination of multiple senses") |

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- Revised framework includes six categories of processes-one most closely related to retention (Remember) and the other five increasingly related to transfer (Understand, Apply, Analyze, Evaluate, and Create).
- These 19 specific cognitive processes are intended to be mutually exclusive; together they delineate the breadth and boundaries of the six categories.
- Remembering involves retrieving relevant knowledge from long term memory. The two associated cognitive processes are recognizing and recalling. The relevant knowledge may be Factual, Conceptual, Procedural, or Metacognitive, or some combination of these.

**1. REMEMBER**

- Remembering knowledge is essential for meaningful learning and problem solving as that knowledge is used in more complex tasks.
- Where teachers concentrate solely on rote learning, teaching and assessing focus solely on remembering elements or fragments of knowledge, often in isolation from their context. When teachers focus on meaningful learning, however, remembering knowledge is integrated within the larger task of constructing new knowledge or solving new problems.
- 1.1 RECOGNIZING
  - 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 (as represented in working memory)
  - SAMPLE OBJECTIVES AND CORRESPONDING ASSESSMENTS
    - In mathematics, an objective could be to recognize the numbers of sides in basic geometric shapes. A corresponding assessment is a multiple-choice test with items such as the following: "How many sides does a pentagon have? (a) four, (b) five, (c) six, (d) seven."
  - ASSESSMENT FORMATS
    - As illustrated in the preceding paragraph, three main methods of presenting a recognition task for the purpose of assessment are verification, matching, and forced choice. In verification tasks, the student is given some information and must choose whether or not it is correct. The true-false format is the most common example. In matching, two lists are presented, and the student must choose how each item in one list corresponds to an item in the other list. In forced choice tasks, the student is given a prompt along with several possible answers and must choose which answer is the correct or "best answer." Multiple-choice is the most common format.
- 1.2 RECALLING
  - Recalling 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 long-term memory for a piece of information and brings that piece of information to working memory where it can be processed. An alternative term for recalling is retrieving.
  - SAMPLE 0BJECTIVES AND CORRESPONDING ASSESSMENTS
    - In mathematics, an objective could be to recall the whole-number multiplication facts. A corresponding test item asks students to multiply 7 X 8 (or "7 X 8 = ?").
  - ASSESSMENT FORMATS
    - Assessment tasks for recalling can vary in the number and quality of cues that students are provided. With low cueing, the student is not given any hlnts or related information (such as "What is a meter?"). With high cueing, the student is given several hints (such as "In the metric system, a meter is a measure of _________ ."). Assessment tasks for recalling can also vary in the 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, as in the preceding examples. With high embedding, the recall task is included within the context of a larger problem, such as asking a student to recall the formula for the area of a circle when solving a word problem that requires that formula.

**2. UNDERSTAND**

- When the primary goal of instruction is to promote retention, the focus is on objectives that emphasize Remember. When the goal of instruction is to promote transfer, however, the focus shifts to the other five cognitive processes, Understand through Create.
- Students are said to Understand when they are able to construct meaning from instructional messages, including oral, written, and graphic communications, however they are presented to students: during lectures, in books, or on computer monitors. Examples of potential instructional messages include an in-class physics demonstration, a geological formation seen on a field trip, a computer simulation of a trip through an art museum, and a musical work played by an orchestra, 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 frameworks. Since concepts are the building blocks for these schemas and frameworks, Conceptual knowledge provides a basis for understanding.
- 2. 1 INTERPRETING
  - Interpreting occurs when a student is able to convert information from one representational form to another. Interpreting may involve converting words to words (e.g., paraphrasing), pictures to words, words to pictures, numbers to words, words to numbers, musical notes to tones, and the like. Alternative terms are translating, paraphrasing, representing, and clarifying.
  - SAMPLE OBJECTIVES AND CORRESPONDING ASSESSMENTS
    - In science, an objective could be to learn to draw pictorial representations of various natural phenomena. A corresponding assessment item asks a student to draw a series of diagrams illustrating photosynthesis. In mathematics, a sample objective could be to learn to translate number sentences expressed in words into algebraic equations expressed in symbols. A corresponding assessment item asks a student to write an equation (using B for the number of boys and G for the number of girls) that corresponds to the statement "There are twice as many boys as girls in this class."

- ASSESSMENT FORMATS
  - Appropriate test item formats include both constructed response (i.e., supply an answer) and selected response (i.e., choose an answer). Information is presented in one form, and students are asked either to construct or to select the same information in a different form. For example, a constructed response task is: "Write an equation that corresponds to the following statement, using T for total cost and P for number of pounds. The total cost of mailing a package is $2.00 for the first pound plus $1.50 for each additional pound." A selection version of this task is: "Which equation corresponds to the following statement, where T stands for total cost and P for number of pounds? The total cost of mailing a package is $2.00 for the first pound plus $1.50 for each additional pound. (a) T = $3.50 + P, (b) T = $2.00 + $1.50(P), (c) T = $2.00 + $1.SO(P - l}."
  - To increase the probability that interpreting rather than remembering is being assessed, the information included in the assessment task must be new. "New" here means that students did not encounter it during instruction.
- If assessment tasks are to tap higher-order cognitive processes, they must require that students cannot answer them correctly by relying on memory alone.

- 2.2 EXEMPLIFYING
  - 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 (e.g., an isosceles triangle must have two equal sides) and using these features to select or construct a specific instance (e.g., being able to select which of three presented triangles is an isosceles triangle). Alternative terms are illustrating and instantiating.
  - SAMPLE OBJECTIVES AND CORRESPONDING ASSESSMENTS
    - In science, a sample objective could be to be able to give examples of various kinds of chemical compounds. A corresponding assessment task asks the student to locate an inorganic compound on a field trip and tell why it is inorganic (i.e., specify the defining features).
  - ASSESSMENT FORMATS
    - Exemplifying tasks can involve the constructed response format-in which the student must create an example-or the selected response format-in which the student must select an example from a given set. The science example, "Locate an inorganic compound and tell why it is inorganic," requires a constructed response. In contrast, the item "Which of these is an inorganic compound? (a) iron, (b) protein, (c) blood, (d) leaf mold" requires a selected response.
- 2.3 CLASSIFYING
  - Classifying occurs when a student recognizes that something (e.g., a particular instance or example) belongs to a certain category (e.g., concept or principle). Classifying involves detecting relevant features or patterns that "fit" both the specific instance and the concept or principle. Classifying is a complementary process to exemplifying. Whereas exemplifying begins with a general concept or principle and requires the student to find a specific instance or example, classifying begins with a specific instance or example and requires the student to find a general concept or principle. Alternative terms for classifying are categorizing and subsuming.
  - SAMPLE OBJECTIVES AND CORRESPONDING ASSESSMENTS
    - In the natural sciences, an objective could be to learn to categorize the species of various prehistoric animals. An assessment gives a student some pictures of prehistoric animals with instructions to group them with others of the same species. In mathematics, an objective could be to be able to determine the categories to which numbers belong. An assessment task gives an example and asks a student to circle all numbers in a list from the same category.
  - ASSESSMENT FORMATS
    - In constructed response tasks, a student is given an instance and must produce its related concept or principle. In selected response tasks, a student is given an instance and must select its concept or principle from a list. In a sorting task, a student is given a set of instances and must determine which ones belong in a specified category and which ones do not or must place each instance into one of multiple categories.
- 2.4 SUMMARIZING
  - Summarizing occurs when a student suggests a single statement that represents presented information or abstracts a general theme. Alternative terms are generalizing and abstracting.
  - SAMPLE 0B.JECTIYES AND CORRESPONDING ASSESSMENTS
    - A sample objective in the natural sciences could be to learn to summarize the major contributions of famous scientists after reading several of their writings. A corresponding assessment item asks a student to read selected writings about Charles Darwin and summarize the major paints. In computer science, an objective could be to learn to summarize the purposes of various subroutines in a program. An assessment item presents a program and asks a student to write a sentence describing the subgoal that each section of the program accomplishes within the overall program.
  - ASSESSMENT FORMATS
    - Assessment tasks can be presented in constructed response or selection formats, involving either themes or summaries. Generally speaking, themes are more abstract than summaries.

