Chapter 7
Effective Learning: A Neurological/Mental Process

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7.1 Background

This text has been written based on more than five decades of teaching and research experience of the author in the field of technical and vocational education, as well as consulting appropriate literature mentioned in the references including discussions which the author used to hold with one of his senior colleagues late Professor PD Kulkarni at NITTTR, Chandigarh. The author enjoys writing and sharing his experiences on the subject of learning, which in fact is connected with God-gifted neurological/mental system of learning. This has been written in the context of higher education which requires "intentional-conscious learners" to develop acquisitive, adaptive, operative, innovative, and ultimately business development competencies [discussed later]. The chapter is based on mental process of learning to imbibe new learning based on existing knowledge of each learner in the neurological system of all humans for furtherance of knowledge. While imparting instructions, majority of teachers in higher education don't pay desired attention of existing knowledge of students for learning knowledge.

There is lot of educational terminology which may cause hindrance to readers, but conscious reading will make the text easy to understand because meaning of each unknown word/term is clearly spelled out. Teaching and learning are interconnected aspects which require clear understanding of domain-specific concepts, principles, and procedures, coupled with appropriate exposure of the world of work in the concerned domain, and clarity of mental learning procedures by all the teachers

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for effective learning at the part of learners. In the process of learning, it is important to understand the difference between teaching and learning.

Teaching is the process of imparting factual information by the teachers to the learners based on the objectives of instruction. It is considered as teacher-centered learning. This may be teaching of concepts, principles, procedures, or practices. In teaching, teachers are active and students are passive listeners. It is considered as traditional method.

Learning is the mental process of acquiring knowledge/information, skills, and attitudes based on the educational objectives so that the learners may use or apply in later situations and under conditions different from those of instruction. Therefore, in learning students are active and teachers are passive. Learning is performance based. It is student-centered learning. Teaching has no meaning if students are not able to perform as per instructions imparted. Therefore learning is change in the behavior of students for achieving desired performance.

Therefore, teachers are expected to select appropriate **teaching strategies** and **teaching methods** which advocate active participation of learners during instruction, which tends to minimize the use of lecture method, in which students are relatively passive, and promotes the choice of more learner active methods such as tutorials, laboratory/workshop sessions, seminars, self-instructional packages, industrial experiences, project work, problem-based learning (PBL), etc.

Teachers are also expected to use teaching tactics which are specific ways that one chooses to implement a particular method in a particular case/situation to cause better learning to bring about desirable change in the behavior of the learner to work effectively in the world of work. It is brought about by using teaching strategies, methods, and tactics to achieve desired educational/instructional objectives.

In the ancient days learning was a matter of speculation for philosophers and theologians. Later in the early twentieth century, learning was taken out of the purview of philosophers and taken over by scientists. Human beings learn in two ways. In one, they notice stimuli from the environment and respond impulsively to satisfy their basic needs like hunger and thirst and then go on to satisfy their other needs like physical security, maintaining a sense of social belongingness, and self-esteem. These were the areas studied by early behaviorists. In their theory, there was no role played in learning by neurological/mental events of a learner. Later, social cognitive theorists accepted that all learners who observe and imitate a model behavior make use of memories to retain images of the behavior similar to that of a model. It was here for the first time that **conscious aspect of learning** was noticed by the researchers.

When all deficient needs mentioned above were fulfilled, the learner resorted to self-actualization. Self-actualization means trying to improve one's own knowledge and skills consciously in order to perform well in the society. This aspect of conscious learning was picked up by cognovits who developed further theories called **information processing, constructivism, and contextual learning** by focusing their attention on neurological/mental events of a learner. In today's context, people have to think before they act. Hence cognition is becoming a dominant perspective in the educational research. In view of its dominance in higher education, this

chapter is trying to introduce more of mental process of learning in detail, based on author's study, practice, and gaining experience in this domain.

7.2 Information Processing View of Learning

The information process theory explains how learner uses his memory system comprising of sensory registers [SR], working memory [WM], and long-term memory [LTM] to receive new information from the environment, store it temporarily in working memory to process it for understanding, and organize new information and store it permanently in LTM. LTM processes this integrated new information for retrieving it for later use. Later they developed the concept of **metacognition,** which means knowing the process of learning both incidentally and consciously. Using this knowledge, the learner knows how to convert himself/herself into an **intentional learner,** which means an intentional learner is expected to take control of his/her own learning, monitor the learning, and maintain motivation to continue learning for the entire life.

The cognovits have made further advances in the areas of **nature of knowledge,** i.e., factual concepts, schemas, scripts, personal theories, and world views in an individual and also scientific and professional knowledge acquired collectively by researchers and professionals. It is important to distinguish between the personal **idiosyncratic** [individual/distinctive] knowledge and scientific knowledge because the formal higher education is intended to make the student from his/her idiosyncratic knowledge to the scientific knowledge. Figure 7.1 provides details regarding neurological/mental information processing view of learning.

As mentioned earlier, information processing theory is based on the use of a leaner of three memory systems – sensory registers [SR], working memory [WM], and long-term memory [LTM].

7.3 Part I – Long-Term Memory [LTM]: Storage of Information

- Sensory registers [SR], i.e., eyes, ears, smell, taste, and kinetic movements, receive new information from the environment through seeing, hearing, touch, taste, smell, and actions (see Fig. 7.1 under SR). This information is normally held for just 2 s.
- This information moves from SR to WM where it is held for a longer time (2–20 s) and consciously for understanding by linking the new information to what is already stored in LTM. This helps the learner to make the raw information received from SRs more differentiated, elaborated, and organized [discussed later].

