Information Processing Theory of Learning

Cognitive psychology represents one of the more dominants approach in psychology today. Even though there are widely varying views within cognitive psychology, there are a few basic principles that most cognitive psychologists agree with.

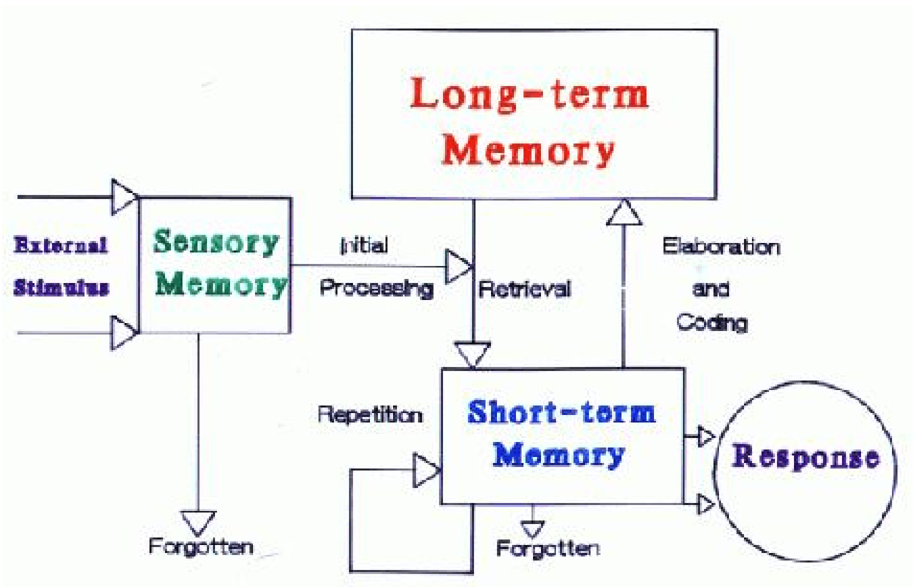
I. <u>General Principles/Assumptions</u>

1. The first is the **assumption of a limited capacity** of the mental system. This means that the amount of information that can be processed by the system is constrained in some very important ways. Bottlenecks, or restrictions in the flow and processing of information, occur at very specific points.
2. A second principle is that a **control mechanism is required** to oversee the encoding, transformation, processing, storage, retrieval and utilization of information. That is, not all of the processing capacity of the system is available; an executive function that oversees this process will use up some of this capability. When one is learning a new task or is confronted with a new environment, the executive function requires more processing power than when one is doing a routine task or is in a familiar environment.
3. A third principle is that there is a **two-way flow of information** as we try to make sense of the world around us. We constantly use information that we gather through the senses (often referred to as bottom-up processing) and information we have stored in memory (often called top-down processing) in a dynamic process as we construct meaning about our environment and our relations to it. This is somewhat analogous to the difference between inductive reasoning (going from specific instances to a general conclusion) and deductive reasoning (going from a general principle to specific examples.) A similar distinction can be made between using information we derive from the senses and that generated by our imaginations.
4. A fourth principle generally accepted by cognitive psychologists is that the human organism has been **genetically prepared to process and organize information in specific ways**. For example, a human infant is more likely to look at a human face than any other stimulus. Given that the field of focus of a human infant is 12 to 18 inches, one can surmise that this is an important aspect of the infant's survival. Other research has discovered additional biological predispositions to process information. For example, language development is similar in all human infants regardless of language spoken by adults or the area in which they live (e.g., rural versus urban, Africa versus Europe.). All human infants with normal hearing babble and coo, generate first words, begin the use of telegraphic speech (e.g., ball gone), and overgeneralize (e.g., using "goed to the store" when they had previously used "went to the store") at approximately the same ages. The issue of language development is an area where cognitive and behavioral psychologists as well as cognitive psychologists with different viewpoints have fought many battles regarding the processes underlying human behavior. Needless to say the disussion continues.
5. Cognitive processes are critical in determining what is learned.
6. Learning is an internal process that may or may not result in a behavior change.
7. Inferences can be drawn about cognitive process by observing how people respond to specific stimuli.
8. Some learning processes are specific to humans.
9. People are actively involved in their own learning.
10. People are selective about the things they process and learn.
11. People impose their own meaning on environmental events (i.e., interpret/construct our own understanding/knowledge of our environment). This is a constructivist approach to learning and memory, i.e., the construction of our knowledge from our own experiences.

