CHAPTER 6

ANALYSIS AND INTERPRETATION

Introduction

The analysis and interpretation of data is useful in drawing sound conclusions and valid generalizations about the results of the study. Analysis means the process of systematically searching and arranging the data so that the findings can be drawn. It involves working with the data, organizing them, breaking them into manageable units, coding them, synthesizing them and searching for patterns. Interpretation refers to developing ideas about the findings and relating them to the literature and to the broader concerns and concepts. It involves explaining and framing our ideas in relation to theory, other scholarship and action as well as showing why the findings are important. Thus, the analysis of data is to find out the facts contained in the collected data and the interpretation of data means the careful, logical and critical examination of the results of analysis.

This chapter includes the analysis and interpretation of the study on the basis of its objectives. Though the first two objectives have been analyzed in previous chapters, a brief discussion is included in this chapter. The components of cognitive science have also been analyzed. The researcher has selected five components of cognitive science for the present study—attention, creativity, intelligence, learning and problem solving. For each of these components, the theories, the problems in using these components in teaching learning process and the pedagogical implications have been discussed.

Emergence of Cognitive Science

The historical development of cognitive science has already been discussed in the theoretical framework of the study. The researcher divided the historical development of cognitive science into two stages for the convenience of understanding—early history of cognitive science (historical developments in its contributing disciplines which may have effected in the emergence of cognitive science) and the formal conception of cognitive science. The epistemological discussions in philosophy laid the foundation of cognitive science and the queries related to cognition in other branch disciplines of cognitive science—psychology, linguistics, anthropology, neuroscience and artificial intelligence built upon it to formalize as the discipline of cognitive science. Rationalism in the field of philosophy; cognitive revolution in the field of psychology; notion of universal grammar and psycholinguistics in the field of linguistics; cognitive anthropology; controversy between monism and dualism, and localism and holism in the field of neuroscience and attempt to understand human cognition through simulation of intelligence in machine have built up the vast discipline of cognitive science. All these disciplines came together in commitment towards a common goal of understanding cognition or the mind. They realized their common goal in the symposium held on information science at the MIT, Boston on 11^{th} September, 1956, which is taken as the formal birth of cognitive science.

Cognitive Science in Indian Perspective

The concept of cognitive science is so pervasive in Indian philosophy and psychology that a separate chapter has been dedicated for its elaborate analysis and discussion in the present study. Indian psyche is constituted of heterogeneous elements from different schools of Indian philosophy. Very extensive interpretations of mind and cognition are found in the schools of philosophy.

The Vedas have elaborate discussions on intuition, mind and intellect. The Buddhist philosophy has considered the mind as the sixth sense which allows us to have correct knowledge of the world. The Jaina philosophy has interpreted knowledge as the intrinsic property of the individual. Samkhya philosophy also believes that mind and intellect plays a great role in producing knowledge. The Nyaya philosophy holds that the mind processes the information carried by the senses. The Yoga philosophy believes that different nature and constitution of the mind leads to differences in perception of the external world. The Vedanta, the Buddhist and the Mimamsa philosophy regarded cognition as self-luminous. But according to the Vedanta, a cognition cognizes itself and according to the Buddhist, a cognition is not apprehended by any other cognition and Mimamsa believes that cognition is not inferable from the cognizedness of its object. While Samkhya and Nyaya-Vaisesika believes that cognition is not perceived by itself, according to Jainism, cognition is perceived by itself in apprehending its object. According to Yoga philosophy, our mind cognizes the objects as it really is. From the analysis it is evident that the Indian schools of philosophy have elaborate and concrete discussions on cognition and the mental processes, which is the subject of discussion cognitive science in the modern times.

Components of Cognitive Science

The psychological aspects related to cognition which comes under the field of cognitive science are its components. They constitute the components of cognitive science as they are related to cognition in one or the other way and cognitive science as a field of study attempts to understand them as cognitive processes. The components are—

Attention—Any living being is exposed to a large number of stimuli than can be processed by it. Moreover, these stimuli are of varied nature. Internally, the memories, images, and ideas also need to be considered from moment to moment. But our conscious awareness is limited to some stimuli out of many stimuli in the environment at a particular point of time. This process of selectively concentrating on one aspect of the environment, ignoring the others is cognitive in nature. The cognitive process of selectively concentrating on one aspect of the environment while ignoring other things is called attention. It is the allocation of processing resources. It is a concentration of mental activity. Attention is a complex of cognitive activities which include selecting one from several messages, selecting one from several interpretations of information, selecting one from several plans of action, and selecting one from several actions, which are all cognitive processes. Thus, it constitutes one of the important components of cognitive science.

Perception—The external world is in touch with us through our senses. Our actions are continuously shaped by what we perceive. Perceptual processes involve taking sensory input and transforming it into a more abstract code. Perception is the cognitive process of attaining awareness or understanding of the environment by organizing and interpreting sensory information. It involves signals in the nervous system, resulting from sensation. Perception is achieved by a combination of cognitive processes—some that begin by elaborating the sensory code and others that are inferential and begin with our knowledge of the world.

Memory—Memory is the final step in a series of cognitive activities related to information processing. The processing of information begins with sensation, goes through perception, and lastly the information is recorded or stored for further use. Thus, memory can be defined as the mental storage of information. It refers to the cognitive processes involved in the acquisition, retention and retrieval of the information. The complex cognitive process of memory involves three stages. The first puts information into memory, a process called encoding. Encoding is the process of forming a cognitive representation of information. After there is cognitive representation, it must be kept there. This process is called storage. The process of using the stored knowledge is retrieval. Thus, it can be seen that memory is not a single phenomenon, but reflects a host of related cognitive mechanisms.

Imagery—Imagery is a central cognitive concept. The cognitive psychologists have developed a variety of reliable behavioral techniques to investigate the role of imagery in cognition. The results of several studies suggested that under certain circumstances, imagery was critically involved in various aspects of memory and on-line cognitive processing. A mental image is an internal representation that produces the experiences of perception in the absence of the appropriate sensory input (Wraga & Kosslyn, 2003). In other words, imagery is a perceptual representation stored in short-term memory which corresponds to a particular state of brain. It is a byproduct of the brain and a versatile cognitive ability.

Language—Language involves all of our cognitive abilities. It pervades our thought and mental processes so thoroughly that it is difficult to study any aspect of cognition without involving language in some way. It also requires every aspect of our cognitive capabilities. It is a collection of arbitrary symbols. These symbols hold significance for a language using community. It follows certain rules of combination, thus giving meaning to the context. Cognitive science attempts to understand how human beings comprehend, produce and acquire natural languages. The theories that are primarily concerned with the cognitive dimensions of linguistic aspect constitute cognitive linguistics. Thus language is an indispensable component of cognitive science.

Knowledge Representation—Knowledge is described as representations of facts and concepts organized for future use. A representation is a label or symbol that stands for something in its absence. Mental representations are the product of perceptual processes and the means by which we store information in memory. They provide a means of manipulating, exploring and describing things in their concrete absence. Representation is a central concept in cognitive science. Different research goals emphasized by different disciplines within the cognitive science motivate different questions about representation—what people use, what a computer application needs, or what the nature of logic, language, or imagery might be.

Intelligence—The definition of intelligence has been very subjective and varied. But it certainly has been related to cognition. It is defined as a mental ability. Its definitions incorporate cognitive activities like ability to learn, ability to acquire knowledge, ability to adapt with the environment, abstract thinking ability, problem solving ability, etc. In fact, the main goal of cognitive science is to understand intelligent system. Intelligence is so much inherent to cognitive science as it incorporates human, animal and even machine intelligence. So, intelligence constitutes a very crucial component of cognitive science.

Learning—Learning is regarded as the changes brought about in the cognitive structure of the individual as effect of experience, which is evident through his behavior. It involves cognitive processes like knowledge representation, understanding, perception, thinking and inference. Though earlier, the associationistic theories dominated the concept of learning, at present, the cognitive perspective is gaining more popularity. The cognitive scientists are interested in the cognitive processes underlying learning as well as the influence of learning on the cognitive structure of the individual.

Thinking—Thinking is a cognitive activity. It is always directed to achieve some end or purpose. Problems give birth to thinking and thinking helps in finding out their solution. Thinking is a tool for adapting ourselves to the physical and social environment which we are in. As it is an inner cognitive behavior, it cannot be objectively observed. It involves mental exploration of objects, activities and experiences instead of motor exploration. Therefore, there are some tools of thinking which include images, concepts, symbols and signs and language. Cognitive scientists are interested in developing some general insights into how thought processes take place. They also study particular aspects or dimensions of critical thinking.

Action—Action refers to various movements effected by an individual. The scientific study of action yields insights, distinctions, as well as descriptions of the causal mechanisms underlying action (Pacherie, 2012). An action involves the external stimuli, the sensory organs, the brain, the nervous system, motor cognition and many other cognitive aspects. The central nervous system transfers sensory inputs into motor goals. Then, these goals are converted into signals controlling the muscles that are active during the execution of even the simplest action.

Reasoning—Reasoning is a complex mental process. It is considered as the highest form of thinking. It is a definitive cognitive ability of human beings. It is closely associated with the human activities such as language, science, art, mathematics and philosophy. Reason is a means by which thinking comes from one idea to a related idea. More specifically, it is the way rational beings propose and consider explanations concerning cause and effect, true and false, and what is good or bad. Reasoning may be inductive or deductive. Inductive reasoning is proceeding from particular facts to a general conclusion and is based on experimentations and observations. Deductive reasoning is applying universal truth or generalized principle in solving particular problems. Cognitive science attempts to study and explain how people rationalize, e.g. which cognitive and neural processes are engaged, and how cultural factors affect the inferences that people draw.

Creativity—Creativity is the ability to produce something or some idea which is novel or improve to add value. Theories of creativity have focused on a variety of aspects. The most dominant are—process, product, person and place. A focus on process is shown in cognitive approaches that try to describe thought mechanisms and techniques for creative thinking. A focus on creative product mostly appears in attempts to measure creativity in people, or in creative ideas considered as successful. A focus on the nature of creative person considers more general intellectual habits, such as openness, levels of ideation, autonomy, expertise, exploratory behavior and so on. A focus on place considers the best circumstances in which creativity flourishes including degrees of autonomy, access to resources, etc. The study of the mental representations and processes underlying creative thought belongs to the domains of psychology and cognitive science.

Problem Solving—Problem-solving refers to attempting different ways to solve the problem. A problem has four components—an initial state, the person‘s state of knowledge at the start of a problem; a goal state, the goal that the person wishes to achieve; operations, that the problem solver can use to get to the goal state; the environment that the solver is working in. Problem solving is an extremely complex activity that involves intellectual skills, knowledge and cognitive strategies and meta-strategies that modify attention, perception, the input and the storage of information, and the retrieval of knowledge form memory. It requires several proficiencies. For instance, skills that enable us to comprehend symbol systems and the rules governing the relationship between objects and events, demonstrating knowledge of symbols and rules by expressing them, and competence in manipulating and integrating information relevant to the problem.

Pattern recognition—Pattern recognition is the cognitive process of identifying properties of a system. It is a perception process influenced by available knowledge and experience. It is the capacity of integrating processing, and learning of inter-activating physical value changes. It helps to control the overall behavior by recognizing and carrying out action-reaction and decision functions. It is a necessary concept to understand the mind functioning. Cognitive phenomena related to pattern recognition are detection, perception, previous knowledge, sensation, etc.

Artificial Intelligence—Artificial intelligence refers to the intelligence of machines. Cognitive science studies artificial intelligence in terms of computational modeling of human intelligence. It is concerned with designing intelligent agents. Artificial intelligence programs are based on human knowledge. It enables machines to recognize patterns in complex data, learn from experience and take decisions that are generally taken by humans. It is related to cognitive processes such as logical reasoning, logical decision making, knowledge representation, language, architecture of cognition, etc.

Decision-making—Decision-making is the cognitive process of choosing a preferred option or course of action among various options. It involves some problem-solving, since individuals try to make the best possible choice from a range of options. The focus in decision-making is on the factors influencing preference. The value of decisions is assessed in terms of the consequences of those decisions. Though decision-making may be both individualistic and group activity, but cognitive science studies it at individual level. The study of decision-making incorporates issues of planning, problem solving, psychophysics, memory and social cognition, among others (Shafir, 1999).

Motivation—The driving force that prompts and energizes human beings for an action or to achieve a goal, is motivation. Motivation is a modulating and coordinating influence on the direction, vigor, and composition of behavior (Shizgal, 1999). It is influenced by various factors—internal, environmental and social. The cognitive factors that influence the motivation of a person are the concern of cognitive science. The cognitive view of motivation emphasize that motivation is the bridge between ideas and actions. Another explanation is that motivation leads to decrease in cognitive dissonance.

Consciousness—The process of _consciousness‘ covers a wide range of cognitive functions. It includes voluntary actions, decision making, attention, awareness and self-monitoring along with sensory experiences. It is the normal mental condition of the waking state of humans, characterized by the experience of perceptions, thoughts, feelings, awareness of the external world, and often in humans, self-awareness. Cognitive science has a vague relationship with the phenomenon of consciousness. It is because cognitive science cannot avoid it as a science of cognition as well as it is necessary to draw inferences about processes mediating stimuli and responses, but from the perspective of artificial intelligence, consciousness is not necessary for inner phenomena such as intelligence, thought, cognition and the like. Therefore, the position of consciousness in cognitive science is somewhat obscure. Nevertheless, it constitutes a component of cognitive science since it is not totally out of the scene.

Emotions— An emotion is a psychological state or process that functions in the management of goals (Oatley, 1999). Emotions have been given importance in cognitive science only recently. They influence cognitive processing during judgment and inference, giving preferential availability to some heuristics rather than others. The cognitive scientists are concerned with whether physiological or cognitive aspects influence cognitive emotions, whether it is biased by cultures and whether the emotions or their causes are innate in nature. Thus it is apparent that though emotions are subjective in nature, their relation with cognition cannot be invalidated. Emotions are related to cognition in at least three ways—as stimulants of cognition, in the sense that they involve propositional attitudes and ascribing emotions a _mind-to-world direction of fit‘.

These are the main components of cognitive science, but the list is not exhaustive. From the analysis, it is apparent that all the components of cognitive science are inter-related with each other.

Areas of Cognitive Science in Education

Learning

To understand the educational process, it is necessary to understand learning. The understanding of learning requires knowing about problems of representation, of input (perception), of output (performance), and of thought and inference. Learning has been understood with appropriate depth only recently. It is more than simple accumulation of knowledge. Though accumulation of knowledge is indeed one form of learning, but there are other things that must be considered. It includes restructuring one‘s knowledge, reformulating the basis of understanding as a result of new concepts and new experiences, tuning of behavior, acquiring of skills and understanding to the extent of expertise, smoothness, efficiency, effortlessness.

Kimble defined learning as –relatively permanent change in behavioral potentiality that occurs as a result of reinforced practice.‖

Gardner Murphy believed learning to cover –every modification in behavior to meet environmental requirements.‖

Learning is a process rather than a product. It involves _change in behavior' which is relatively _permanent' resulting from _experience'. This means in learning process, there should be some kind of change in the behavior of the individual, be it positive or negative. But this change should be relatively permanent, temporary changes are not considered as learning. And this change must result due to experience or practice, not due to fatigue or sickness or drugs, etc. Psychologists define experience as the product of interactions between individual and the environment. However, the question remains as _how long new information is retained so as to be considered as permanent or as a learnt behavior'. Learning is a goal-directed process i.e. we modify our behavior largely to adapt ourselves to our environment. It is a construct or an idea that cannot be observed overtly. But it can be inferred from the behavior of the individual. It is difficult to define learning universally as it has been explained from different perspectives by various philosophers and psychologists which led to formulation of a large number of theories of learning. It can be said that a paradigm shift has taken place from the associationist theories to the cognitive theories and now to a whole enterprise of more complex and sophisticated learning programmes.

Learning in Cognitive Science

Cognitive science attempts to understand learning in a broader sense and from an interdisciplinary perspective. From the philosophical viewpoint, empiricism and rationalism provide valuable background for comparing and classifying modern learning theories. According to empiricism, our concepts or ideas come from sense impressions. Knowledge comes from experience, from experience to impression and then to idea. Rational or a priori knowledge of a proposition is also regarded as necessary—being result of an *a priori* judgment. No experience can ever grant such judgements truth but only assumed as strictly universal. A psychologist understands learning as the modification of behavior as a result of experience or training. Two major types of learning are generally distinguished, depending on the level at which the psychological processes are integrated into the cognitive system—elementary (stimulus-driven) learning and complex (representation mediated) learning

(Houde, 2003). In cognitive neuroscience, it is conventional to distinguish between two types of learning, according to whether implicit or explicit memory is involved. Each type calls upon different brain structures. Skill learning involves an adaptive modification of behavior achieved through task repetition. Learning that takes place in intentional memorization situations is called intentional learning (Decety & Koenig, 2003). Artificial intelligence (AI) studies the mechanisms to enable a machine to learn. It aims at building machines capable of adapting and acting more efficiently. Another task of artificial intelligence is simulating certain aspects of human or animal learning. Such simulations improve our understanding of the learning process (Ganascia, 2003). It can be said that cognitive science regards learning as a change in the cognitive abilities rather than in behavior. However the change in cognitive abilities is explicit in the behavior of the individual.

Learning in Education

Leaning is a key concept in the field of education. All the efforts in an educational system are ultimately directed towards improving the efficiency of learning. But due to various factors, learning becomes mere accumulation of knowledge or rote memory or cramming or getting good grades in the test. Learning is largely seen as a product rather than a process. Therefore it is necessary to understand learning and the cognitive processes underlying learning. In pedagogy, it is important to consider the cognitive capabilities that the learners should have and not to develop only knowledge. Further, it is also important to determine how pedagogy will be designed to facilitate the cognitive processes underlying learning. There are twelve cognitive processes underlying learning—prediction, modeling, experimentation, evaluation, diagnosis, planning, causation, judgment, influence, teamwork, negotiation and describing (Schank, 2011). Pedagogy should be designed based on these cognitive processes.

Cognitive Processes Underlying Learning

Roger Schank (2011), a contributor in the making of the field of cognitive science, defined ―learning as improvement in one‘s cognitive processes‖. He listed twelve cognitive processes underlying learning—prediction, modeling, experimentation, evaluation, diagnosis, planning, causation, judgment, social influence, teamwork, negotiation and describing. The first four may be grouped under conceptual processes, next four under analytic processes and the last four under social processes. All these are considered as cognitive processes in the sense that the steps of these processes are based in thought rather than in action.

Prediction: Learning to predict requires repeated practice in each domain of knowledge. This is experiential learning by trial and error. The cognitive issue is building up a large case base according to expectation (prediction) failures.

Modeling: Processes need to be learned in order to effectively participate in them and in order to propose changes in them. This can be learned through designing it, modifying it and participating in simulations of it. This is termed as modeling.

Experimentation: Learning to analyze what has worked out and what has not and why is an important aspect of a rational life. These things can be learned by living and talking about our experiences, thus creating a database stories that we can rely on later. The cognitive task here is story creation, comparison, indexing and modification.

Evaluation: Learning to make judgments is about learning to notice, to describe, and to appreciate. Making value judgment requires understanding what our values are. These are learned consciously.

Diagnosis: Diagnosis means both reasoning from evidence and understanding what constitutes important evidence. In diagnosis both the process and the domain knowledge is important. People learn to do diagnosis and to understand what causes what, consciously. This is knowledge that can be taught by experts as a part of the process of diagnosis.

Planning: Learning to plan has two components—being able to create a plan and being able to modify an existing plan for new purposes. The first one is important to learn how to do, but it is the latter ability that makes one proficient at planning. Planning from first principle is very difficult. Mostly people just modify an old plan by remembering the mistakes in the previous plans and making improvements upon them. One can modify plans from one domain of knowledge to use in another but this is not easy and requires a level of abstraction that is very important to learn.

Causation: A cause has been defined as that which produces something, or as the origin or motive of an action, or as that which explains why something occurs or comes into existence. Aristotle‘s theory of causation held that there are four kinds of causes—efficient causes (which brings about changes), material causes (on which the changes occur), formal causes (distinctive shapes or forms or properties belonging to the final results) and final causes (purposes or aims). Causal knowledge is knowledge fixed to a domain of inquiry. It is important to discuss the cases with others because it helps in indexing them in the mind, enabling retrieval whenever needed.