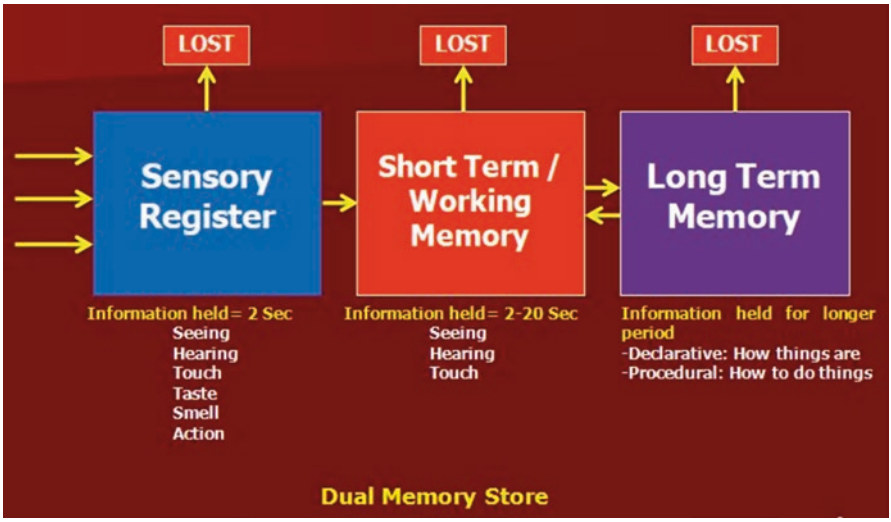

Fig. 7.1 Mental information process through dual memory system

- Such organized knowledge is now moved to LTM for long-term storage and easy retrieval for later use (like Ohm's law).
- This process is now repeated as another set of new information impinges the sensory registers and stored through WM to LTM (like modulus of elasticity).

It is important to note that each type of memory has its own particular feature like **capacity, form, and duration** of stored information.

Sensory register holds unlimited information (capacity) in different sensory registers in the same form as it is received by each of them, but it stays only for less than a second (duration). All information is not attended to by WM. Based on previous knowledge, only part of it moves to WM for further processing.

Working memory can hold only 5–9 units of information in the form of visual, auditory, and touch form and to a lesser extent smell and taste as they play minor role in information processing. WM can hold information for a period between 2 and 20 s depending upon the time required for processing different pieces of information.

WM focuses its attention on information in SR in two ways:

- Attention is automatically drawn to the information in SR when it has moving objects, object of usual size and intensity, novelty, incongruity, and objects and events which are likely to evoke emotions.
- When such information moves to WM, it is held for longer period for cognitive processing. Attention focuses only on some aspects of information held in WM, draws it, and converts it into a meaningful picture.

Long-term memory [LTM] stores knowledge of two types:

- Declarative (how things are)
- Procedural (how to do things)

Its capacity is much large; in fact the more information is stored in LTM, the more it can store.

Declaration knowledge is stored in three forms: **symbolic** (symbols, words, and language), **iconic** (images – visual, auditory), and **enactive** (actions, behaviors, and responses).

Some knowledge in LTM is implicit which is acquired during execution of daily activities, also called incidental activities. This implicit knowledge is not accessible to the conscious processing, but it strongly affects behavior. What is consciously processed and acquired is explicit knowledge and it can be retrieved. In LTM, every piece of information is interrelated.

There are educational implications for all teachers to note. Whatever information teachers wants to pass on to a learner, the learner alone control his/her learning. Learner uses his/her memory to select what he/she thinks is important based on his/her prior learning about the subject. Since initially student's attention is diverted by the nature of information teacher presents, teacher must maintain student's interest in the topic by bringing variety in his/her presentation (change intonation, intermittently asking questions, monitoring student's attention, making them reflect on their past knowledge, etc.). In addition, the teacher has to organize student's learning in such a way that the learner can store and retrieve information in LTM successfully.

Let us now study the process of organizing learning for LTM storage of knowledge, nature of knowledge finally stored, and process of retrieval of stored knowledge.

7.3.1 Construction of Storage

We have seen in the previous section that learner's WM attends only part of the sensory inputs and makes it meaningful based on his prior knowledge about a topic. Thus the learner constructs his/her own knowledge from the partial sensory input he/she notices. This constructed knowledge may not be the same which the teacher wants to convey. Similarly, the learner is likely to interpret any vague information in more than one way. Thus in the ultimate analysis, students do not retain the same information which the teacher has passed on but only that student's mind has constructed.

7.3.2 Storage Process

WM employs six learning processes which facilitates storage of declarative knowledge in LMT: selection, rehearsal, meaningful learning, internal organization, elaboration, and visual imagery which are briefly discussed below.

Selection As already explained before, the learner always selects only that part of sensory input which he/she considers important based on the prior knowledge about the topic the teacher teaches. While the teacher maintains the same speed of presenting information, the learner ultimately listens to only one fifth of the total presentation. The more familiar is the presentation to the learner, the faster is the rate of selection.

Teachers should take care to regulate the pace of presentation so that the leaner selects major portion of his/her presentation. Another way to build redundancy in the presentation is by repeating the same concept in more familiar terms.

Rehearsal Since mental processes for meaningful understanding take time, the new information should be held in WM for some time. This is done by repeating verbally the same information over time. Another way is by elaborative rehearsal, i.e., by trying to explain the new information by linking it with what the learner already knows. This prevents new information from fading from WM. Elaborative rehearsal also prevents rote learning by the learner.

Meaningful Learning This is a very important process in learning. Here the learner neurologically/mentally/cognitively processes the new information by relating his/her existing knowledge stored in LTM. When the new information is in the nonverbal form such as pictures, sound, smell, taste, and touch, it is first given a "label" which provides meaning to the nonverbal information.

Internal Organization Relating new information to the information already stored, as is done in meaningful learning, is called "external organization." But any new information also has its own internal structure. For example, new concepts are organized into hierarchy of subordinate concepts like animals are classified into "vertebrates" [like fish, mammals, birds, reptiles, amphibians] and "invertebrates" [like mollusk, insects, creepy-crawlies, etc.]. Short sentences can be organized into a proportional network which is interdependent on the agent, object, and relationship, e.g., Mary has an uncle. Mary is the agent, and object is uncle has relation and then converted into proportional network.

Elaboration When learner receives new information, say a concept word, the whole meaning is not clear. Learner tends to impose meaning by adding statements based on his/her prior knowledge. Thus, the leaner tries to make his/her understanding of the ambiguous information more precise. But these statements must be accurate and in tune with scientific assumptions. If the assumptions on which it is based are accurate and in tune with scientific assumptions, this is the better way of under-

standing new but vague information, and the understanding is also improved when the additional statements the learner uses are precise. Such elaborated new information is effectively stored in LTM.