II. Models of Human Information Processing

A. Stage Model of Information Processing

One of the major issues in cognitive psychology is the study of memory. The dominant view is labeled the "stage theory" and is based on the work of Atkinson and Shiffrin (1968). This model will be discussed in more detail below.



This model proposes that information is processed and stored in 3 stages.

1. **Sensory memory / Sensory Registry** (STSS). Sensory memory is affiliated with the transduction of energy (change from one energy form to another). The environment makes available a variety of sources of information (light, sound, smell, heat, cold, etc.), but the brain only understands electrical energy. The body has special sensory receptor cells that transduce (change from one form of energy to another) this external energy to something the brain can understand. In the process of transduction, a memory is created.

   The sensory registry is a temporary store (holding place) of unanalyzed information in memory. Its storage capacity is generally very limited as information can only remain here for brief amounts of time, i.e., less than 1/2 second for vision; about 3 seconds for hearing.

   It is absolutely critical that the learner attend to the information at this initial stage in order to transfer it to the next one. There are several important points that we should consider as we attempt to get the learner's attention.

2. **Primary / Short-term memory** (STM).

   Short term memory was postulated to explain short term forgetting effects (as distinct from longer term effects). However, it is now believed that short term forgetting has the same character as long term forgetting. It just happens quicker because it involves information that is not learned as well. The shape of the forgetting curves are the same.

   Between sensory and long term memory.
   Place to rehearse new information from sensory buffers.
   Limited capacity (Miller's 7 plus or minus 2).
   Probability of encoding in LTM directly related to time in STM.

   Short-term memory specifically refers to holding information in conscious awareness for a short period of time. It is the result of our attenuating to an external stimulus, an internal thought, or both. It will initially last somewhere around 20-30 seconds unless it is repeated (maintenance rehersal) at which point it may be available for up to 20 minutes.

Another major limit on information processing in STM is in terms of the number of units that can be processed at any one time. Miller (1956) gave the number as 7 $\pm$ 2, but more recent research suggests the number may be more like 5 $\pm$ 2 for most things we are trying to remember.

There are three major concepts for getting information into STM:

First, individuals are more likely to pay attention to a stimulus if it has an **interesting feature**.

Second, individuals are more likely to pay attention if the stimulus activates a **known pattern**.

Call to mind relevant prior learning

Third, because of the variability in how much individuals can work with it is necessrary to

Point out important information

There are two major concepts for retaining information in STM: organization and repetition.

Specific examples of organization include:

Component (part/whole)--classification by category or concept

Sequential -- chronological; cause/effect; building to climax

Relevance -- central unifying idea or criteria

Transitional (connective) -- relational words or phrases used to indicate qualitative change over time

Chunking (grouping into units) is a major technique for getting information into short-term memory

Repetition must be done after forgetting begins. Researchers advise that the learner should not repeat immediately the content (or skill), but wait a few minutes and then repeat.

1. **<u>Secondary / Long-term memory</u>** (LTM)-- elaboration, distributed practice
   Specifically refers to information which has been removed from conscious awareness, but is retrievable after extended periods of time.