- 2.5 INFERRING
  - 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 of each instance and, most important, by noting relationships among them. For example, when given a series of numbers such as 1, 2, 3, 5, 8, 13, 21, a student is able to focus on the numerical value of each digit rather than on irrelevant features such as the shape of each digit or whether each digit is odd or even. He or she then is able to distinguish the pattern in the series of numbers (i.e., after the first two numbers, each is the sum of the preceding two numbers).
  - The process of inferring involves making comparisons among instances within the context of the entire set. For example, to determine what number will come next in the series above, a student must identify the pattern. 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 13 and 21). This is an example of executing, which is a cognitive process associated with Apply. Inferring and executing are often used together on cognitive tasks.
  - Inferring is different from attributing (a cognitive process associated with Analyze). Attributing focuses solely on the pragmatic issue of determining the author's point of view or intention, whereas inferring focuses on the issue of inducing a pattern based on presented information. Another way of differentiating between these two is that attributing is broadly applicable to situations in which one must "read between the lines," especially when one is seeking to determine an author's point of view. Inferring, on the other hand, occurs in a context that supplies an expectation of what is to be inferred. Alternative terms for inferring are extrapolating, interpolating, predicting, and concluding.
  - SAMPLE OBJECTIVES AND C0RRESP0NDING ASSESSMENTS
    - In mathematics, an objective could be to learn to infer the relationship expressed as an equation that represents several observations of values for two variables. An assessment item asks a student to describe the relationship as an equation involving x and y for situations in which if x is 1, then y is 0; if x is 2, then y is 3; and if x is 3, then y is 8.
  - ASSESSMENT FORMATS
    - Three common tasks that require inferring (often along with implementing) are completion tasks, analogy tasks, and oddity tasks. In completion tasks, a student is given a series of items and must determine what will come next, as in the number series example above. In analogy tasks, a student is given an analogy of the form A is to B as C is to D, such as "nation" is to "president" as "state" is to ______ The student's task is to produce or select a term that fits in the blank and completes the analogy (such as "governor"). In an oddity task, a student is given three or more items and must determine which does not belong. For example, a student may be given three physics problems, two involving one principle and another involving a different principle. To focus solely on the inferring process, the question in each assessment task could be to state the underlying concept or principle the student is using to arrive at the correct answer.
- 2.6 COMPARING
  - Comparing involves detecting similarities and differences between two or more objects, events, ideas, problems, or situations. 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 from 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.
  - SAMPLE OBJECTIVES AND CORRESPONDING ASSESSMENTS
    - In the natural sciences, a sample objective could be to learn to compare an electrical circuit to a more familiar system. In assessment, we ask "How is an electrical circuit like water flowing through a pipe?“
    - Comparing may also involve determining correspondences between two or more presented objects, events, or ideas. In mathematics, a sample objective could be to learn to compare structurally similar word problems. A corresponding assessment question asks a student to tell how a certain mixture problem is like a certain work problem.
    - If a student has figured out that answer given by another student is wrong and trying to give their version of correct answer, he/she is using “Comparing” or “Recognize + Comparing + Evaluating”
  - ASSESSMENT FORMATS
    - A major technique for assessing the cognitive process of comparing is mapping. In mapping, a student must show how each part of one object, idea, problem, or situation corresponds to (or maps onto) each part of another. For example, a student could be asked to detail how the battery, wire, and resistor in an electrical circuit are like the pump, pipes, and pipe constructions in a water flow system, respectively.

- 2.7 EXPLAINING
  - 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 a formal theory often the case in the natural sciences) or may be grounded in research or experience (as is often the case in the 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 the chain affects a change in another part. An alternative term for explaining is constructing a model.
  - SAMPLE 0BJECTIYES AND CORRESPONDING ASSESSMENTS
    - In the natural sciences, an objective could be to explain how basic physics laws work. Corresponding assessments ask students who have studied Ohm's law to explain what happens to the rate of the current when a second battery is added to a circuit or ask students who have viewed a video on lightning storms to explain how differences in temperature affect the formation of lightning.
  - ASSESSMENT FORMATS
    - Several tasks can be aimed at assessing a student's ability to explain, including reasoning, troubleshooting, redesigning, and predicting. In reasoning tasks, a student is asked to offer a reason for a given event. For example, "Why does air enter a bicycle tire pump when you pull up on the handle?" In this case, an answer such as "It is forced in because the air pressure is less inside the pump than outside" involves finding a principle that accounts for a given event.
    - In troubleshooting, a student is asked to diagnose what could have gone wrong in a malfunctioning system. For example, "Suppose you pull up and press down on the handle of a bicycle tire pump several times, but no air comes out. What's wrong?" In this case, the student must find an explanation for a symptom, such as "There is a hole in the cylinder" or "A valve is stuck in the open position."
    - In redesigning, a student is asked to change the system to accomplish some goal. For example, "How could you improve a bicycle tire pump so that it would be more efficient?" To answer this question, a student must imagine altering one or more of the components in the system, such as "Put lubricant between the piston and the cylinder."
    - In predicting, a student is asked how a change in one part of a system will effect a change in another part of the system. For example, "What would happen if you increased the diameter of the cylinder in a bicycle tire pump?" This question requires that the student "operate" the mental model of the pump to see that the amount of air moving through the pump could be increased by increasing the diameter of the cylinder

**3. APPLY**

- Apply involves using procedures to perform exercises or solve problems. Thus, Apply is closely linked with Procedural knowledge.
- 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).
- When the task is a familiar exercise, students generally know what Procedural knowledge to use. When given an exercise (or set of exercises), students typically perform the procedure with little thought. For example, an algebra student confronted with the 50th exercise involving quadratic equations might simply "plug in the numbers and turn the crank."
- When the task is an unfamiliar problem, however, students must determine what knowledge they will use. If the task appears to call for Procedural knowledge and no available procedure fits the problem situation exactly, then modifications in selected Procedural knowledge may be necessary. In contrast to executing, then, implementing requires some degree of understanding of the problem as well as of the solution procedure. In the case of implementing, then, to understand conceptual knowledge is a prerequisite to being able to apply procedural knowledge.

- 3.1 EXECUTING
  - Executing is more frequently associated with the use of skills and algorithms than with 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 a predetermined answer. An alternative term for executing is carrying out.
  - SAMPLE OBJECTIVES AND CORRESPONDING ASSESSMENTS
    - A sample objective in elementary level mathematics could be for students to learn to divide one whole number by another, both with multiple digits. The instructions to "divide" signify the division algorithm, which is the necessary Procedural knowledge. To assess the objective, a student is given a worksheet that has 15 whole-number division exercises (e.g., 784/15) and is asked to find the quotients. In the natural sciences, a sample objective could be to learn to compute the value of variables using scientific formulas. To assess the objective, a student is given the formula Density = Mass/Volume and must answer the question "What is the density of a material with a mass of 18 pounds and a volume of 9 cubic inches?"
  - ASSESSMENT FORMATS
    - An execution task is "Solve for x: x 2 + 2x - 3 = 0 using the technique of completing the square." Students may be asked to supply the answer or, where appropriate, select from among a set of possible answers. Furthermore, because the emphasis is on the procedure as well as the answer, students may be required not only to find the answer but also to show their work.
- 3.2 IMPLEMENTING
  - Implementing occurs when a student selects and uses a procedure to perform an unfamiliar task. Because selection is required, students 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.
  - Implementing is more frequently associated with the use of techniques and methods than with skills and algorithms. Techniques and methods have two qualities first, the procedure may be more like a "flow chart" than a fixed sequence; that is, the procedure may have "decision points" built into it (e.g., after completing Step 3, should I do Step 4A or Step 4B?). Second, there often is no single, fixed answer that is expected when the procedure is applied correctly.

- Apply category as structured along a continuum. It starts with the narrow, highly structured execute, in which the known Procedural knowledge is applied almost routinely. It continues through the broad, increasingly unstructured implement, in which, at the beginning, the procedure must be selected to fit a new situation. In the middle of the category, the procedure may have to be modified to implement it. At the far end of implementing, where there is no set Procedural knowledge to modify, a procedure must be manufactured out of Conceptual knowledge using theories, models, or structures as a guide. So, although Apply is closely linked to Procedural knowledge, and this linkage carries through most of the category of Apply, there are some instances in implementing to which one applies Conceptual knowledge as well. An alternative term for implementing is using.
- SAMPLE 0BJECTIVES AND CORRESPONDING ASSESSMENTS
  - In mathematics, a sample objective could be to learn to solve a variety of personal finance problems. A corresponding assessment is to present students with a problem in which they must choose the most economical financing package for a new car. In the natural sciences, a sample objective could be to learn to use the most effective, efficient, and affordable method of conducting a research study to address a specific research question. A corresponding assessment is to give students a research question and have them propose a research study that meets specified criteria of effectiveness, efficiency, and affordability. Notice that in both of these assessment tasks, the student must not only apply a procedure (i.e., engage in implementing) but also rely on conceptual understanding of the problem, the procedure, or both.
- ASSESSMENT FORMATS
  - In implementing, a student is given an unfamiliar problem that must be solved. Thus, most assessment formats begin with specification of the problem. Students are asked to determine the procedure needed to solve the problem, solve the problem using the selected procedure (making modifications as necessary), or usually both.