Judgment: There are two forms of judgments—through experience (without knowing the reasons) and through reasoning based on evidence. To learn to make objective judgments, one needs constant feedback either from a teacher or a colleague or from reality. They should be able to analyze their successes and failures and articulate their reasoning.

Influence: Here, influence means understanding how others respond to our behavior and recognizing consciously and unconsciously how to improve the process. Conscious awareness about mistakes can help in learning to behave differently.

Teamwork: It refers to understanding our own as well as others roles and responsibilities as members of a team. It is learning how to achieve goals in a group, consciously allocating roles, managing inputs from others, coordinating actors and handling conflicts.

Negotiation: It refers to making a deal. That is to analyze the positive and negative sides of a deal and consciously selecting a better option than the other.

Describing: It refers to creating and using conscious descriptions and analysis of situations to identify faults. Describing is important in order to get help from people who may know more about the situation than we do. It is important even to put the small incidences in order so as to understand the situation better.

Theories of Learning

Psychologists have tried to understand ‗learning' by explaining it through behaviorism (classical and operant conditioning). But some psychologists disagreed to the behavioral explanation of learning. These psychologists (at first, the gestalt theorists) explained it as a cognitive process. After this, many cognitive theories were proposed.

The cognitive theories of learning are backed by rationalism rather than empiricism. They emphasize on the changes in mental processes that people use in their efforts to understand the world. From a cognitive perspective, learning is a change in a person's mental structures resulting in demonstration of different behaviors. These –mental structures‖ include schemas, beliefs, goals, expectations, and other components. Cognitive learning theories stress the importance of mental processes and focus on what is happening in the learner. An underlying principle of all cognitive theories is that the mental processes allow learners to actively interpret and organize information. The cognitive theories are based on some general assumptions—

a) Cognitive processes are the focus of study.
b) Knowledge is organized.
c) Though objective and systematic observations of behavior should be the focus of scientific inquiry, inferences about unobservable mental processes can often be drawn from such behavior.
d) Learning involves the formation of mental associations that are not necessarily reflected in overt behavior changes.
e) Individuals are actively involved in the learning process.
f) Some learning processes may be unique to human beings.
g) Learning is a process of relating new information to previously learned information.

Many cognitive theories have emerged after the Gestaltists established themselves as a diversion from the traditional connectionist approach on the account of difficulty in explaining the learning process or behavior involving higher cognitive abilities. Here a brief account of the cognitive theories has been presented.

Gestalt Theory

Three German psychologists—Max Wertheimer, Kurt Koffka and Wolfgang Kohler developed a new approach of studying behavior. This approach considered learning as the result of organization of perception (insight) by the learner. The German word ‗Gestalt' means form, pattern, structure—an integrated whole. The basic idea underlying this theory is that a thing cannot be understood by the study of its constituent parts but by the study of it as a totality or whole. Learning is not interpreted by random steps, not by trial and error, not by conditioning, but interpreted as purposive, exploratory and creative. While learning, the learner perceives the situation as a whole and after seeing and evaluating the different relationships takes the proper decision in an intelligent way.

Tolman's Theory

Though E. C. Tolman was a behaviorist, he combined the advantages of cognitive theories and connectionist theories. His theory includes aspects like knowledge, thinking, planning, inference, purpose and intention. He developed molar approach to behavior, in place of molecular approach. Molar behavior is purposive and goal oriented. It means that behavior is guided by the goal determined by the cognitive structure of the organism. He developed the concept of ―cognitive map‖. It refers to acquisitions, representation and use of spatial information to perform tasks. According to him, learning is an affair of sign gestalt, formation, refinement, selection and invention.

Lewin's Cognitive Field Theory

Kurt Lewin, another gestalt psychologist emphasized more on the development of behavior and motivation than on previous experiences of the learner for developing insight. He gave concepts like life space,

topology, valence, etc. to understand the mental structure. According to him, learning is behavior, locomotion from one region of life space to another. This leads to change in cognitive structure which is learning. Lewin‘s psychological interest was in the motivating conditions of person-environment situations. Whereas behaviorists study psychology as a series of events, the _field‘ in _field psychology‘ implies that psychologically interpreted everything happens at once.
_Field‘ is defined as _the totality of coexisting facts which are conceived of as mutually interdependent‘.

Piaget's Theory

According to Piaget, human infants do not start out as cognitive beings. Instead, out of their perceptual and motor activities, they build and refine psychological structures. He proposed knowledge as a process, a set of actions that a person may perform. For him, to know something is to act on that thing, which can be either physical or mental or both. He believed that children move through four stages of development—sensori-motor, preoperational, and concrete operational and formal operational. Three important characteristics of this theory are (a) it is a general theory, (b) the stages are invariant and (c) the stages are universal.

Bruner's Theory

Jerome S. Bruner developed a cognitive model of learning. His theory explains how subject matter can be best learnt practically. Bruner's theoretical framework is based on the theme that learners construct new ideas or concepts based upon existing knowledge. Learning is an active process which includes selection and transformation of information, decision making, generating hypotheses, and making meaning from information and experiences. According to him, three issues should be considered in the teaching-learning process—nature and ability of learners, the structure of knowledge and the nature of knowledge acquisition process. He provided some modes of representation, i.e. specific ways of presenting the subject matter by which learning becomes easier. These are—enactive mode, iconic mode and symbolic mode. These play a vital role in learning.

Ausubel's Theory

According to David Ausubel, if learners have properly internalized the material learnt, they can easily reproduce it. The more the material is presented to the learner systematically, the more the process of internalization will be facilitated. Learning is internalized by progressive differentiation process and integrative reconciliation process. His work focused on verbal learning. He dealt with the nature of meaning, and believes that the external world acquires meaning only as it is converted into the content of consciousness by the learner. Meaning is created through some form of representational equivalence between language and mental context. It involves two processes—reception and discovery. The subsumption theory advocates that when information is subsumed into the learner‘s cognitive structure it is organized hierarchically. For meaningful learning to take place, a stable cognitive structure is essential.

Vygotsky's Theory

Like Jean Piaget, Lev Vygotsky also believed that children are active seekers of knowledge, but he considered them in a wider context. According to his theory, rich social and cultural contexts profoundly affect children‘s cognition. He believed that all higher cognitive processes develop out of social interaction. A special concept, the zone of proximal (or potential) development (ZPD), explains how this happens. It refers to a range of tasks that the child cannot handle alone but can accomplish with the help of adults and more skilled peers. According to Vygotsky‘s theory of learning, cognitive development is influenced by social factors, cultural factors and language.

Constructivism

This theory propounds that the learners construct their understanding of the topics they study, rather than recording understanding delivered from others. Constructivism refers to the idea that learners construct knowledge for themselves—each learner individually (and socially) constructs meaning—as he or she learns. It emphasizes that new learning is interpreted in the immediate context of current understanding. There is no single unified view of constructivism. Constructivists disagree on the nature of knowledge and the importance of different elements in the knowledge construction process. There are mainly two viewpoints.

Cognitive Constructivism: It is based on Piaget‘s work. It focuses on individual, internal constructions of knowledge. Social interaction acts only as a catalyst for individual cognitive conflict.

Social Constructivism: It is strongly influenced by Vygotsky‘s work. It suggests that knowledge exists in social context and is initially shared with others instead of being represented solely in the mind of an individual.

The constructivist theory is based on the following principles—

1. Learning is an active process in which the learner constructs meaning out of sensory input.
2. Learning consists both of constructing meaning and constructing systems of meaning.
3. The construction of meaning takes place in the mind. But it is necessary to provide activities which engage both the mind as well as the hands.
4. Learning is influenced by language used.
5. Learning is a social activity and is intimately associated with social interaction.
6. Learning is contextual—it is influences by our lives, relationships, beliefs, prejudices and fears.

7. Learning takes place upon the base of previous knowledge. It is not possible to assimilate new knowledge without having some previous knowledge to build on it.

8. Learning is not instantaneous—it requires some time for significant learning to take place.

9. Motivation is a key component of and plays a significant in learning.

Information Processing Theory

Information processing is a cognitive theory that examines the way knowledge enters and is stored in and retrieved from memory. This model has three major components—

i) Information stores—These are repositories that hold information. These are analogous to a computer‘s main memory and hard drive. It includes sensory memory, working memory and long term memory.
ii) Cognitive processes—It refers to the cognitive processes that move information from one store to another. These involve attention, perception, rehearsal, encoding and retrieval.
iii) Metacognition-- It refers to knowing about and having control over our cognitive processes. It integrates the cognitive processes so as to use them strategically.

Learning Systems

The learning systems are the contribution of artificial intelligence. These are software programs which are capable of learning. A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks T, as measured by P, improves with experience E (Mitchell, 1997). The main characteristics of the new generation of learning programs are that they are basically problem-solving programs, capable of undertaking heuristic search, with a reasonable storehouse of methods like generate-and-test and means-end analysis.

BACON is a learning system that discovers empirical laws by using two complementary techniques. The first is the detection of regularities in data. The second is construction of new attributes in terms of more primitive ones. The first technique leads to useful generalizations and also directs the second technique. Together the two lead the search for more data which could lead to further generalizations.

In 1964, Bobrow developed a computer program named ―STUDENT‖. It was designed to solve algebra word problems. Its performance was compared to that of human problem solvers by Paige and Simon. They intended to describe human behavior while solving algebra word problems. Further testing determined that STUDENT could not account for human solution processes that rely on semantic knowledge. Its limitations led to the development of UNDERSTAND. According to Hayes and Simon (1974), UNDERSTAND was based on two assumptions—

i) To understand a written problem, the text is read and encoded both semantically and syntactically; and

ii) A representation must be made of the newly encoded information.

The resulting representation must include a problem space. A problem space consists of the set of problem elements, the initial state, the goal state, an operator or a set of operators and the restrictions under which the operator may be applied. UNDERSTAND reads the problem text, then rereads it, to semantically and syntactically analyze the structure and match it against a set of requirements specified as input for the General Problem Solver. Hayes and Simon (1974) contended that an individual solves a problem using two interactive processes, an understanding process and a solving process. The understanding process generates a problem space from the problem text, and the solving process uses the problem space to search for steps toward solving the problem. Even though the solving of a problem follows the understanding, the model shows that these are not sequential stages, but rather, interactive stages. These two processes are not sequential, rather interactive.

Another contribution of AI in the field of learning is Dendral. Its primary aim was to study hypothesis formation and discovery in science. It chose a specific task in science for this—to help organic chemists in identifying unknown organic molecules, by analyzing their mass spectra and using knowledge of chemistry. The software program Dendral is considered the first expert system because it automated the decision-making process and problem-solving behavior of organic chemists.

The Automated Machine (AM), another learning program was developed by Doug Lenat. It works by generating and modifying short Lisp (programming language) programs. These are then interpreted as defining various mental concepts. The system has elaborate heuristics for choosing which programs to extend and modify. It is chosen on the basis of the experiences of working mathematician in solving mathematical problems. It is composed of many data structures called –concepts‖ and –heuristic rules‖ and a simple flow of control.

Thus we can see that mere conditioning cannot explain all types of learning. Some psychologists explained learning on the basis of cognition or cognitive processes. Cognitive processes include creating mental representations of physical objects and events, and other forms of information processing. Cognitive learning is the result of sensory. It is defined as the acquisition of knowledge and skill by mental or cognitive processes; the procedures for manipulating information 'in our brain'. It is a powerful mechanism that provides the means of knowledge, and goes beyond simple imitation of others. The cognitive theories of learning developed starting from the concept of insightful learning to constructing meaning and to the modern, sophisticated learning programs. While gestalt psychologists explained learning on the basis of insight, Tolman described it as a molar behavior which works on sign gestalt, Kurt Lewin went on to describe it on the basis of psychological field. Piaget related cognitive development to biological development. Bruner emphasized constructing new knowledge on the basis of prior knowledge. David Ausubel emphasized the importance of internalization of meaning for learning. While constructivism itself grew as a very attractive topic for the contemporary psychologists, Vygotsky emphasized more on social constructivism. Recently, the information processing theory has gained much popularity. The importance of the information processing concept in learning has led to development of various learning programs or systems, which are usually based on problem solving.

Problems in the classroom

The classroom is a place where the teacher teaches the learners. The essence of teaching is in learning. But the teacher faces various problems regarding learning in the classroom setting.

- **Understanding the inherent meaning of learning**: One major problem concerning learning is to understand the term ‗learning' itself. While coping with the content and the technology to deliver it, the teacher‗s focus is sidetracked from the actual meaning of learning. If the teacher is able to understand the inherent meaning of learning and adopts the appropriate approach towards it, it becomes easier for both the learners to learn and the teacher to teach.
- **Perplexed goal of learning**: Learning is a purposeful activity. If the goal of learning is disoriented, learning cannot take place. Cognitive science regards learning as ‗change in cognitive abilities'. Most of the time, the teacher misinterpret this very purpose of learning as mere ‗accumulation of information'.
- **Cannot relate new knowledge with the existing ones:** The teacher has to base the new learning upon some existing conceptual knowledge. It has to be anchored on the existing knowledge base. If the conceptual base of the learner is not strong or if the teacher cannot relate the new learning with the existing one, it cannot be said that

proper learning has taken place and even if it takes place, it is not enduring.

- **Mismatch of content and pedagogy:** The content is always designed with some goals and learning objectives in view. It is not the content that our education system wants us to learn but the values inherent in those content. If the pedagogy to deliver the content is not appropriate for that particular content, the very purpose of the curriculum may be diminished.
- **Knowledge versus learning:** There is a difference between acquiring knowledge and learning. Learning is a broader term than mere acquiring knowledge. However, acquiring knowledge may be a part of learning. It is difficult for an average teacher to understand this difference and most teachers treat them equally. Everything can neither be taught nor learnt. So, being capable of using the knowledge acquired through learning to tackle situations in one‘s life is actual learning.
- **Fragmented learning:** In a hurry to deliver more information within a short period, the teacher often presents fragmented knowledge to the learners which become difficult for them to understand. They know the contents but they cannot relate them.
- **Lack of practice time:** Whatever the learners learns, they need some time to internalize it through some practice. But most of the times the learners are not given adequate time for practicing, for which the learners cannot internalize the concepts.
- **Providing appropriate environment for knowledge construction:** It is said that children are natural knowledge constructor. They construct knowledge form their surroundings. But it is difficult for the teacher to control all the components of the environment all the time.
- **Individual difference:** Learning is both an individualized and a social process. Every individual has his own characteristics according to which pedagogy is to be designed and the individuals also have to support each other in knowledge construction.

Pedagogical Implications of Learning

Learning theories may be looked at as a continuum running from behaviorist through cognitive/social to constructivist. It is understood from the continuum that the cognitive processes although unobservable are real and can precede, influence and modify behavior. Learning itself is not directly observable. It is evident from a change in knowledge, which in turn makes a change in behavior possible. Moreover, humans are social beings. Their cognition is not isolated and they also learn by observation and imitation. Social interaction facilitates the organization of cognition. Learning is a process of knowing and knowing is a form of action. In learning, the knower engages positioning themselves in relation to the knowable. When engagement occurs, they become a more or less transformed person. Pedagogy is the science and practice of the dynamics of knowing. In general, the cognitive theories of learning have the following implications on the educational process—

1. Cognitive processes influence learning.
2. With growth, children become capable of increasingly more sophisticated thought.
3. People organize the things they learn.
4. New information is most easily acquired if it is associated with previous knowledge.
5. People control their own learning.

Ivie (1998) explained pedagogy on the basis of Ausubel's learning theory and arranged instruction in a sequence of five logical steps— (1) ascertaining if the student already possesses relevant concepts in his or her cognitive structure.
(2) providing appropriate advance organizers, which are used to anchor the new material within established cognitive structure. (3) presenting the new material in an organized fashion, checking to make sure the student is subsuming the new information under appropriate organizers. (4) providing sufficient practice (drill) so that the material is thoroughly learned, becoming an integrated part of the student's cognitive system. (5) guiding the student through a problem solving situation that utilizes higher order thinking skills. Kumar and Gupta (2009) supported for pedagogy based on cognitive

constructivism, in which the role of the teacher is to facilitate discovery by providing the necessary resources and by guiding learners as they attempt to assimilate new knowledge to old and to modify the old to accommodate the new. Teachers must take into account the knowledge that the learner currently possesses when deciding how to construct the curriculum and to present the sequence, and structure new material. The role of the teacher in Piaget‘s theory is to provide a classroom full of interesting things to encourage the children to construct their own knowledge and to have the ability to explore. Direct experience, making errors, and looking for solutions are vital for the assimilation and accommodation of information. Whiteley (2006) addressed the issues of implementing Socratic Method and Bloom‘s taxonomy of cognitive domain in Virtual Classroom Setting. According to him, the Socratic approach can be effectively used to help learners to achieve the higher order learning level of Bloom‘s Taxonomy of cognitive domain. In this method, the teacher‘s role is to direct the learners in the right direction, but without providing the answers. Rittle-Johnson & Star (2007) found that comparing and contrasting varied solution methods to the same problems helps in learning mathematics. It requires written record of all-to-be compared solution methods, preferably with solution steps aligned; explicit opportunities to identify similarities and differences in methods; instructional prompts to encourage learners to consider the efficiency of the methods. Comparing contrasting solutions seemed to support gains in procedural knowledge because it facilitated learners‘ exploration and use of alternative solution methods. Comparison of multiple solutions helped them move beyond rigid adherence to a single solution method to more adaptive and flexible use of multiple methods. However, this method was not found to be helpful in gaining conceptual knowledge.

Apart from these, we may draw pedagogical implications of each cognitive theory of learning—

- The pedagogical implications of the Gestalt theory directs towards emphasis on insight. The teacher should present the picture of whole subject matter in the class first, and then he should come to its parts. This theory advocates for adopting problem solving approach in the class. The teacher should provide appropriate problem situations to the learners. The teacher should relate the present knowledge with the past knowledge, because the insight of the learner is based upon his past experiences. Ivie (1998) has also supported that the teacher should look for the status of previous knowledge in the cognitive structure of the learner. This theory advocates for developing reasoning, thinking and imagination powers and thus the creative potentials of the learners. So the teacher should always encourage these.

- The pedagogy implied by Tolman‘s theory is that the teacher should make the behavior of learners purposive and goal directed during the whole teaching learning process. The goals should be set beforehand and the behavior of the learners should be directed towards the goals. The teacher should use reward and punishment for reinforcing behavior. Gestalt principles should be followed in order to make the teaching material meaningful i.e. more importance should be given to whole learning than to part learning. Ivie (1998) and Kumar & Gupta (2009) have regarded organized pattern of the learning material important for effective learning. Providing cues by the teachers help the children to proceed further to solve the problems. Cognitive mapping helps an individual to know the progress of the tasks performed. So, the teacher should help the learners to structure the cognitive map.
- Lewin‘s learning theory implies that proper psychological as well as physical environment should be provided to pupils in the class in order to help them cross the barriers and develop insight in them. The teacher should help different pupils in formulating their respective goals keeping in view their needs and capacities. The teacher should strengthen the valence by making the goals attractive for learners and by raising their aspiration level. The teacher should use reward and punishment procedure regularly. The teacher should make efforts to reduce tension of learners as much as possible, as tension may lead them away from their goal.

- The concepts of assimilation, accommodation and equilibration provided in Piaget‗s cognitive development theory suggest the importance of the optimal conditions for an individual‗s learning and development. Thus the pedagogy implied is to encourage children to discover for themselves through spontaneous interaction with the environment, which has been also stated in the study by Kumar & Gupta (2009). Teachers should provide a rich variety of activities designed to promote exploration. A classroom following Piaget‗s learning theory does not try to speed up development. Instead, he believed that appropriate learning experiences build on children‗s current level of thinking. The teacher should plan activities for individuals and small groups rather than just for the total class. It highlighted the importance of drives and motivation in the field of learning and development. It has utilized the concept of equilibration for this purpose. Moreover, teacher must understand the processes children use to get to the answer in addition to checking the correctness of the answer.
- The pedagogy based on Ausubel‗s theory suggests more emphasis on internalization of the meaning of the content. Systematic presentation of the content or the learning material facilitates internalization. The teacher should use didactic, expository methods of teaching. Most notable contribution of Ausubel‗s learning theory is the advance organizer. It is a tool or a mental learning aid to help learners integrate new information with their existing knowledge, leading to ―meaningful learning‖ as opposed to rote memorization. The study conducted by Ivie (1998) suggests that opportunity for adequate practice should be given to the learners for integrating the new knowledge in cognitive system and appropriate advance organizers should be used. Mayer and Wittrock (2006) identified instructional methods that are intended to promote meaningful learning, such as providing advance organizers that prime appropriate prior knowledge during learning, asking learners to explain aloud a text they are reading, presenting worked out examples along with commentary, or providing hints and guidance as

learners work on an example problem. Meaningful learning also helps in transfer of problem-solving.

