CHAPTER II
THEORETICAL PERSPECTIVE

The investigator is planning to pursue the research in science education which is the area of her specialization. So, she prepares to review the theories related to science education.

2.1 Science Education – Goals

The rapid advancement of science and technology as well as globalization makes the world as the network of global village thereby enhancing the quality of human life. This kind of advancement of science and technology has made “knowledge” a big resource and it is believed that in the 21st century only those countries which possess a wealth of knowledge would excel. Here lies the necessity to promote scientific literacy. Since the future of our nation lies in the hands of our children, we need to make a strong foundation for scientific thinking and to promote scientific consciousness in children.

Teaching and learning of science helps to increase the span of one’s knowledge of science helping him to understand himself and his environment as accurately as possible. Science also enables everyone to utilize one’s thinking and imagination. This quintessence of science is clearly observed in the words of famous physicist Einstein, “the whole of science is nothing more than a refinement of everyday thinking”. Therefore, science education serves three major purposes. First, it prepares pupils to study science at higher levels of education. Second, it prepares pupils to enter the workforce, pursue occupations, and take up careers. Third, it prepares them to become more scientifically literate.

With a view to strengthening the quality of science education, earlier commissions such as Radhakrishnan Commission (1948-49) and Indian Education Commission (1964-66) reported that education should be developed so as to accelerate modernization and to improve the quality of life. National Policy of Education (1986 & 1992) has also given emphasis on the need for developing abilities, values and skills like creativity, spirit of inquiry, problem-solving and decision-making skills. Therefore, present scenario of science education gives top priority on promoting more scientifically literate and creative individuals. To achieve
this goal, we should plan science education with a view to enabling pupils to acquire the required conceptual understanding of science to develop creativity and such skills as problem-solving, decision-making skills and the like. We should also try to cultivate scientific temper and critical thinking to acquire requisite theoretical knowledge and practical technological skills to enter the world of work and also to nurture the curiosity and aesthetic sense using appropriate pedagogical approaches.

Modern pedagogical approaches like model-based strategies, metacognitive strategies and brain-based learning strategies suggest that learners must develop awareness of themselves as thinkers and learners, practise strategies for effective thinking and to cultivate habits of creative and intelligent behavior that are needed for lifelong learning. This implies the need for creating a suitable thinking environment to realize the goals of science education of 21st century. Recent developments in thinking and learning emphasize the role of the structure and functions of brain in enhancing cognitive functions. Hence, recent studies focus on developing more innovative strategies for activating all regions of brain to enhance thinking and learning. So the present challenge is to develop educational programmes with a view to enabling all individuals to become effective thinkers and learners for realizing the vision of our future.

2.2 Conceptual Understanding

‘Concepts’ are categories that group objects, events, and characteristics on the basis of common properties (Zacks and Tversky, 2001). Concepts are elements of cognition that help to simplify and summarize information (Hahn & Ramscar, 2001; Klausmeier, 2004; Medin, 2000). They also help to improve the efficiency of their memory, communication, and use of time. In the words of Bruner, Goodnow and Austin (1956), a concept is the network of inferences that are or may be set into play by an act of categorization involves (p.244). Bruner et al. (1956) view categorizing as the ability to “render discriminably different things equivalent, to group the objects and events and people around us into classes to respond to them in terms of their class membership rather than uniqueness”(p.1). Hence, this act of categorization involves critical thinking skills.

Concepts are the building blocks of thought and hence, understanding of concepts improves our thinking process and helps to structure knowledge on a strong
foundation by removing misconceptions. So conceptual understanding is considered as a key aspect of learning.

Researchers have identified several principles for promoting conceptual change. They are

- Conceptual change is more likely to occur when existing misconceptions are identified before instruction begins.
- Pupils are most likely to revise their current beliefs about the world when they become convinced that these beliefs are incorrect.
- Pupils must be motivated to learn correct explanations for the phenomena they observe.
- Some misconceptions may persist despite instruction designed to contradict them.

(Ormrod, 2000, p.288)

### 2.2.1 Theories of concept learning

Concept learning is regarded as the identification of concept attributes which can be generalized by discriminating examples from non-examples. Modern views of concept learning suggest that prototypes and exemplars are used to identify members of a category in learning a concept. Prototype is the best representative of its category whereas exemplars are specific examples of a given category that is used to classify an item. Prototypes are built from experiences with many exemplars. Both prototypes and defining attributes are important in learning a concept.