**4. ANALYZE**

- Analyze involves breaking material into its constituent parts and determining how the parts are related to one another and to an overall structure.
- Although learning to Analyze may be viewed as an end in itself, it is probably more defensible educationally to consider analysis as an extension of Understanding or as a prelude to Evaluating or Creating.
- The process categories of Understand, Analyze, and Evaluate are interrelated and often used iteratively in performing cognitive tasks.

- 4.1 DIFFERENTIATING
  - 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, or important from unimportant information, and then attends to the relevant or important information.
  - More specifically, differentiating differs from comparing in using the larger context to determine what is relevant or important and what is not. For instance, in differentiating apples and oranges in the context of fruit, internal seeds are relevant, but color and shape are irrelevant. In comparing, all of these aspects (i.e., seeds, color, and shape) are relevant. Alternative terms for differentiating are discriminating, selecting, distinguishing, and focusing.
  - SAMPLE OBJECTIVES AND C0RRESP0NDING ASSESSMENTS
    - In the natural sciences, an objective could be to select the main steps in a written description of how something works. A corresponding assessment item asks a student to read a chapter in a book that describes lightning formation and then to divide the process into major steps (including moist air rising to form a cloud, creation of updrafts and downdrafts inside the cloud, separation of charges within the cloud, movement of a stepped leader downward from cloud to ground, and creation of a return stroke from ground to cloud).
    - Finally, in mathematics, an objective could be to distinguish between relevant and irrelevant numbers in a word problem. An assessment item requires a student to circle the relevant numbers and cross out the irrelevant numbers in a word problem.
  - ASSESSMENT FORMATS
    - Differentiating can be assessed with constructed response or selection tasks. In a constructed response task, a student is given some material and is asked to indicate which parts are most important or relevant, as in this example: ''Write the numbers that are needed to solve this problem: Pencils come in packages that contain 12 each and cost $2.00 each. John has $5.00 and wishes to buy 24 pencils. How many packages does he need to buy?“
    - In a selection task, a student is given some material and is asked to choose which parts are most important or relevant, as in this example: "Which numbers are needed to solve this problem? Pencils come in packages that contain 12 each and cost $2.00 each. John has $5.00 and wishes to buy 24 pencils. How many packages does he need to buy? (a) 12, $2.00, $5.00, 24; (b) 12, $2.00, $5.00; (c) 12, $2.00, 24; (d) 12, 24.“

- 4.2 ORGANIZING
  - 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 pieces of 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.

- SAMPLE OBJECTIYES AND CORRESPONDING ASSESSMENTS
  - In mathematics, a sample objective could be to learn to outline textbook lessons. A corresponding assessment task asks a student to read a textbook lesson on basic statistics and then generate a matrix that includes each statistic's name, formula, and the conditions under which it is used.
- ASSESSMENT FORMATS
  - Organizing involves imposing a structure on material (such as an outline, table, matrix, or hierarchical diagram). Thus, assessment can be based on constructed response or selection tasks. In a constructed response task, a student may be asked to produce a written outline of a passage. In a selection task, a student may be asked to select which of four alternative graphic hierarchies best corresponds to the organization of a presented passage.

- 4.3 ATTRIBUTING
  - 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 presented material, attributing involves an extension beyond basic understanding to infer the intention or point of view underlying the presented material. An alternative term is deconstructing.
  - SAMPLE OBJECTIVES AND CORRESP0NDING ASSESSMENTS
    - A corresponding assessment task asks a student whether a report on Amazon rain forests was written from a pro-environment or pro-business point of view. This objective is also applicable to the natural sciences. A corresponding assessment task asks a student to determine whether a behaviorist or a cognitive psychologist wrote an essay about human learning.
  - ASSESSMENT FORMATS
    - Attributing can be assessed by presenting some written or oral material and then asking a student to construct or select a description of the author's or speaker's point of view, intentions, and the like.
    - For example, a constructed response task is "What is the author's purpose in writing the essay you read on the Amazon rain forests?" A selection version of this task is "The author's purpose in writing the essay you read is to: (a) provide factual information about Amazon rain forests, (b) alert the reader to the need to protect rain forests, (c) demonstrate the economic advantages of developing rain forests, or (d) describe the consequences to humans if rain forests are developed."
    - Alternatively, students might be asked to indicate whether the author of the essay would (a) strongly agree, (b) agree, (c) neither agree nor disagree, (d) disagree, or (e) strongly disagree with several statements. Statements like "The rainforest is a unique type of ecological system" would follow.

**5. EVALUATE**

- Evaluate is defined as making judgments based on criteria and standards. The criteria most often used are quality, effectiveness, efficiency, and consistency.
- The standards may be either quantitative (i.e., Is this a sufficient amount?) or qualitative (i.e., Is this good enough?). The standards are applied to the criteria {e.g., Is this process sufficiently effective? Is this product of sufficient quality?).
- Not all judgments are evaluative. Most of the cognitive processes, in fact, require some form of judgment. What most clearly differentiates Evaluate as defined here from other judgments made by students is the use of standards of performance with clearly defined criteria. Is this machine working as efficiently as it should be? Is this method the best way to achieve the goal? Is this approach more cost effective than other approaches? Such questions are addressed by people engaged in Evaluating.

- 5.1 CHECKING
  - Checking involves testing for internal inconsistencies or fallacies in an 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.
  - SAMPLE OBJECTIVES AND C0RRESP0NDING ASSESSMENTS
    - A sample objective in the sciences could be to learn to determine whether a scientist's conclusion follows from the observed data. An assessment task asks a student to read a report of a chemistry experiment and determine whether or not the conclusion follows from the results of the experiment.
  - ASSESSMENT FORMATS
    - Checking tasks can involve operations or products given to the students or ones created by the students themselves. Checking can also take place within the context of carrying out a solution to a problem or performing a task, where one is concerned with the consistency of the actual implementation (e.g., Is this where I should be in light of what I've done so far?).

- 5.2 CRITIQUING
  - Critiquing involves judging a product or operation based on externally imposed criteria and standards. In critiquing, a student notes the positive and negative features of a product and makes a judgment based at least partly on those features. 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 its likely effectiveness and its associated costs (e.g., requiring all power plants throughout the country to restrict their smokestack emissions to certain limits). An alternative term is judging.
  - SAMPLE OBJECTIVES AND C0RRESP0NDING ASSESSMENTS
    - In the natural sciences, an objective could be to learn to evaluate the reasonableness of a hypothesis (such as the hypothesis that strawberries are growing to extraordinary size because of the unusual alignment of the stars).
    - In mathematics, an objective could be to learn to judge which of two alternative methods is a more effective and efficient way of solving given problems (such as judging whether it is better to find all prime factors of 60 or to produce an algebraic equation to solve the problem "What are the possible ways you could multiply two whole numbers to get 60?").
  - ASSESSMENT FORMATS
    - A Student may be asked to critique his or her own hypotheses or creations or those generated by someone else. The critique could be based on positive, negative, or both kinds of criteria and yield both positive and negative consequences.
    - For example, in critiquing a school district's proposal for year-round schools, a student would generate positive consequences, such as the elimination of learning loss over summer vacation, and negative consequences, such as disruption of family vacations.

## 6. 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.
- The processes involved in Create are generally coordinated with the student's previous learning experiences. 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 situation.
- To some persons, creativity is the production of unusual products, often as a result of some special skill. Create, as used here, however, although it includes objectives that call for unique production, also refers to objectives calling for production that all students can and will do.
- Although many objectives in the Create category emphasize originality (or uniqueness), educators must define what is original or unique. Can the term unique be used to describe the work of an individual student (e.g., "This is unique for Adam Jones") or is it reserved for use with a group of students (e.g., "This is unique for a fifth-grader")? It is important to note, however, that many objectives in the Create category do not rely on originality or uniqueness.
- 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 a 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.
- We recognize that composition (including writing) often, but not always, requires the cognitive processes associated with Create. For example, Create is not involved in writing that represents the remembering of ideas or the interpretation of materials. We also recognize that deep understanding that goes beyond basic understanding can require the cognitive processes associated with Create. To the extent that deep understanding is an act of construction or insight, the cognitive processes of Create are involved.

- 6.1 GENERATING
  - 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 a new representation of the problem may suggest different solutions.
  - When generating transcends the boundaries or constraints of prior knowledge and existing theories, it involves divergent thinking and forms the core of what can be called creative thinking.
  - Generating is used in a restricted sense here. Understand also requires generative processes, which we have 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.
  - SAMPLE 0B.JECTIVE AND CORRESPONDING ASSESSMENT
    - In the natural sciences, an objective could be to learn to generate hypotheses to explain observed phenomena. A corresponding assessment task asks students to write as many hypotheses as they can to explain strawberries growing to extraordinary size. Again, the teacher should establish clearly defined criteria for judging the quality of the responses and give them to the students.