LTM Storage Process: How we get information into LTM

Visual imagery -- mental picture; can be extremely beneficial for reinforcing information and in the recall of information. *Encourage students to form visual images that capture what they are learning. *Present ideas in a visual manner -- e.g., pictures, charts, graphs.

coding -- strategies designed to improve memory through the use of a coding strategy external to the material being learned (Loci (locations); Pegword (number, rhyming schemes); Rhyming (songs, phrases); Inital letter)

Semantically specifically refers to what meaning we give to the information we are storing.

Meaningful Learning: refers to learning new information by relating it to previously learned information. Can be promoted in the classroom via multiple connections between new information and prior knowledge. For example, encouragement of students to learn new information by making it practical to them so that it will make sense to them.

Elaboration: refers to expanding on new information based on what one already knows. This often is beneficial in enhancing learning and remembering something more effictively.

Knowledge base: refers to information already in LTM. If we can relate new information to information already stored in memory, it will be a lot easier to learn and store. In order to take advantage of one's knowledge base however, that knowledge base must be relevant to the current new information. One's awareness of the relevance of prior knowledge can be extremely varied --

most individuals are unaware of just how much prior information relates to something newly encountered.

Mnemonics:

-- Define: Specific memory aids and tricks designed to help individuals learn & remember info.

- Often beneficial when new information is difficult to learn meaningfully
- What are some of the drawbacks to using mnemonic devices to learn some types of information? (exceptions to rules surrounding the info., etc.)
- Method of Loci

  The ancients remembered things by imagining taking a familiar walk, and placing the things to be remembered at locations along the way. This method works because

it organizes the material to be remembered

it encourages elaborative processing and memorable imagery.

Context-Dependent Learning

Physical and emotional context may be inadvertently coded as retrieval cues, along with the intended cues. Consistent with this idea, various studies show that recall is better when tested in the same context (physical or emotional) as in which learning took place.

(After learning this, I used to study for important exams in the same room as I would take them.)

However these results are variable.

<u>LTM and the Retrieval Process</u>

How quickly and reliably we recall information depends on:

Activation: How long since we last used the information.

Strength: How well we have practiced it.

Experimental Evidence: (Anderson 1976)

3. Subjects learn some sentences. Some sentences are studied twice as long as others.
4. Subjects must discriminate sentences they learned from distractors. They are tested for each sentence more than once, with varying intervening sentences.

Results:

Both amount of study and how recently the information was accessed affect speed of response.

However amount of study matters only if the information was not recently accessed (an **interaction** effect).

	Delay (number of intervening items):	
Degree of Study:	Short (0-2)	Long (3 or more)
Less Study	1.11 seconds	1.53 seconds
More Study	1.10 seconds	1.38 seconds

5. **<u>Working Memory</u>**

A concept closely related to primary memory is "working memory" (WM). However, working memory refers to a more complex attentional capacity for simultaneously storing and processing the information that is needed during cognitive performances. Specifically, working memory is a context specific, transient, prospective system that provides for selective temporary pooling and manipulation of information necessary for complex cognitive tasks such as planning, problem-solving, learning, comprehension, language, and reasoning (Baddeley, 1992, Pennington **xxxx**). When the task has been completed, the information is discarded from the mental work space (Domjan, 1993).

Because working memory is a limited capacity system, the pooling of information for manipulation is selective. The capacity of WM should not be viewed as a simple one of storage, but rather as operational capacity (Carpenter & Just, 1989). Working memory is distinct from short-term memory (STM) and long-term memory (LTM) in that it is context specific and transient (i.e., able to handle that which is unique and novel in context). It is also a prospective memory system with the ability to selectively access information from other memory systems (Pennington, **xxxx**). Prospective here refers to the ability to remember "processes and strategies involved in planning, monitoring, and organizing memory" (Shimamura, Janowsky, & Squire, p. 191, 1991) to be used in future actions.

Unlike long term memory, which has a large clinical body of research, working memory has only recently become the focus of intense clinical study. It is often assayed in intelligence or cognitive examinations using span tests, in which patients are asked to repeat a set of digits in reverse order (if I read "8-9-3-2-1-9", you would say "9-1-2-3-9-8") or alphabetize a group of words that had been read aloud. Studies of patients with various frontal lobe lesions do not show a systematic deficit in storage. These studies indicate that working memory is not one process; rather, it is made up of several separable processes.