Visual Imagery Visual imagery is a mental picture of how objects and events look like. Visual image supports understanding of verbal information/material. For example, the label "chair" is better understood when it is visualized as a picture showing four legs supported by a seat and a back. Similarly, event labels are better understood such as "visits to a restaurant" by visualizing activities one engages in a restaurant. Such combination of verbal text with its visual image helps effective storage of the text in LTM.

7.3.3 How Procedural Knowledge Is Acquired

A teacher does not teach merely declarative knowledge. He/she also teaches procedural knowledge. However, the process of learning procedural knowledge is different. Most of the procedural knowledge like driving a car and reading textual material for understanding is a complex combination of psychomotor skills and physical and mental activities. Only simple physical processes are learned in terms of actual behavior, e.g., riding a bicycle. But learning complex behavior requires a combination of physical and mental activities. The learner has to learn mental components as declarative statements that are learning information about how to organize mental activities. These verbal statements are required to be learned as explained above, i.e., by meaningful learning, internal organization, elaboration, and visualization and thus are stored in memory first. These elaborated statements are then used by the learner to mentally guide actual execution of procedures.

Since all this knowledge is to be acquired consciously, a lot of space and attention is consumed by WM. This slows down the speed of learning actual procedures. However, continued practice initially under guidance of declarative statement increases the speed of learning procedures. The use of declarative statement gets reduced till the procedures are learned to the level of automaticity. At this stage, the use of declarative statements fades completely. Further live demonstrations of procedures, illustrations, and visual imagery speed up the mastery of procedures.

7.3.4 Factors Affecting LTM Storage

Having understood how to learn complex declarative and procedural knowledge with the use of WM and cognitive processes, one should note the factors which may reduce the effectiveness of learning. These are listed below.

7.3.5 Use of WM

Storage of new information is effective when it is related to the learner's prior knowledge. The process of relating has to be done properly. WM must first retrieve the related previous information from the LTM and hold it simultaneously with the new information and search for accurate relationship. When the learner cannot do it, the teacher should guide him/her to retrieve and hold both and final relationship between them. Thus teacher is no more considered as mere information giver but a facilitator of learning by a student.

7.3.6 Influence of Prior Knowledge

Prior knowledge has great influence on understanding of new information. Learner must have therefore accurate prior knowledge. Knowledge containing misconceptions distorts the understanding. If such misconceptions are noticed, then teacher should take immediate corrective actions before presenting the new information, and the teacher should compel students to make explicit what he/she knows about the new topic already. Teacher should at this stage note any misconceptions and correct them.

7.3.7 Expectations

Learner generally, based on his/her prior experience of the subject matter, expects what he/she is going to listen or read or observe. If these expectations are not accurate, he/she misinterprets new information. Teacher should alert students what he/she is going to present is not repetition of the past trend, especially when teacher uses terms which are not closely related to learner's prior experience.

7.3.8 Verbalization

As already mentioned, in learning complex procedural knowledge, the use of verbal statements speeds up the learning. Teachers should encourage students to verbalize and self-instruct and guide execution of procedural knowledge. This enhances effective storage of both declarative and procedural knowledge in LTM.

7.3.9 Enactment

It means a learner is engaging in overt psychomotor behavior, i.e., actually doing something in some way that actually reflects what is being learned, for example, drawing geometry, drawing of a sketch of a neuron to study how nervous system works, etc. This is called enactive form of learning which reinforces understanding of the concepts.

7.3.10 Repetition and Review

Review and practicing information and procedures over a period of weeks, months, and often years improve retention of information and performance. Pay attention to the information during each review to review concepts, schemas, scripts, personal theories, and worldviews, and reflect over it. Such reflections involve additional elaborations, different contexts, and more associations. Such continued practice promotes atomicity in storage and retrieval of information from LTM. Teacher should encourage such frequent reviews and practice in the classroom.

7.4 Part II – Long-Term Memory: Nature of Knowledge

Declarative knowledge is stored in two forms in the LTM.

Episodic memory contains memories of one's personal life, and **semantic memory** contains general knowledge about the world independent of personal experience. Episodic memory resides in the parietal lobe and semantic memory in the frontal lobe of the brain, which is the seat of thinking. **Procedural knowledge** also resides in episodic memory and semantic memory, while responses in various parts of the brain in the motor cortex.

7.4.1 How Information Is Encoded in LTM?

Same information is represented or encoded in different forms primarily in images in various sensory cortices – visual, auditory, touch, motor, smell, and taste – but while learning in the classroom we use more of visual images. Visual images are the result of perception which does not record aspects of real objects. Hence image represents partial reality.

7.4.2 Encoding in Terms of Symbols

It is encoded in terms of symbols, words, numbers, or any other pictorial symbols. No symbol has any similarity with actual objects, events, touch, smell taste, or emotions but represents them in terms of their meaning. These remind them if properly associated during learning just like seeing construction of a road. The most common symbol in the classroom is verbal codes.

7.4.3 Encoding in Terms of Meaning

Propositions are small units of information containing a subject, object, and relationship between them. Each proposition may be true or false. For example, look at this sentence: Mary's uncle, whom she adores, owns a Ferrari which is red. It consists of four propositions

- Mary has an uncle.
- Mary adores her uncle.
- The uncle owns a Ferrari.
- Ferrari is red.

Each proposition has a meaning because it describes a particular relationship between the subject and the object or each proposition may be true or false. Thus people store information in terms of proposition. This is yet another way of organizing verbal knowledge.

7.4.4 Encoding in Terms of Actions Which Are Also Called Productions

Learner's physical or mental activities are encoded in terms of procedural knowledge. In a verbalized form these are all in the form of IF and THEN statements. For example "IF I want to speed up bicycle, THEN I should paddle faster. Thus IF part specifies the conditions under which action takes place, THEN statement specifies which action takes place. Such verbal statements are integral parts of procedural knowledge. It integrates behavioral and mental activities. Learner has to learn these production statements consciously in which WM plays an important part as a supervisor and guides overall execution of procedures.