- Bruner‘s theory regards children as active problem solvers. They can explore difficult subjects by themselves. The teacher‘s responsibility is to expose them to the opportunities to explore. This theory believes that children can be taught any subject at any stage of development in a way that fits the child‘s cognitive abilities. The teacher should encourage intuitive and analytical thinking capacity of the children. Instead of giving external competitive goals like grades or class ranking, the teacher should develop interest in the subject matter, as it is the best stimulus for learning. The teachers should structure the knowledge in such a way that enables the learner to most readily grasp the information. Understanding the fundamental structure of a subject makes it more comprehensible. Details are better retained when placed within the context of an ordered and structured pattern. The teacher should also take care of effective sequencing, as sequencing or lack of it can make learning easier or more difficult. No one sequencing will fit every learner, but in general, the sequence should be in increasing difficulty. Another implication is that the teacher should select and pace the rewards and punishments appropriately.
- The pedagogy implied by Vygotsky‘s theory is to use information about the two levels of Vygotsky‘s zone of proximal development in organizing classroom activities. The two levels are ‗what a child can do independently‘ and ‗what the child can do when assisted by an adult or more competent peer‘. It can be done in the following ways:
  - ∗ Instruction should be planned to provide practice in the zone of proximal development for individual children or for groups of children.
  - ∗ Cooperative learning activities should be planned with groups of children at different levels who can help each other learn.
  - ∗ Scaffolding should be a component of pedagogy, where the adult provides hints and prompts to the learner at different levels.

Therefore, the teacher must plan activities that encompass not only what children are capable of doing on their own but also what they can learn with the help of others. A significant application of Vygotsky's theory is _reciprocal teaching‘. In this method, teacher and learners collaborate in learning and practicing four key skills: summarizing, questioning, clarifying, and predicting. It particularly improves learners‘ ability to learn from text. Gradually the teacher‘s role is reduced and the learner becomes independent. Another implication that can be drawn from Vygotsky‘s theory is _collaborative learning‘. Here, the group members should have different levels of ability so that more advanced peers can help less advanced members (McLeod, 2007).

- According to the information processing theory of learning, a well developed schema helps to incorporate the new knowledge in an organized manner and to reduce the load on working memory. So, this theory implies that the teacher should focus on relationships among the items of information that the learners are expected to learn. The organization of information is very important in promoting learning. The teacher can organize the information in several ways—charts, matrices, hierarchies, outlines, graphs, tables, flowcharts, maps, etc. Developing procedural knowledge to the point of automaticity has important implications for teaching. The teachers should provide the learners with as many opportunities as possible to practice in a variety of contexts for reaching the automatic stage. The teacher can make use of chunking (process of combining separate items into larger, more meaningful units), automaticity (mental operations that can be performed with little awareness or conscious effort, essential for higher cognitive skills) and dual processing (verbal instruction supplemented with visual representations) to overcome the limitations of working memory. Attracting and maintaining learner‘s attention are crucial first steps in teaching. Teachers should plan their lessons so that the learners attend to what is being taught and ignore irrelevant stimuli. Background knowledge in the form of schemas affects perception and subsequent learning. The teacher can check learners‘ perceptions by asking open-ended questions. The teachers can also use organizers to capitalize on imagery—the process of forming mental pictures, which also facilitate problem-solving. Teachers can make use of tools like teacher questioning, examples, analogies and mnemonic devices to encourage learner elaboration. The teacher should develop the metacognitive abilities of the students to enable them to effectively use strategies—plans for accomplishing learning goals. Teachers should be aware of the wide and varied background knowledge of the students. The challenge of dealing with this wide variety can be addressed by—asking students what they know about the topic the teacher is planning to teach; providing background experiences with rich examples and representations; using open-ended questions to assess students‘ perception; and using the experiences of students in the class.

- The constructivist theory believes that learning can be only through construction of meaning. It implies:
  - ∗ The teacher has to focus on the learner in thinking about learning (not on the subject/lesson to be taught).
  - ∗ There is no knowledge independent of the meaning constructed or attributed to experience by the learner.

Learners mostly use examples to construct their understanding. So, the teacher should provide them with a variety of examples and representations of content. Social interaction facilitates learning. Interactions along with the teacher‘s support keep the learners active. Providing the appropriate amount of support is a very sophisticated process, so as not to reduce the learners‘ active role in the learning activity. So, the teacher needs to take care of this. Learners‘ constructions are most meaningful to them if they can relate their learning to the world outside the classroom. The teacher should relate the theoretical knowledge with the surrounding of the learner. For example, identifying the longitude and latitude of their school or writing a persuasive essay for a school or class newspaper, designing an advertisement for a particular group or their own school, etc. Representation of content is important in the construction of understanding. The contents which are difficult to represent with concrete materials or in actual situations, can be illustrated using technology.

- Learning systems are helpful for generalization, problem solving, decision making, etc. Teachers in classroom need to understand the underlying processes in these processes and try to make them effective in the classroom. The learning systems are also designed to serve the purpose of improving the learning of the students in the pedagogical situation. The learning system, Bacon, for example, implies that the teacher should help the students in finding out the common elements in the contents and generalization and construction of new meaning based on earlier ones. UNDERSTAND implies that problem solving requires understanding the problem and then finding a solution. The teacher should at least try to ensure to the level of understanding. Dendral is a learning system for decision-making and problem solving.

Problem Solving

Problem solving is a critical cognitive activity that pervades many aspects of our day-to-day lives. It is a higher order cognitive ability. In order to understand problem solving, it is important to decide what constitute a ‗problem'. Goldstein (2005) tried to give a complete definition of a problem as ―a problem occurs when there is an obstacle between a present state and a goal and it is not obvious how to get around the obstacle‖. Hayes (1989) defined problem solving as ―transforming a given situation into a desired situation or goal‖. According to Mayer and Wittrock (2006), problem solving is ―cognitive processing directed at achieving a goal when no solution method is obvious to the problem solver‖. So, ‗problem' is a situation in which there is a difference between one's current state and one's desired or goal state, without any clear way of getting from one to the other. Searching for the way to move from the current state to the goal state is ‗solving' the problem. Problem solving is the process that an organism implements in order to try to get from the current state to the desired state. It refers to any activity in which both the cognitive representation of prior experience and the components of a current problem situation are reorganized in order to achieve a designated objective (Ausubel et. al, 1978). It is the analysis and solution of tasks or situations that are complex or ambiguous and that pose difficulties or obstacles of some kind. It is the analysis and transformation of information towards a specific goal (Lovett, 2003). It is thinking in terms of some problems and solutions, that is, thinking is stimulated by some problems, which arises when the individual selects a goal and something obstructs him to reach the goal. Skinner (1968) defined it as ―a process of overcoming difficulties that appear to interfere with the attainment of a goal‖. A problem situation has three major components: an initial state (the present situation), a goal state (the desired situation) and strategies (for getting from the initial state to the goal state). Apart from these three components, it also includes prior knowledge and experiences and decision making ability of the individual. Thus, problem solving is the process, by which a person represents the goal to be accomplished, determines a procedure for reaching the goal, executes that procedure, and evaluates the success of the solution attempt (Novick, 2003).

Problem Solving in Cognitive Science

Problem solving is a major component of cognitive science. It is studied in several disciplines of cognitive sciences, particularly in psychology, where it is addressed in conjunction with cognitive functions such as attention, control, learning, reasoning and so on using a symbolic or connectionist approach (Ghallab, 2003). Problem solving may occur inside a mind, inside a computer, in some combination of both, or in interaction with an external environment. Studying how humans solve problems comes under cognitive psychology. In psychology, problem solving is understood as a deliberate and purposeful act on the part of an individual to realize the set of goals or objectives by following some systematic step for removal of the obstacles in the path of the realization of these goals. It is an important area in the field of Artificial Intelligence (AI). Artificial Intelligence (AI) studies how computers solve problems. The researches on AI have both borrowed from and contributed to research on human problem solving. It includes a number of important conceptual and algorithmic contributions. It produced systems, applied to different tasks that can solve problems at the level of professionally trained humans. These AI programs are usually called expert systems. While the computer's process appears to be more systematic and even compulsive, the human's process is more intuitive. The expert systems are modified as and when new knowledge becomes available. The field of neuroscience provides the neurological and mental processes involved in problem solving. The areas of the brain involved in this process are—occipital lobe (processing of visual information and eye movement), temporal lobe (short term memory and sorting new information), parietal lobe (processing somato-sensory information), pre-motor area (initiating and modifying movements), hippocampus (formation of new memories and finding shortcuts and new routes between familiar places) and prefrontal cortex (planning and executing strategies). These areas, while being the major areas used during problem solving, are not a definitive list.

Problem Solving in Education

A major goal of education is to help students learn to use what they have learned to solve problems in new situations. Problem solving occupies an important position in the teaching learning process. It comprises a fundamental component of education because teachers are interested in improving students' ability to solve problems. Another reason for its significance in education is the difficulty level of problem solving. Most often students have very poorly developed problem solving abilities and they approach problems in haphazard ways (Reif, 2008). Teachers always try to improve the problem solving abilities of the learners, but their efforts often turn out to be inadequate. Though they are able to solve particular problems, difficulty arises in generalization. That is, they can solve similar problems but cannot use the knowledge gained from previous problem solving process to solve a new kind of problem. Therefore, it is a challenge for the teachers to improve problem solving abilities of the learners. For this, it is necessary to understand better the cognitive processes underlying good problem solving and to develop pedagogy to teach problem solving effectively. Some other questions posed for the educational system, which can be answered on the basis of cognitive science researches are: whether problem-solving courses should attempt to teach problem solving as a single skill or as a collection skills; whether problem-solving courses should focus on the product or process of problem solving; whether problem solving should be taught as a general course or within specific domains; whether problem solving should be taught before or after students have mastered corresponding lower-levels.

Cognitive Mechanisms in Problem Solving

Problem solving involves the operation of the various representational and executive mechanisms. Gagne (1980) provided a description of the cognitive activities that appear to be involved in problem solving which include intellectual skills, verbal knowledge and cognitive strategies. Intellectual skills are those capabilities that develop as a result of cognitive growth. It is the ability of the individual to generalize basic skills such as number concepts, and to understand and use rules when confronted by problems. Verbal knowledge or declarative knowledge refers to the meaningful organization of large bodies of general and specific knowledge. Cognitive strategies are cognitive tools that enable us to select and operate upon intellectual skills. It involves skills that enable them to comprehend symbol systems and rules governing the relationship between objects and events.

Mayer and Wittrock (2006) distinguished among four major cognitive processes in problem solving: representing, in which the problem solver constructs a cognitive representation of the problem; planning, in which the problem solver devises a plan for solving the problem; executing, in which the problem solver carries out the plan; and self-regulating, in which the problem solver evaluates the effectiveness of cognitive processing during problem solving and adjusts accordingly. During representing, the problem solver seeks to understand the problem, including the given state, goal state, and permissible operators, and the problem solver may build a situation model—that is, a concrete representation of the situation being described in the problem. Mayer and Wittrock (2006) listed five kinds of knowledge in order to be successful problem solvers: facts (knowledge about characteristics of elements or events); concepts (knowledge of a categories, principles, or models); strategies (knowledge of general methods); procedures (knowledge of specific procedures); and beliefs (cognitions about one's problem-solving competence) or about the nature of problem solving. Facts and concepts are useful for problem representation, strategies are needed for planning a solution, procedures are needed for executing the plan, and beliefs can influence the process of self-regulating.

Strategies of Problem Solving

Psychologists and educationists have devised some strategies to solve problems in an economical and effective way. A strategy means a systematic plan for generating possible solutions that can be tested to see if they are correct. The main advantage of cognitive strategy is that they permit the problem solver to exercise some degree of control over the task at hand. They allow individuals to choose the skills and knowledge that they will bring to bear on any particular problem. Two important strategies of problem solving are—

1. Algorithm: An algorithm involves systematically exploring and evaluating all possible solutions until the correct one is found. Here, every possible step is listed till the correct solution of the problem is found. It is a set of rules which is systematically applied in a specific order, to all possibilities and their outcomes. But it is not applicable for complex problems. It is expensive in terms of time and energy.
2. Heuristics: It is a problem solving strategy in which hypotheses about problem solutions are generated and tested in a time saving and systematic way. It is based on informal, intuitive and speculative strategies. Heuristics are cognitive short-cuts for guiding operator selection in problem solving. Heuristics is applied in a problem space—the universe of all possible actions that can be applied to solve a problem. Its limitation is that it does not guarantee an acceptable solution. Some commonly used heuristics are—means-end analysis (looking for the action that will lead to the greatest reduction in difference between the current state and goal state), working forward (starting at the beginning and trying to solve the problem from the start to the finish), working backward (starting with the desired result and trying to work backwards until the initial state is attained), using analogy (making use of experiences, training and practice to find a solution for

similar problems), sub goal analysis (the complex goal is divided into easily attainable sub-goals), generate and test (simply generating alternative courses of action, not necessarily in a systematic way, and then notices in turn whether each course of action works). The simplest heuristic is repeat-state avoidance or backup avoidance, whereby individuals prefer not to take an action that would take them back to a previous problem state. But this is not helpful when a person has taken an inappropriate action and actually needs to go back a step or more.

In Fredericksen‘s (1984) review of cognitive theory and problem solving, he listed details of how a general class of problems might be addressed which included the following:

(a) Get the complete picture without being concerned about the small details

(b) Withhold judgment until all relevant information has been gathered

(c) Simplify the problem using words, diagrams, symbols or equations

(d) Try changing the way the problem is presented

(e) State questions and vary the form of the question

(f) Remain flexible in approach and challenge the assumption being made

(g) Try working backward

(h) Work toward sub-goals that are part solutions

(i) Use analogies and metaphors

(j) Verbalize the problem

Bransford et al. (1986) suggested a simple problem solving sequence in the form of an easily learned mnemonic—IDEAL—Ideal, Define, Explore, Act and Look. In 1957, Newell and Simon developed the General Problem Solver, a computer program. It used means-ends analysis to find solutions to a range of well-defined problems.

Another important strategy is the Basic Problem Solving Strategy which includes two general guidelines—decomposing tasks (decomposing complex tasks into simpler sub-problems) and successive approximations (not to attempt the problem in one single major effort, but in successive approximation). This strategy decomposes the solution process into several successive phases—

(a) Describing the problem—In this phase, a clear description of the problem, its initial state and the goal state are produced.

(b) Analyzing the problem—The problem is put into a form which will facilitate the subsequent construction of its solution by identifying the useful knowledge, analyzing the problem more theoretically and providing a more analytic description of the problem.

(c) Constructing the solution—This is the most important and complex phase. Here the problem is decomposed into carefully chosen sub-problems which are then successively solved leading to the actual solution.

(d) Assessing the solution—It is assessed whether the solution obtained in the preceding phase is correct and useful by providing some general criteria for checking the solution. If the solution is not satisfactory, the problem solver must go back to revise it appropriately.

(e) Exploiting the solution—This phase suggests reflecting about the problem so as to exploit one‘s work for future purposes. This is not necessary for the solution of the problem but will help the problem solver in future problem solving.

Approaches to Problem Solving

The behaviorist approach

The behaviorists viewed problem solving as a _reproductive‘ process. That is, organisms faced with a problem applied behavior that had been successful on a previous occasion. Successful behavior was itself believed to have been arrived at through a process of trial-and-error. Thorndike‘s law of effect greatly influenced the behaviorist view of problem solving.

The cognitive approach

The Gestalt Theory

The Gestalt psychologists believed that a problem occurs because of the way in which a situation is initially perceived, and that its solution emerges suddenly from reorganizing it in such a way that its real structure becomes apparent. They argued that problem solving was a ‗productive' process. In particular, in the process of thinking about a problem, individuals sometimes "restructured" their representation of the problem, leading to a flash of insight that enabled them to reach a solution. According to them, insight problems require problem solvers to go beyond associations among various parts in order to perceive the problem as a whole. They speculated on a few ways in which insight might occur like extended unconscious leaps in thinking, greatly accelerated mental processing or some kind of short-circuiting of normal reasoning processes. The research by the Gestaltists revealed many interesting problem-solving results. However the approach taken was descriptive so it did not constitute a systematic exploration of the processes of problem solving.

Information Processing Theory

Some contemporary psychologists have borrowed ideas from research on artificial intelligence to understand problem solving. They consider the mind as analogous to a computer program which operates in discrete steps (information processing) to reduce the difference between existing states and sub-goals. On this basis, the problem space theory of problem solving was proposed by Allen Newel and Herbert Simon in their book *Human Problem Solving (1972)*. The theory is based on a human-computer metaphor in which problem solving involves carrying out a series of mental computations on mental representations. In this theory, people solve problems by searching in a ‗space'. The problem space consists of the initial (current) state, the goal state, all possible states in between and a set of operators that can be applied to move from one state to another. The problem begins in the initial state, an operator is applied that generates a new state and so on until the goal state is reached. Operators are the actions that people take in order to move from one state to another. The problem spaces can be very large. So the significant issue is how people navigate their way through the possibilities or how do they choose operators. There are three ways in which operators can be acquired: trial-and-error (behaviorist account of problem solving), direct instruction and analogies (using elements in examples from one domain to aid problem solving in another domain). For example, a common search heuristic is means-ends analysis, in which an operator is applied that will satisfy the problem-solver's current goal. If there is a constraint that blocks the application of the operator, then a goal is set to remove the constraint, and thus it proceeds. Information processing theory informs educational programs aimed at teaching strategies for solving problems. However this theory is criticized on the basis that the problem space concept and the derived search methods can only be applied to well-defined problems.

In the second half of 20th century, two main approaches to problem solving arose in Europe, one initiated by Donald Broadbent and the other one by Dietrich Dorner. Both the approaches share an emphasis on relatively complex, semantically rich, computerized laboratory tasks, constructed to resemble real-life problems. However, they differ in their theoretical goals and methodology. Broadbent‘s approach emphasized the distinction between cognitive problem-solving processes that operate under awareness versus outside of awareness. It typically employed mathematically well-defined computerized systems. On the other hand, Dorner‘s approach was more concerned with the cognitive, motivational, and social components of problem solving. It utilizes very complex computerized situations that contain up to 2,000 highly interconnected variables. Almost simultaneously, in North America, researchers began to investigate problem solving separately in different natural knowledge domains based on Herbert Simon‘s work on ‗learning by doing‘ in semantically rich domains.

Thus the focus of the researches in problem solving was shifted from extracting a global theory of problem solving to development of problem solving within a certain domain i.e. on the development of expertise.

Problems in Classroom

There are some common obstacles to solving problems like—

- Functional fixedness: It refers to the tendency to regard the functions objects and ideas as fixed. Functional fixedness is also sometimes called response set. It is the tendency for a person to frame or think about each problem in a series in the same way as the problem, even when doing so is not appropriate to later problems.
- Negative transfer. When the experience of solving an earlier problem impedes the solution of a later one, it is known as negative transfer.
- Improper problem representation. Inability to represent and interpret the problem in a way that the nature of the problem and the initial state and the goal state are clear to the problem solver impedes successful problem solving.

The teacher has the challenges of dealing with the following limitations that the students pose while teaching problem solving. Some problems that the students face in solving problems are—

(1) Students approach problems haphazardly. They lack a systematic approach towards problem solving. In the hurry to search the solution, they overlook understanding of the problem.
(2) They lack the background knowledge that would solve the problem solving procedure. They try to construct the solution of a problem while they are ill-prepared and not aware of some knowledge useful for the problem solving task.
(3) They lack knowledge of how to apply the background knowledge appropriately. Though they have the background knowledge, they are not sure of which knowledge to apply when, where and how (Ross, 2007).