Baddeley's Theory of WM.

Alan Baddeley, in his landmark book Working Memory, captures three decades of psychological work on working memory systems. Many working memory experiments simply consist of stimuli that are to be remembers for a few seconds. A typical task might ask you to remember a few letters, numbers, or features of an object. Typically, there is a brief delay, after which the subject is 'probed', or asked what he or she remembers. From extensive studies like these, Baddeley proposed a model of working memory that involved three distinct subsystems. The best described is the 'phonological loop', a system that draws upon speech resources. For example, if I wanted to remember a set of numbers, I might catch myself whispering to myself -- it turns out that speech systems are an integral part of working memory. The second component is the visuospatial sketchpad, a parallel system akin to an artist's sketchbook for stimuli that cannot be verbalized, such as spatial information. The third main unit is the central executive, a system responsible for supervisory attentional control and cognitive processing. This last system, though poorly defined, is most alluring because it represents the very stuff of thought.

The primary problem with Baddeley's theory of working memory is that it treats WM as nothing more than a mere extension of STM. This early theory of WM doesn't necessarily meet the criteria that has evolved over the few decades from several disparate, but related domains.

Articulatory Loop

Rehearsal limitations are due to limits in how long it takes verbal material to decay, not how many items we can store. Hence, the faster we can rehearse, the more we can store (Baddeley, 1986).

Experimental support:

Word length effect. How long it takes to read words predicts how many words will be remembered. (Try experiment.)

Articulatory loop is called the **phonological loop** due to evidence that it involves speech.

We can rehearse about 1.5 seconds of verbal material before it decays.

Time in the loop is *not* related to probability of coding in LTM.

Baddeley's model proposes that we have a **visuospatial sketchpad** as well as the phonological loop. These hold information for use by a **central executive.**

There is evidence that a particular area of the frontal cortex is involved in working memory.

Where is Working Memory in the Brain?

The rich psychological research, the simplicity and fundamental nature of working memory systems, and the adaptability of working memory experiments make it ripe for new brain imaging technologies. Both PET and fMRI capitalize on properties of cerebral blood flow to make inferences about underlying neural activity. Founded upon Baddeley's model of working memory, investigators have begun to explore neural correlates of working memory. Several neuroimaging studies provide evidence for a distinct neurological basis for a phonological loop, as well as separate processes for storage of items and retrieval. During the storage phase of verbal working memory tasks, activity is found in Broca's area (involved in speech production) in addition to supplementary and premotor areas (involved in movement) in frontal cortex, and is strongly consistent with activity in areas involved in preparation of speech from other neuroimaging studies. In addition, different networks are involved in retrieval as compared with storage in the left lateralized frontal cortex.

The neural correlates of spatial or object storage, in pursuit of the visuospatial sketchpad, is somewhat more tenuous. Neuroimaging studies yield that there are different areas activated in spatial or object memory tasks compared to those in verbal working memory tasks. Neuroimaging studies also suggest a difference in storage systems compared with retrieval systems in spatial or object working memory, indicating that there are again separate networks at work.

The Elusive Central Executive

The most fascinating line of inquiry confronts the idea of a 'central executive', a control system that mediates attention and regulation of processes occurring in working memory. The idea of a central executive was first postulated by Baddeley. Many investigators have seen evidence supporting the idea of a central executive; they have observed higher cognitive activity in an area in the prefrontal cortex, called DLPFC (Dorsolateral Prefrontal Cortex - An area on the lateral aspect of the brain near the front that is associated with executive function, decision making, and working memory.), during difficult tasks. This area shows activity during object working memory, and what are termed 'executive processes', such as planning, focusing attention on an object, switching between tasks, and 'inhibition' of short term storage (which are often tested using probes designed to distract subjects). One powerful design to study executive processes is to tax working memory systems to its capacity, or to present the subject with two tasks to perform simultaneously. As the reasoning goes, if you make working memory systems work hard, the central executive will intervene to manage the increased load. Examples of such difficult tasks include remembering a set of numbers while doing simple math or the famous Stroop task, where color names are presented in different colors ("red", for example, might be presented in green text).