All these four codes are interconnected. Bringing a verbal code in WM enables WM to pull all other codes like images, propositions, and productions, creating a total picture of a concept represented by that verbal code.

Teachers and students should note that words and sentences are primarily means of communication with another. Every sentence then becomes meaningful, if the

verbal code can retrieve all other codes with it and contribute to the total meaning of all words. Each word is then called a **concept**.

7.4.5 Concepts

The word "concept" indicates a class of objects and events having similarities (also called characteristics, attributes, or features). Concepts are of two types: concrete and abstract.

Concrete Concepts are easily identifiable by physical and observable characteristics of objects and events they represent. Learning is required to learn how to classify these objects and events by responding to their observable features such as size, color, shape, and touch. Only later, these features are given labels. The word MILK is recognized as something which is white and has a particular taste. The word RED refers to a particular color of certain wavelength. These concrete concepts are learned easily.

In contrast, **abstract concepts** do not have observable characteristics, for example, intelligence, charisma, work, cousin, stress, strain, etc. They are, therefore, learned by formal definitions. Generalizations while learning abstract concepts do not occur by responding to concrete stimuli as in the case of concrete concepts.

Concepts are learned by examination of **instances.** Instances are examples of objects and events referred to by the concept level. Instances are of two types: positive instances and negative instances. Positive instances contain all features of a concept class which also follows rules of combination – simple, conjunctive, disjunctive, and relational "you and I" are positive instances of the concept "person."

Negative instances contain all features which are not part of a given concept. "You and I" are the negative instances of the concept "cow." For exact understanding of a concept, a learner must have to identify both positive and negative instances of a given concept.

Teachers should teach a concept first by defining features of a given concept and must provide numerous positive instances of a concept class and also negative instances of what the concept is not.

Failure to recognize all negative instances leads to undergeneralization (when some positive instances are not classified as a concept member), and failure to recognize negative instances leads to overgeneralization (when even some negative instances are considered as positive instances).

7.4.6 Schemas and Scripts

Concept is the simplest way to organize the knowledge of the world around, but the actual world is not that simple but is large and complex. Humans learn to grasp this complexity through schemas and scripts and personal theories.

Schemas are a connected set of concepts and facts related to specific objects and events. An example of schema is say about "FACULTY OFFICE" in an institute. Such schema affects how we perceive and remember new situations. When we visit a faculty office, we look around through the connected network of concepts such as desk, chair, and shelves. Scripts are schemas about events such as what goes on in a restaurant or in dispensary.

Schemas and scripts reduce information overload on WM by focusing on things according to schemas and scripts when they process objects and events. Schemas and scripts also help people to organize their experiences and use it to predict and interpret in the future.

7.4.7 Personal Theories

People use different ways of understanding the world around. One way is to understand in the ways useful to them by aligning themselves with day-to-day observations of physical, organic, and social environment and develop theories about how objects and events behave and are related to each other. He/she knows that a physical object can be converted from a coffee pot to a bird's feeding pot, but one cannot convert a rabbit into a mouse.

Concepts people form are influenced by such personal theories about how the world works. When people come to develop personal theories about the social world, they develop theories which help them to deal with the social groups in order to survive. One such theory currently dominant in education is the general assumption that learning and teaching can be learned by practicing on the job. It still persists, even though there is criticism about the quality of education because it suits the educationists as they can carry on their activities smoothly and without debate.

In general personal theories are about physical, organic, and social world based on their observation of their usefulness in carrying out their daily/routine activities smoothly, but they may not be in line with the real scientific theories.

7.4.8 World Theory

People's personal theories are restricted to a particular domain, i.e., physical, organic and social world. People's worldviews in contrast are a general set of beliefs and assumptions about reality on a wide variety of phenomena. For example:

- Life and universe came into being through random acts of nature or as part of divine plan and purpose.
- Objects in nature like rocks and trees have some degree of consciousness or are incapable of consciousness.
- People's success and failures in life are results of their own actions or divine intervention or random occurrence.

Worldviews are culturally transmitted through adult's day-to-day interaction with one another. These are integral part of one's life and taken for granted. Hence this knowledge is implicit but it influences the behavior.

However, there are many worldviews that impede learning of the classroom subjects. For example, a learner who assumes that his success in examination depends on God's help alone prays to God instead of working systematically applying scientific principles of learning. When the teacher notices these worldviews, he/she should strive to bring about conceptual change in both personal theories and worldviews.

7.4.9 Challenge to Promote Conceptual Change

The conceptual change is a challenging task for both the teachers and the students because:

- People are comfortable with existing beliefs and always look for information that confirms their existing beliefs and ignore contradictory information.
- Many beliefs are integrated into a coherent set of beliefs with many interrelationships among them. Changing any misconceptions involves changing an entire body of organized knowledge, for example, changing earth-centered view of the earth, sun, and stars revolving round the earth.
- Often these beliefs are integral part of one's culture and religion and hence almost impossible to change due to emotional involvement.

7.4.10 Promoting Conceptual Change

To bring about conceptual change, the teacher should:

- Determine students' current beliefs about the topic taught by informally asking him/her or by administering pretests.
- Teach scientific knowledge more meaningfully by bringing in it contradictions with students' old knowledge and process in depth.
- Provide them with evidence that blatantly contradicts their existing beliefs thus creating cognitive dissonance. Such dissonance can be created by organizing new experiments, demonstrations, hands-on experience, and better explanations by the teachers, allowing students to think and promote self-reading habits, discussion and debates, seminars, etc.
- Help students to bring their existing beliefs and new scientific knowledge simultaneously in their WM for conscious comparison.
- Monitor students' understanding of new knowledge and skills throughout the year.

7.5 Part III – Long-Term Memory: Retrieval and Forgetting

Students should learn to retrieve stored information systematically. Retrieval works in certain ways. Retrieved knowledge from LTM can only be selective and not exhaustive. One cannot search the whole knowledge from LTM for finding a particular portion of that knowledge one wants to use for making new information meaningful. The prerequisite for this in the first instance is to store knowledge in an organized form of network of concepts.

Having done this, make use of retrieval cues. Where to find cues are hints about desired information in LTM. There are four types of cues, namely, identity cues, associate cues, frame cues, and contextual cues.