(4) They get stuck not knowing how to arrive at a solution. They focus most of their attention on the actual construction of a problem solution, but spend little prior time on carefully describing and analyzing a problem.

(5) They rely predominantly on their accumulated knowledge of their previously encountered similar problems, rather than on reasoning based on a few general concepts and principles.

(6) Teachers most commonly teach problem solving by means of examples and practice. The reasoning part of the problem solving procedure is mostly ignored.

(7) Teachers rarely emphasize the important decision processes needed for problem solving. Decision processes include how to search for potentially useful options and how to make sensible choices among these.

Pedagogical Implications of Problem Solving

The pedagogical implications of cognitive science on problem solving involve the strategies of the teachers to teach problem solving in the classroom, i.e. what to teach and how to teach. To facilitate problem solving among the students the teacher has to ensure that the learners have the ability of—decision-making, recovering from impasses and pursuing a systematic approach. Teaching problem solving focuses upon how to derive maximum information from the problem as presented, how to formulate a suitable strategy for its solution, enact that strategy, and monitor performance until the goal is achieved. Two important things to be considered here are what to teach and how to teach. Ashman and Conway (1989) have listed a number of skills required to enhance problem solving skills, i.e. what to teach. These are—

* Teaching cognitive processes (strategies and executive mechanisms underlying successful performance in any specific task)
* Teaching how to deal with the structure of the problems (for example, using appropriate strategies or plans to deal with ambiguities in the instructions)
* Teaching the recognition of patterns within the problem (looking for relationships and rules based upon experience and practice)

* Teaching problem solving procedures (systematically applying steps to search, scan organize, set goals, plan and monitor)
* Teaching the knowledge base (forming the information network required to complete the task)
* Teaching development of knowledge structures (how information is organized to ensure that success generalizes to other situations)
* Providing practice with feedback (reinforcing performance and the development of insight)
* Using models of instruction (using approaches that systematically address problems)

An effective approach to problem solving requires—a problem solving strategy and well organized domain knowledge. The most important aspect in pedagogy is to focus on decision processes. These should be taught within the framework of a systematic problem solving strategy. However, perhaps the most widespread approach to training in problem solving is to instruct the learner in various general principles that have emerged from theoretical analysis of the thinking process and from comparative observations of successful and unsuccessful problem solvers (Ausubel et al, 1978).

Proficiency in problem solving is best achieved in recognizing the essence of a given problem and the application of the proper problem solving heuristics. The teacher may facilitate problem solving in the learners by—

- **Using mental models:** Limjap (2002) recommend use of mental models in problem solving. It involves using diagrams or drawings used to represent the structure of the concept. Using this, the learner is able to map the essence of the model into the essence of the concept, and match or transfer specific conceptual aspects of one domain into another. This cognitive process promotes reflective abstraction.
- **Focus on process and not the product:** Limjap (2002) believes that the focus of instruction should not be on the product but on the process of problem solving. Proficiency in problem solving is best achieved in recognizing the essence of the problem and the application of the proper heuristics.

- **Using intuition and logic:** Barb and Quinn (1997) advocate that the teacher should emphasize on developing the students‘ problem solving skills and refining their strategies using intuition and logic. The ultimate goal of this instructional method is to help learners build a good knowledge base in solving world problems.
- **Using variable problem contexts:** According to Bernardo (1997), presenting concepts in variable problem contexts enables the students to appreciate the meaning and use of a particular concept or procedure in a variety of contexts. Teaching strategies that promote analogical transfer should be used. For example, presenting students with a context problem and then asking them to make their own problem using a different context.
- **Using text editing skills:** Problem solvers are asked to identify missing information from problems or point out information that is irrelevant to the problems. This activity enhances the problem solvers‘ awareness of their own thinking process. Such awareness helps learners identify their points of strengths and weaknesses and regulate their own ways of knowing (Limjap, 2002).
- **Using guided instruction in the use of metacognitive strategies:** This was supported by a number of scholars, particularly, Bernardo (1997) and Schoenfeld (1987). The teachers model the metacognitive processes in problem solving when they present solutions to their students. The teacher thinks aloud and exhibits the whole process of arriving at the correct solution. This demonstrates the complexity of the process involved in solving problems and the fact that there are many possible ways of arriving at the correct solution.
- **Factors influencing problem solving:** Simone (2008) identified four factors which favoured successful problem solving—identifying the main problem/issue; having higher quality problem definition; relating the solution to the problem well and using resources more effectively. So, the teacher should give importance to each of these factors.
- **Importance of concrete thinking:** The teacher should not underestimate the fact that novices find abstract thinking difficult. Though teachers commonly present an abstract principle and then an example to illustrate

the principle, the students use this example to refine how the principle works. Specific (content-based) thinking is important both for the novices and the experts (Ross, 2007).

- **Sufficient time:** The teacher should give enough time for wrestling with the problem and to ask question wherever, whenever and whatever necessary in an effort to understand it. If the teacher gives the solution immediately, the pupils do not get time to exercise their mental faculties.
- **Sufficient time for understanding the problem than for finding solution:** The teacher should teach the learners to spend significant time in describing and analyzing a problem before trying to construct its solution. Pupils mostly put their attention and effort in searching for the solution while ignoring the description and analysis of the problem.
- **Proper representation of the problem:** It is very necessary to put the problem in front of the students in such a manner that they can grasp what it means or to guide them to proper representation of the problem at hand.
- **Facilitating analogy:** Facilitating analogy between a previously solved problem and a current problem by giving solvers a hint to think back to the previous problem and making the source and target problems superficially similar.
- **Meaningful learning:** Max Wertheimer (1959) made the classic distinction between learning by rote and learning by understanding. According to him, the rote method of instruction leads to good performance on retention tests (i.e., solving similar problems) and poor performance on transfer tests (i.e., solving new problems). In contrast, learning by understanding leads to good retention and good transfer performance. He claimed that rote instruction creates reproductive thinking—applying already learned procedures to a problem—whereas meaningful instruction leads to productive thinking—adapting what was learned to new kinds of problems.

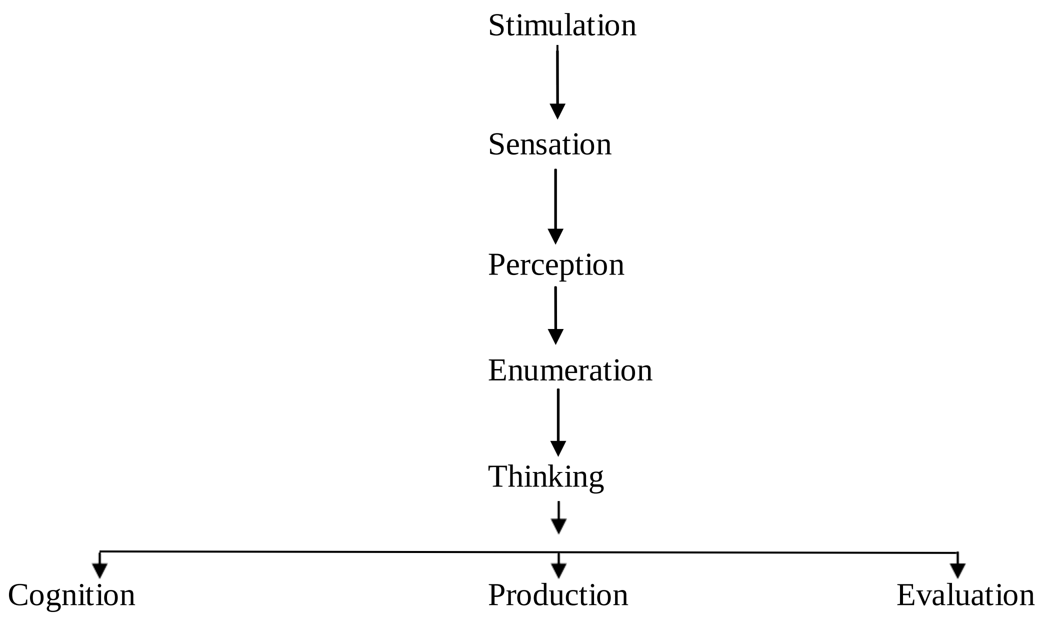
Apart from these, there are some programs which have been designed to teach problem solving skills to the learners—the Productive Thinking Program developed by Martin Covington, Richard Crutchfield, and Lillian Davies, Instrumental Enrichment developed by Reuven Feuerstein, and Odyssey described by Raymond Nickerson. Although none of these programs is currently popular, but courses based on these four criteria are likely to be successful.

It can be seen that cognitive science focuses more on the internal representation of both the problem as well as the solution. Moreover, it emphasizes that the while teaching problem solving, the solution process is more important than the solution itself. The students should not be taught to find solutions to a particular problem or type of problem but they should be encouraged to generate solutions for different types of problems on the basis of solution processes of the problems encountered earlier. Their metacognition should be guided and they should be given sufficient time to ponder over the problem. Moreover, the teacher should always keep in mind that the problem solving process of the experts and the novices differ substantially.

Creativity

The human mind is wonderful in many ways and one of these is its capacity to generate novel ideas, which is commonly known as creativity. Creativity is one of the most highly valued qualities of human beings which enormously affect all spheres of life. The nations which learn best how to identify, develop and encourage creativity in their people, are always in an advantageous position. Creativity is an important contributor in changing history and in re-shaping the world. It essentially relates to potential of an individual for generating new ideas, forms and practices. Creativity is the result of the convergence of basic cognitive processes, core domain knowledge, and environmental, personal, and motivational factors which allow an individual to produce an object or behavior that is considered both novel and appropriate in a particular context. It is the capacity to produce something that is both new and adaptive (Lautrey & Lubart, 2003). It is a complex phenomenon as it is determined by a wide range of factors. It requires a multifaceted approach even to understand it partially. However, the degree and quality of creative expression is relative. It varies from individual to individual and from age to age, as one grows in years, experience and maturity and thus enhances the status of an individual (Roy, 2001).

Guilford defined creativity as a staunch exponent of cognitive functioning. His sole emphasis was on the model of structure of intellect. He drew a distinction between convergent and divergent thinking. Convergent thinking is converging different ideas into one single point while divergent thinking means opening up different options from one single point. The former involves aiming for a single, correct solution to a problem, whereas the latter involves creative generation of multiple answers to a set problem. A structure can be developed from his explanations of creativity as follows—



6.1. Fig. Schematic representation of Guilford's ideas on creativity

The figure shows that the process of creative thinking starts with a vibration in the brain cell (stimuli) which leads to sensation, perception, enumeration and thinking. The ultimate products are cognition, production and evaluation.

Barlett defined creativity as an adventurous thinking or a getting away from the main track, breaking out of the mould, being open to experience and permitting one thing to lead to another.

According to Spearman, creativity is the power of human mind to create new contents by transforming relations and thereby generating new correlates.

Torrance conceives creativity as composed of constellation of general abilities, personality variables and problem solving traits, which he considered, can be enhanced through memory, adaptability, self-discipline, introversion, divergent thinking ability and supportive climate.

Sigmund Freud‘s psychodynamic approach to creativity suggests that creativity arises as a result of frustrated desires for fame, fortune and love. The energy that was previously tied up in frustration and emotional tension in the neurosis is sublimated into creative activity. However, he later retracted this view.

Thus, creativity can be called as the novel, original, useful and genuine cognitive output of divergent thinking.

Creativity in Cognitive Science

The study of creativity in psychology has sparked a new interest in the creative cognition approach where the idea is to understand creative processes using the methods and concepts of cognitive sciences (Lautrey & Lubart, 2003). Cognitive science tries to understand what cognitive processes are most associated with creative outcomes, the extent to which machines can be creative, the factors that limit creativity, the techniques that are supposed to enhance creativity, and the sources of individual differences in creative performance.

In philosophy, there are two theories of creativity—inspirationist theory and rationalist theory. According to the inspirationist theory, genuine creativity is largely, if not entirely, a matter of inspiration—the sudden, involuntary, and inexplicable outpouring of innovative ideas and actions, the source of which is a sacred instance (a spirit or muse) or the unconscious mind. The rationalist theory believes that all creativity is ultimately reducible to a form of calculation or more or less deliberate problem solving. However, there are many intermediate theories in between these two extremes.

In linguistics, creativity is related to generativity (Abeille, 2003). Linguistic creativity is our faculty to understand or produce an apparently unlimited number of new words and new sentences. In generative grammar, proposed by Noam Chomsky (one of the leading contributor in the cognitive science conference in 1956), linguistic creativity is governed by formal grammar. A formal grammar is defined as a finite set of rules which, when applied to an equally finite set of vocabulary words can generate a potentially infinite set of well-formed sentences.

According to Joel Chan, a cognitive scientist at the University of Pittsburgh, from neurological point of view, creativity is –a collection of cognitive abilities and tendencies, that, when applied to a problem or pursuit, results in the creation of something that is appropriate to the problem/pursuit, and also new/original in some sense‖ (Christensen, 2013). The processes (or factors) behind creativity are attention, analogy/metaphorical thinking, network organization of memory, forgetting, imagination, environment and experiences.

In artificial intelligence, creativity of machines is the main discussion. A number of attempts have been made to get computers to function creatively. An important goal of such computational approaches is to develop a better understanding of human creativity through simulation.

In the 1990s, various approaches in cognitive science that dealt with metaphor, analogy and structure mapping converged, and a new integrative approach to the study of creativity in science, art and humanities emerged under the name ‗conceptual blending'. According to conceptual blending theory, elements and vital relations from diverse scenarios are "blended" in a subconscious process, which is assumed to be ubiquitous to everyday thought and language.

Creativity in Education

Creativity has been identified as a key component for survival and resilience. It provides the foundation for art, science, philosophy, and technology. Education holds the responsibility to develop and foster creativity among learners. If education aims at generating productive human beings, it is necessary to understand and nurture their creative potential. The educational system supports them in the process of discovering and enjoying their creative potential. Understanding, identifying, and nurturing creative potential is relevant in education and therefore should be taken into account when developing education programs, strategies, and policies to achieve quality education (Chavez-Eakle, 2010). To inspire, stimulate and sharpen the creative mind, good education, proper care and provision of opportunities for creative expression are essential. All these can be given only by the teachers, parents and the society. They are required to help the learners in nourishing and utilizing their creative abilities to the utmost. This can be achieved by acquainting the teachers and parents with the real meaning of the creative process, the cognitive processes underlying creativity and the ways and means of developing and nurturing creativity.

Nature of the Creative Process

The nature or basic structure of creative process or processes has been controversial. The controversies concerns whether the expression ―the creative process‖ refers to a single type of process or activity, the extent to which creative activity can be adequately described as a type of problem solving or means-end-analysis, etc. However, even if there are controversies, its nature can be simply described as—

- Creativity is universal. It is not confined to any individual, groups of individuals, caste, color or creed, age, location or culture. The difference is in the degree of demonstrating creativity.
- Creativity is both innate and acquired. The child is born with some creative abilities as well as the influence of cultural background, experiences, education and training in the nurturing of creativity cannot be denied.
- Originality and novelty are the most important natures of creativity. However there are questions on the concept of originality.
- Creativity is a relative concept. There are no absolute standards for assessing the creativity of a product. A creative piece is evaluated and its degree of creativity is determined in relation to others of its kind.
- Creativity is a departure from the stereotyped, rigid and closed thinking. It encourages and demands complete freedom to accept and express the multiplicity of responses, choices and lines of action.
- Creativity should have some utility value. It means that the product of the creative process should be such that it will be useful in some way to at least a group of people, if not all.
- Creativity and intelligence are conspicuously related. They do not necessarily go hand in hand. One is not the essential pre-requisite of the

other. However, a minimum level of intelligence is required for successful creative expression.

Theories/Models of Creativity

Scholars have differing views about ‗what is creativity'. Many theories and models have emerged in the attempt to understand creativity more intensely and comprehensively. Models of creativity differ from each other in their scope, in the factors they emphasize, and in the tendency to state creativity as stable or flexible. At first, creative behaviors were regarded as a reflection of differences in individual personalities. Beginning from Guilford, creativity began to be viewed as a set of traits which, though stable, were influenced by motivation and temperament (Brown, 1989). Creativity was seen as a result of a set of traits such as problem sensitivity, fluency, flexibility, complexity, evaluation, the use of novel ideas, the ability to break down existing symbolic structure, and the general tendency to organize ideas into larger patterns. Slightly differing from Guilford, Torrance viewed creativity as the combination of ability, skill and motivation (Ford and Harris, 1992). There are two types of theories or approaches to creativity—componential theories of creativity and cognitive models. The componential theories hold that creativity occurs when a variety of biological, cognitive and social factors merge or interact. They provide a global account of the factors that interact to determine the creative impact of novel ideas. The cognitive models focus more narrowly on the way in which basic cognitive processes operates on existing knowledge structures to produce novel ideas. They focus on the acts of problem identification and solution-generation as the keys to creative production.

Taylor's Level theory of creativity

According to the level theory, creativity may be described as existing at five levels in an ascending hierarchy. A person is said to be creative to the extent that he is able to reach these levels. The five levels are the following—

(a) Expressive creativity—This stands for spontaneous expression without reference to originality and quality of the product.

(b) Productive creativity—At this level, a person is able to produce something innovative.
(c) Inventive creativity—This level is marked by the presence of ingenuity with a clear emphasis on novel use of old things.
(d) Innovative creativity—At this level, one is able to develop new ideas or principles with the help of highly developed abstract conceptualizing skills.
(e) Emergentive creativity—This fifth and highest level of creativity is rarely achieved. The most abstract ideational principles or assumptions underlying a body of art or science are made to use of at this level of creation.

Freud's Psychoanalytic Theory of Creativity

The school of psychoanalysis considers creativity to be a means and product of one‘s emotional purging. Creativity is considered as an opportunity for sublimation and catharsis. Psychoanalysis proposes that creativity wells up from unconscious drives. Though there are differing opinions about how this occurs, various psychoanalytic schools of thought generally suggest that creativity is a by-product of primary processes. The link between primary processes (specifically sexuality), and creativity is important. It suggests that there is an energy (biological creativity), which can be sublimated into higher psychological processes when the primary gratification urges of the id are inhibited. Freud takes a pathological view of the creative process. He felt that only unhappy people experienced daydreams and fantasies, which are an integral part of the creative process. To Freud there was great similarity between neurosis and creativity. He felt both originated in conflicts stemming from wish fulfillment and biological drives. He considers creativity as attempts for the expression of their repressed desires, mostly sexual in nature. According to him, the creative process is an alternative to neurosis, that is a defense mechanism protecting against neurosis, leading thus to the production of a socially acceptable source of entertainment and pleasure. The unconscious plays a major role in the act of creation. That is, the act of creation is made possible by the libido, the energy of the id, and by a defense mechanism—sublimation. Thus, psychoanalytic theory explains creativity as sublimation of sexual drives. It is not an act in itself, but rather mental relief from pain, anxiety, or sexual tension.

Arieti's Theory of Creativity

Silvano Arieti (1914-1981) was a professor of psychiatry at New York Medical College. His theory represents the contemporary views about the nature and meaning of the terms creativity, the creative process and creative output. This theory believes that both creativity and mental illness involve the transformation of reality and therefore are parallel to one another. However the distinction lies in that while creative persons aim to change reality for broader, useful and social purposes and self-actualization, psychotics want to transform reality within the framework of their private world regardless of serving any useful purpose to themselves or the society. Therefore, creative persons cannot be called as mentally ill. In fact, a creative person enjoys good mental health which energizes his cognitive abilities to create something unique or novel. Arieti considers the creative process as a _magic syntheses of the two modalities, the primary process and the secondary process and may thereby be termed the _tertiary processes'. According to him, there are four stages of the creative process—

(a) Primary: It includes a non-judgmental, non-disciplined playing with images, symbols, inner expressions of our inner lives. (Memory, traces of past perceptions, subjective experiences and impressions). Images are the "first germ of creativity" and give birth to intuition and empathy. All these happen in the right hemisphere of the brain.
(b) Secondary: It corresponds to conscious cognition or to logic—a process of choosing, deciding and putting order and form into our imaginations. These are the actions of the left hemisphere of the brain.