A few neuroimaging studies using these difficult tasks support the notion of a central executive control system. In one fMRI study conducted at the University of Pennsylvania, participants had to place objects in a category and decide whether two visual displays differed by rotation. In the dual task condition, frontal areas showed increased activity, including DLPFC and the anterior cingulate gyrus (an attentional area; An area of the brain associated with motor control, pain perception, cognitive function and emotional arousal. A component of the limbic system.). Both areas are active in attention and inhibition tasks, and the anterior cingulate has been implicated in PET studies of the Stroop test. Despite these studies, the concept of a central executive still remains tantalizing and mysterious, and much further exploration remains to be done.

III. Alternative Information Processing Models

In addition to the stage theory model of infomation processing, there are a three more that are widely accepted.

1. The first is based on the work of Craik and Lockhart (1972) and is labeled the "**levels-of-processing**" theory. The major proposition is that learners utilize different levels of elaboration as they process information. This is done on a continuum from perception, through attention, to labeling, and finally meaning. The key point is that all stimuli that activate a sensory receptor cell are permanently stored in memory, but that different levels of processing (i.e., elaboration) contribute to an ability to access that memory. Evidence from hypnosis and forensic psychology provide some interesting support for this hypothesis. This approach has been extended by Bransford (1979) who suggests that it is not only how the information is processed, but how the information is accessed. When the demands for accessing information more closely match the methods used to elaborate or learn the information, more is remembered.

   Depth of Processing

   Craik and Lockhart (1972) proposed that strength of memory depends on how *deeply* information is processed, not on how long it is processed. This specific model views human memory as a "by-product of depth of analysis".

   Deeper levels of analysis are associated with more elaborate, longer lasting and stronger memories. What is needed for real learning is meaning, and the extraction of meaning involves the deeper levels of processing. Processing levels can be viewed as a continuum: at one extreme, a brief sensory analysis, a sight or a sound, will give rise to memory traces that are transient and easily disrupted. At the other end of the continuum, the process of deep semantic analysis will lead to a more permanent memory.

   This 'levels' approach assumes that information that seems immediately meaningful, perhaps because it is highly familiar, is easily remembered because it is compatible with previously existing cognitive structures. Such material will be easier to process to deep levels. Depth of processing will be affected by several things: the amount of attention given, the relation to existing cognitive structures, and the amount of time available for analysis.]

   Craik and Tulving (1975) undertook a long series of experiments in order to find empirical evidence for this idea. The usual procedure followed in their experiments was to present words to subjects and to ask a variety of questions designed to influence depth of processing. Shallow levels of processing were achieved by asking about the nature of the typescript, "Is the word in capital letters?"; intermediate levels by asking for a judgement about phonemic similarity "Does the word rhyme with...?"; deep encodings were encouraged by asking whetherthe word would fit into a certain sentence or semantic category "Is the word a member of the following group...?". The deepest level of encoding took the longest time and produced the highest subsequent retention. However, time to encode was shown not to be the critical factor. A complex but shallow task will take longer to perform but will still yield lower memory scores than an easy but deeper processing task. What is critical is the richness of elaboration with which the information is encoded.

The crucial point of Craik & Lockhart's (1972) theory is that learning is a by-product of comprehension. Although this point was buried in the literature of the cognitive psychology of memory, it underpins the constructionist approach to education which emphasises the importance of the learner's activity - active versus passive learning.