There are two main theories of concept learning. One view assumes that concept learning is an associative process; the other, that concept learning is a cognitive process.

According to Hull (1920), concept learning is a form of discrimination learning (Klein, 2011). Concepts have both relevant and irrelevant attributes. On each trial of a concept learning study, a subject determines whether the object or event shown is characteristic of the concept. A subject responding correctly is reinforced by feedback. As a result of this, response strength to the attributes characteristic of the concept is increased. Hull proposed that associative processes control concept learning. Hence, according to associative view, concepts are learned by associating the concept name with specific instances of the concept. This view was supported by
most psychologists until the late 1950s, when further research revealed that cognitive processes also are involved in concept learning.

Cognitive process of concept learning emphasizes the involvement of cognitions in concept learning. According to Bruner et al. (1956), a concept is learned by testing hypotheses about the attributes of the concept or about the rules defining the concept. If the first hypothesis formed is correct, the individual has learned the concept. However, if the hypothesis is incorrect, another hypothesis will be generated and tested. Hypothesis testing will continue until a correct solution is discovered. Levin’s (1966) studies have shown that individuals can test more than one hypothesis at a time (Klein, 2011).

Associative learning and hypothesis testing are not mutually exclusive means of learning a concept. A concept can be learned using either method, but is learned best when both means are employed. Reber, Kassin, Lewis, and Canter (1980) found that subjects acquired a concept most rapidly when they learned both the rules defining the concept and specific instances of the concept (cited in Klein, 2011, pp.323-325).

2.3 Strategies for Teaching Concepts

- **Concept attainment model**

  Concept attainment model is one approach to teaching concepts that asks pupils to form hypotheses about why particular examples are members of a category and what that category (concept) might be. This approach is considered as a way of helping students construct an understanding of specific concepts and practical thinking skills such as hypothesis testing (Joyce, Weil and Calhoun, 2000; Klausmeier, 1992) (cited in Woolfolk, 2004, p. 311).

  Concept attainment strategy was developed by Bruner with the intention of introducing, teaching and nurturing students’ critical thinking skills. According to Bruner et al., (1956), concept attainment is the search for and listing of attributes that can be used to distinguish exemplars from non-exemplars of various categories.

  In this strategy, pupils are given the specific steps or structure to scaffold their thinking. Viewing exemplars compared to non-exemplars of a concept enables pupils to inductively increase their understanding of the many facets of the concept. This inductive lesson structure leads pupils step by step to an in-depth understanding of a
new idea and scaffolds their thinking as they piece together essential attributes of the target concept (Reid, 2011).

- **Analogical instruction**

  A recent approach to teaching concepts that also emphasizes connections with prior knowledge is called analogical instruction (Bulgren, Dashler, Schumaker, & Lenz, 2000) (cited in Woolfolk, 2004, p.317). By identifying known inference that relates to a new concept, teachers and students can map the analogies between the known and the new, then summarize an understanding of the new concept by explaining the similarities and differences between the known and the new concept.

  Analogies have also been used in problem-solving. This approach has proved helpful for teaching scientific or cultured knowledge in heterogeneous secondary classes that include students who are less academically prepared and students with learning disabilities.

- **Discovery learning**

  In discovery learning, the teacher presents examples and the students work with the examples until they discover the interrelationships. Bruner believes that classroom learning should take place through inductive reasoning, that is, by using specific examples to formulate a general principle. Encouraging inductive thinking in this way is sometimes called the rule method.

- **Expository teaching model**

  According to Ausubel (1963, 1977 & 1982), people acquire knowledge primarily through reception rather than through discovery (Woolfolk, 2004, p.315). Ausubel’s expository teaching model stresses meaningful verbal learning – verbal information, ideas and relationships among ideas, taken together. Ausubel believes that learning should progress deductively; from the general to the specific, or from the rule or principle to examples. In this approach, teachers present materials in a carefully organized and sequenced form. After presenting advance organizer, the next step in a lesson using Ausubel’s approach is to present content in terms of basic similarities and differences, using specific examples.

- **Concept mapping**

  Once students have a good sense of a concept, they should use it. This might mean doing exercises, solving problems, writing, reading, explaining or any other
activity that requires them to apply their new understanding. This will connect the concept into the students’ web of related schematic knowledge (Woolfolk, 2004). This approach, concept mapping is used to develop the network of schematic knowledge of concept and thus helps to understand the concept.