(c) Tertiary: It refers to the sum of the other processes which is greater than the sum of the parts; and the ability to differentiate similarities from manifold experience.

(d) Fourth: The artist knows he is an artist when his creative piece is socially appreciated. In this way all energy becomes connected again and the artist's ultimate vocation, to return energy to the universe by way of transformed matter, is accomplished.

Finke's Theory of Creative Cognition and Geneplore Model

In 1992, the Geneplore model was proposed by Ronald A. Finke and his colleagues. It is based on the creative cognition approach to understand creativity. This approach attempts to understand creativity scientifically by adapting the concepts, theories, methods and frameworks of cognitive psychology. It precisely characterizes the fundamental cognitive operations that produce creative and non-creative thoughts. Creative cognition emphasizes that creative capacity is an essential property of normative human cognition (Ward, Smith & Finke, 1999). Creative activities, in general, can be described as an initial generation of possible ideas or solutions followed by extensive exploration of those ideas.

This model considers both generative and exploratory cognitive processes and provides a useful framework within which to describe basic cognitive creativity. It characterizes the development of novel and useful ideas as resulting from interplay between generative processes and exploratory processes. Two processing stages suggested in this model are—

- Generative phase—Here, mental representations called pre-inventive structures are generated. Generative processes such as retrieval, conceptual combination, and analogical reminding are assumed to result in ideas. These ideas vary in their apparent novelty, aesthetic appeal or other factors that would influence the creative person‘s perception that how far they can solve the current problem. People can use such properties to determine which ideas to develop by way of exploratory processes that modify, elaborate and consider the implications, assess the limitations, or otherwise transform the ideas. They may be untested proposal or even a mere germ of idea, but they hold some basic criteria of creativity—originality and appropriateness.

- Exploratory phase—Here, the pre-inventive structures are interpreted in meaningful ways. It includes the search for novel or desired attributes in the mental structures, the search for metaphorical implications of the structures and potential function of the structures, the evaluation of structures from different perspectives or within different contexts, the interpretation of structures as representing possible solutions to problems, and the search for various practical or conceptual limitations that are suggested by the structures.

Amabile's Model

The Componential theory of creativity was developed by Teresa Amabile (1950-) in 1983. In her model, creativity is considered as a constellation of personal characteristics, cognitive abilities and processes, and social environment factors. Creativity is the production of a novel and appropriate response, product, or solution to an open-ended task. Here, appropriateness implies valuable, correct, feasible or fitting to a particular goal. Moreover, it must be open-ended (heuristic). The theory describes the creative process and the various influences on the process and its outcomes. It is based on the assumptions that there is a continuum from low, ordinary level of creativity to the highest levels of creativity and that there are degrees of creativity in the work of any single individual, even within one domain. The level of creativity that a person produces at any given point in time is a function of the creativity components operating, at that time, within and around that person (Amabile, 2013).

Level of Creativity= fn (Components of creativity)

According to Amabile, there are four components of creativity—three within the individual and one outside the individual. The first three are domain-relevant skills, creativity-relevant processes and task motivation. The component outside the individual is the social environment.

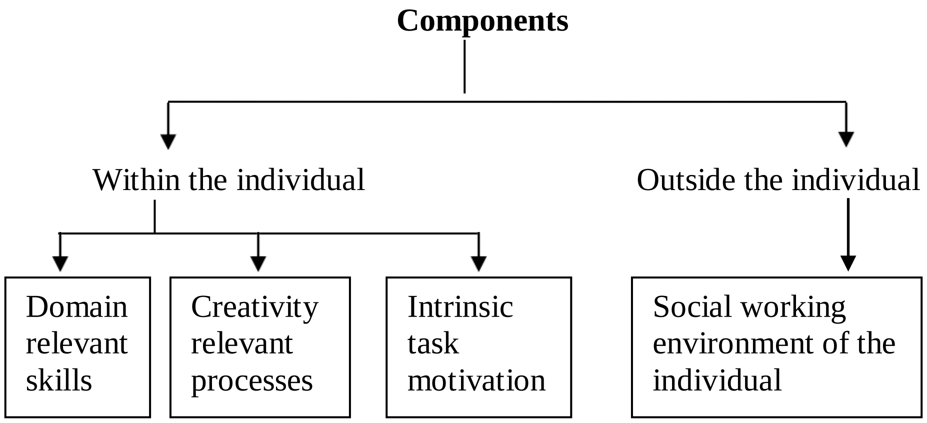


Fig. 6.2. Components of Creativity

- Domain relevant skills—These include knowledge, expertise, technical skills, intelligence and talent in the domain in which the problem solver is working. They comprise the raw materials upon which the individual can draw throughout the creative process.
- Creativity-relevant Processes—These include a cognitive style and personality characteristics that are conducive to independence, risk-taking and taking new perspectives on problems, as well as a disciplined work style and skills in generating ideas, ability to use wide, flexible categories for synthesizing information and a tolerance for ambiguity.
- Intrinsic task motivation—It refers to the motivation to undertake a task or solve a problem because it is interesting, involving, personally challenging, or satisfying. People are most creative when they are intrinsically motivated towards that task.
- Social environment—It includes factors like attitude of the people towards new ideas, risk-taking behaviors, non-conformity, openness, freedom, support, recognition, etc. These factors may serve either as obstacles or stimulants to creativity.

According to the componential theory, all these components affect the creative process. The process consists of some sub-processes like identifying the problem and its nature, preparing to solve the problem by gathering information and improving any required skills, generating ideas for solving the problem, testing or validating the chosen solution, and communicating that solution to others. However, the sequence is flexible. The sub-processes repeat themselves till a creative outcome is attained. Creativity should be highest when an intrinsically motivated person with high domain expertise and high skill in creative thinking works in an environment highly supportive for creativity.

Graham Wallas's Model

Graham Wallas (1858-1932) in his work *Art of Thought*, published in 1926, presented the stage model of the creative process. In this model, creative insights and illuminations may be explained by a process consisting of 5 stages—

(i) *Preparation* (preparatory work on a problem that focuses the individual's mind on the problem and explores the problem's dimensions)

(ii) *Incubation* (where the problem is internalized into the unconscious mind and nothing appears externally to be happening)

(iii) *Intimation* (the creative person gets a "feeling" that a solution is on its way)

(iv) *Illumination* or insight (where the creative idea bursts forth from its preconscious processing into conscious awareness)

(v) *Verification* (where the idea is consciously verified, elaborated, and then applied)

Sometimes, these five stages are treated as four stages regarding "intimation" only as a sub-stage. According to Wallas, creativity is the process which allowed humans to quickly adapt to rapidly changing environments, thereby contributing in the human evolutionary process.

Gruber's Model

Howard E. Gruber (1922-2005), the foremost contemporary interpreter of the creative process, has regarded creativity as the merging of personal knowledge, affect and purpose. Gruber demonstrates that creation is not the result of "a set of properties that a person has in a certain moment and carries around with him." He gives importance to ‗how' of creativity than to ‗what' of creativity. His approach towards creativity is developmental. Accordingly, he regards creativity as the result of developmental changes in knowledge systems. These changes results from different situations that a person encounters over time. He viewed the subject as being creative based on an interpretation that takes into account changes over time. His ―evolving systems‖ approach is based on three basic propositions—

1. Each creative person is a unique configuration.
2. It is a challenge in the field of creativity research to determine means of describing and explaining each unique configuration.
3. A theory of creativity that chooses to look only at common features of creative people is missing the main point of each life and evading the responsibility of research on creativity (Gruber & Davis, 1988).

The methodology developed by Gruber is described in (Brower, 2003) as being characterized by the following six features—

a) Viewing the individual's work in a continuum rather than in discrete.
b) Paying attention to a person's organization of related systems, e.g., knowledge, purpose, affect, physical world.
c) Identifying sources of deviation amplification.
d) Starting with someone whose creativity is unquestionable.
e) Emphasizing micro-genesis.
f) Hermeneutical distanciation.

Greene's Model

Richard Tabor Greene, a pioneer in the field of creativity research, attempted a very comprehensive model of creativity. He listed seven types of models, with six models in each type. That is, total 42 models. The seven types of models are arranged in such a way that there is a progression from global, complex, collections of many things to local, particular, specific small numbers of things moving from number one to seven.

(1) Catalog type—It includes models that are collections of large numbers of factors affecting creativity or constituting creation itself.
   (a) Recommendations (b) Traits (c) Question finding (d) Darwinian system (e) Combined thought type (f) Garbage can
(2) Blend type—It also concerns numerous factors. It includes
   (a) Culture mixing (b) Discipline combinatories (c) Trait balancing (d) Paradox balancing (e) Scale blending (f) Fractal marketing
(3) Social type—It concerns less numerous sets of factors and includes
   (a) Community of ideas (b) System model (c) Social computation (d) Social movement (e) Space sharing (f) Participatory art & design
(4) System types—It also concerns less numerous sets of factors. It includes
   (a) Non-linear systems (b) Darwinian (c) System effects (d) Surprise (e) Adjacent beyond (f) Population automation
(5) Purity type—It contains fewest number of factors
   (a) Sub-creations (b) Productivity (c) Performance (d) Influence (e) Investing (f) Info design
(6) Self type—It also contains fewest number of factors.
   (a) Courage (b) Anxieties channeled (c) Extended self development (d) Interest ecstasy (e) Career invention (f) Performance creativity

(7) Mind type—It contains fewest of all factors.

(a) Insight (b) Cognitive operators extremes (c) Making sense (d) Hint type recognition (e) Experience realization forms (f) Representational topologies

As the mind type models are most relevant to the present study, we will consider only these models of creativity and discuss them in brief. Under mind types, there are six models.

The **Insight Model** of creativity attributes two parts—the accumulation of failed trials and the sudden appearance of insights or illuminations that show the way to creativity. It breaks these down into steps in a process of insight building and occurrence. Insights occur on various size scales and therefore, are fractal in nature. There may be smaller insights within larger insights and short term insights within long term ones.

The **Cognitive Operator Extremes Model** is a model of ordinary cognitive operations carried to extremes, of speed, accuracy, breadth, depth, and so on. It emphasizes on cognitive skills. Creativity results when one or more cognitive operations are deployed to the extremes.

The **Making Sense Model** regards creativity as the ability to create new things, meanings, senses, explanations, procedures and ways of work as they find the existing beliefs, values, procedures and ideas inadequate. They see flaws and faults with even the most commonly accepted ideas and concepts.

The **Hint Type Recognition Model** considers creativity as a large scale thorough-going dislocation of perception. It is attention focused on clues, connections and sequence of these clues, circular arguments and other traces of partial understanding of reality. It is based on inverted perception. This inverted perception results in creativity.

According to the **Experience Realization Forms Model,** creativity is giving form to already realized experiences. It involves tapping into more direct, unmediated layers of experience, thought, and perception.

The **Representational Topologies Model** regards creativity as changes of representations. There may be various viewpoints with respect to different individuals, fields, or areas of knowledge. These viewpoints remain rudimentary till these are turned into meaningful representations, thus resulting in creativity.

However, Greene draws on seven models among the 42 models to frame his own model of creativity—the 4 Cycle model. The seven models included in the 4 Cycle model are: traits model, question finding model, Darwinian system model, insight model, population automaton model, sub-creations model and culture mix model. These seven models represent a combination of all the types of models with three models from the catalog type and one each from the others. Thus, it can be seen that Greene‗s model of creativity is a vast, comprehensive and detailed model. Among them, the mind type model consists of six models. These models have explained creativity based on insight, cognitive operations, meaning, perception, experience and representation.

It should be noted here that the theories of creativity are not exhaustive. There are many more theories. However, as it is not possible to mention all the theories, the researcher has presented only the theories which are appealing to the present study. To summarize, Taylor explained creativity in a level of hierarchy—expressive, productive, inventive, innovative and emergentive; the school of psychoanalysis considers it to be an opportunity for sublimation and catharsis; according to Arieti, it is a synthesis between the primary process and secondary process; for Finke, it is generation and exploration of ideas; Amabile understood it in terms of components—personal characteristics, cognitive abilities and processes and social environment; Wallas understood creativity as a process of five stages—preparation, incubation, intimation, illumination and verification; Gruber regards it as the merging of personal knowledge, affect and purpose; Greene attempted to give a comprehensive and detail account of creativity by considering all the factors related to creativity.

Problems in Classrooms

Our educational system, though gives importance to creativity in policies and papers, do not foster creativity in the actual classroom. Its rigid routine and definite time frame stifles the creativity of the students.

Some common misconceptions about creativity also hinder development of creativity in the classroom. For instance, misconceptions about creativity as mysterious (undefined), magical (only certain people have the ―gift‖), madness (to be creative you have to be strange or abnormal), and the ‗eureka' concept (Cole, Sugioka & Yamagata-Lynch (1999). These beliefs on the part of the teacher or even in students hinder the teaching of creativity.

It is a fundamental fact that most children spend the majority of their day in a highly structured, perhaps overly rigid learning environment. The teachers have to tackle the problem of preserving the child's inherent and natural curiosity and creativity. This highly structured environment may result due to excess media consumption, because students are spending much time interacting with smart phones, video games and television, standardized testing or other root causes

The nature of the creative person poses as a problem for the teacher in the classroom like—non-conformity to the contemporary trends, hyper-activity, high verbality, not following the routines, etc. It becomes difficult for the teacher to balance between the nature of such creative children and the academic routine that they have to follow. However, there is evidence that creativity and divergent thinking are not totally contrasted with academic achievement and convergent thinking. The major difference between the two types of thinking is that in academic achievement the tendency is to reproduce already established conclusions and in creative thinking the tendency is to go beyond it.

The main problem in regard to creativity in classroom is the debate between providing a structured or unstructured learning environment for the students. Though the highly structured classroom also has excellent provisions for fostering creativity, it is questionable whether it can be limited within these structures.

Pedagogical Implications of Creativity

Creativity is universal, though not equal in all. It is not the exclusive property of the rare and genius only, but a tender bud that resides in varying measures within every child. It can be taught, enhanced and nurtured (Elshout, 1995). This must be realized and believed by the teacher. And accordingly, the pedagogic practice should be sensitive, stimulative and imaginative. There should be great emphasis on learning creativity in domain or subject-matter contexts and on helping students see the potential use of creativity in real life-situations. Developing creativity should be viewed as a long-range process leading to adult creative achievement and self-fulfillment (Elshout, 1995).

Hamza & Griffith (2006), Cole, Sugioka & Yamagata-Lynch (1999), McWilliam (2007) and Lin (2011) consider ‗an open as well as challenging environment', ‗collaboration—both student-student and teacher-student', and ‗appreciation of the learner's individuality' as inevitable for fostering creativity. Use of techniques like brainstorming, thumbnail sketches, synectics, matrixes, etc. is helpful for developing creativity (Hamza & Griffith, 2006; Cole, Sugioka & Yamagata-Lynch, 1999). The teacher should stand back in the classroom but always be in a supportive position (Cole, Sugioka & Yamagata-Lynch, 1999; Lin, 2011). Direct instruction should be avoided, rather teaching should be experimental and error-welcoming (Cole, Sugioka & Yamagata-Lynch, 1999; McWilliam, 2007). Less emphasis should be given on grading and standardization and the standard for assessment should be based on creativity (Cole, Sugioka & Yamagata-Lynch, 1999; McWilliam, 2007; Lin, 2011). For this, apart from traditional examination system, self-assessment and peer assessment (McWilliam, 2007) and giving assignments (Cole, Sugioka & Yamagata-Lynch, 1999) are appropriate.

The teacher's own orientation about creativity is important. He should be sufficiently professionally and emotionally secure to depart from traditional methods and conclusions, open to receive various non-conformities. He should teach children not the subject matter. He should seek new methods of presentation.

Creativity requires a free environment to be fostered. Most often teachers breed conformity and passivity by expecting routine, fixed responses from children and thus kill the potential creativity. The teacher should allow adequate freedom to the children in responding to a situation. They should be encouraged to think out as many ideas as they can for the solution of a problem.

Creativity is fostered by self-confidence and therefore, the teacher should try to build up confidence among the learners. Lack of confidence develops shyness which hinders fostering of creativity. The self confidence of the learners can be built up by respecting the individuality of each learner.

The teacher should teach the learners to develop a positive attitude towards every work and towards the failures which may come on the way. If the failures make them disappointed they may be reluctant to attempt again and thus impede creativity.

Creative expression requires appropriate opportunities and atmosphere. This can be given by the teacher by taking full advantage of the curriculum. Not only does the creative person reveal his interest and aptitude in a wide variety of fields, but perceiving new interrelationships among different fields is a mark of creativity. There should be variety for curricular choice and activity. Co-curricular activities can be used for providing opportunities for creative expression. Existing creations and creators, local and global, should be exhibited to the students.

Rather than teaching the children to memorize and recite facts, the teacher should try to engage them in creative problem solving, as this has a direct link to an increase in creative learning. It can be done by activating multiple senses and enabling children of different learning styles to succeed. It opens up more doors in the brain and allows more ways for learning. Moreover, children struggle to articulate things in a verbal or written manner. They might find better success in it using their hands and their minds to explore a particular topic.

Team teaching is also helpful in fostering creativity in classroom. It is a teaching technique in which the pupils are exposed to a variety of subjects and their interrelationships and a variety of teachers and teachings.

Another technique that can be used by the teachers to foster creativity is brainstorming. It is a group technique. It consists of having group members suggest ideas as rapidly as possible, prohibiting criticisms, encouraging speaking out, and evaluating at a later session, holds possibilities that have not yet been thoroughly tested.

Gaming technique also helps the children in the development of creative traits. It means teaching the learners through games having some creative value. This technique provides learning experiences in a relaxed, spontaneous and evaluative situation.

Another factor influencing creativity is social interaction. Creativity is characterized by optimum growth in social interaction. The teacher may observe pupil interaction and use sociometry to get clues about the degree of interaction. Accordingly, the teacher can help the students in socializing when necessary.

Moreover, there are various programs which have been developed to teach creativity (Elshout, 1995). Creative problem solving is one of the most widely promulgated models for teaching creativity. Isaken & Treffinger (1985) published a comprehensive set of training materials. Their work builds upon the materials for creative problem solving developed by Parnes. Parnes (1975) reviewed the history of and research on creativity and concluded that it is eminently teachable and the skills generalized to usefulness in real-life situation. Perhaps the most widely known creativity training system is deBono‘s CoRT program (1976). This program consists of a set of training materials used by the teachers and students in the classroom. Another famous creativity program, the Purdue Creative Thinking Program (Feldhusen, 1983) is a set of 36 units of instruction on the skills and personal factors of creativity.

Intelligence

Intelligence is a very relative term that has been defined variously. According to Webster‛s New World College Dictionary (3rd edition), intelligence is ‗the ability to learn or understand from experience, ability to acquire and retain knowledge; mental ability…‘ Some experts like Edwin Boring, defined intelligence operationally, simply as ‗what intelligence tests test‘. It relies on tests to define intelligence and ultimately is circular (Sternberg, 2003).

Wechsler defined intelligence as ―the capacity to understand the world and the resourcefulness to cope with its challenges‖. He also suggested that ―intelligence is the capacity to act purposefully, to think rationally, and to deal effectively with the environment‖ (Wechsler, 1958).

Some of the critical elements of intelligence, as decided by some experts (Lewis Terman, Edward Thorndike, Ulric Neisser and Douglas Determent), particularly in two symposia (in 1921 and 1986), are—(a) adaptation in order to meet the demands of the environment effectively, (b) elementary processes of perception and attention, (c) higher level processes of abstract reasoning, mental representation, problem solving, decision-making, (d) ability to learn, and (e) effective behavior in response to problem situations.

However, we can find at least two major consensual definitions of intelligence. First, from "Intelligence: Knowns and Unknowns" a report of a task force convened by the American Psychological Association in 1995:

> *Individuals differ from one another in their ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought. Although these individual differences can be substantial, they are never entirely consistent: a given person's intellectual performance will vary on different occasions, in different domains, as judged by different criteria. Concepts of "intelligence" are attempts to clarify and organize this complex set of phenomena.*

Another widely accepted definition of intelligence is given by "Mainstream Science on Intelligence," a treaty signed by 52 intelligence researchers in 1994: a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience.