Having said all of that, in short:

1. Shallow processing of information involves the information being processed in thw ways that it actually looks or how the human senses actually record it. With shallow processing, the information will not be remembered as well as it would with deep processing.
2. In deep processing, information is processed in terms of its meaning, this meaning may be analysed in terms of other association, images ,or past experiences which are related to the information being processed.

With either shallow or deep processing, a memory trace is created. In shallow processing, the memory trace will be fragile and information will be quickly forgotten. With deep processing, the memory trace will be durable and information will be remembered.

Processing Meaning:

Some lab studies compare tasks that require processing meaning of words versus form (e.g., what letters do they have).

Elaboration:

Other studies show benefits of connecting the items to be remembered to other related information (e.g., elaborating on sentences to be remembered, or rhyming).

Intention does not matter:

Subjects in deeper processing conditions do better regardless of whether they know they will need to remember the processed items.

What are the implications for your study habits?

PQ4R Method

P:

Preview the material

Q:

Make up questions

R:

Read, trying to answer the questions

R:

Reflect while you read. Think of examples, relate it to what you know.

R:

Recite the information in each section after you've read it. Re-read what you can't recall.

R:

Review the major points and the answers to your questions at the end.

Question generation is at least as beneficial as question answering.

Questions generated before the material rather than after may be more beneficial

2. Two other models have been proposed as alternatives to the Atkinson-Shiffrin model: **parallel-distributed processing** and **connectionistic**. The parallel-distributed processing model states that information is processed simultaneously by several different parts of the memory system, rather than sequentially as hypothesized by Atkinson-Shiffrin. Work done on how we process emotional data somewhat supports this contention. The stage-theory model shown above differs slightly from that first proposed in order to incorporate this feature.

3. The **connectionistic** model proposed by Rumelhart and McClelland (1986) extends the parallel-distributed processing model. It is one of the dominant forms of current research in cognitive psychology and is consistent with the most recent brain research. This model emphasizes the fact that information is stored in multiple locations throughout the brain in the form of networks of connections. It is consistent with the levels-of-processing approach in that the more connections to a single idea or concept, the more likely it is to be remembered.

4. **Spreading Activation Model**

When information becomes easier to access as a result of having been used recently, we say it is more *activated.*
This activation spreads between semantically related concepts.
Empirical Evidence: Various.
Subjects are faster at confirming that a pair of words are both words if the second word is an associate of the first, for example, "bread, butter" (Meyer and Schvaneveldt 1971).
Given a word, subjects are asked to give an associated word. Their response is faster if subjects have responded with an associated word on a previous trial (Perlmutter and Anderson, figure 6.8).
Speed of activation seems to be about 200ms (as measured by Ratcliff and McKoon, 1981).
Implication: Text is easier to read if semantically related words are used.

IV. <u>Organization (types) of knowledge</u>

Declarative Memory
Semantic Memory-- facts and generalized information (concepts, principles, rules; problem-solving strategies; learning strategies)
Schema / Schemata -- networks of connected ideas or relationships; data structures or procedures for organizing the parts of a specific experience into a meaningful system (like a standard or stereotype)
Proposition -- interconnected set of concepts and relationships; if / then statements (smallest unit of information that can be judged true or false)
Script -- "declarative knowledge structure that captures general information about a routine series of events or a recurrent type of social event, such as eating in a restaurant or visiting the doctor" (Stillings et al., 1987)
Frame -- complex organization including concepts and visualizations that provide a reference within which stimuli and actions are judged (also called "Frame of Reference")
Scheme -- an organization of concepts, principles, rules, etc. that define a perspective and presents specific action patterns to follow
Program -- set of rules that define what to do in a particular situation
Paradigm -- the basic way of perceiving, thinking, valuing, and doing associated with a particular vision of reality (Harman, 1970)
Model -- a set of propositions or equations describing in simplified form some aspects of our experience. Every model is based upon a theory or paradigm, but the theory or paradigm may not be stated in concise form. (Umpleby)
Episodic Memory-- personal experience (information in stories and analogies)
Procedural Memory-- how to (driving a car, riding a bike)
Imagery -- pictures