2.4 Concept Attainment Model

Concept attainment model was developed in 1960s from the research of Bruner et al., (1956). Their work, “A study of Thinking” reveals that the nature of concepts forms the basis for understanding all types of concept learning, whatever teaching strategy is used. This model is designed to help students learn concepts for organizing information and to help students become more effective at learning concepts. Boulware and Crow (2008) reported that this instructional technique focuses on developing comprehension of words and ideas associated with a concept rather than on its name or what the concept is called. Research showed that concept attainment model is an effective strategy in developing reasoning ability and general science ability of students (Singh, 2011).

2.4.1 Concept attainment model – Assumptions

Concept attainment model focuses on decision-making processes and categorization processes leading up to the creation and understanding of a concept. All concepts are composed of the same basic elements. Thus, the means of acquiring any concept is essentially the same. Another assumption is that there are more or less effective strategies for forming concepts or categorizing. Hence, the main two contributions of Bruner’s research, nature of concept and strategies for concept attainment are considered as the theoretical background of concept attainment.

a. Nature of concepts

According to Bruner, any concept has three elements – exemplars or examples, attributes and attribute values.

Exemplars or examples are the instances of a concept. Bruner refers to those examples which contain all the characteristic features or essential attributes in them as positive examples. The absence of one or more essential attributes makes negative examples. In concept formation, examples of a concept are grouped together; in concept attainment, the negative and positive examples are tested and searched for their features.
Every example, both positive and negative, can be described in terms of its attribute values. Attributes are the features of objects. Every concept has essential and non-essential attributes. Essential attributes are the common features of the concepts, whereas some of the slight differences among examples of a category reflect as non-essential attributes. Every instance of the concept has all the essential attributes of the concept. What makes one concept different from another is the combination of attributes. The distinguishing attributes and their value-range are called criteria attributes. If anyone criteria attribute is missing from an object, that object is an example of a different concept. There are some non-essential features which make it difficult to find the common essential features of a concept are known as noisy attributes. Each attribute has an attribute value. The attribute refers to the basic category, whereas the attribute value is the specific content of that category. Most attributes have a range of acceptable values.

Based on the study of Bruner’s theory of concepts, Weil and Joyce (1978) identified six elements of concepts for concept attainment process. They are name, attributes (essential and non-essential), exemplars or examples (positive and negative), and rule. Name is the term or label given to a category. For e.g., “Force”, “mass”, “velocity” etc. Attributes and exemplars are explained earlier in this section. Rule is a statement specifying the essential attributes of a concept. It should evolve at the end of the concept attainment process.

Bruner also described three types of concepts – conjunctive, disjunctive and relational. Conjunctive concepts are defined by the joint presence of several attributes. Disjunctive concepts require the presence of some attributes and the absence of others. Relational concepts have several attributes, but these bear some kind of relationship to one another (Weil and Joyce, 1978, pp.53-54).

b. Strategies for concept attainment

According to Bruner, strategy is the sequence of decisions people make as they encounter each instance of a concept. Bruner and his associates identified two learning conditions in concept attainment – selection and reception. In selection conditions, the examples are not marked “yes” or “no”. An individual selects one and inquires whether it is a “yes” or a “no”. In reception conditions, the teacher presents the examples in a prearranged order, labelling them as “yes” or “no”. The type of
instructional condition (reception or selection) influences the particular thinking strategy that the student will employ. Bruner and his associates have identified six strategies – four selection strategies and two reception strategies (Weil and Joyce, 1978, p.38). They are presented in Figure 2.1.

The two scanning strategies are based on the use of a concept – hypothesis, whereas focusing strategies utilize attributes for searching. Successive scanning consists of testing one hypothesis at a time, whereas simultaneous scanning uses many hypotheses at one time. Focus gamblers use a positive instance as a focus and change more than one attribute at a time; conservative focusers find a positive instance and choose instances that alter one attribute at a time.