Thus, intelligence can be seen as a sort of mental energy of an individual in the form of mental or cognitive abilities, available with an individual that enables him to handle his environment in terms of adaptation to face novel situations as effectively as possible. This includes ability to learn, think rationally, solve problems and make decisions effectively.

In Indian philosophy, intelligence is regarded as the soul of civilization and all human progress and culture. Kautilya defined it as the capacity for works. Jamini, in his Purvamimamsa Sutra, mentions of the peculiar character of the intellect of certain persons. The Vedanta Sutra regards intelligence as a strong power which is dormant in infancy. It grows and develops gradually with years, reaching perfection in adolescence. The Buddhist source also supports this view. The Rigveda tells us of the mental inequalities existing in different personalities. Gotama, in his Nyayasutra, mentions about three distinct levels of intelligence such as—laukika or ordinary abilities below average, average intelligence, and pariksaka or superior intelligence, ability to make independent investigations by means of arguments and proofs. The Nirayavaliyao, the eleventh Jaina canon mentions four talents such as intuitive or _autpattiki‗, disciplined or _vainayiki‗, the talent acquired by practice or _karmaja‗ and the developed talent or the talent reaching perfection in the maturity of age called _parinamiki‗.

Intelligence in Cognitive Science

Intelligence is so much proximally related to cognitive science that the main aim of the field of cognitive science is to understand _intelligence‗ or various intelligent systems. _Intelligence‗, we can say, is the centre of attraction in cognitive science. Roger Schank, a well known cognitive scientist defined intelligence as ―the ability to diagnose well, to plan well, and to be able to understand what causes what‖ (Schank, 2011). From cognitive science point of view, all types of intelligence are considered—human, animal and machine. The contributing disciplines of cognitive science aids in their own ways towards a common goal of understanding intelligence. In psychology, intelligence has been treated in various ways by various psychologists. But for everyone, the inherent goal was to understand the psychological bases of intelligence. Psychology contributes to cognitive science by giving various cognitive theories of intelligence which explains the cognitive processes underlying intelligence. According to Luger, the field of cognitive psychology is dedicated to finding the common set of principles underlying all instances of intelligence (Luger, 1994). In linguistics, intelligence refers to an enhanced ability of an individual to use one or several languages to convey spoken or written communications to others. People who have a high degree of this type of intelligence usually impart information in a refined manner. They have an ability to teach and explain things to others. Thus cognitive science takes the cognitive processes underlying linguistic intelligence from the field of linguistics. Anthropology contributes the evolution of intelligence in general and particularly in humans. Neuroscience studies the neurological factors that may be responsible for the variation of intelligence within a species or between different species. Artificial intelligence is a field which not only studies but also applies intelligence in machines. Cognitive science as a field of study attempts to understand intelligence considering it from all these points of view.

Intelligence in Education

Intelligence is relevant to the field of education in two senses. First, the education system has to be designed in such a way as to cater to different levels and types of intelligence of the students. Second is that if intelligent can be developed, the education system holds the responsibility of developing it. The teacher has to deal with students of different levels and types of intelligence in the classroom. And accordingly adjust his pedagogical methods. The teacher can do this efficiently only if he understands ‗what intelligence is' and the underlying cognitive processes of intelligence. According to Schank (2011), the educational system should aim at –making people more intelligent‖ rather than only strengthening their knowledge-base. If we consider intelligence in this sense, intelligence becomes the main focus of the whole education system. The teacher has to design his pedagogy with the aim of improving intelligence based on the cognitive processes underlying intelligence.

Theories of Intelligence

The theories of intelligence have evolved through a succession of paradigms. The major paradigms have been those of psychological measurement (often called psychometrics); cognitive psychology, which concerns itself with the mental processes by which the mind functions; the merger of cognitive psychology with contextualism (the interaction of the environment and processes of the mind); and biological science, which considers the neural bases of intelligence. Broadly, the theories of intelligence may be divided into two types—factor or psychometric theories and cognitive theories. The factor/psychometric theories are—monarchic theory, multifactor theory, two factor theory, group factor theory, sampling theory, hierarchical theory and structure of intellect theory. The cognitive theories include Cattell and Horn‘s theory, Jensen‘s theory, Champion and Brown‘s theory, Sternberg‘s Information Processing theory and Gardener‘s Multiple Intelligence theory. While the traditional theories of intelligence focus on measuring and quantifying intelligence, the cognitive theories focus on examining the cognitive processes which cause intelligent or unintelligent behavior.

Psychometric theories

Psychometric theories have generally sought to understand the structure of intelligence. Underlying the psychometric theories is a psychological model according to which intelligence is a composite of abilities measured by mental tests. It is additive, and therefore it is assumed that less of one ability can be compensated for by more of another ability in test performance. Such theories have generally been based on and tested by the use of data obtained from paper-and-pencil tests of mental abilities that include analogies, classifications and series completions.

The first of the major psychometric theories was that of the British psychologist Charles E. Spearman. He noticed the fact that: People who did well on one mental ability test tended to do well on the others, and people who did not do well on one of them also tended not to do well on the others. Spearman devised a technique for statistical analysis, which he called factor analysis and believed to provide an analysis of the underlying sources of these individual differences. Spearman's factor analyses of test data suggested to him that just two kinds of factors underlie all individual differences in test scores. The first and more important factor is the general factor or _g‘, which is said to pervade performance on all tasks requiring intelligence. The second factor is specifically related to each particular test and is named as specific factor or _s‘. But Spearman could not explain exactly what the general factor might be. However, in 1927, he tried to explain it by labeling it as "mental energy."

The American psychologist L.L. Thurstone disagreed not only with Spearman's theory but also with his isolation of a single factor of general intelligence. Thurstone argued that the appearance of just a single factor was an artifact of the way Spearman did his factor analysis and that if the analyses were done in a different and more appropriate ways, seven factors would appear which Thurstone referred to as the "primary mental abilities." The seven primary mental abilities identified by Thurstone were

(i) verbal comprehension (involved in the knowledge of vocabulary and in reading);
(ii) verbal fluency (involved in writing and in producing words);
(iii) number (involved in solving fairly simple numerical computation and arithmetical reasoning problems);
(iv) spatial visualization (involved in mentally visualizing and manipulating objects, as is required to fit a set of suitcases into an automobile trunk);
(v) inductive reasoning (involved in completing a number series or in predicting the future based upon past experience);
(vi) memory (involved in remembering people's names or faces); and
(vii) perceptual speed (involved in rapidly proofreading to discover typographical errors in a typed text).

However, some other psychologists such as Philip E. Vernon and Raymond B. Cattell, suggested another possibility. In the view of Philip Vernon, abilities are hierarchical. Vernon‘s model postulates *g* to be at the apex of the generality-to specificity hierarchy followed by two factors verbal-educational (*v:ed*) and spatial-mechanical (*k:m*). This is followed by minor group factors, namely numerical and verbal ability as components of *v:ed* and spatial and mechanical ability as components of *k:m*. Finally, at the bottom of the hierarchy, follows the specific components of these minor group factors.

Some psychologists were even against the hierarchical theory. An American psychologist, J.P. Guilford, proposed the structure-of-intellect theory. He classified the intellectual abilities into a systematic framework or structure. His view is that each intellectual ability has its own uniqueness and some kind of intellectual ability is necessary for executing some task. In his structure-of-intellect, he divided the intellectual abilities into three broad categories—operation, content and product. There are five kinds of operations, four kinds of contents, and six kinds of products. These various facets of intelligence combine multiplicatively, for a total of 5x4x6, or 120 separate abilities.

The psychometric theories were criticized for their inability to say anything substantial about the processes underlying intelligence. Moreover, the number of abilities was going up with each successive psychometric theory. They were unable to honor parsimony, one of the important features of a scientific theory. The cognitive psychologists proposed a solution to these problems, which was to study directly the mental processes underlying intelligence.

Cognitive theories

The era of psychometric theories of intelligence was dominated by individual differences in people's test scores. Lee Cronbach‘s view that ‗some psychologists study individual differences and others study commonalities in human behavior but never do the two meet‘ has led to the development of cognitive theories of intelligence. He pleaded for unity of these ‗two disciplines of scientific psychology‘. Underlying most cognitive approaches to intelligence is the assumption that intelligence comprises a set of mental representations (e.g., propositions, images) of information and a set of processes that can operate on the mental representations. A more intelligent person is assumed to represent information better and, in general, to operate more quickly on these representations than does a less intelligent person. The fundamental unit of analysis in cognitive theories is: a mental process acting upon a mental representation in all the models.

Sternberg's Information Processing or Triarchic Theory

At a time when two extreme viewpoints were prevalent regarding intelligence—intelligence in terms of a single general factor and intelligence in terms of multiple factors—Robert J. Sternberg, an American psychologist suggested an alternative approach to studying the cognitive processes underlying human intelligence. He proposed a middle-of-the road view between the two extremes in the study of intelligence. Sternberg viewed intelligence as multifaceted, and so-called general ability is viewed as part of the array that might require higher cognitive processes. According to his theory, ―the processes of human intelligence are universal but their instantiations in behavior are contextually bound‖ (Sternberg, 1999).

Sternberg‗s definition of intelligence is ―a mental activity directed toward purposive adaptation to, selection and shaping of, real world environments relevant to one‗s life‖ (Sternberg, 1985). The information processing approach is the manner in which one proceeds to perform a mental task or solve a problem, gathers information and makes use of this information for completing the task or solving the problem in hand. Sternberg believed that information processing takes place following certain steps—encoding, inferring, mapping, application, justification and response.

The triarchic theory suggests three aspects of intelligence—analytical, creative and practical. Analytical abilities are involved in analyzing, evaluating, critiquing, and comparing and contrasting things. Secondly, creative abilities are involved in creating, exploring, discovering, inventing, imagining and supposing. Thirdly, practical abilities are involved in applying, using, implementing and putting into practice. These three aspects along with tasks involved and examples of each of these abilities are presented in the table below.

Table 6.1. Sternberg's three aspects of intelligence with tasks and examples

Abilities	Tasks	Examples
Analytical abilities	analyzing, evaluating, critiquing, and comparing and contrasting things	Choosing the best option, criticizing a theory or a personality, comparing between two things or ideas
Creative abilities	creating, exploring, discovering, inventing, imagining and supposing	writing short stories with unusual titles, drawing artwork based on novel topics, creating advertisements for dull products
Practical abilities	applying, using, implementing and putting into practice	Everyday practical reasoning problems, solving practical mathematics problems, planning routes using maps

His Triarchic theory is also based on three sub theories—

(a) Componential Sub theory—He advocated that the intellectual functioning of an individual is decided mainly by the components. There are three components serving distinct functions—

Meta-components: These are executive processes used in problem solving and decision making that involves the majority of managing our mind. They tell the mind how to act.

Performance components: These are the mental processes used for the execution of a task, such as task perception, relation perception, applying relations to another set of terms, etc.

Knowledge acquisition components: These are the processes used in acquiring new information. It can be used to synthesize old ideas in some original and creative ways.

(b) Experimental sub theory—This theory proposes that intelligence represents the ability or capacity of an individual to deal with new tasks, problems and situations by adopting an information processing approach with as little conscious efforts as possible.

(c) Contextual sub theory—It deals with the mental activity involved in attaining fit to context. Through the processes of adaptation, shaping and selection, individuals create an ideal fit between themselves and their environment.

Cattell and Horn's Theory

Cattell, in 1971, suggested that general ability can be subdivided into two further kinds of abilities, fluid and crystallized. Fluid abilities are the reasoning and problem-solving abilities measured by tests such as the analogies, classifications, and series completions described above. Fluid intelligence is the capacity to think logically and solve problems in novel situations, independent of acquired knowledge. It is the ability to analyze novel problems, identify patterns and relationships that underpin these problems and the extrapolation of this using logic. It is required for learning and problem solving, especially scientific, mathematical and technical problem solving.

Crystallized abilities can be said to derive from fluid abilities. These include vocabulary, general information, and knowledge about specific fields. Crystallized intelligence is the ability to use skills, knowledge, and experience. But it is not memory or knowledge, though it relies on accessing information from long-term memory. It is not innate; rather it is specially learned and dependent on education and culture. It can be identified through one‘s stock of vocabulary, general knowledge, the knowledge of customs, traditions and rituals, manner of behaving in the society, handling of machines and tools, craftsmanship and art, computation and keeping of accounts and various other such tasks requiring knowledge, experience and practice. These two types of intelligence intermingle and interact to produce overall intelligence.

John L. Horn, an American psychologist, added to this theory that crystallized ability more or less increases over the life span, whereas fluid ability increases in the earlier years and decreases in the later ones.

Jensen's Theory of Mental Functioning

Arthur Jensen gave a working definition of intelligence as the ‗g‘ factor of an indefinitely large and varied battery of mental tests. According to his theory of mental functioning, the functioning of one‘s mind depends upon the type and degree of intelligence one possesses. He demonstrated clear cut genetic differences in the average intelligence of races and social classes. He suggested that two genetically based levels of intelligence exist—associative abilities include ability to remember, reproduce, identify, discriminate, synthesize, associate, assimilate, transfer and apply, etc. while conceptual abilities involve ability to carry out higher order of thinking, reasoning, analyzing and the capacity of problem solving.

Moreover, Jensen suggested that intelligence of an individual consists of two dimensions—intellectual breadth and intellectual altitude. Intellectual breadth consists of the intellectual fund of general information, vocabulary, practice and skill of handling tools and machines, ways and manners of behaving in society, etc. It depends upon the environment, attitude, values, interests, experiences and training. Intellectual altitude consists of high level cognitive abilities like abstract and divergent thinking, logical reasoning, imagination and conceptualization, problem solving, etc. Thus, the intellectual ability of an individual is built up on the base provided by his intellectual breadth and height maintained by his intellectual altitude.

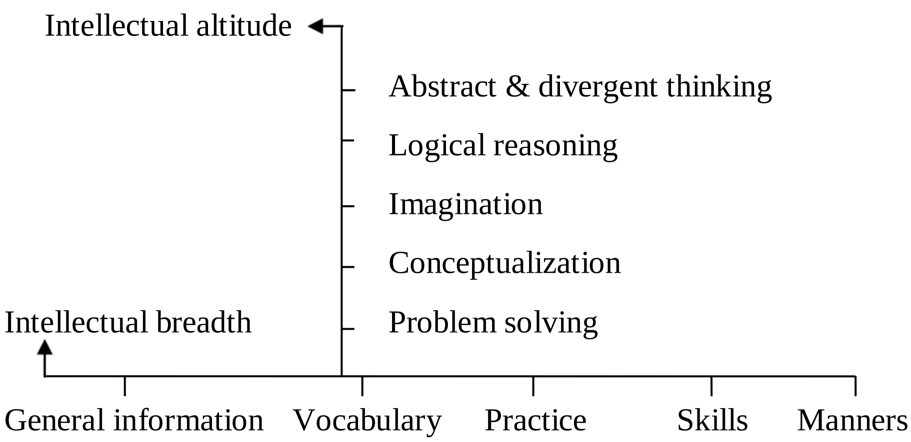


Fig. 6.3. Two Dimensions of Intelligence

Gardner's Multiple Intelligence theory

Howard Gardner viewed intelligence as ‗the capacity to solve problems or to fashion products that are valued in one or more cultural settings'. His theory argues that intelligence does not adequately encompass the wide variety of abilities humans display. He challenged the notion of general intelligence. Instead he gave a broad base to the concept of intelligence and its measurement by providing a multiple frame. He described intelligence or cognitive competence as a set of an individual's multiple abilities, talents and mental skills related to a multiple number of domains of knowledge in a particular cultural setting. He originally identified seven core intelligences: linguistic, logical-mathematical, spatial, bodily kinesthetic, musical, interpersonal and intrapersonal. In 1999, he added an eighth, the naturalistic intelligence and work continues on the ninth category—existential intelligence.

Linguistic intelligence: It involves sensitivity to spoken and written language, all kinds of linguistic competence—abilities, talents and skills. Components are syntax, semantics and pragmatics as well as written or oral expression and understanding. Examples: verbal persuasion, writing a term paper skillfully.

Logical-mathematical intelligence: It consists of the capacity to analyze problems logically, carry out mathematical operations, and investigate issues scientifically. Components include deductive reasoning, inductive reasoning, scientific thinking, logical puzzles, calculations, etc. Examples: solving mathematical problems easily and accurately, developing and testing hypotheses.

Spatial intelligence: It involves the potential to recognize and use the patterns of wide space and more confined areas, representation and manipulation of spatial configuration and relationship. Examples: Completing a difficult jigsaw puzzle, assembling a complex appliance.

Musical intelligence: It involves skill in the performance, composition and appreciation of musical patterns. It includes capacity for pitch discrimination, sensitivity to rhythm, texture and timbre, etc. Examples: Singing, playing a musical instrument, composing tunes.

Bodily kinesthetic intelligence: It involves body movement and doing—using one‘s body or its various parts to perform skillful and purposeful movements. It is the ability to use mental abilities to coordinate bodily movements. Examples: Dancing, gymnastics, etc.

Interpersonal intelligence: It involves interaction with others—abilities to understand individuals other than one‘s self and one‘s relation to others, and also ability to act productively, based on understanding of others. Examples: Sensing when to be tactful, sensing ‗subtext‘ or implied message in a person‘s statements.

Intrapersonal intelligence: This area has to do with introspective and self-reflective capacities—ability to know own self. It includes knowledge and understanding of one‘s own cognitive strengths, styles and mental functioning, as well as one‘s feelings, range of emotions and skills to utilize one‘s fund of knowledge in practical situations. Examples: Noticing complex of ambivalent feelings in oneself, identifying true motives for an action in one.

Naturalistic intelligence: This area is related to nature, nurture and relating information to one‘s natural surroundings. People having naturalistic intelligence have greater sensitivity to nature and their place within it, the ability to nurture and grow things, etc. Examples: Identifying species of plants or animals, noticing relationships among species and natural processes in the environment.

The most fundamental difference between the views on intelligence held by Gardner and Sternberg is in how each perceives the way intelligence operates in the world. Sternberg takes a "horizontal" view of intelligence (Gardner, 1999). That is, Sternberg believes that each component of intelligence will operate on any material. While, Gardner takes a "vertical" view of intelligence, arguing that specific intelligences operate on specific materials. If an individual is appreciating a poem, for instance, two intelligences are operating at the same time—musical and linguistic.

Newell and Simon's theory

Some cognitive scientists have pursued different paths in the study of human intelligence, like building of computer models of human cognition. Two leaders in this field have been the American psychologists Allen Newell and Herbert A. Simon. In the late 1950s and early 1960s they worked with a computer expert, Clifford Shaw, to construct a computer model of human problem solving. It was called the General Problem Solver. It could solve a wide range of structured problems. Their program relied heavily on a heuristic procedure called "means-ends analysis," which, at each step of problem solving, determined how close the program was to a solution and then tried to find a way to bring the program closer to where it needed to be. In 1972, Newell and Simon proposed a general theory of problem solving, much of which was implemented on the computer.

Most of the problems studied by Newell and Simon were very well structured. It involved discrete steps that would lead from the beginning to the end of a problem. The biggest problem for a computer program (or even for a human) is in deciding which of the innumerable steps will most contribute towards solving the problem.

A common observation in all of the cognitive theories is their primary reliance on the serial processing of information. It is assumed that people process chunks of information one at a time, seeking to combine the processes used into an overall strategy for solving a problem. But some psychologists challenged the idea. They suggested that cognitive processing is primarily parallel. According to them, humans actually process large amounts of information simultaneously. It has long been known that the brain works in such a way, and it seems reasonable that cognitive models should reflect this reality.

However, it was difficult to distinguish between serial and parallel models of information processing. This difficulty was solved by subsequently advanced techniques of mathematical and computer modeling. And this led to proposal of ‗parallel distributed processing' models of mind by various researchers like David E. Rumelhart and J. L. McClelland. These models postulated that many types of information processing occur at once, rather than just one at a time.