- Identity cues are labels which are identical to the labels one has used for storing information.
- Associate cues are generally category words that relate themselves to the specific word one is looking for. For example, a concept word "clothing" brings to the mind specific items like hat, shoes, shirt, and trouser, and one might be looking for "shirt."
- Frame cues are organizational structure which guides to search for information and provide numerous cues. Where natural organization structure is not available as in the case of isolated facts, the structure is imposed by employing mnemonics. For example: F/Y = E/R = M/I, i.e., F, Y, E, R, and M are parts of bending equation. The equation can be learned and stored as For Your Easy Remembrance Mug it.
- Another example may be regarding minerals. Minerals can be metal and stones. Metals may be rare, common, and alloys. Stones can be precious and for masonry, and similarly this can be further extended, stored, and retrieved.
- Contextual cues are cues which refer to the physical environment in which the knowledge is originally acquired. For example, divers remember things better when they are under water rather than when on shore because they learn many things when they are under water.

7.5.1 Construction and Retrieval

Students must remember that during retrieval they only retrieve a small portion of knowledge and the rest they themselves fill up by what seems logical or consistent with their existing knowledge and beliefs about the topic. Hence students are required to be careful to check the accuracy of the retrieved knowledge and avoid distortions. There are external ways to ensure accuracy of the retrieved information as explained later regarding this.

7.5.2 Forgetting

Information stored in LTM gets more difficult to retrieve if students tend to forget what was stored in LTM. Students tend to forget because of several reasons. It simply decays if not used for a long time. Often information is stored with few connections. There is a tendency to repress information that creates anxiety and is never therefore retrieved. Finally some information never gets really stored in the first place or if stored was never consolidated by repletion and review. It is therefore necessary to bear in mind to keep on revising from time to time the stored information for its application at appropriate time.

7.5.3 General Principles of Retrieval During Instruction

- Teachers are expected to present information in an organized form – hierarchy, propositional network, cause and effect relationship, and concept maps. Students are required to store this information in similar form.
- Teachers should bring to students' attention the right way to retrieve information about any topic.
- Teachers should ensure that general concepts and principles should be related to various situations in which students are likely to use these in their daily life.
- Teachers should help students to devise various external cues such as maintaining information in diary calendar, for example, writing appointments, meetings, and also revising weekly. Also they should keep on reminding them regarding the assignments.
- It is important to conduct review of the knowledge previously learned by asking students both lower-level and higher-level questions.
- Teachers should remember that retrieving information for answering higher-level questions needs time. Give time to students to search for information and solve the problems. Such exercises should be conducted from time to time.
- Classroom assignment/seminars after every 2–3 weeks at undergraduate level encourage students to review and reflect on information learned.

7.5.4 Metacognition, Self-Regulated Learning, and Study Strategies

Meta cognition is the students' knowledge about their own learning process/style such as: how they learn in stimulus-response situation, by observations and limitations, use of cognition for perception of environment, processing of information

using memory for acquiring new information, development of knowledge such as declarative and procedural, to store and retrieve this knowledge for use in their daily lives, to control emotions and feelings during the process of learning, and to keep motivation to continue learning for one's entire lifetime.

Educationists now believe that students should be taught about this metacognitive knowledge along with their subject teaching. They believe that this knowledge will help students to take control of their learning. Taking control of their own learning means learning to set their own goals and standards and to control their motivation to learn and emotions to maintain continuity of learning, attention control, self-monitoring of learning process, seeking external help when needed, and self-evaluation of results of learning.

Such self-regulated learning develops when students get opportunities to study independently and get exposure to self-regulatory models like teachers, parents, and peers. Teachers must help students to set their goals, focus attention, choose learning strategies, and monitor progress. Over a period of time, students become self-regulated learners.

The students must know what exactly is meant by "strategy." It is intentional use of one or more cognitive processes to accomplish a particular task. Effective learning strategy includes:

- Meaningful learning and elaboration
- Internal organization of new material
- Note-taking
- Identifying important information from instructions and reading materials
- Summarizing
- Comprehension monitoring by frequently asking low- and high-level questions
- Employing mnemonics to organize isolated information

However, adopting such techniques of an intentional learner by students often is delayed, or even obstructed, if they develop inaccurate beliefs about the sources of knowledge. These beliefs are called epistemological beliefs. Such beliefs are always two dimensional:

- The certainty of knowledge imparted by the teacher or experts [either certain or uncertain]
- Simplicity of knowledge structures [knowledge is either discrete or complex and integrated]
- Sources of knowledge [either teachers or experts or constructed by the learner]
- Speed of learning [knowledge is learned quickly or gradually]
- Nature of learning ability [learning ability is fixed at birth or learning ability is in learner's control and can improve with practice]

7.6 Effects of Epistemological Beliefs on Learning

- **Beliefs regarding certainty of knowledge:** students, who believe that the information received by them from a teacher is final, jump to the conclusions based on this knowledge. Those who believe that even expert's knowledge is subjective learn critically and meaningfully and are ready to undergo conceptual change.
- **Belief regarding simplicity of knowledge and its structure:** students, who believe that knowledge consists of discrete facts, learn knowledge in a rote fashion. Those who believe that knowledge is complex and integrated learn it meaningfully and organize it internally and elaborately during the study.
- **Beliefs regarding the source of knowledge:** Learner who believes that knowledge exists outside him/her and resides in experts will remain a passive listener. Those who believe that knowledge is ultimately acquired by the leaner himself/herself become an active learner and learn new information meaningfully.
- **Beliefs regarding criteria for determining the truth:** A learner who believes that the knowledge of experts contain the ultimate truth will generate passivity. Those who believe even experts' knowledge is subjective treat the knowledge with a critical mind.
- **Belief in the speed of learning:** Students who believe that one can learn quickly are satisfied with a single reading. In the event of failure to understand, gives up reading or dislike the topic/subject/course of studies. Those who believe that learning is essentially gradual continue their efforts to understand.
- **Belief in the learning ability:** Those who believe that learning ability is fixed at birth give up challenging tasks. Those who believe that learning ability is in their control pursue a variety of learning strategies, till they master the subject.