![Figure 2.1. Strategies of concept attainment.](image)

The two reception strategies are wholist and partist. In the wholist strategy the first positive instance of the concept is taken and compares all the attributes of the first instance to those of subsequent instances and modifies the hypotheses accordingly. The wholist strategy is similar to focusing. In the partist or part-scanning strategy, the choice of a hypothesis is based on only part of the initial example. If the initial hypothesis is not confirmed, the partist refers back to all previous instances and changes the hypothesis.
Weil and Joyce (1978) presented three types of concept attainment model based on the learning conditions and strategies. They are

i) The Reception–Oriented Concept Attainment Model

ii) The Selection–Oriented Concept Attainment Model

iii) Unorganized Materials Model

The reception model is more direct in teaching students the elements of a concept and their use in concept attainment. The selection model permits students to apply the awareness of conceptual activity in a more active context, one that permits their own initiation and control. The analysis of concepts in unorganized data transfers concept theory and attainment activity to a real-life setting. The reception-oriented concept attainment model is described in the following section.

2.4.2 The reception–oriented concept attainment model

i. Syntax

The phases of the reception model as cited by Joyce, Weil and Calhoun (2008) are outlined in Figure 2.2.

ii. Principles of Reaction

The model emphasizes that during the flow of lessons the teacher supports students’ hypotheses but emphasizes the hypothetical nature of the discussion and helps to create dialogue in which students test their hypothesis against others. In the later phases, the teacher should focus the students’ attention toward analysis of their concepts and strategies and should encourage analysis of the merits of various strategies rather than attempt to seek the one best strategy for all people in all situations.

iii. Social system

The model has moderate structure. The teacher selects the concept, selects and organizes the material into positive and negative examples, and sequences the examples. The teacher controls the action, but student interaction is encouraged in subsequent phases. In the reception model, the structure moves from high to moderate, whereas in the selection model students control the sequence and hence, it is low structured.
iv. Support system

Well organized material which contains positive and negative examples is the essential support required for the model. When students are presented with an example, they describe its characteristics, which can then be recorded.

v. Instructional and nurturant effects

The major instructional effects of the model are

- Nature of concepts
- Concepts, conceptual systems and their application
- Concept –learning strategies

The nurturant effects are

- Conceptual flexibility

Figure 2.2. Syntax of reception-oriented concept attainment model.
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- Inductive reasoning
- Tolerance of ambiguity

Hence, concept attainment model is used to help students acquire a new concept, enrich and clarify their thinking on previously acquired concepts, teach them both the concept and the nature of conceptual activity and help them become aware of their own thinking process and strategies. It is an effective means of making the most powerful ideas and also it can be used as an effective evaluation tool to determine whether the concepts introduced earlier have been mastered. Most of the researches on concept attainment model say that it is an appropriate model for teaching specific materials and for developing students’ reasoning skills and it is also applicable to children of all ages and grades.

2.5 Creative Thinking

“The Preservation of this nation’s way of life and future security depends upon its most important national resources; intellectual abilities and, more important, creative abilities. It is time, then, that we learn all we can about those resources”.

( Guilford, 1952, p.2)

Creative mind demands the capacity to think in novel ways, branches out from the conventional, adopts alternative ways of thinking, sees new relationships between the related things, etc., This sort of a search for new alternatives has led to the advancement in all fields. Without creativity, the society will become stagnant. Creativity provides a base for excellence. In today’s competition world, it is considered as a powerful resource for survival. If we want our education system to survive the changes brought by the knowledge explosion, we must mobilize the creative talents of our children. In order to realize this goal, our present education system should adopt the research findings and suggestions regarding the approaches and techniques for nurturing creativity of children and also conduct more researches on creative teaching and creative learning.

Nature of creative thinking

Creative thinking is an important feature of decision making. It is the phenomenon of awakening new insights, rearranging old learning and examining
assumption to formulate new theories and paradigms, or creative awareness. It is the process of revealing, selecting, swapping around, and blending one’s stock of facts, ideas and skills.

As a cognitive activity, creativity engages a range of mental abilities and processes such as remembering, imagining, planning, organizing, deciding, determining, perceiving, learning, recognizing and interpreting (Martinsen and Kaufmann, 1999; Weisberg, 2006), but its essential distinguishing features are problem redefinition and ideation (D’Cruz, 2008, p.24).

Redefining the problem provides the opportunity to look at a problem from different viewpoints, allowing diverse perspectives not immediately available to us to come to the fore. Ideation involves the generation of alternatives, triggered via the use of imagination, associational thinking and other generative processes such as conceptual combination, analogical transfer, and so on. Problem redefinition and ideation allow novel and unique ideas to emerge. They are followed by evaluation which ensures the usefulness of the ideas. So it is considered as a complex cognitive phenomenon, encompassing both process and outcome. Therefore, creativity is a cognitive activity falling in the realms of thinking, problem-solving and information processing, that is, engages problem redefinition and ideation processes, followed by an evaluative component, to give rise to outcomes which are original, useful and ethical.