        - An objective from the field of mathematics could be to be able to generate alternative methods for achieving a particular result. A corresponding assessment item is: "What alternative methods could you use to find what whole numbers yield 60 when multiplied together?" For each of these assessments, explicit, publicly shared scoring criteria are needed.
    - ASSESSMENT FORMATS
        - Assessing generating typically involves constructed response formats in which a student is asked to produce alternatives or hypotheses. Two traditional subtypes are consequences tasks and uses tasks.
        - In a consequences task, a student must list all the possible consequences of a certain event, such as "What would happen if there was a flat income tax rather than a graduated income tax?" In a uses task, a student must list all possible uses for an object, such as "What are the possible uses for the World Wide Web?" It is almost impossible to use the multiple-choice format to assess generating processes.
- 6.2 PLANNING
    - 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.
    - Teachers often skip stating planning objectives, instead stating their objectives in terms of producing, the final stage of the creative process. When this happens, planning is either assumed or implicit in the producing objective. An alternative term is designing.
    - SAMPLE OBJECTIVES AND C0RRESP0NDING ASSESSMENTS
        - In the natural sciences, a sample objective could be to learn to design studies to test various hypotheses. An assessment task asks students to plan a way of determining which of three factors determines the rate of oscillation of a pendulum.
        - In mathematics, an objective could be to be able to lay out the steps needed to solve geometry problems. An assessment task asks students to devise a plan for determining the volume of the frustrum of a pyramid (a task not previously considered in class). The plan may involve computing the volume of the large pyramid, then computing the volume of the small pyramid, and finally subtracting the smaller volume from the larger.
    - ASSESSMENT FORMATS
        - Planning may be assessed by asking students to develop worked-out solutions, describe solution plans, or select solution plans for a given problem.
- 6.3 PRODUCING
    - Producing involves carrying out a plan for solving a given problem that meets certain specifications.
    - Producing can require the coordination of the four types of knowledge. An alternative term is constructing.
    - SAMPLE OBJECTIYES AND C0RRESP0NDING ASSESSMENTS
        - In producing, a student is given a functional description of a goal and must create a product that satisfies the description. It involves carrying out a solution plan for a given problem. Sample objectives involve producing novel and useful products that meet certain requirements.
        - In science, an objective could be to learn to design habitats for certain species and certain purposes. A corresponding assessment task asks students to design the living quarters of a space station.
        - The specifications become the criteria for evaluating student performance relative to the objective. These specifications, then, should be included in a scoring rubric that is given to the students in advance of the assessment.
    - ASSESSMENT FORMATS
        - A common task for assessing producing is a design task, in which students are asked to create a product that corresponds to certain specifications. For example, students may be asked to produce schematic plans for a new high school that include new ways for students to conveniently store their personal belongings.

- **AN EXAMPLE 0F EDUCATI0NAL OBJECTIVES IN C0NTEXT**
  - Suppose, for example, that a teacher has a very general objective for her students: She wants them to learn about Ohm's law. She devises an instructional unit accordingly.
  - An example of Factual knowledge is that current is measured in amps, voltage in volts, and resistance in ohms.
  - An example of Procedural knowledge is the steps involved in using the formula for Ohm's law (voltage = current X resistance) to compute a numerical value.
  - An example of Conceptual knowledge is the structure and workings of an electrical circuit that consists of batteries, wires, and a light bulb. An electrical circuit is a conceptual system. in which there are causal relations among the elements (e.g., if more batteries are added in serial, the voltage increases, which causes an increase in the flow of electrons in the wires as measured by an increase in current).
  - As an example of Metacognitive knowledge, the teacher may intend students to know when to use mnemonic strategies for memorizing the name of the law, the formula, and similar relevant items. She also may want them. to establish their own goals for learning Ohm's law and its applications.
  - An objective for recalling factual knowledge is that students will be able to recall what the letters stand for in the formula for Ohm's law. An objective for recalling procedural knowledge is that students will be able to recall the steps involved in applying Ohm's law.
  - For Conceptual knowledge, an objective is that students will be able to draw, from memory, a picture of an electrical circuit. Because this objective focuses on recalling, each student's drawing is evaluated in terms of how closely it corresponds to a picture presented in the textbook or previously on the chalkboard.
  - An objective pertaining to recalling metacognitive knowledge is that students remember "When stuck in a hole, stop digging." In other words, when their first approach to solving a problem or arriving at an answer is not succeeding, they remember to stop and assess other possible approaches. Again, with the emphasis on Remember, students may be queried about whether, when their first approach to a problem bogged down, they remembered the slogan.
- **MAKING SENSE OF AND USING WHAT WAS LEARNED**

  When the concern of the teacher turns to promoting transfer, he or she needs to consider the full range of cognitive process categories. Consider the myriad of possibilities inherent in the following list:
  - An objective for interpreting factual knowledge: "Students should be able to define key terms (e.g., resistance) in their own words."
  - An objective for explaining conceptual knowledge: "Students should be able to explain what happens to the rate of current in an electrical circuit when changes are made in the system (e.g., two batteries that were connected in serial are reconnected in parallel)."
  - An objective for executing procedural knowledge: ‘The student will be able to use Ohm's law to compute the voltage when given the current (in amperes) and the resistance (in ohms)."
  - An objective for differentiating conceptual knowledge: "The student will be able to determine which information in word problems involving Ohm's law (e.g., wattage of light bulb, thickness of wire, voltage of battery) is needed to determine the resistance."
  - An objective for checking procedural knowledge: "The student will be able to determine whether a worked-out solution to a problem involving Ohm's law is likely to be effective in solving it."
  - An objective for critiquing metacognitive knowledge: "The student will be able to choose a plan for solving problems involving Ohm's law that is most consistent with his or her current level of understanding.“
  - An objective for generating conceptual knowledge: "The student will be able to generate alternative ways of increasing the brightness of the light in a circuit without changing the battery.“

- **USING THE TAX0N0MY TABLE IN ANALYZING THE W0RK 0F OTHERS**
  - When anyone uses the framework to analyze the work of others, they encounter the same complexities we faced in aur vignette analyses. Teachers may be handed objectives (e.g., state or local standards) or assessments prepared by others (e.g., statewide or standardized tests). They may be asked to analyze another teacher's units or conduct observations in fellow teachers' classrooms. These analyses all require attributions of intent, which are difficult when objectives lack important words or phrases or when peripheral words or phrases are misleading.
  - For all these reasons, placing an objective in the Taxonomy Table requires that one determine the intentions of the teacher [or author(s) in the case of materials prepared by others] in relation to the meaning of the objective, the purpose of the instructional activities, and the aim of the assessments.

- **THE LEARNING QUESTION**
  - "Students should learn to use laws of electricity and magnetism (such as Lenz' law and Ohm's law) to solve problems.“
  - We must relate the verb, "use," to one of the six major cognitive process categories and the noun phrase, "laws of electricity and magnetism," to one of the four types of knowledge. The verb is fairly easy: "use" is an alternative name for implement, which is associated with the category Apply. With respect to the noun, laws are principles or generalizations, and knowledge of principles and generalizations is Conceptual knowledge.
  - Now we have answered the "learning question." We want students to learn to apply conceptual knowledge.
  - Note also that we based our decisions on assumptions we made about the teacher's intention. For example, our inference that we are dealing with implementing rather than executing is supported not only by the inclusion of the verb "use" but also by the phrase "in problems" in the statement of the objective. Because problems are unfamiliar (rather than familiar) tasks, implementing seems more appropriate than executing.