To sum up, students with advanced epistemological beliefs believe that knowledge is complex, learning is gradual, and learning ability is in their control. They make high-level achievement in the class, bring even more advanced view of learning and knowledge, acquire advanced integrated set of ideas, and continue to search for the truth.

7.6.1 A Case Study

In one of the class session of 'Structural Design', teacher solved a problem and arrived at the quantity of steel required in a beam and converted the amount of steel required in to number of bars as well as working out section of the beam for a particular loading condition. One student asked the teacher that sir, if we use only one bar equal to total number of bars in the centre of the beam, will beam fail? Teacher said that beam may fail or not but you will fail. After getting snubbed, the student asked that sir excuse me, if we don't add steel how the beam will fail? Teacher asked the student to get out of class. These are the situation of discouragement when teachers themselves have never conducted actual research in the laboratories.

It is a long story.

Interestingly what is true of students is also true of teachers. Many teachers believe that knowledge and abilities are fixed, teach and assess students accordingly, ask lower-level questions in testing and assignments to prepare them for qualifying a paper pencil test to solve five questions out of eight for the award of a degree, which is the glamour of the society.

7.6.2 The Intentional Learner

Truly, effective learning is intentional. It involves intentional use of cognitive processes and engagement in cognitive and metacognitive activities directed at thinking and learning something, setting goals and objectives, and setting many learning strategies. The learner is thus in a driver's seat with the teacher by his/her side with a roadmap and considerable knowledge about how to drive a car.

7.6.3 A Case Study

> This author was pursuing his M.Tech. in civil engineering at Punjab Engineering College Chandigarh. There was a subject called 'Foundation Designing'. This subject was to be taught by Late Professor KL Bhanot. He was a teacher and researcher who would involve students in the self-directed process of learning. He wanted that students should have conceptual understanding of concepts, principles and procedures to shape them as intentional learners. When the class of Foundation Engineering came up, he told the students (15 in number) that he is not going to teach until each student solve 35 problems of undergraduate level. He told that we need not to come to him at study at our own level to find solution to the given 35 problem as prerequisite to undergo a course in Foundation Engineering at Postgraduate level. Those who solve these problems in total may see him for conducting a pretest. We were allowed to consult each other to find solutions to the given problems. Moment 6 or 7 students approached him regarding their understanding of these problems; he will ascertain individually whether students understand the concepts and principles involved, he will now assign a task to conduct soil investigation of a live building to determine safe bearing capacity of soil by all students. When students would have completed this assignment, he would ask for work out design for the foundation of a column as per loading conditions. He will provide hints/guidance wherever students felt the difficulty. Through this process he ensured that students develop clear understanding of concepts, principles and procedures in the students coupled with self learning and problem solving skills in almost all students. Such a strategy became instrumental that learning becomes permanent part of LTM.

Intentional learning also involves learning many basic processes as explained in above case study at the level of automaticity, such as retrieving word meaning and connecting ideas to similar ideas in LTM, but overseeing the process is carried out by a conscious goal-directed learner using a variety of learning.

And study strategies, deciding what to focus on and how to make sense of new information, drawing references for use in his/her own life circumstances.

Intentional learning is especially important when conceptual changes are needed which involves

- Attending to and thinking about new information; notice discrepancies between it and his prior knowledge.
- Making considerable effort to acquire mastery of new subject matter as explained in above case study.
- Bringing to table a variety of learning and study strategies that maximize changes of revising the current beliefs and bring students in line with scientific concepts.

7.7 Why Students Are Not Motivated to Learn?

There are so many reasons in respect of this. One of the most important aspects is that higher education is teacher centered whereby nobody is interested in developing students are lifelong learners. Observations reveal that the focus is on passing the information to qualify an examination and not on learning/development of students as professionals by a large number of institutions offering undergraduate/postgraduate courses. Most of the faculty lack domain-specific knowledge and skills as well as understanding of pedagogical principles highlighted in this chapter.

Students are also casual. It has been experienced that 10–20% of students on a daily basis are found absent because they don't find teaching-learning process meaningful and motivating. Neither faculty nor students are not focus directed to achieve competencies to develop cognitive, psychomotor, and affective domains.

Barring some institutes of national importance, Head of Institutions and Senior Professors mostly seen sitting in their offices, more or less having no concern about what is happening in the classes. Practical work is not given desired seriousness because of the emphasis of evaluation in the current scenario. Students therefore get bored in such a scenario.

- Besides above, some of the pedagogical aspects are either uninformed or misinformed about effective strategies of learning.
- They have epistemological beliefs that lead them to underestimate or misrepresent a learning task.
- Students often have mistaken belief that they are already using effective study strategies.
- Often students have little prior knowledge of the subject from which they can draw meaningful learning.
- Often teachers do not give learning task that lend the students' use of sophisticated learning strategies by asking them only lower-level questions.
- Majority of students somehow have a goal of passing examinations as mentioned above.
- It is also true that most of the students think that sophisticated thinking like solving open-ended problems or an attempt to undertake a live problem as project

work or innovative something, etc., requires too much time and energy and is not worthwhile.

There are so many other reasons like lack of proper planning of curricular, cocurricular, and extracurricular activities at macro and micro levels for overall personality development of students. This is also because majority of students and faculty are residing outside the campuses and only attend the institutions from a specified time of instruction.

7.8 Theories of Knowledge Construction

7.8.1 Levels of Development

Knowledge is constructed/developed by individual learner, community of researchers, and team members at the workplaces at individual, level, and workplace level which is entirely dependent on existing knowledge in LTM which is briefly touched below:

Individual level: At the individual level the knowledge constructed/developed by the learner is an **idiosyncratic/individual competency** and may not be in tune with what the teachers want to convey. If the student persists in maintaining misconceptions, then he/she will not learn scientific knowledge. When students pass his/her examination somehow, he/she forgets his/her knowledge. Therefore, teacher should examine student's prior knowledge, detect his misconceptions, and correct these.

Collective level: At the collective level, the researchers discover laws of nature and invent new products and processes. This knowledge is publically shared by all researchers and passed on to the younger generation as a more valid and reliable knowledge.