2.6 Strategies for Developing Creative Thinking

Creative ability is universally present in all human beings is a widely held belief (Davis, 1999; Guilford, 1950; Nickerson, 1999) (cited in D’Cruz, 2008, p.17). Indeed, as with other cognitive abilities, the ability to be creative is present in all of us from the time of birth. Yet, the environment does little to develop these abilities. Research has shown that environments that encourage independence, risk taking and intrinsic motivation have been found most conducive to creativity (Anderson et al., 1970; Richardson, 1988; Shaughnessy, 1991). In creating this type of creativogenic environment, it is recommended that teachers accept and encourage creative thinking, emphasize that everyone is capable of creative; and, serves as a stimulus for creative thinking through various approaches and techniques. Various techniques of creative problem-solving are used to develop the creative efficiency. These techniques
facilitate solutions that are creative, i.e., solutions characterized by freshness, appropriateness, imagination, new relationships between ideas and significant transformations of the initial definition of the problem. There are different techniques and strategies of creative problem-solving such as, attribute listing, morphological analysis, brainstorming, inquiry training and synectics.

- **Attribute listing**

  This technique was developed by Craword (1954). According to him, magic inspiration is not the only, or even major source of creativity (cited in Wallach, 1971). Much creativity arises from changing the attribute of an object or an activity, or from grafting on to the object or an activity, an attribute or attributes of some other object or activity.

  In ‘attribute listing’, ‘the attempt first is made to list the basic but modifiable attributes or properties or specifications of a particular object or activity. Then an attempt is made to search for alternatives to the present attribute. It is a very powerful technique for improving product design.

- **Morphological analysis**

  Morphological analysis is a variant of attribute testing and was developed by Zincky in 1957 (cited in Wallach, 1971). It facilitates the imagination by enabling the individual to focus on one aspect of the object or activity at one time. It involves combining the major attributes of the major variables of a problem into a grid so that all possible combinations can be considered.

- **Brainstorming**

  Brainstorming is a popular method of group thinking developed by Osborn (1953) (cited in Wallach, 1971). It is a technique with which problem is attacked from all possible angles to generate a large number of ideas in order to arrive at the best solution. In a brainstorming session, a group of students sit around a table to brainstorm a specific problem. Each participant presents the ideas which come to his mind. No member of the group is allowed any criticism on the idea put forward by another one. The main objective underlying this is that of freeing a person from the usual inhibitions that operate to block his creative process. Encouraging creativity through everyday interaction with students, teachers should use this technique of
brainstorming. This also helps to develop self-confidence and sense of resourcefulness.

- **Inquiry training**

Inquiry training model was developed by Suchman (1962) to teach students a process for investigating and explaining unusual phenomena (cited in Rather, 1998). He identified the components of the inquiry process and built them into the instructional model to which he called inquiry training. The main objective of this model is to develop scientific process skills such as organizing the data, reasoning about cause-effect and then formulating and testing hypotheses.

In “inquiry training”, students are presented with a problem situation and are asked to inquire into it. The questions asked by the students have to be worded in the way that they are answered by a ‘yes’ or a ‘no’. Thus, at the first stage of the inquiry process, students are taught to verify the facts of the situation. As the students become aware of the facts, they form hypotheses which guide them in their future inquiry. Finally, they reach the final explanation. The main emphasis in this approach is on becoming aware of and mastering the inquiry process and not the content of any particular problem situation.

- **Synectics**

One of the major contributions made in the area of approaches to creative thinking is Synectics, designed by Gordon (1960). The word ‘Synectics ‘derived from the Greek word ‘synectikos’ which means “joining together of different and apparently irrelevant elements”. Initially, Gordon developed this technique to enhance creativity of the industrial personnel. Later, Gordon has adapted Synectics for use with school children. Synectics uses metaphor and analogy to make the creative process explicit for students through strategies for exploring the unfamiliar and creating something new.

