2.1 CREATIVITY

“Teachers have the responsibility of gearing the educational system to meet the National and Societal needs by creating an atmosphere, which promotes the spirit of autonomy and creativity. The teachers have to instill in their students the spirit of scientific temper and rational approach”.

-V.N. Rajasekharan Pillai,
Vice Chairman, U.G.C., New Delhi

“Creativity at its highest level has probably been as important as any human quality in changing history and in reshaping the world”

- Calwin W. Taylor

The interests of psychologists and educationists, in the study of Creativity started in 1950. Barrow (1963) said, that in history creativity has never been recognized so positively and so well as it is realized today. Today’s competitive world requires a competitive brain, for which creativity is the most important factor. The rapid growth of knowledge and technology, have compelled to understand the value of a creative man for industrial development and country’s defense. Many contemporary psychologists and educationists have found out through their researches that the creative abilities of individuals can be considerably improved and nurtured through radical reforms in the system of education. Hence, it is necessary to understand the concept of “Creativity”.

WHAT IS CREATIVE THINKING?

Creativity makes our lives happy and comfortable. An ordinary individual engaged in a simple occupation, if creative can through creativity add new quality and beauty to his products. The impact of creativity is to make an activity or object better,
richer, more productive and fruitful. Creativity is the most important inborn instinct of a child. Children can be creative and can experience the process of creativity. This brings us to the questions as to what is creativity.

The Mathematician Poincare (1952) expressed the thoughts of many distinguished scientists on the origin of ideas when he said:

“When we arrived at Coutances, we got into a brake to go for a drive, and, just as I put my foot on the step, the idea came to me, though nothing in my former thoughts seemed to have prepared me for it.......”

The same point was further developed by Mary Henle (1962):

“Perhaps the most astonishing thing about creative thinking is that creative thinkers can tell us so little about it”.

Creativity is a concept we often come across in our everyday life. One hears of creative people, admires creative objects of art or reads creative books. Yet despite our almost innate understanding of what it means to be creative there is much confusion about what creativity really is (Mumford and Gustafson, 1988). Some define creativity in terms of “Problem Solving Ability” (Cattel, 1971; Klahr and Simon, 1999); “A Personality Trait” (Mackinon, 1962); based on the “Production of Ideas” (Guilford, 1967); or as “Recognition of Ideas” (Tyler, 1978).

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

Further, it can also be defined, “as the tendency to generate or recognize ideas, alternatives, or possibilities that can be useful in solving problems, communicating with others and entertaining ourselves and others (Robert E. Franken, 2002).

MEANING CREATIVITY

The New Encyclopedia Britannica defined, “Creativity is the ability to make or otherwise bring into existence something new, whether a new solution to a problem, a
new method or device or new artistic object of form”. This is the most obvious approach to the subject, since the products being public and readily available are more easily assessed. Torrance (1969)“Creative thinking is the process of sensing gaps or disturbing, missing elements forming ideas or hypothesis, possibly modifying and retesting and finally communicating the results”. The latter definition gives more importance to the process of thinking than the product of it, while the former emphasizes the product.

Some of the hierarchical definitions are given by various people:

Wallach and Kogan (1965) defined creativity as “Greater creativity should be indicated by the ability to produce more associations and to produce more that are unique”. Richards (1988) defined “Creativity is an escape from mental stuck ness in decision making and problem solving”. Frank Barron defined “Creativity is energy being put to work in a constructive fashion.”

By Foster, the Humorous and intellect definition was given. it states Creativity is like letting down a bucket into the subconscious and bringing up things you did not know that you know, and mixing them with things of ordinary day life that you do not know. Out of that mixture you make a work of art. What you have finished it, you look at it and wonder how on earth you did it. And indeed you did not do it on earth. It is mysterious”.

Murray’s an elaborate definition follows “Creativity is going beyond lesser forms of intelligence, and is daringly expensive kind of thinking and learning. It requires intuitive sensing, imaginative positing, playful manipulation, waiting, watching, and being open to the unexpected; allowing and taking advantage of “Happy Accidents”, coping with risk, confusion and anxiety; and being able to relinquish old patterns in order to synthesize the new, the better, the more meaningful – a long series of leaps of imagination, a strange and risky business in which the maker never quite knows what he is making until he has actually made it’.

Different authors have stated most of the available definitions of Creativity with emphasis on one or more of these view points – “Psychological”, “Environmental”, “Cultural”, “Physical” and “Intellectual”. At least five components
of creativity have been stressed – ‘The Act’, ‘The Object’, ‘The Process’, ‘The Person’ and ‘The Environment’. Hallman (1963) explains these components in the following manner. According to him:

- Creativity is a whole act, a unitary instance of behavior.
- Creativity terminates in the production of objects or forms of living, which are distinctive.
- Creativity evolves out of certain mental process.
- Creativity co varies with specific personality transformation, and
- Creativity occurs within a particular kind of environment.

These definitions of Creativity, formulate the following generalizations:

1. Creativity is present to a larger or smaller degree in everyone.
2. Creativity requires the attainment of a new perspective – new at least to the person, achieved by bringing together previously unrelated experiences.
3. Creativity demands intensity.
4. A person must approach his or her environment in a holistic manner.
5. Creative persons must assume childlike states with regard of fantasy - play and thought.
6. Creative persons are spontaneous, flexible, and open to experience.
7. Human spontaneity is a source of Creativity.