Local level: At the local level at the workplaces, the teams develop its own knowledge about their own products, and services developed by team members are not shared publically.

It is necessary for both teachers and students to know that the nature of knowledge developed at each level has its own role to play. What however more important is to know that all these levels employ principles of learning described in the chapter.

7.9 Promoting Effective Learning in Higher Education

Promoting effective learning in higher education depends on the competency of faculty in domain-specific knowledge and skills, relevant industrial/field experience, understanding of educational objectives, neurological/mental process of

learning, and use of appropriate instructional strategies. These aspects are briefly discussed below.

7.9.1 Role of Faculty in Effective Learning of Learners

The author based on his experiences considers that the faculty in higher education, particularly in the case of technical education, is required to be clear in respect of following effective instruction to conceptual change and conscious learners.

- Clarity/mastery of discipline/domain-specific concepts, principles, procedures, and applications both in theory and in practice. Without these domain-specific competencies, what is described in this chapter may not be converted into action. Besides this, the faculty is required to possess appropriate industrial/field exposure to relate teaching-learning process with actual workbench requirements, i.e., world of work. Further, he/she is required to supplement experiences gained to offer consultancy to the industry in the respective areas of specialization for developing sophisticated/higher-order problem-solving/innovative skills in the students. This will help the teacher to relate the instructions with actual requirements.
- Practice for mastering subject matter must be continued on an ongoing basis.
- Faculty must be clear about Educational Objectives sated by Bloom and others. Educational objectives lay considerable emphasis of developing learners in cognitive, psychomotor and affective domains. These have been further analyzed in the development of acquisitive skills, adaptive skills, operative skills, and innovative skills for making the learners effective in the world of work which are briefly described below

  – **Acquisitive capabilities:** The capability to acquire knowledge of technologies depends on the ability to search for, assess, and transfer technologies for effective functioning in various functional areas like R&D, design and drawing, planning, shop floor management, quality control operations, repair and maintenance, marketing and sales, etc. To acquire acquisitive capabilities, students primarily require learning-to-learn skills, some aspects of which are:

    Willingness to learn continuously and grow in the identified domain
    Doing self-analysis to assess one's strengths and weaknesses
    Setting learning goals for oneself
    Scanning for and access learning resources from various sources
    Organizing one for self-learning and achieving the goals
    Not to be satisfied with what one knows
    Have the urge to learn continuously

- **Adaptive capabilities:** This relates to the ability to modify existing processes or product design so that the process is better adapted to local factors and the product reflects local market preferences. In addition to making use of new machines and technologies, this will necessitate computer handling skills. Presently, technical education is lagging far behind including new technologies, processes, and equipment in the teaching-learning process. In addition, students must be proficient in the following:

  Use of available graphic tools like AutoCAD
  Use of software to make effective computer-based presentations
  Familiar with and use of various patented softwares and programming language
  Use of the Internet effectively to gather information and exchange information with others

- **Operative capabilities:** This involves shop floor know-how, knowledge of codes and standards, management techniques, industrial engineering, diagnostic skills, communication, and interpersonal skills.
- **Innovative skills:** This involves the ability to anticipate future demands and to develop new designs, prototypes, processes, and technologies. This will require problem-solving skills which will require understanding of the following aspects:

  Clarity of domain-specific concepts and principles.
  Recognize various parameters related to the problem.
  Find innovative solutions based on the root cause of the problem.
  Evaluate alternate solutions and implement the solution for evaluating its impact.

- Clear understanding of "pedagogical principles" discussed above for planning and delivery of instructions in a logical way, converting teaching into learning by making use of appropriate strategies. Students learn more effectively when appropriate strategies are put to action within the context of any subject matter and specific learning tasks. For this purpose it is essential that teachers are required to understand the implication of various learning experiences to develop appropriate competencies in the students as per educational objectives (see Fig. 7.2).

It is observed from above diagram that student-centered learning experiences like well-planned tutorials, laboratory/workshop sessions, seminars, industrial training, and project work lead to convert teaching into learning for conceptualizing concepts, principles, and procedures taught in the classroom by lectures which become instrumental in developing intentional learners.

Further, teachers must also understand that instructional process is not a one-way traffic. Continuous teaching becomes boring. The rate of learning and cumulative learning is a nonlinear function. The maximum attention span of an adult learner is about 15–20 min. See Fig. 7.3 for details.