2.7 **Synectics’ Theory of Creative Process**

Synectics is one of the better-known models to emerge from the search of the development of creativity in individuals or groups. Gordon developed Synectics procedures to develop creative potential groups within the industrial organizations. Gordon means this Synectics process as the method of directing creative potential to the solution of technical and theoretical problems. This theory uncovers the
psychological mechanisms present in one’s creative activity. “Synectics” defines ‘creative process’ as the mental activity in problem–stating, problem-solving situations where artistic or technical inventions are the result” (Gordon, 1961, p.33). The Synectics mechanisms are intended to induce appropriate psychological states and thus promote creative activity. Weaver and Prince (1990) also suggest Synectics as a creative problem–solving process carrying participants from problem analysis to the generation and development of new ideas. Kawenski (1991) described a six- week course for students in her article, “Encouraging creativity in Design”, and reported that synectics was stressed for actual problem solving.

Gordon has put forward the following assumptions about creativity which are different from traditional views.

- Creativity is important in everyday activities .Gordon emphasizes creativity as a part of our daily work and leisure lives.
- Creativity can be described and can be trained directly to promote the creative process in individuals.
- Creative invention in the arts, sciences and engineering are similar and are characterized by the same underlying intellectual processes.
- Individual and group inventions are similar.

Gordon developed the synectics procedures based on the following assumptions about the psychology of creative process.

- Creative capacity of individuals and groups can be increased by bringing the creative process to consciousness and by developing conscious aids to creativity.
- Emotional component is more important than the intellectual, the irrational more important than the rational.
- Emotional, irrational elements must be understood in order to increase the probability of success in a problem–solving situation

(Gordon, 1961, p.6)
Gordon has also found that five interrelated states of mind must be present in order that an individual could move through the creative process and make a breakthrough in order to contribute to a final solution. They are – detachment and involvement, deferment, speculation, autonomy and hedonic response. These psychological states necessary for creative activity are presented in Figure 2.3.

Figure 2.3. The psychological states of creative mind.

**Metaphoric Activity – the basic activity**

Synectics uses metaphors and analogies to enhance creative thinking. Metaphoric activity is the basic activity of the approach. Through this, creativity would become a conscious process. Metaphors establish a relationship of likeness, the comparison of one object or idea with another by using one in place of the other. Through these substitutions the creative process occurs, connecting the familiar with the unfamiliar or creating a new idea from two familiar ideas (Passi and Martis, 1993, p.5).
Metaphors introduce a conceptual distance between the individuals and the object and allow them to think reflectively. This conceptual distance creates emotional involvement by providing the individual with the freedom and the structure to move into new ways of thinking. Research findings also showed that the effective use of analogies and metaphors by teachers can increase student attention, reduce anxiety, improve critical thinking, enhance concept learning, and create a positive classroom environment.

Gordon identified three types of metaphors: direct analogy, personal analogy and compressed conflict. **Direct analogy** is a simple comparison of two objects or concepts. The comparison need not have to be identical in all respects. It may be very close or very distant. **Personal analogy** requires the individual to get subjectively involved with the object. The involvement or identification may be with a person, plant or animal, or with a nonliving thing. Gordon identified four levels of involvement in personal analogy. They are given below

a. First person description of facts
b. First person identification with emotions
c. Empathetic identification with a living thing
d. Empathetic identification with a non-living object

The purpose of these levels is to provide guidelines for how well conceptual distance has been established. The more creative produces the greater the conceptual distance.

Third metaphor is the **compressed conflict**. It is two–word phrase in which the words seem to contradict each other. The greater the distance between the two frames of reference with respect to a single object, the greater the mental flexibility.

### 2.8 Synectics Model

The sequence of metaphoric activity is the basis of the phase of the model. There are two strategies based on synectics procedure – Creating something new and Making the strange familiar. Creating something new strategy is designed to make the familiar strange, to help students see old problems, ideas or products in a new, more creative light. This strategy helps the students to see familiar in unfamiliar ways by using analogies to create conceptual distance. The second strategy, Making the Strange Familiar (MSF) strategy is designed to make new unfamiliar ideas more
meaningful using familiar analogies. This strategy is used to increase students’ understanding and internalization of a new or difficult material. Synectics model of MSF strategy is explained in detail in the following section.