- **THE INSTRUCTION QUESTION**
  - Although the objective can be classified in one cell , when we consider different instructional activities a teacher may use, we see a much more complex and differentiated picture.
  - In general, if students are to implement scientific laws, they might (1) determine the type of problem they are confronting, (2) select a law that will likely solve that type of problem, and (3) use a procedure in which the law is embedded to solve the problem. As we described, then, implementing involves both Conceptual knowledge (i.e., knowledge of the type or category of problem) and Procedural knowledge (i.e., knowledge of the steps to follow to solve the problem). Instructional activities might help students develop both types of knowledge.
  - Note the verbs used in the decomposition of this single objective: "determine," "select," and "use." , we see that determining that something belongs to a category is the definition of classifying (Understand), selecting is an alternative term for differentiating (Analyze), and using is an alternative term for implementing (Apply). The instructional activities should help students engage in classifying and differentiating as well as implementing.
  - Because students may make errors in classifying, differentiating, and implementing, it also seems reasonable to emphasize Metacognitive knowledge during instruction. For example, students might be taught strategies for monitoring their decisions and choices to see whether they "make sense." "How do I know this problem is a certain type?" "If it is, how do I know which laws to use?" In addition to being able to recall these strategies, students may be taught to implement them.
  - It may be advisable to focus some of the instructional activities on so-called higher-order cognitive processes. Because implementation often involves making choices along the way, students should be taught to check as they go and critique the final result or solution. Both checking and critiquing fall in the Evaluate category.
- **THE ASSESSMENT QUESTION**
  - If assessment tasks do not include unfamiliar tasks and/or do not require students to select relevant and appropriate Procedural knowledge, then it is more likely that executing rather than implementing is being assessed
  - The teacher decides she is as concerned about students using the correct procedure as she is about their getting the right answer. The teacher sees the assessment as formative in nature. She gives her students ten electrical and mechanical problems and asks them to solve each problem, showing their work.
  - For each of the ten problems, score points are given for "selecting a correct procedure." The teacher's scoring rubric requires that students are able to classify the problem correctly (understanding conceptual knowledge, one point), select the appropriate law (analyzing conceptual knowledge, one point), and select a procedure that follows from the law and is likely to solve the problem (analyzing procedural knowledge, one point). Since she considers the procedure and the result to be equally important, having given three points for selecting the correct procedure for solving each problem, she gives three points for arriving at the correct solution to the problem (i.e., implementing procedural knowledge).
- **DIFFERENTIATING OBJECTIVES FR0M ACTIVITIES**
  - It is easy to slip into the mode of trying to categorize learning activities rather than intended learning outcomes. To test the framework, one of us would suggest a verb-for instance, "estimating"- and ask where it belongs. Initially, we found that estimating was difficult to categorize. When we paired it with knowledge so that it became an objective, however, classifying became much easier.
  - Students should learn to estimate the product of two large numbers." This objective reduces to students learning a three-step procedure: (1) rounding to the nearest power of ten, (2) multiplying the remaining one-digit, nonzero numbers, and (3) adding the correct number of zeros. In this context, estimating means executing an estimation procedure, or applying procedural knowledge.
  - "The student will learn that doodling helps him or her to relieve stress temporarily when working on difficult problems." This might be a strategy within Metacognitive knowledge. The phrase "learn that" suggests simple recall (i.e., "know that"). The objective, then, would take the form remember metacognitive knowledge. The point is that it makes sense to try to classify "doodling" when it is placed in a knowledge context; without that context, it makes no sense.
  - Many "verbs," particularly those associated with undesirable student behavior (e.g., disrupt, agitate), are not likely to be included in Statements of educational objectives. Consequently, they are not usefully classified within our framework.
- **SOME HELPFUL HINTS**
- We offer four helpful hints that should increase your probability of classifying objectives correctly: (1) consider the verb-noun combination, (2) relate the knowledge type to the process, (3) make sure you have the right noun or noun phrase, and (4) rely on multiple sources.
- **CONSIDER THE VERB-NOUN COMBINATION**
  - "Students should be able to identify various literary devices (e.g., similes, metaphors, hyperbole, personification, alliteration) used in novels." Clearly, the verb is "identify." In Table 5.1, inside back cover, identifying is an alternative term for recognizing, which is in the process category Remember. If we categorized this as a Remember objective, however, it would be inappropriate. A more complete reading of this objective suggests that the intention is for students to learn to identify examples of literary devices in novels. Finding examples is exemplifying, which is associated with the process category Understand. This inference is consistent with the fact that literary devices are concepts (that is, classes of things sharing common attributes). More likely, then, the objective has the form understand conceptual knowledge.

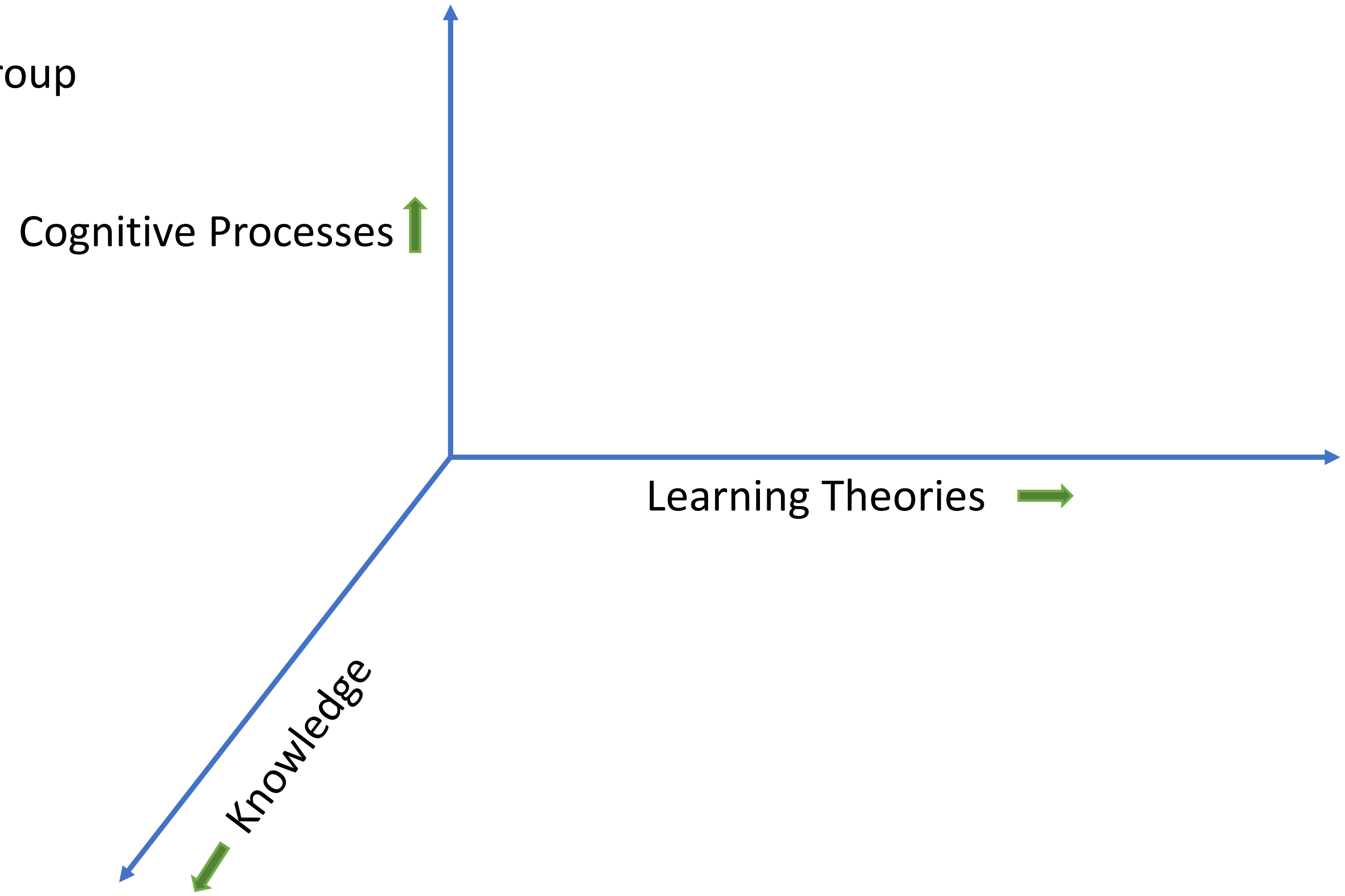
- **RELATE TYPE OF KNOWLEDGE TO PROCESS**
  - For objectives that involve Remember, Understand, and Apply, there generally is a direct correspondence between process category and type of knowledge. We do intend, for example, students to recall facts (remember factual knowledge), interpret principles (understand conceptual knowledge), and execute algorithms (apply procedural knowledge).
  - When Analyze, Evaluate, and Create are involved, however, the correspondence between process category and type of knowledge is less predictable.