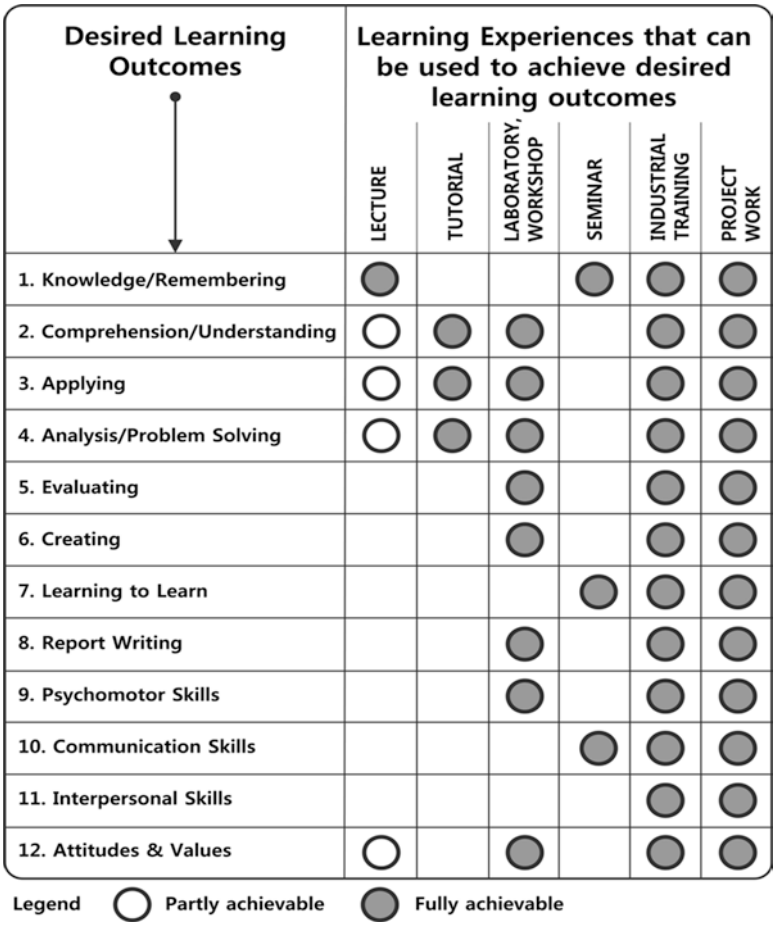

Fig. 7.2 Relationship between learning outcomes and learning experiences

Instead of continuous teaching beyond 20 min, variations of stimuli like asking questions, giving demonstrations, etc., are essential to maintain the attention and interest of students. Teachers are expected to ensure that the entire teaching should be based on existing knowledge of students required to impart new knowledge. Matching eye with also students and recapitulating the teaching from time to time are also important aspects.

- Appropriate communication skills (written, oral, listening, body language), i.e., ability to communicate, presentation skills in a variety of formal and informal situations for creating appropriate environment and drawing attention of the students during the presentation, blackboard writing skills for developing the subject logically for proper comprehension by the students, and motivational skills for creating a climate of better learning and promoting confidence and optimistic attitudes in the students are other competencies of effective instruction.

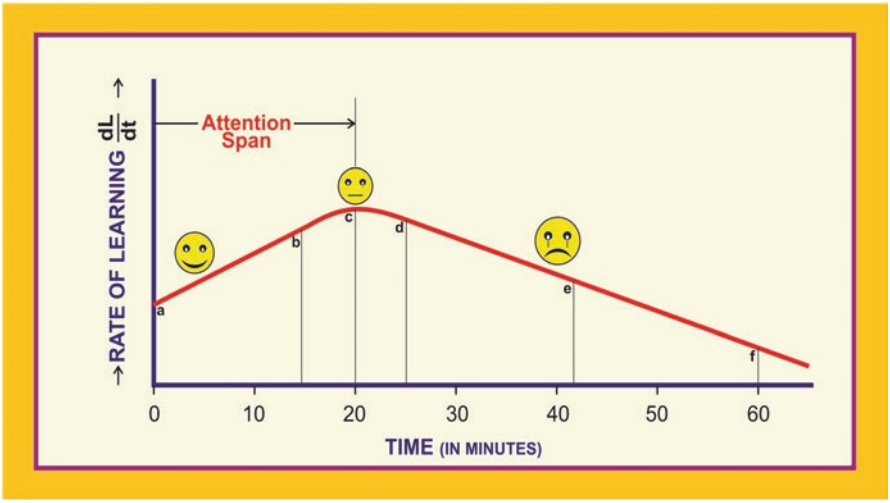

Fig. 7.3 Rate of learning

- Research methodology/problem-solving skills for generating new ideas, developing prototypes, and motivating students toward discovery learning are other requirements of higher education toward meaningful learning, internal organization, elaboration, and visualization. Teachers are also expected to examine beforehand the epistemological beliefs of students and try to change those beliefs that impede learning.
- Maintaining punctuality, planning and time management skills for effective functioning, and playing a role model before the students for their professional and personal growth are others parts of teachers' responsibility.
- Principals and professors have other additional responsibilities besides teaching. They need different set of skills like institutional management, research methodology, curriculum processes, etc.

7.9.2 A Case Study

The author was working as Director Quality Improvement to train students and teachers in systematic learning with the aim of producing professions possessing lifelong learning skills by adopting appropriate strategies by adopting planned procedures. There were some successes and failures to. It was observed that teachers were filling the formality to plan lessons, maintain desired information. When coming to actual situation, no such strategies mentioned in this chapter (though transmitted/taught) to the faculty during actual teaching learning process because teachers and students are tuned to cover the course of studies with the aim of qualifying a paper pencil test to achieve maximum pass percentage of students for the purpose of advertisement to general public for greater admissions and not with the aim of producing professionals having appropriate competencies to design new products, prototypes, systems as per requirement of the world of work or community. One of the reason for such a shortcoming in the system of higher education that Head of Institutions

and Heads of Department in majority of institutions take teaching-learning process very lightly and are also not competent in field of Educational Technology.

Readers will be surprised to note that project work being so important is not given desired attention to produce self/intentional learners. One project was given to all the students, 55 in number under the guidance of only one teacher to conduct a normal task, not utilizing even 5% knowledge imparted to organize execution of project work. Some students who were active prepared a Project Report and other students had a copy of the project report well bound, with even knowing the title of the project assignment.

This is happening in majority of institutions to complete a formality for award of degree qualification, for which the society has glamour.

Higher education thus needs overhauling. This has been considerably debated while formulating the New Education Policy 2020 for revitalizing higher education in India.

The All India Council for Technical Education has also evolved a mandatory "Comprehensive Training Policy for Technical Teachers" comprising of eight modules, namely:

- Orientation Towards Technical Education and Curriculum Aspects
- Professional Ethics and Sustainability
- Communication Skills, Modes, and Knowledge Dissemination
- Instructional Planning and Delivery
- Technology Enabled Learning and Lifelong Self-Learning
- Student Assessment and Evaluation
- Creative Problem-Solving, Innovations, and Meaningful R&D
- Instructional Management and Administrative Procedures

It is expected that senior administrators take this policy for the development of faculty to produce appropriate technical manpower.

7.10 Conclusion

People working within and outside the system of higher education require changing their mindset toward teaching-learning in higher education which is currently focusing on attaining a degree qualification by passing an examination only. Students, teachers, and educational managers consider that their knowledge about learning and teaching is derived from their experience on the job. Unfortunately, very few of these beliefs are publically debated. Thus the educational practices thrive on the belief that the skills described in this chapter come to them automatically while practicing on the job. They are not aware of the scientific basis of how learning occurs as a neurological/mental process of conscious learning. Very few educationists can be convinced today that they need to make an effort to learn first and then teach students how to learn. New steps are being taken by the Ministry of Education and All India Council for Technical Education in this direction, as briefly described above.

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