**Making the Strange Familiar (MSF) Strategy**

The metaphoric mechanism used in MSF strategy is analysis, not for creating conceptual distance.

i. **Syntax**

The MSF strategy involves seven phases. In phase one, the students are provided with information. Then in phase two, teacher suggests a direct analogy and in phase three, students personalize the direct analogy. Students make connections between the material and the analogy and explain the similarities between the new information and the direct analogy in the next phase. In phase five, the students explain the differences. As a measure of their acquisition of the new information, the students can suggest and analyze their own familiar analogies for phase six and seven. The syntax of the model is given in Figure 2.4.

ii. **Principles of Reaction**

The teacher accepts all student responses and ensures that students feel no external judgment on their creative expression. The teacher suggests analogies that help students their thinking. The teacher asks evocative questions to initiate metaphoric activity. This kind of open–ended queries helps to clarify students’ thoughts and stimulate creative thinking. The teacher can also act as an exemplar of the model.

iii. **Social System**

The model is moderately structured. Teacher initiates and guides the students through the metaphorical problem solving. The discussions are open-ended. Norms of cooperation, “play of fancy”, and intellectual and emotional equality are essential. The rewards are internal.
Figure 2.4. The syntax of synechics model of teaching—making the strange familiar strategy.

iv. Support System

The support system consists of teacher familiarity with synechics procedures, a comfortable environment, and a laboratory or other appropriate resources of scientific or design problems needed to be considered.
v. **Instructional and Nurturant effects**

Instructional effects are

- uses group cohesion and develops general creative power
- Enhances creative capacity in subject domain
- Stimulates creativity through metaphoric activity
- Develops problem solving capacity

Nurturant effects are

- Attains self-esteem
- Becomes adventurousness
- Achievement of curricular content

Synectics procedures can be used with students in all areas of the curricula, the sciences as well as the arts. They can be used both in teacher–student discussion in the classroom and in teacher-made materials for the students. Synectics is useful in many types of learning situations and almost in all curricula like creative writing, exploring social problems, problem solving, creating a design or product and broadening one’s perspective of a concept. (Passi and Martis, 1993, p.8)

**2.9 Integration of the models of Bruner and Gordon**

“Theory is change. It is change in ourselves, because it is change in the brain. Thus the art of teaching must be the art of changing the brain”.

(Zull, 2002, p.xiv)

Concepts are considered as building blocks for schema and frameworks and thus, the learning of concepts provides a basis for understanding. According to Anderson and Krathwohl’s revised cognitive taxonomy (2000), conceptual knowledge and deep understanding can help individuals as they attempt to transfer what they have learned to new situations, thereby overcoming some of the problems of ‘inert’ knowledge which means lack of understanding at deeper level. This conceptual understanding becomes the prerequisite to apply the procedural knowledge, to analyze, to evaluate and then to create new ideas. The two highest cognitive processes, evaluating and creating have the same level of complexity and are similar to critical and creative thinking. Thus, concept leaning helps students develop higher level thinking skills. There are several approaches to concept learning. Among those
approaches, concept attainment model is proved to be an effective strategy to learn concepts. It is also effective for teaching higher-level thinking skills including inductive reasoning, hypothesis formation, logical reasoning, and analytical thinking (Reid, 2011). In this approach, students construct, refine and apply concepts through teacher-directed activities using examples and non-examples and they learn to hypothesize, identify critical and non-critical attributes, and define and label particular concepts. Hence, the structure of the concept attainment model provides students with sequenced opportunities to see relationships among ideas, hypothesize, analyze, categorize, verbalize their cognitive strategies, critique the strategies of others, and observe how their own cognitive skills have progressed over time (Dell’Olio and Donk, 2007, p.135).

Many studies reveal that conceptual understanding as well as thinking skills can be enhanced by the effective use of examples and analogies (Orgill and Thomas, 2007). Analogies often help us make the strange familiar; people may understand new information more adequately by relating it to something already known. According to Harrison and Coll (2008), analogies and metaphors are powerful higher-order thinking tools that help scientists and everyday people make sense of the natural phenomena that surround them. Metaphors and analogies are used in Gordon’s synectics process to enhance creative thinking (Wald & Weil, 1974; Joyce & Weil, 1996; Weaver & Prince, 1990; Talwar & Sheela, 2004; Pany, 2008; Paltasingh, 2008).

Since research reflects the effectiveness of the models of Bruner and Gordon in enhancing conceptual understanding, developing critical and creative thinking and also for reducing misconceptions, the integrated approach of these models should be helpful for integrating different regions of our brain. In the present scenario, it is highly essential to provide a thinking environment aims at activating the brain of learners. According to modern developments in neuroscience and pedagogical approaches, shaping of behavior and thus, learning is taking place in our brain, not within the classroom.