- Evaluate conceptual knowledge. We typically do not intend students to learn to critique (Evaluate) a set of criteria (Conceptual knowledge). Rather, we intend them to learn to critique something based on or in terms of the criteria. The something might be a hypothesis advanced by a scientist or a solution to a problem proposed by a legislator. The criteria on which the evaluation is based may include reasonableness and cost effectiveness, respectively. Thus, evaluate conceptual knowledge becomes in essence evaluate [based on] conceptual knowledge or evaluate [in terms of] conceptual knowledge.
- Create. Again, we intend for students to learn to create something-poems, novel solutions to a problem, research reports. Students typically are expected to rely on more than one type of knowledge during the creative process. Suppose, for example, we intend for students to learn to write original research reports about famous Americans in history based on themes and supporting details derived from materials about them. We could classify this objective as Create (write original research reports) Conceptual knowledge (themes) and Factual knowledge (supporting details). This classification would be not only confusing but also likely incorrect. We do not necessarily intend for students to create conceptual and factual knowledge. However, we do intend them to create [original research reports based on] conceptual and factual knowledge. As in the preceding case of Evaluate, students are to Create something based on some knowledge. With Create, students may well use all the knowledge at their disposal (Factual, Conceptual, Procedural, and Metacognitive).
- When objectives involve the three most complex cognitive processes, knowledge provides the basis for the cognitive processes and often. multiple types of knowledge are required.

- **MAKE SURE YOU HAVE THE RIGHT NOUN**
  - We encountered statements of objectives in which the nouns and noun phrases did not help us determine the appropriate type of knowledge. In general, the verbs in these objectives indicated more complex cognitive process categories (i.e., Analyze, Evaluate, and Create).
    - Students should learn to outline textbook lessons.
    - Students should learn to critique proposed solutions to social problems.
    - Students should learn to design sets for various plays.
  - In each case, the verb is easily identifiable and quite easily classified. Outlining is an alternative term for organizing [Analyze], critiquing is associated with Evaluate, and constructing is an alternative term for producing [Create]. The noun phrases in these cases are "textbook lessons," "proposed solutions to social problems," and "sets for various plays."
  - What is missing from these statements, and what must be made explicit before the objectives can be classified correctly, is the knowledge that students need to organize lessons (e.g., the organizing principles), critique proposed solutions (e.g., the evaluation criteria), or plan sets (e.g., the design parameters).

- Miscellaneous Points
  - Cognitive dimension is different from the Knowledge dimension in the sense that

For a particular subject and class group



# 4. 21st Century Skills

## a. Critical Thinking

| Critical thinking specific abilities | Critical thinking Dispositions |
|---|---|
| 1. Analysing arguments, claims, or evidence (Ennis, 1985; Facione, 1990; Halpern, 1998; Paul, 1992); | Open-mindedness (Bailin et al., 1999; Ennis, 1985; Facione 1990, 2000; Halpern, 1998); |
| 2. Making inferences using inductive or deductive reasoning (Ennis, 1985; Facione, 1990; Paul, 1992; Willingham, 2007); | Fair-mindedness (Bailin et al., 1999; Facione, 1990); |
| 3. Judging or evaluating (Case, 2005; Ennis, 1985; Facione, 1990; Lipman, 1988; Tindal & Nolet, 1995); | The propensity to seek reason (Bailin et al., 1999; Ennis, 1985; Paul, 1992); |
| 4. Making decisions or solving problems (Ennis, 1985; Halpern, 1998; Willingham, 2007). | Respect for and willingness to entertain others' viewpoints (Bailin et al., 1999; Facione, 1990). |
| | Flexibility (Facione, 1990; Halpern, 1998); |
| | The desire to be well-informed (Ennis, 1985; Facione, 1990); |
| | Inquisitiveness (Bailin et al., 1999; Facione, 1990, 2000); |

- Other abilities or behaviors identified as relevant to critical thinking include asking and answering questions for clarification (Ennis, 1985); defining terms (Ennis, 1985); identifying assumptions (Ennis, 1985; Paul, 1992); interpreting and explaining (Facione, 1990); reasoning verbally, especially in relation to concepts of likelihood and uncertainty (Halpern, 1998); predicting (Tindal & Nolet, 1995); and seeing both sides of an issue (Willingham, 2007).

## b. Collaborative learning

i. Johnson et al. (1990) pointed out 5 basic elements in CL. CL is not simply a synonym for students working in groups. A learning exercise only qualifies as CL to the extent that the following elements are present:

| Elements in Collaborative learning | Examples |
|---|---|
| 1. Clearly perceived positive interdependence | Team members are obliged to rely on one another to achieve the goal. If any team members fail to do their part, everyone suffers consequences. Members need to believe that they are linked with others in a way that ensures that they all succeed together. |
| 2. Considerable interaction | Members help and encourage each other to learn. They do this by explaining what they understand and by gathering and sharing knowledge. Group members must be done interactively by providing one another with feedback, challenging one another's conclusions and reasoning, and perhaps most importantly, teaching and encouraging one another |
| 3. Individual accountability and personal responsibility | All students in a group are held accountable for doing their share of the work and for mastery of all of the material to be learned. |
| 4. Social skills | Students are encouraged and helped to develop and practice trust-building, leadership, decision-making, communication, and conflict management skills. |
| 5. Group self-evaluating | Team members set group goals, periodically assess what they are doing well as a team and identify changes they will make to function more effectively in the future. |

## c. Problem Solving

| Problem Solving Strategies | Comments |
|---|---|
| 1. General heuristics approach (Rubenstein (1975)) | |
| 2. Generate-and-Test Strategy(Resnick, 1985) | Trial and error type of approach |
| 3. Means–Ends Analysis. (Resnick, 1985) | 1.From goal to initial state(Working backwards)<br>2.From initial to goal state(Working forwards) |
| 4. Analogical Reasoning (the base or source; Anderson, 1990; Chen, 1999; Hunt, 1989) | One works the problem through the familiar domain and then relates the solution to the problem situation (Holyoak & Thagard, 1997). |
| 5. Brainstorming. (Isaksen & Gaulin, 2005; Mayer, 1992; Osborn, 1963) | • Define the problem.<br>• Generate as many solutions as possible without evaluating them.<br>• Decide on criteria for judging potential solutions.<br>• Use these criteria to select the best solution.. |

- **ASSESSING SKILL IN PROBLEM-SOLVING (pp. 213 – 230)[1]**
    - Problem Recognition Tasks – ask students to recognize and identify the particular type of problem given examples represent; helps students focus on diagnosing the problem first rather than rushing to try to solve it; helps faculty assess how well students can recognize various problem types, the first step in matching problem type to solution method; e.g. in psychology – given 6 case studies, identify whether each scenario represented substance abuse, family conflicts, depression, or academic stress
    - Documented Problem Solutions – ask students to solve 2 or 3 problems (easy and difficult) and briefly explain each solution step in writing; students learn to keep track of the steps; teachers can gain insight into the students' problem-solving skills – the explanation of the steps (the process) is emphasized not the actual solution (the product)
- **EXAMPLE PROBLEMS IN CLASS[2]**
- The use of example problems can serve as a tool for developing problem-solving skills as well as knowledge. All aspects of a problem-solving strategy can be utilized in an example problem.
- Once the problem statement is read from the text or hand-out, I ask the class to determine the given facts, what we are asked to find, and draw a diagram.
- Once this is completed, I ask the students to provide the solution steps. If a step is incorrect, we will still follow it until the class realizes that something is wrong.
- This shows students that it is OK to make a mistake, a common emotional block to creativity.
- By testing each solution procedure, we can determine errors in reasoning and also show alternate solutions.
- We check our results at each step in the process to determine the reasonableness of our answer.
- Different heuristic techniques can be utilized with different example problems to aid in the solution process [15] (see Table 2 for examples).
- Students can be asked to provide heuristics. Another approach is to try at least one new heuristic each week in class.
- Once the solution is obtained, the answer is checked to ensure reasonableness and accuracy.
- If a difficulty arises at any step in the process, this is the time to let the students loop back through the process or use heuristics to become "unstuck." Once the solution is complete, I ask the students questions which relate to the problem to increase their understanding. Which variable can we control? What happens to the solution if various variables are changed? It may be necessary to guide the students in this process. As their skills develop, the guidance can be reduced.