PASS Theory

The Planning, Attention-Arousal, Simultaneous and Successive (PASS) theory of intelligence was first proposed in 1975 (Das, Kirby & Jarman, 1975). It challenges g-theory on the grounds that the brain is made up of interdependent, but separate, functional systems. It proposes that cognition is organized in three systems and four processes—

(1) Planning—It involves executive functions responsible for controlling and organizing behavior, selecting and constructing strategies, and monitoring performance.
(2) Attention process—It is responsible for maintaining arousal levels and alertness, and ensuring focus on relevant stimuli.
(3) Simultaneous and Successive processing—It comprises two processes to encode, transform, and retain information. Simultaneous processing is engaged when the relationship between items and their integration into whole units of information is required. Successive processing is required for organizing separate items in a sequence. These four processes are functions of four areas of the brain. Planning is broadly located in the front part of our brains, the frontal lobe. Attention and arousal are combined functions of the frontal lobe and the lower parts of the cortex, although the parietal lobes are also involved in attention. Simultaneous processing and Successive processing occur in the posterior region or the back of the brain. Simultaneous processing is broadly associated with the occipital

and the parietal lobes while Successive processing is broadly associated with the frontal-temporal lobes.

David Perkins theory

David Perkins analyzed a number of different educational theories and approaches to education in his book *Smart Schools* (1992). His analysis strongly supports of Gardner's theory of multiple intelligences. He provided strong evidence that education can be considerably improved by more explicit and appropriate teaching for transfer, focusing on higher-order cognitive skills, and the use of project-based learning. He argued that IQ has three major components or dimensions.

1. Neural intelligence. This refers to the efficiency and precision of one's neurological system. There is general agreement that neural intelligence has a "use it or lose it" characteristic. It is clear that neural intelligence can be maintained and, indeed, increased, by use.
2. Experiential intelligence. This refers to one's accumulated knowledge and experience in different areas that lead to expertise in a particular area. Experiential intelligence is based accumulated knowledge and experiences in a time period, in both informal and formal learning environments. People who live in "rich" learning environments have a significant intelligence advantage over people who grow up in less stimulating environments. Therefore, experiential intelligence can be increased by rich and stimulating environments.

3. Reflective intelligence. This refers to one's broad-based strategies for solving problems, for learning, and for approaching intellectually challenging tasks. It includes attitudes that support persistence, systemization, and imagination. It includes self-monitoring and self-management. It is like a control system that helps to make effective use of neural intelligence and experiential intelligence. The habits of mind included under reflective

intelligence can be learned and improved through approaches like metacognition.

The American psychologists Earl B. Hunt, Nancy Frost, and Clifford E. Lunneborg, in 1973, showed one way in which psychometrics and cognitive modeling could be combined. They showed that individual differences in cognitive tasks were related (although rather weakly) to patterns of individual differences in psychometric intelligence test scores. They argued that the basic cognitive processes might be the building blocks of intelligence.

Problems in Classroom

The most critical problem with intelligence in the classroom is its broad and relative concept. It is easy to deal with a concept which is definite and can be easily described. But the complexity of the concept of intelligence creates various problems for the teachers to deal with the intelligence of the students. Though the theories proposed by various psychologists come for the rescue of the teacher, but the variations in their opinions again create problem for them.

Sternberg‗s theory is criticized in regard to practical applications. He has repeatedly implied that he has evidence for a general factor of practical intelligence that is largely independent of g and that predicts life success at least as well as g, if not better. However, sufficient evidence cannot be found in support of this. The major points of criticism focus on the difficulties of reliably measuring ―unconventional‖ (e.g., creative and practical) abilities and differentiating them psychometrically from abilities measured by more conventional tests of intelligence and achievement.

Applying Gardener‗s multiple intelligence theory in the classroom has some problems. The theory may be misinterpreted regarding intellectual relativism. Students' failures may be explained away as being an example of a different kind of intelligence, and not accounted as failure. This theory suggests that ‗someone may be good in one intelligence but not in another‗. But this assertion is not supported by correlation studies. On the basis of such studies, it is argued that persons who excel in one type of intelligence usually excel in several others; and many times in all. The third major criticism of multiple intelligences as an application in schools is that there is a risk of teachers excusing students from doing well in an area in which they are weak. The goal of the students is to succeed in all areas defined as intelligence by Gardner, and not default to their strengths. Another criticism is that the distinction between developmental stage and "intelligence" is not sufficiently well accounted for.

Pedagogical Implications of Intelligence

Intelligence has been always an interesting subject for the teachers as well as the students. However, its discreet nature makes it difficult for everyone to have an accurate or perfect definition of it. This subject attracts the teachers as he has to understand and measure the intelligence of his students as well as of himself to design his pedagogy appropriately. Of all the cognitive theories of intelligence, the theory of multiple intelligences is most relevant to the field of education, particularly to pedagogy.

Fogarty (1998) provided some guidelines which are derived from various theories of intelligence and have classroom implications. These are—emotional safety and care for all learners; rich learning environment in which science equipment, art supplies, tools and workbenches, toys and building blocks, optical illusion posters, etc. are present; teaching of mind-tools and skills of life which include critical thinking skills, creative thinking skills, social skills, technological skills, visual skills, skills in the performing arts, and skills of the elite athlete; develop skillfulness of the learners through formal teaching-learning structures, independent readings, research, dialogue, discussion, articulations of peer coaching, mentoring, or internships and with experiences; provide challenges through experience of doing, i.e. inviting the learner to become an integral part of the teaching learning process; target multiple dimensions of intelligence, i.e. learning is structured in naturally integrated ways that call upon various intelligences; transfer learning through reflection; assessment measures should be balanced and integral to all other interactions.

Haier & Jung (2008) posed some prospects of neuroscience research for education. The neuroscience findings point to ways of assessing the strengths and weaknesses of individual brains so that education can be more precisely targeted to individual students. They also speculated that if neural factors may increase the growth of regional gray matter or white matter, drugs may be developed to stimulate them and target specific cognitive abilities like intelligence. Another prospect is whether brain information in general and for specific individuals can improve education from the baseline of current practices. They view to translate new information from the field of neuroscience in the field of education through collaborative work of educators and brain researchers.

Sternberg's theory has three major implications for educational psychology. First, all types of intelligence should be taught. Students need to capitalize on their strongest abilities as well as to develop the abilities in which they are weak. Second, students' strongest abilities are directly related to their learning styles. So, the teachers should know the learning preferences of their students and, try to capitalize on them. Third, assessment system should be diverse to assess variable abilities.

Gardner‘s multiple theory of intelligence is well adapted to today‘s classrooms which are full of diversities—both in terms of students and the curriculum.

1. The most important pedagogical implication of Multiple intelligence theory is the organization of teaching to allow multimodal delivery in response to diversity in students‘ talents and activities. Teachers need to expand their repertoire of techniques, tools, and strategies beyond the typical linguistic and logical ones (Armstrong, 2000). Gardner defines a skilled teacher as "a person who can open a number of different windows on the same concept" (Gardner, 1993).
2. This theory holds the fact that there is more than one way to be –smart.‖ It is not important to label student‘s talents or intellectual strengths. It may be more important simply to provide important learning and knowledge in several ways drawing on more than one possible form of intelligence or skill.
3. Engagement in more authentic methods of assessment than traditional educational testing (Dixon & McPhee, 2001).

4. Multiple Intelligence theory is based on the concept of individual differences. Teachers who employ Multiple Intelligences techniques in the classroom also recognize the importance of the chalkboard and lecture in their pedagogy. According to Gardner, using various pedagogical approaches allows the teacher to reach more students in more effective ways.

Table 6.2. Pedagogical Implications of Gardner's theory (Armstrong, 2000)

A child who is highly...	will tend to think...	enjoy...	and learn from...
Linguistic	in words	reading, writing, storytelling and word games	books, journals, dialogue, stories and debate
Logical-Mathematical	by reasoning	experiments, puzzles and calculations	chemistry sets, trips to the planetarium and science museums
Spatial	in images	drawing, visualizing and doodling	paints, clay or play dough, videos, art museums and movies
Bodily-Kinesthetic	through physical sensations	dancing, running, building, manipulating objects and gesturing	role playing, sports and hands-on instruction
Musical	in rhythm and melodies	signing, playing music, drumming and listening	singing, concerts and playing musical instruments
Interpersonal	by exchanging ideas with others	leading, organizing and parties	friendship, clubs, group games and mentors
Intrapersonal	in relation to their feelings and goals	reflecting, planning, meditating and dreaming	spending time alone, independent study and making choices
Naturalist	through the environment and natural forms	pets, growing plants and nature hikes	observing through binoculars and microscope, and interaction with plants and animals

Attention

Human mind is the most complex system on earth. Most of its features are unique. One of such features is to attend to particular stimuli in the environment while ignoring some others. Our sensory systems are continually exposed to various sights, sounds, smells, and other signals from the external environment. Moreover, mental representations of events that just occurred seconds ago, to events from the distant past, to events only imagined in the present or future are also active. A very early definition of attention given by William James is: "It is the taking possession in the mind, in clear and vivid form, of one out of several simultaneous possible objects or trains of thought. Focalization and concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others" (James, 1890). It is the cognitive process of selectively concentrating on one aspect of the environment while ignoring other things. It has also been referred to as the allocation of processing resources. It is involved in the selective directedness of our mental lives. It is related to the organization and management of individuals; in the exercise and selection of what one is accustomed to and how one is accustomed to it, attention becomes knowledge of the self that embodies regulatory practices (Sobe, 2004). According to Ross, ―Attention is the process of getting an object of thought clearly before the mind.‖

Thus, attention is the process of concentrating on specific information from the environment while ignoring other information. It is a process carried out through cognitive abilities and helped by emotional and conative factors to select something out of the various stimuli present in one‘s environment and then to bring it to the centre of one‘s consciousness in order to perceive it clearly for deriving the desired result.

In all the concrete attentive acts, two processes of sensorial adjustment and ideational preparation coexist—

(a) Adjustment of the sensory organs—The sense organs and the bodily muscles are adjusted most energetically in the sensorial attention. Even intellectual attention is accompanied with some degree of excitement of the sense organs.

(b) Ideational preparation—The preparation of the ideational centre exists wherever our interest in the object—be it sensible or ideal—is derived from, or in any way connected with, other interests, or the presence of other objects, in the mind. This is more relevant to intellectual attention, as the thing attended to here is an idea, an inward reproduction or conception.

Attention in Cognitive Science

Initially, the term ‗attention' was under the purview of philosophy which later came under psychology. Different philosophers have put forward their views on it. Aristotle noticed that everything that our sense organs sense is not perceived clearly. Augustine interpreted attention as an effort of the soul. Descartes distinguished active attention from passive attention. Leibniz discussed the relation between attention, perception and consciousness. Thus the empirical concept of attention was formed. Attention is also a topic of philosophical interest because of its apparent relations to a number of other philosophical phenomena like consciousness, will and understanding of other minds. In psychology, attention is interpreted as the cognitive activity of selecting a particular stimulus out of numerous stimuli in the environment. It encompasses various cognitive activities that are carried out on representations and involve amplification and attenuation mechanisms. Such mechanisms temporarily change the efficiency of our mental processes and have behavioral consequences (Camus, 2003). Neuroscience studies the neural basis of attention. Analysis of the neural characteristics of attention brings out the predominant role played by certain structures. These structures are organized into complex circuit or network that is responsible for the fundamental features of attentional processes. A central question is how the brain learns to detect relevant sensory features while ignoring irrelevant ones in order to successfully guide behavior. At the neuronal level this process corresponds to the tuning of a cell's response profile, via synaptic modification, to become sensitive to the relevant features of a given category. Thus attention is the cognitive system that controls the quantity and quality of information that enters the individual's mind. The information that is selected enters the individual's cognitive system and then undergoes further processing.

Attention in Education

Attention is a prerequisite to learning and a basic element in classroom motivation. It is even believed that attentional skills are central to successful learning. Helping students to ―pay attention‖ has always been a central concern of the teachers. So, attention may be related to education in two ways. Learning requires the students to pay attention to the task at hand. And attention as a skill may also be taught to the learners. Teachers must understand the basic mechanisms and processes that regulate attention. As William James put it ―An education which should improve this faculty (attention) would be the education par excellence.‖ Attention is closely related to the processes and products of learning, and therefore forms an important component of education. Probably, holding attention of the learners in the classroom is the most difficult part of teaching. Because attending to a single stimulus continuously with the same intensity for a long duration is difficult. The role of attention is to select information from the text that the learner is exposed to. Therefore the teacher should keep this in mind while designing his pedagogy. The ability to attend with focus, clarity, and purpose is a skill everyone needs. Students are particularly in need of good attention skills. They must be able to attend to instructions, focus on the details of assignments, and stay on task until an assignment is completed. The key point for the teachers to realize is that maintaining attention is a skill. It has to be trained and practiced. Catering to short attention spans by offering materials that can be managed with short attention spans will not develop the skill of maintaining attention.

Cognitive Basis of Attention

Attention encompasses various cognitive activities that are carried out on representations. Attention is related to the way the cognitive system processes information. In 1958, Donald Broadbent proposed a two-stage processing view in which an initial parallel processing stage is followed by a second sequential one. In 1970s, some researchers such as Michael Posner, Richard Shiffrin and Walter Schneider gave another view based on the distinction between two types of processes—

(i) Automatic Processes—It involves rapid parallel processes that do not require attention. Target detention is said to be automatic when it is defined by a single elementary property, on a single dimension such as colour, brightness, size or shape that can be analyzed by prewired, specialized detectors functioning in parallel.

(ii) Controlled Processes—These are slow, serial and strategically determined. When the target is defined by a combination of two elementary properties belonging to two different dimensions and for which there is no dedicated analyzer, detection is controlled.

Historical Development of Theories of Attention

In the early modern period a variety of explanatory roles were assigned to attention by a number of different writers.

Descartes‘ (1596-1650) account of attention describes about its important epistemic role: clarity and distinctness realize their epistemic potential only when attention is paid to the ideas that have them. Descartes' epistemology is a move from radical doubt to certainty about the truth of particular clear and distinct ideas. Attention mediates this transition from doubt to certainty.

Locke (1632-1704) gives a theory of the explanatory role that attention plays. According to him, ―when the ideas that offer themselves are taken notice of, and, as it were, registered in the memory, it is attention‖ (*Essay Concerning Human Understanding*). He believes that attention does not need any new substantive theory. They are, in Locke's theory, simply ‗modes of thinking‘. Locke's modal view of attention implies that no substantive theory of attention is needed once our theory of thinking is in place, but it also entails that attention cannot figure in the explanation of how thinking itself is possible.

Berkeley‘s (1685-1753) account of attention can be found in the second edition of the *Principles of Human Knowledge*. According to him, it is attention and, in particular, the withholding of attention that is supposed to explain the possibility of thinking about abstractia without the need to postulate Abstract Ideas.

Over the course of the eighteenth century the concept of attention was increasingly treated as a phenomenon with explanatory work to do, and so as a phenomenon for which a substantive independent theory is needed. During this period the explanations for theories of attention broadened in two directions. The first move was (i) away from the idea that attention acts on already-received ideas and (ii) towards the idea that attention is involved in the initial reception of those ideas. Locke had characterized attention as the registration of already-received ideas into memory. But by 1769, attention's role as a regulator of cognitive input was regarded as definitive of it. Attention was said to be that state of mind which prepares one to receive impressions. According to the degree of attention objects make a strong or weak impression.

The eighteenth century theories moved towards including a role for attention in the production of behavior and in the explanation of the reception of ideas. Dugald Stewart (1792) retained Locke's view that attention has an essential role to play in determining which things get stored in memory. He added to that view the claim that attention also has a role in determining which particular memories get recalled and in the explanation of the development and deployment of at least some skilled behaviors.

The diversity among the phenomena that attention was expected to explain continued to grow. It continued to include phenomena from across the psychological spectrum from perception, to thought, to action. This diversity among the psychologists resulted into a chaotic situation. At the end of the 19^{th} and the beginning of the 20^{th} century, the theorists of attention wanted to get this chaos into order. William James in his *The Principles of Psychology (1890)*, attempted to play down the more complex perceptual aspects of attention. However, he does assign attention to an important explanatory role in the production of behavior. He claimed that volition is attention.

Bradley (1886) advocated a view according to which attention is not the sort of phenomenon for which an independent and substantive theory can either be given or is required. He claims that no particular attention-processes can be identified since any function whatever of the body or the mind will be active attention if it is prompted by an interest and brings about the result of our engrossment with its product. There is no primary act of attention, there is no specific act of attention, and there is no one kind of act of attention at all.

In the early 20th century behaviorism dominated the psychological scenario and as such the explanation of attention as well. Behaviorists tended to neglect attention, but they did not ignore it entirely. In the middle of the 20th century behaviorism's dominance waned, cognitive psychology established itself, and a new theoretical approach to the explanation of attention was developed.

Donald Broadbent, the author of *Perception and Communication (1958),* claimed that the human brain is subject to capacity limitations as well as that these limitations are clustered so that there is a single bottleneck in capacity that is especially critical to the brain's information handling. The bottleneck was said to occur at the junction of two systems operating in series. The first system has a large capacity for information processing and operates automatically on all of the stimuli to which the subject is exposed. The second system has a much smaller capacity and is therefore selective.

In the decades following Broadbent, a great many psychologists devoted themselves to the task of locating the attentional bottleneck that he had postulated and were guided to some degree by Broadbent's two-systems-and-a-bottleneck theory of information processing. The question of whether a given task is attention demanding was understood to depend on the question of whether the performance of that task requires the engagement of the small-capacity system that comes after the bottleneck of attention. Research into the attention demands of particular tasks therefore became another way by which to approach the issue of where the attentional bottleneck is located.

Models or Theories of Attention

Psychologists use the concept of attention to explain how we are able to select some aspects of our environment while ignoring some others. A number of models/theories of attention have been developed by various scholars.

Various researches place attention as an inferred process that can be assessed only indirectly. As a paradigm amenable to the study of attentional phenomena, however, discrimination learning is especially important, for it points up two types of conceptualizations of attention (pre-reception and post-reception models), both of which stem logically from early formulations of the discrimination learning process.

The pre-reception models of attention focus on a process which operates prior to the associative learning of an instrumental response and the discriminative stimuli which signal reward, thus emphasizing the manner in which these cues are selectively attended to.

The post-reception models of attention deal with a response process that is an integral part of associative learning. In particular these models are concerned with the manner in which the organism may perceptually organize, interpret, or code the discriminative stimuli into stimulus compounds to which the instrumental response leading to reward can be attached.

Though the models/theories of attention are vague and ambiguous, recently researchers have developed some computational models of attention which provide useful insights into how the brain selectively processes parts of its inputs on the basis of measures of saliency and task relevance.

Gating Models of Attention

According to this model, attention acts as a _gate' into short term memory. It regulates the flow of sensory information into conscious awareness. When the attentional cue is detected, the attention _gate' is opened and the information is admitted into memory. To avoid overflow of memory capacity, the gate is automatically closed for a short while after opening. This prevents other stimulus items from entering memory. The strength of an item stored in the memory depends on the gating function G and the time at which the item occurred with respect to gate opening. The interaction is multiplicative: a stimulus S passes through the attention gate with output strength G X S.

Attention is directed to the selected location by a gating mechanism that allows the stimuli near the selected location to be conveyed to the higher processing centers and suppresses stimuli at other locations. The topographic representation of an input sensory field is called a saliency map. Each location in a saliency map contains a value that represents how different or salient that location is, compared with other locations in sensory field.

Shifter circuits were proposed as a computational model for how the brain may solve the problem of routing the selected information to higher centers in a position and size invariant way within the context of visual information processing. The primary components of shifter circuits are the control neurons. They set the size and position of the attentional window and modulate the strength of synaptic connections from the lower level to a higher level such that only the information from the attended region in the lower level is routed to higher level.

Filter Theory of Attention

Donald Broadbent (1926-1993), an influential English experimental psychologist propounded the filter theory of attention. It is considered as one of the most famous theories within the human information processing framework. It is an abstract, functional account of attention. It describes component stages of processing that are assumed to intervene between a given stimulus and the corresponding response.

In regard to information processing in humans, the outside world acts as the sender and the participant is the receiver. The limited capacity channel connects the sender with the receiver. Limited capacity means that there is an upper limit of the amount of information that can be transmitted down the channel at any given time. The central idea is that at an abstract level, the human central nervous system comprises a limited capacity information transmission channel. Sensory information is initially registered in parallel, but further processing operates in a serial mode. Moreover, because of the constraint of the limited capacity channel, only some of the information presented to the senses can be dealt with at once. Some of this information needs to be selected as being currently relevant—the rest is ignored. This notion of selection indicates to the notion of attention in the theory.