Recently, many research works focus on developing higher order thinking skills through brain-learning approach. According to neuroscience and biology of learning, all learning is brain-based. Learning makes changes in all of our neural systems. Our brain always seeks novelty. If the teacher is not providing novelty, the
brain will become fatigue and the neurons become “less responsive”. So presenting the ideas through examples in the form of visuals, activities etc., will activate different neural areas which are the cognitive parts of the brain.

How does learning come from the structure of the brain? How do abstract ideas and concepts become meaningful and thus, make changes in the structure of brain? Here lies the significance of biology of learning.

Biology of learning

In the words of Zull (2002), Kolb’s learning cycle arises naturally from the structure of our brain (p.19). Cerebral cortex of the brain senses the environment, adds up or integrates what it senses, and generates appropriate movement. The sensing function refers to the receipt of signals from the outside world. Sense organs picked up the signals and then these signals are sent on to special regions of the brain for each of the senses. Integration means that these individual signals get added up so that whatever is being sensed is recognized in the sum of these signals. The small bits merge into bigger patterns that become meaningful things like images or language. In human brain these meanings are then integrated in new ways that become ideas, thoughts and plans.

Kolb’s learning cycle (1984) based on the ideas of Dewey and Piaget plays a major role in the nature of brain learning. The cycle describes that learning originates in concrete experience and then it requires reflection, develops abstractions and active testing of these abstractions.

Figure 2.5 illustrates that concrete experience comes through the sensory cortex, reflective observation involves the integrative cortex at the back, creating new abstract concepts occurs in the frontal integrative cortex, and active testing involves the motor brain. In short, our brain has the capacity to reflect, develop ideas and the actions continually.
We are always in the middle of a multitude of learning cycles, getting new ideas about their meaning, and testing these ideas. But the cycle goes not only in one direction but it bounces back and forth between reflection and ideas all the time as we think about experiences. Similarly, the signals from the different regions of the brain bounce back and forth between different parts. Therefore, teachers should provide experiences and help students to develop their own abstract ideas and explanations using their integrative frontal cortex, and should encourage them to actively demonstrate their ideas using motor brain. But how do these experiences tend to change the structure of brain during learning?

Learning is change. It is change in ourselves, because it is change in brain or we can say that it is change in the neuronal networks. In the words of Zull, neuronal networks are knowledge. Each learner brings his own special set of neuronal networks to class. These are considered as prior knowledge of learners. Teachers cannot remove these existing neuronal networks in learner’s brain. But it may be possible to reduce the use of particular networks, or to use other networks in their place, and some networks may die out or weaken with disuse. So teachers should find ways to build on
existing neuronal networks. These existing neuronal networks are the prior knowledge of students. This prior knowledge is physical, real and concrete.

Students are not necessarily aware of all their prior knowledge. For example, if students may not have the abstract concept of momentum, students have never connected with the word ‘momentum’. But they probably know heavy things are harder to stop than lighter things, and they do know that fast-moving objects can hit you hard, even if they are small objects. In this case, teachers can discover the bits and pieces of neuronal networks present in students and provide appropriate concrete examples, analogies or experiences to build up the abstract concept of momentum. Hence, teachers can start with the effective presentation of prior knowledge in the form of concrete examples, analogies, and metaphors in their pedagogy.

Metaphors are sets of neuronal networks that possess specific relationships to each other in the brain and thus embody the concept of the relationship itself (Zull, 2002, p.127). Metaphors, analogies, concrete examples and stories are so powerful in concept learning. The power of these comes from the physical relationship of the neuronal networks from which it is constructed. So, effective presentation of concrete experiences in the form of examples, analogies and metaphors should help in learning. These changes of neuronal networks help to develop thinking skills of learners. This sort of active integration of all parts of brain helps to realize our cognitive goals of education. Therefore, biology of learning highlights the necessity to develop and use instructional patterns in providing creative environments that leads to change in learner’s brain. It also suggests that teachers should adopt more creative pedagogical approaches through the effective use of concrete experiences involving examples, analogies and metaphors for teaching abstract concepts and should also provide opportunities to integrate all the parts of brain for developing higher-order thinking skills and make the change of brain. These integrative instructional patterns will not only enable us to become successful in learning but will also equip us for life. This will help us to realize our own potential to contribute to the development of society. This highlights the necessity to develop and adopt whole-brain approaches to mould a society consisting of high level problem-solvers, decision-makers and inventors using the biology of learning.