**TABLE 2**

- Some Heuristics or Guides
    1. Solve a simpler problem. Many times, a student can become immersed in a complicated problem and become "stuck." Simplifying the problem to a stage where the student recognizes the solution approach can aid in developing the actual solution procedure.
    2. Overcome excess anxiety. When a student becomes " stuck," they can develop a large amount of anxiety, which prevents effectively developing a solution. Awareness is the first step to combating this.
    3. Communicate your difficulty to another person. It is sometimes very beneficial to try to explain your situation to another person who is familiar with the subject. Describe what you have done and what you are trying to do. Often this will help to point out additional information or errors in reasoning.
    4. Brainstorming. When "stuck" on a problem, generate a list of words or phrases which immediately come to mind. Write everything down and defer judgment until you have exhausted the flow of information. Once this is completed, analyze the list and use judgement to determine any new relevant information.
    5. Personal analogy. Pretend that you have entered the system under study. Try to imagine what you see, feel, etc. This helps to "visualize" the situation.
    6. Look at extreme cases. Ask yourself a lot of "what if" questions to get a "feel" for how you think the system will respond. Have will to doubt. Focuses attention on different aspects of the problem.
    7. Incubation. Sometimes it is helpful to stop actively working on the problem when "stuck." Let the problem "incubate" for a while. Some insight may "pop up" into your conscious domain, or upon your return to the problem, you can see errors in reasoning or other obstacles to the solution that was not previously obvious.
- A good strategy to teach students is the one suggested by the mathematician Gyorgy Polya (5) because it is simple and straightforward, and it sounds right. Polya's strategy is recognized by many people as the sort of thing they have done when they have solved some problem successfully. The steps in Polya's strategy are as follows:
- DEFINE-
    - Identify the actual problem
- THINK ABOUT IT –
    - What are the attributes of the problem?
    - Identify the area of knowledge involved
    - Collect information

[1]Classroom Assessment Techniques,Taken from Classroom Assessment Techniques: A Handbook for College Teachers, 2nd edition by Thomas A. Angelo & K. Patricia Cross
[2]PUTTING PROBLEM SOLVING TO USE IN THE CLASSROOM ,RICHARD D. NOBLE University of Colorado Boulder, CO 80309

- PLAN –
  - Flowchart a solution
  - Think of alternate plans
  - Translate
- CARRY OUT PLAN
  - Solve the problem
- LOOK BACK
  - Verify that problem solved was the one originally defined.
  - Check reasonableness and math
  - Check criteria and constraints
  - Study related problems
  - Identify applications
  - Identify and memorize order-of magnitude numbers
  - Develop successive approximation strategies
  - Study the problem-solving skills learned
  - Communicate results
- Polya's original strategy included four steps: DEFINE, DEVISE A PLAN, CARRY OUT PLAN, and LOOK BACK. Woods added the THINK ABOUT IT step

**TABLE 1**
**Bloom's Taxonomy of Knowledge**

| Level | Course | Laboratory |
|---|---|---|
| **Knowledge**—Recall memorized information. | What is Fourier's law of heat conduction? | Measure velocity of fluid in a pipe at five points along the cross-section. |
| **Comprehension**—Solve recognizable problem. | If the temperature gradient through a plance wall is tripled, what is the resulting change in the heat flux? | Compare the measured velocity distribution with laminar flow theory. |
| **Application**—Use memorized knowledge to solve unfamiliar problem. | What is the steady-state heat flux through a composite wall, given k's and boundary temperatures. | Determine the relevant data needed to test the laminar flow theory in pipes. |
| **Analysis**—Bring together remote relationships to solve problem. | A fire breaks out in a room adjacent to a fuel tank. How long before the fuel explodes? | Determine why the experiment for flow through a pipe does not agree with laminar flow theory. |
| **Synthesis**—Create alternative solutions to an open-ended problem and select best one. | Design a heat exchanger. Specify type and construction details. | Design an experiment to measure the velocity distribution in pipes. |



[15]. Schoenfeld, A., "Explicit Heuristic Training as a Variable in Problem Solving Performance," J. for Research in Mathematical Education, May 1979.

- Meaningful learning provides students with the knowledge and cognitive processes they need for successful problem solving.
- Problem solving occurs when a student devises a way of achieving a goal that he or she has never previously achieved, that is, of figuring out how to change a situation from its given state into a goal state (Duncker, 1945; Mayer, 1992).
- Two major components in problem solving are problem representation-in which a student builds a mental representation of the problem-and problem solution-in which a student devises and carries out a plan for solving the problem (Mayer, 1992).
- Consistent with recent research (Gick and Holyoak, 1980, 1983; Vosniadou and Ortony, 1989), the authors of the original Handbook recognized that students often solve problems by analogy. That is, they reformulate the problem in a more familiar form, recognize that it is similar to a familiar problem type, abstract the solution method for that familiar problem type, and then apply the method to the to-be-solved problem..

## d. Creativity

i. Creativity occurs through a process by which an agent uses its ability to generate ideas, solutions, and products that are novel and have value (or usefulness)[7]

ii. To observe Creativity in a classroom, Parameters used in the Torrance Test of Creative Thinking (TTCT) like fluency, originality, flexibility, and elaboration has been used

| Behavioural Involvement(Visual) | Verbal(Auditory) |
|---|---|
| 1. Involvement in the task(Intrinsic Motivation)[Example: involvement, work on stability, set breaking, and pace planning, and playfulness, exploration, enjoyment, and concentration] | Concrete Focus [Example: talking about the task] |
| 2. Exhibited Uncertainty[Example: self-initiated backtracks] | Concept Identification)[Example: analogies, "ahas," and transitions. Unexpected changes in thought and sudden inspirations characterized this aspect of the process.] |
| 3. Assuredness[Example: confidence, pace, and not encountering difficulty] | Difficulty [Example: problems with self and negative exclamations, characterizing individuals who said negative things both about their own abilities and about the task in general.] |
| | Wide Focus [Example: goal statements and irrelevant-to-task comments] |
| | Striving [Example: difficulty, transitions, questioning how to do something, repeating something, and exclamations (both positive and negative).] |

Looking Inside the Fishbowl of Creativity: Verbal and Behavioral Predictors of Creative Performance
John Ruscio , Dean M. Whitney & Teresa M. Amabile Published online: 08 Jun 2010

- For instance, Torrance (1979) used fluency and flexibility as two measures for creativity, which in the novelty hierarchy are represented by ‘many’ and ‘varied’.[1]
- Performance in this activity is scored on three scales: Fluency, Flexibility, and Originality.
- Fluency is defined as "the test taker's ability to produce a large number of ideas with words”.
- Flexibility is defined as "a person's ability to produce a variety of kinds of ideas, to shift from one approach to another, or to use a variety of strategies."
- Originality is defined as "the subject's ability to produce ideas that are away from the obvious, commonplace, banal, or established." (Torrance, 1974b, p. 57) [2]
- Fluency Examples
    - Math-Describe ways to see the number 24 (number sense).
    - Science-List things that require energy.
- Flexibility Examples
    - Science-List beneficial things about fossil fuels, how the British view U.S. reactions to the BP oil spill, or alternate hypotheses for lab inquiry.
- Originality Examples
    - Math-Show 24 as a shape.
    - Science-Create an illustrated lab report from the point of view of one of the chemicals or a Glog of the sights and sounds of a cell’s life.
- Elaboration Examples
    - Math-Explain the steps on a poster or Glog. Decorate 3D shapes to show their dimensions and characteristics.
    - Science-Annotate a diagram or image of an insect, plant, cell, etc.[3]

[1] STUDYING ENGINEERING DESIGN CREATIVITY1 Developing a Common Definition and Associated Measures PRABIR SARKAR, AMARESH CHAKRABARTI Indian Institute of Science, Bangalore, India .p11
[2]A METHODOLOGICAL STUDY OF THE TORRANCE TESTS OF CREATIVITY ROBERT W. LISSITZ AND JOSEPH L. WILLHOFT University of Maryland
[3] Grow Creativity! By Candace Hackett Shively

More Examples

- Please write down as many as possible scientific uses as you can for a piece of glass. For example, make a test tube. (fluency, flexibility and originality)
- If you can take a spaceship to travel in the outer space and go to a planet, what scientific questions do you want to research? Please list as many as you can. For example, are there any living things on the planet? (fluency, flexibility and originality)
- Please think up as many possible improvements as you can to a regular bicycle, making it more interesting, more useful and more beautiful. For example, make the Tyres reflective, so they can be seen in the dark. (fluency, flexibility and originality)
- Suppose there was no gravity. Describe what the world would be like. For example, human beings would be floating. (fluency, flexibility and originality)
- Please use as many possible methods as you can to divide a square into four equal pieces (same shape). Draw it on the answer sheet. (flexibility and originality)
- There are two kinds of napkins. How can you test which is better? Please write down as many possible methods as you can and the instruments, principles and simple procedures. (flexibility and originality)
- Please design an apple-picking machine. Draw a picture and point out the name and function of each part. (flexibility and originality)