V. Concept formation

definition -- development of categories used to group similar events, ideas or objects
assisting concept formation
name and define concept to be learned (advance organizer)
a. reference to larger category
b. define attributes
identify relevant and irrelevant attributes (guided discovery)
give examples and nonexamples (tie to what is already known -- elaboration)
use both inductive and deductive reasoning
inductive -- example --> definition
deductive -- definition --> examples
Name distinctive attributes (guided discovery)

VI. Factors Affecting Retrieval

1. Making multiple connections with existing knowledge -- the more connections, the easier it will be to remember and retrieve the information at will.
2. Learning information to mastery -- the more we are able to master the current information, the easier it is to accommodate and assimilate new information that is related. The more we are able to master a piece of information, the easier it is to recall it at will and the faster it becomes automatized.
6. Using information frequently -- the more we use or do something, the better we get at it. Practice is always beneficial to learning and mastery of skills & knowledge. Frequent use eventually leads to automaticity.
7. Having a relevant retrieval cue -- whatever we use to help us retrieve information must be relevant or we will have difficulty in retrieving.

VIII. Forgetting: Gone, or Inaccessible?

Do we forget because the information is gone, or do we forget because we can't access information that is still there?

Difficult to distinguish the two. However, there is evidence that we retain more than we can retrieve.
Experiment: (Nelson 1971)

Learn paired associates (numbers to nouns)
Tested 2 weeks later to see which were remembered.
Then given new material to learn that had some of the "forgotten" numbers, both with and without their original nouns.

Results:

Subjects relearned the original associations faster (in spite of the fact that they could not recall them).

This suggests that some associative information was retained.
One possible interpretation: strength of memories decay gradually. If these strengths fall below a certain threshold, we can't recall the information, but the remaining memory trace is still there to facilitate relearning.
Note: Don't generalize these laboratory results to the debate on repressed memories of childhood abuse, etc.

I. <u>Why we Forget</u>

1. Failure to retrieve -- refers to failure to locate information currently existing in LTM.
2. Reconstruction Error -- refers to the occurrence of only partial information being retrieved from LTM; we construct "logical" memory by using the retrieved information plus one's general knowledge of our world.
3. Interference -- refers to various assumptions/characteristics, usually among similar items, in LTM that interfere or compete with one another during the retrieval process.
4. Decay -- refers to information becoming weakened over time; may be due to insufficient use of the information.
5. Failure to store -- refers to the fact that the information was never processed in a way that promoted its storage in LTM.

USING THE INFORMATION PROCESSING APPROACH IN THE CLASSROOM

Principle	Example
1. Gain the students' attention.	Use cues to signal when you are ready to begin. Move around the room and use voice inflections.
2. Bring to mind relevant prior learning.	Review previous day's lesson. Have a discussion about previously covered content.
3. Point out important information.	Provide handouts. Write on the board or use transparencies.
4. Present information in an organized manner.	Show a logical sequence to concepts and skills. Go from simple to complex when presenting new material.
5. Show students how to categorize (chunk) related information.	Present information in categories. Teach inductive reasoning.
6. Provide opportunities for students to elaborate on new information.	Connect new information to something already known. Look for similarities and differences among concepts.
7. Show students how to use coding when memorizing lists.	Make up silly sentence with first letter of each word in the list. Use mental imagery techniques such as the keyword method.

8. Provide for repetition of learning.	State important principles several times in different ways during presentation of information (STM). Have items on each day's lesson from previous lesson (LTM). Schedule periodic reviews of previously learned concepts and skills (LTM).
9. Provide opportunities for overlearning of fundamental concepts and skills.	Use daily drills for arithmetic facts. Play form of trivial pursuit with content related to class.

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