Broadbent schematically described the theory as—

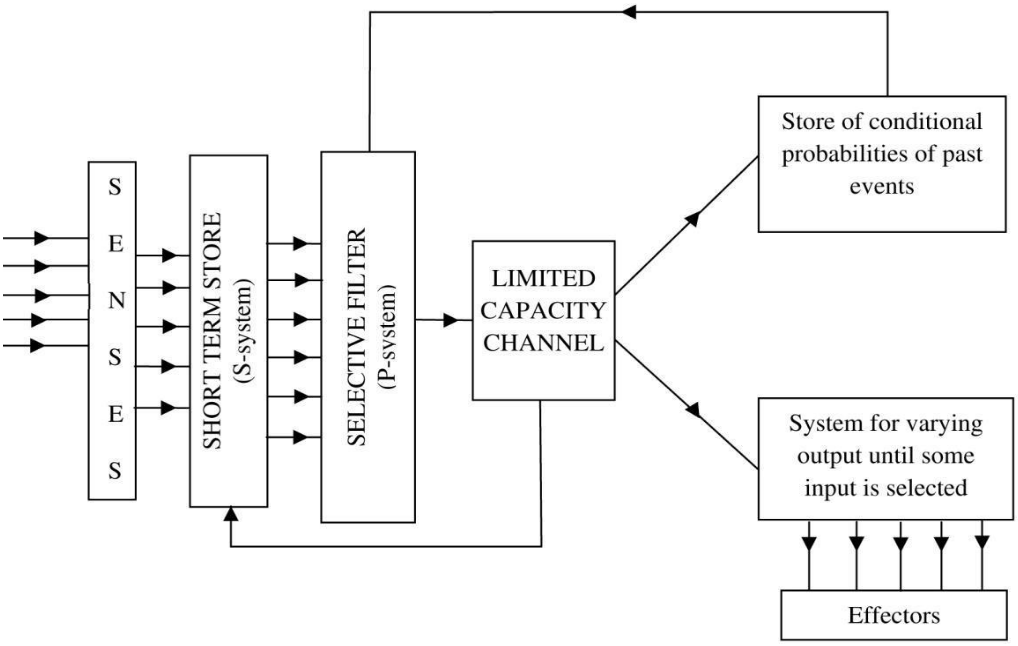


Fig. 6.4. Schematic representation of Broadbent's Filter Theory

Figure 3 shows that input to the senses is registered initially and is then forwarded to a short term store or sensory memory system (S system) in parallel. There is a large amount of sensory stimulation all of the time. It is assumed that, because of this, the S system handles various kinds of information in parallel. Now, the concern is to decide which aspects of this stimulation are worthy of attention. This is done by the selective filter. The basic idea of selection by filtering is that a selective filter affects the output of items from the short term store so as to pass them on for further processing. The filter operates on the information stored in the sensory memory, and such information specifies only the physical characteristics of stimuli. Those aspects of stimulation that possess a common physical attribute are selected and all the rest are filtered out. Another important point about short term memory is that items will decay from the store within a matter of seconds if they are not read out by the filter (assuming that probability of being selected increases directly as a function of its physical intensity). It is assumed that the filter can switch between different selection criteria but that such switches take time, because the filter can only follow one physical cue at once. So some information from the cue will likely be lost during the time it takes to switch the filter.

Items that are selected for read out by the filter are passed on to the limited capacity channel (P or perceptual system). If the system is in danger of information overload then any item selected for read out can be passed back from the P system and rehearsed, such that it is re-circulated into the short-term store. In this way, the limitations of the central channel are overcome to a certain extent.

Broadbent suggests that the P system affects perceptual-semantic categorization, in that items in the P system are assigned to their corresponding mental categories. The output from the P system coded post categorical information. Sensory information is initially registered in the S system in some raw form that codes the physical nature of the stimulus, while outputs from the P system code the categorical nature of the stimulus—semantic information is made explicit.

The original filter theory suffers from various sorts of processing constraints. Moreover, the limited capacity channel (P system) provides a structural bottleneck. The upper limit of the capacity channel for a limited amount of information is its structural constraint. While the upper limit on how quickly any item can be cleared from the S system is the processing constraint.

Late Filtering Accounts of Selection

In the late filtering account of attention, selection takes place at a much later stage of processing and involves much more complex categories than physical stimulus properties. Deutsch and Deutsch (1963) discussed data that were taken to reveal semantic analysis of unattended material. Here, semantic analysis means the assignment of importance to the various stimuli. They took the evidence to show that

‗all sensory messages which make impact on the organism are perceptually analyzed at the highest level‘.

Such a view has also been developed by Duncan (1984). According to him, each stimulus is fully identified before any selection takes place. This means that a representation of the stimulus is derived that codes its physical characteristics, its name if this is applicable, and its category assignment. According to Kahneman (1973), the late filtering model implies that ‗the meanings of all concurrent stimuli are extracted in parallel and without interference‘. Therefore any form of selection only takes place at a post categorical stage of processing prior to response execution. That means, everything is identified but that the critical constraints relate to responding.

Though the debate between early and late selection eventually led to fruitlessness, several capacity limitation based theories were developed. There are theories according to which attention corresponds to a capacity bottleneck (like Broadbent), but it is a bottleneck that moves, depending on the demands of the task at hand (Lavie & Tsal, 1994). Other theories retain Broadbent‘s idea that attentional selectivity is the result of capacity limitations, but rejects the early and late selection theories because they reject the idea that those capacity limitations are clustered into a single bottleneck.

Feature Integration Theory

This theory was developed by Anne Treisman (1935-), one of the most influential cognitive psychologists in the world. It is also known as the attenuated filter model of attention. She defined fundamental issues of how information is selected and integrated to form meaningful objects and memories that guide human thought and action. Some evidence were reported which indicate that unattended messages may be analyzed at the semantic level. This led to a modification of the original filter theory. Experiments showed that occasionally the subjects followed the content of the message across the channels for one or two words after the messages switched but they then immediately reverted back to the attended channel. It led to the conclusion that some form of semantic analysis of the unattended message must have been taking place. This finding led Treisman to suggest that, in contrast to the original all-or-nothing filter in original filter theory; unattended messages were attenuated and were not completely blocked out from further analysis. The filter operates to dampen down the unattended message but it does not block it out completely.

This theory is based on _the binding problem‘. The binding problem is the problem of knowing how to put together the properties that are detected in separate specialized detection centres. Treisman‘s proposed solution to the binding problem is based on the fact that spatial representations are present everywhere simultaneously, and the idea that there is only one thing to be seen in any place at any time. She proposes that we achieve a correctly bound representation by moving a variously sized _window‘ from one location in the perceptual scene to another. This window blocks out the information from all but a single location, and all the features found at that location can then be _bound‘ as being features of the same object. The area covered by the window within which features are bound is taken to correspond to the region to which attention is being paid. As the features of the stimuli found at one location are integrated, it is known as Feature Integration Theory.

Coherence Theories

In 1970s, Ulreic Neisser and others showed through an experiment that when appropriately trained, a subject can perform two attention involving tasks concurrently without much interference between them. Neisser interpreted that, insofar as there is a bottleneck that attention is needed to manage, it must often be a bottleneck in behavioral co-ordination, rather than in simple information processing capacity.

In 1987, Odmar Neumann and Alan Allport also presented similar views. However, they emphasized that the constraints are placed on cognition by the need to maintain a coherent course of action.

According to them, the function of attention is not the management of capacity limitations. Instead, it is the management of capacity excess. It is because we can process multiple stimuli that we get distracted by them, not because we can‘t process them, that we need mechanisms of attention to provide selectivity and focus. Thus, attention serves to lend coherence to, and to prevent competition and interference between, the activities of components in a system that has the capacity to handle far more stimuli than those pertaining to the subject‘s current task.

Competition Theories

The coherence theories are natural accompaniments to views according to which the mechanisms of attentional selection are something other than the capacity bottlenecks. The clearest non-bottleneck mechanisms for achieving selectivity are competitions. Well organized competitions can always select one winner, however well and however numerous the competitors are.

Competition based mechanisms for achieving selectivity come in at least two varieties: in a simple race mechanism, each of the competitors independently completes a process that is comparable along some dimension of variation with the processes completed by the other competitors. The competitor that achieves the highest value on the relevant dimension of variation is selected as the winner. Another is struggle (race mechanism), in which the competitors also involve in active suppression of other competitors along with their own processing.

Spotlight Theories

Bottleneck metaphors attempt to locate the cognitive resources that operate only on attended stimuli. Spotlight theories attempt to say which features of a stimulus determine whether attention is being paid to that stimulus at any given moment. The central idea suggested by the spotlight metaphor is that the determinant of whether or not a stimulus is attended is the stimulus‘s location. It resembles the idea that we have a small field of vision and it is hard to see things outside of this spotlight region, although attention can be shifted by moving this light.

Problems in the classroom

Attention comprises one of the most important components or say factors in a teacher‘s agenda while teaching in a classroom. It is one of the main challenges for the teacher to hold the attention of students in the classroom.

- ***Numerous stimuli:*** The learners are exposed to a number of and a variety of stimuli in and outside the classroom. Directing their interest towards the desired task or bringing the focus of their mind to the task at hand is a problem.
- ***Identify natural interest:*** The challenge for the teacher is to identify the natural interest (natural distractions) of the learners and direct their attention towards the task without forcing them.
- ***Exposure:*** How much of exposure will be good to hold the attention of the students is another question to be answered. The teacher has to decide on the amount of exposure. It has to be enough to attract the attention of the learner as well as limited to the degree that they are not distracted by exposure to a large number of stimuli.
- ***Catering to different natural interests:*** It is also difficult to cater to different natural interests of the learners. Presenting the learning materials to the learners so as to attract their natural attention is also a problem.
- ***Split attention effect:*** Instructional split attention occurs when learners are required to split their attention between and mentally integrate several sources of physically or temporally disparate information, where each source of information is essential for understanding the material. It increases the cognitive load of the learners. Handling the split attention effect of the students is another issue to be addressed in pedagogy.
- ***ADHD:*** Another problem faced by the teacher is to deal with the Attention Deficit Hyperactivity Disorder children. They are characterized by deficits in response inhibition, error monitoring, attentional disengagement, attentional networks, and motivational style (delay aversion).

- ***Feedback:*** Whether paying attention by the learners need feedback is another question. If yes, then when and how this feedback should be given is also a question.

Pedagogical Implications of Attention

Attention constitutes an important concept in the pedagogical process. The importance of attention in a pedagogical situation can be inferred from the fact that the first event of instruction is gaining attention (Gagne, 1974). Good instructional design directs the learners' attention, helping them to avoid distractions and "information overload". It is claimed by some teachers that every form of education is an education of attention above all. The call of education is to introduce a degree of co-ordination, meaningfulness and direction into the chaotic and uncoordinated reactions of the child. The fundamental principle of education lies in the selection of those most essential and most important reactions that have to be preserved. Therefore, it is essential for the teachers (pedagogue) to understand the nuts and bolts of attention. If a teacher understands the philosophical, psychological and neural basis of attention, it becomes helpful for designing as well as practicing his pedagogy.

Jang, Schunn and Nokes (2011) suggest that simply manipulating the spatial format of instructions, leaving learning task materials alone, may suffice to significantly improve both task performance and learning. The study shows that the act of distributing instructions while holding task material format constant is enough to improve learning significantly. In terms of theoretical implications for the split-attention effect, the results suggest that the effect appears not to be binary in nature (as the integrated vs. separated framework would suggest); rather, there appear to be degrees of effects as access costs increase (e.g., integrated displays < distributed displays < stacked displays along a dimension of access cost).

The results of the study by Baijal, Jha, Kiyonaga, Singh, & Srinivasan (2011) are that conflict resolution, indexed by current trial performance, regardless of previous trial conditions, was significantly improved in the students attending the concentrative meditation training (CMT) vs. other school, in all age groups. Concentrative attention is that which is restricted to a specific focus. While conflict adaptation was not improved in this group, relative to the Control group in terms of reaction time, there was an improvement in terms of accuracy. This CMT-related benefit during previous trial analysis, involved a convergence of age and trial conditions in which proactive control was least likely to have been engaged. That is, the CMT group's accuracy was significantly better than the Control group, when the current trial was incongruent and preceded by a congruent trial. This context may maximize the need to employ reactive control, and it was only under these circumstances that the CMT outperformed the control group.

Despite its importance to learning, focused attention is rarely if ever systematically trained or cultivated in most educational settings.

Another aspect of attention related to pedagogy is that it can be developed as a skill among the learners. Shapira, Brown & Astin (2008) suggest that attention and the behavioral responses associated with it may be flexible skills that can be cultivated through concentration and mindfulness meditation practices.

Zylowska et al. (2008) and Woolacott (2007) also suggest that meditative practice may help to improve the deficits associated with Attention Deficit Hyperactivity Disorder (ADHD), as assessed by computer-based tasks in controlled laboratory settings and parental report. For concentrative meditations, first the focus is set and attempt is made to retain it on a particular object (such as the sensation of breathing or a word), the loss of the intended focus is noticed, after this, unintended focus is discontinued (e.g., worrying about some impending task), and then the intended focus is restored. Research suggests that meditative practices can enhance specific aspects or subsystems of attention.

Commenting on attentional feedback and rewards, Watling, Mansvelder, Roelfsema & Ooyen (2010) suggest that the attentional feedback and reward signals are both necessary and sufficient to explain the formation of the category specific internal representations that have been observed to accompany learning.

During the early years of the child, attention is almost reflexively instinctive in nature. Gradually, it turns into voluntary orientation through gradual, lengthy and complex training guided by the most important needs of the organism and in turn, guiding the full course of its behavior. This reflex and passive character of attention which makes the child seem to belong less to himself than to every object which happens to catch his notice, is the first thing which the teacher must overcome.

Therefore, the child‘s interest (involuntary attention) has great pedagogical importance. An important issue in pedagogy is to take the appropriate path in between the path followed by the child‘s natural interest and the path mapped out by the tasks required for the child. Education means neither simply following the child‘s natural inclinations nor a fruitless struggle against these inclinations. It is a path in between and requires combining the two extremes together into a unified whole. Education proceeds by taking these inclinations as the starting point. But it intervenes actively in these natural inclinations of the child, brings them together, grouping them, preserving some of them, stimulating some of them, and in this way, introduces the spontaneous process of the child‘s inclinations into the organizing and shaping channel of the social environment in the school.

Teaching in general is possible only in as much as it relies on the child‘s own interests. Therefore, the teacher should work alongside the child‘s natural interest or attention. He should orient the subject matter according to the natural inclination of the child and from there he can gradually demand attention for the required tasks. The question is how far this interest may be directed along the path of the actual subject being studied. The teacher has to design his pedagogy in such a way as to utilize the natural interests of children in motivating the children towards the task in hand.

Thus, the analysis has helped in building a historical background of the field of cognitive science, both in western and Indian perspectives. The analysis of the components has brought out that the psychological aspects related to the mind or cognition constitute the field of cognitive science. Although many of these components are relevant in education, five components were further analyzed to find out the pedagogical problems and the pedagogical implications. These are—learning, problem solving, creativity, intelligence and attention. The concepts, the cognitive theories and the pedagogical implications of these components have been analyzed theoretically from the perspective of cognitive science. The cognitive theories of learning which have been discussed are Gestalt theory, Tolman‘s theory, Lewin‘s theory, Piaget‘s theory, Bruner‘s theory, Ausubel‘s theory, Vygotsky‘s theory, Information processing theory and the learning systems. The pedagogical problems related to learning and the pedagogical implications for each theory have been analyzed. Likewise, the cognitive approaches to problem solving (Gestalt theory and Information processing theory), the problems of teaching problem solving and the pedagogical implications have been analyzed. The cognitive theories of creativity included Taylor‘s Level theory, Freud‘s psychoanalytic theory, Arieti‘s theory, Creative Cognition theory, Amabile‘s theory, Wallas‘ model, Gruber‘s model and Greene‘s model. The pedagogical problems of creativity and the implications of the cognitive theories and cognitive science research have been analyzed. Intelligence constitutes an important component of cognitive science. The theories of intelligence considered in cognitive science are Sternberg‘s Triarchic theory, Cattell and Horn‘s theory, Jensen‘s mental functioning theory, Gardner‘s Multiple Intelligence theory, Newell and Simon‘s theory, PASS theory and Perkin‘s theory. The analysis shows that pedagogically, Gardner‘s theory has more implications than the other theories. The Gating model of attention, the Filter theory, the Feature Integration theory, Coherence theories, Competition theories, Spotlight theories have been analyzed to understand the cognitive perspective of attention. The pedagogical problems related to attention and the implications of cognitive science research on attention have been analyzed.

So far the problems related to the components have already been discussed with the respective components. However, on the basis of the works and models referred by Ivie (1998), Whiteley (2006), Rittle-Johnson & Star (2007), Kumar & Gupta (2009), Limjap (2002), Ross (2007), Hamza & Griffith (2006), Lin (2011), Fogarty (1998), Jang, Schunn & Nokes (2011), etc. the researcher has developed a chart to make it convenient to follow the pedagogical problems and implications of cognitive science, which is presented below.

Table 6.3. Pedagogical Problems and Implications of Cognitive Science

Components	PEDAGOGICAL PROBLEMS	PEDAGOGICAL IMPLICATIONS OF COGNITIVE SCIENCE
LEARNING	Concept of learning	Instructions in learning processes
	Perplexed goal of learning	Instructions in learning processes
	Relating new learning to previous learning	Insight based on past experience, so past and present should be presented together
	Mismatch of content and pedagogy	Problem-solving approach More importance to values in the content than to content itself
	Differentiating learning from knowledge accumulation	Comparing-contrasting solutions procedures helps in gaining procedural knowledge Instruction in learning processes
	Fragmented learning	Follow Gestalt principle (whole to part) Insightful learning
	Less time for practice	Adequate time for practice for internalization and meaningful learning
	Knowledge construction	Use of Socratic method among students as well as with teacher Provide necessary resources (classroom full of interesting things)
	Social and individual nature of learning	Collaborative learning with small groups to respect individuality
CREATIVITY	Rigidity	Open and challenging environment Creative problem solving
	Excess media consumption	Techniques like brainstorming, thumbnail sketches, synectics, matrixes, etc.
	Structured environment	Experimental and error-welcoming teaching
	Balancing between nature of creative students and others	Appreciation of learner's individuality Self-confidence of learners
	Misconceptions about creativity	Teacher must believe and realize that creativity can be taught Sensitive and imaginative pedagogic practice

INTELLIGENCE	Creating environment for fostering intelligence	Rich learning environment Emotional safety Challenges through experience
	Evaluating intelligence	Authentic methods of assessment Diverse assessment of school achievement
	Handling intellectual relativism	Teaching all types of intelligence Multimodal delivery (techniques, tools and strategies) Avoid labeling intelligence Consider individual differences
PROBLEM SOLVING	Haphazard problem solving	Consider all factors of problem solving Promote meaningful learning rather than rote learning
	Lack of background knowledge	Using mental models to represent the structure of concepts Using intuition and logic to develop problem solving skills
	Application of background knowledge	Guide metacognition Variable problem context should be used Facilitate analogy
	Not focusing on the problem	Recognizing the essence of the problem Giving sufficient time to ponder over the problem Proper representation of problem
	Using only knowledge rather than reasoning	Focus on the process of problem solving rather than its product Use of concrete thinking (examples)
	Decision-making process	Focus explicitly on decision-making process
ATTENTION	Handling numerous stimuli	Concentrative meditation training
	Catering to different natural interests	Intervene in natural interests, bring them together, group them, preserve some, stimulate some and channelize others.
	Spilt attention	Distributing instructions while holding task material format constant
	Attention Deficit Hyperactivity Disorder	Meditative practices

From the analysis, it is evident that an integrated approach is needed to the knowledge and information along with the integrated level of understanding of the learner or the child for effective pedagogy. Thus, the analysis carried out in the present chapter will help to bring out the concrete major findings of the study.