# [8] Automated Chi-squared test

```
import pandas as pd
import numpy as np
from scipy import stats
from scipy.stats import chi2_contingency



A = pd.read_excel('D:/vivek/Research/New_topic/design thinking/transcripts/all_in_one_vignette.xlsx')
A_Arr=np.array(A)
r,c=np.shape(A_Arr)
Pval=np.zeros([c,c])
ChiSq=np.zeros([c,c])
for j in range(c):
    B=np.array(A_Arr[:,j])
    for k in range(c):
        C=np.array(A_Arr[:,k])

        f00=0
        f01=0
        f10=0
        f11=0
        for i in range(r):
            if B[i]==1 and C[i]==1:
                f00=f00+1
            elif B[i]==0 and C[i]==1:
                f01=f01+1
            elif B[i]==1 and C[i]==0:
                f10=f10+1
            elif B[i]==0 and C[i]==0:
                f11=f11+1

        Data_Obs=np.array([[f00,f01,f00+f01],[f10,f11,f10+f11],[f00+f10,f01+f11,f00+f10+f01+f11]])
        Data_Exp=np.array([[(f00+f10)*(f00+f01)/(f00+f10+f01+f11),(f00+f01)*(f01+f11)/(f00+f10+f01+f11),f00+f01],[(f00+f10)*(f10+f11)/(f00+f10+f01+f11),(f01+f11)*(f10+f11)/(f00+f10+f01+f11),f10+f11],[f00+f10,f01+f11,f00+f10+f01+f11]])
        Dev=(Data_Obs-Data_Exp)**2/Data_Exp

        ChiSq[j,k]=sum(sum(Dev))
        Pval[j,k]=stats.chi2.pdf(ChiSq[j,k],1)

header = pd.MultiIndex.from_product([list(A.columns)])
df2 = pd.DataFrame(Pval,columns=header,index=header)
df2.to_excel("PVal.xlsx")


header = pd.MultiIndex.from_product([list(A.columns)])
df2 = pd.DataFrame(ChiSq,columns=header,index=header)
df2.to_excel("ChiSq.xlsx")
```

**Nonparametric Statistics**

•Nonparametric statistics are easy to use but do not offer the pinpoint accuracy of other statistical models.

•This type of analysis is often best suited when considering the order of something, where even if the numerical data changes, the results will likely stay the same.

•A histogram is an example of a nonparametric estimate of a probability distribution.

•Nonparametric statistics make no assumption about the sample size or whether the observed data is quantitative.

•The main reasons to apply the nonparametric test include the following:

1. The underlying data do not meet the assumptions about the population sample
2. The population sample size is too small
3. The analyzed data is ordinal or nominal

| Nonparametric Tests | Parametric Tests |
|---|---|
| Mann-Whitney U Test | Independent Samples T-test |
| Wilcoxon Signed Rank Test | Paired Samples T-test |
| Kruskal-Wallis Test | One-way ANOVA |
| Chi-squared Test | |

3. Correlation among variables
   i. Choosing a Statistical test
      a) Data type – Categorical variable
      b) One sample
      c) The test is supposed to seek a relationship among variables.

   Based on these answers **Chi-Square Test** for Independence has been chosen for hypothesis testing.

   ii. Chi-Square Test for Independence
      a) $\chi^2 = \sum(O_i - E_i)^2/E_i$

         where $O_i$ is the observed value, and $E_i$ is the expected value.
      b) Under the null hypothesis, this sum has approximately a chi-squared distribution whose number of degrees of freedom is (number of rows-1)*(number of columns-1)
      c) To calculate the p-value, we need $\chi^2$ and degrees of freedom

- Findings from correlational research can be used to determine prevalence and relationships among variables, and to forecast events from current data and knowledge. In spite of its many uses, prudence is required when using the methodology and analysing data.[Importance and use of correlational research Elizabeth A Curtis[1], Catherine Comiskey[1], Orla Dempsey[1] DOI: 10.7748/nr.2016.e1382 ]

## •Purpose of Correlation Analysis

•The primary purpose of correlation analysis is to:

•**Discover Relationships:** Correlation analysis helps researchers and analysts identify patterns and relationships between variables in their data. It answers questions like, "Do these variables move together or in opposite directions?"

•**Quantify Relationships:** Correlation analysis quantifies the strength and direction of associations between variables, providing a numerical measure that allows for comparisons and objective assessments.

•**Predictive Insights:** Correlation analysis can be used for predictive purposes. If two variables show a strong correlation, changes in one variable can be used to predict changes in the other, which is valuable for forecasting and decision-making.

•**Data Reduction:** In multivariate analysis, correlation analysis can help identify redundant variables. Highly correlated variables may carry similar information, allowing analysts to simplify their models and reduce dimensionality.

•**Diagnostics:** In fields like healthcare and finance, correlation analysis is used for diagnostic purposes. For instance, it can reveal correlations between symptoms and diseases or between financial indicators and market trends.

## Importance of Correlation Analysis

- **Decision-Making:** Correlation analysis provides crucial insights for informed decision-making. For example, in finance, understanding the correlation between assets helps in portfolio diversification, risk management, and asset allocation decisions. In business, it aids in assessing the effectiveness of marketing strategies and identifying factors influencing sales.
- **Risk Assessment:** Correlation analysis is essential for risk assessment and management. In financial risk analysis, it helps identify how assets within a portfolio move concerning each other. Highly positively correlated assets can increase risk, while negatively correlated assets can provide diversification benefits.
- **Scientific Research:** In scientific research, correlation analysis is a fundamental tool for understanding relationships between variables. For example, healthcare research can uncover correlations between patient characteristics and health outcomes, leading to improved treatments and interventions.
- **Quality Control:** In manufacturing and quality control, correlation analysis can be used to identify factors that affect product quality. For instance, it helps determine whether changes in manufacturing processes correlate with variations in product specifications.
- **Predictive Modeling:** Correlation analysis is a precursor to building predictive models. Variables with strong correlations may be used as predictors in regression models to forecast outcomes, such as predicting customer churn based on their usage patterns and demographics.
- **Identifying Confounding Factors:** In epidemiology and social sciences, correlation analysis is used to identify confounding factors. When studying the relationship between two variables, a third variable may confound the association. Correlation analysis helps researchers identify and account for these confounders.

In summary, correlation analysis is a versatile and indispensable statistical tool with broad applications in various fields. It helps reveal relationships, assess risks, make informed decisions, and advance scientific understanding, making it a valuable asset in data analysis and research.

[https://www.appinio.com/en/blog/market-research/correlation-analysis]

# 4. Chi-Square Test for Independence results

$H_o$ : Learning theories and 21st Century skills are independent
$H_a$ : Learning theories and 21st Century skills are dependent

| Observed | Behaviourism | Cognitivism | Constructivism | TOTAL |
|---|---|---|---|---|
| Critical thinking | 8 | 19 | 11 | 38 |
| Problem-solving | 6 | 17 | 9 | 32 |
| Creativity | 6 | 23 | 15 | 44 |
| The ability to work collaboratively | 2 | 8 | 7 | 17 |
| TOTAL | 22 | 67 | 42 | 131 |
| | | | | |
| Expected | Behaviourism | Cognitivism | Constructivism | TOTAL |
| Critical thinking | 6.38 | 19.44 | 12.18 | 38 |
| Problem-solving | 5.37 | 16.37 | 10.26 | 32 |
| Creativity | 7.39 | 22.50 | 14.11 | 44 |
| The ability to work collaboratively | 2.85 | 8.69 | 5.45 | 17 |
| TOTAL | 22 | 67 | 42 | 131 |
| | | | | |
| Deviation | Behaviourism | Cognitivism | Constructivism | |
| Critical thinking | 0.41 | 0.01 | 0.11 | |
| Problem-solving | 0.07 | 0.02 | 0.15 | |
| Creativity | 0.26 | 0.01 | 0.06 | |
| The ability to work collaboratively | 0.26 | 0.06 | 0.44 | |
| | | | | |
| Chi-squared | 1.87 | | Significance level = 0.05 | |
| p-value | 0.93 | | | |

p-value(0.93>0.05) suggests that data does not support a rejection of the null hypothesis

$H_o$ : Constructivism and The ability to work collaboratively are independent
$H_a$ : Constructivism and The ability to work collaboratively are dependent

| Observed | | The ability to work collaboratively | | |
|---|---|---|---|---|
| | | y | n | total |
| Constructivism | y | 7 | 2 | 9 |
| | n | 12 | 19 | 31 |
| | total | 19 | 21 | 40 |
| | | | | |
| Expected | | The ability to work collaboratively | | |
| | | y | n | total |
| Constructivism | y | 4.275 | 4.725 | 9 |
| | n | 14.725 | 16.275 | 31 |
| | total | 19 | 21 | 40 |
| | | | | |
| Deviation | | The ability to work collaboratively | | |
| | | y | n | |
| Constructivism | y | 1.74 | 1.57 | |
| | n | 0.50 | 0.46 | |
| Chi-squared | 4.27 | Significance level = 0.05 | | |
| p-value | 0.04 | | | |

p-value(0.04<0.05) suggests that data support a rejection of the null hypothesis. This means The ability to work collaboratively, and Constructivism are dependent

# The End