**PROCESS OF CREATIVE THINKING**

There is a considerable body of literature that provides insight into the nature and nurture of creativity and the positive effects of fostering creativity in classroom situations.

*Creativity, as the term is being used in the present context, involves thinking of ideas in novel ways, branching out from the conventional, adopting alternative ways of thinking, seeing unusual implications and finding new relationships between apparently unrelated things to arrive at original ideas.*

In creative thinking, a person recognizes the real problem, focuses on different aspects of the problem, is able to become aware of the hidden aspects, open it up or redefine it, identifies sub problems that are more manageable or can be solved, comes
out with alternative solutions and alternative explanations. Researches have shown that the more alternatives a person or group produce, there is greater likelihood of success in solving problems creatively. Thus flexibility in thinking of alternative ideas is important for creative production. Looking for alternatives, however, requires some effort. As soon as a person recognizes a problem, he may find immediately that he knows what to do, if the person is unable to recall any solution or cannot recall any satisfactory solution; he will still be motivated to obtain more information and make some guesses concerning suitable alternatives. It requires deliberate effort to look for additional alternatives when the person is not satisfied with one or more of the alternatives. A quantity of ideas are generated that would otherwise not be produced/considered. At this stage it is important to avoid the temptation of accepting too easily the alternatives that occur immediately or to avoid premature solutions to the problem and keep one’s mind open for creative ideas.

Thus creative thinking and problem solving require a mental leeway from the obvious and habitual ways of thinking. Here the motivational factors are especially important in the production of original ideas. The person must be motivated and comfortable with being different to produce original ideas. In order to facilitate originality of ideas, there has to be some “playing with” the ambiguities, and imaginatively experimenting with various ideas or combination of ideas. At this stage, if adults find something genuine to praise concerning the problem solving or thinking efforts of students’ under their direction, this helps in sustaining their efforts. Following this, the problem solver is led to recognize the weaknesses and deficiencies of his solutions or ideas.

Finally on the basis of these experiences, the problem solver is encouraged to fill in gaps, redefine the problem, and press his thinking further or whatever is needed to obtain creative solution.

From the foregoing, it is clear that expression of creativity depends on the complex interplay of many factors like personal qualities, skills, attitudes and motivations, which are key to the realization of potentialities within everyone. These are essentially related to creativity and are necessary for creative achievement and
creative performance in any area of human endeavor. All of these qualities may not be required in equal measure for creative achievement in all, but the presence of these abilities, skills and attitudes facilitates creation, and their interaction contributes to the emergence of creative thinking and behavior. The nature of Creativity is summarized in the following figure.

Figure 2.1: The Nature of Creativity
PROCESSES ASSOCIATED WITH CREATIVITY

The process of creativity has some important components. They are

1. **Delineating or Defining the problem**
   ✓ Gives direction to our thinking
   ✓ Recognizes the various patterns that our brain generates are potentially important or useful.
   ✓ Facilitates arriving at a solution more quickly.

2. **Knowledge**
   ✓ Gives ability to generate new alternatives or new ideas
   ✓ Facilitates acquiring the required knowledge base
   ✓ It is the soil to nourish new ideas.

3. **Constructing images and categories**
   ✓ Involves bringing together pieces of information. It is like several patterns of neurons forcing in the brain simultaneously – Dreaming (Holson, 1988).

4. **Synthesis**
   ✓ Involves putting together components to create a whole.

5. **Suspension of Judgment**
   ✓ Facilitates creativity to run its course.

ABILITIES, SKILLS ASSOCIATED WITH CREATIVITY

Following are the abilities associated with Creativity. They also form the measurable components of creativity.

➢ **Fluency**
   • Generation of many ideas, responses, solutions, questions or suggestions (verbal or non-verbal).
   • Flow of ideas or thoughts. Number or Quantity of relevant responses or ideas.
➢ **Flexibility**

- Generation of a variety of ideas, questions, causes and solutions, as indicated by shifts in approaches or changes in direction of thinking like giving different uses of objects, different interpretations of a picture, story or different possibilities for solving a problem.
- Shifts trains of thought to avoid becoming locked into one track. Involves bisociate matrices or to bring unrelated aspects of experience together. It is the ability to make the “Familiar Strange” (J.P. Guilford and E. Paul Torrance)

➢ **Originality**

- Thinking of unusual, uncommon, novel and off – the – beaten – track ideas, questions, suggestions, solutions, or ways of doing things as a result of seeing new relationships among ideas, combining remote ideas, stretching beyond the obvious and commonplace, improving things on new lines and looking at the same thing from a new angle.
- The ability to see what most people do not. It is the acceptance of bisociation (J.P. Guilford and E. Paul Torrance).

➢ **Elaboration**

- Adding details to the basic idea, a figure or an object and making it fanciful.
- Looking into to the implications of ideas.
- The ability to expand one’s view of a thing or process (J.P.Guilford and E. Paul Torrance).

➢ **Sensitivity**

- Ability to sense problems, detects missing information and anomalies to spot the uncommon.
- Sensitivity to feelings, textures, sight, smell and sound.
- Subjective involvement with a problem and awareness that the odd, the unusual, and the inconsistent may be present in a given situation (J.P.Guilford and E. Paul Torrance).
- **Curiosity**
  - Inquiring, observing, wondering, exploring, asking questions, toying with ideas, pondering over the mystery of things and objects around, following a particular hunch and then seeing what will happen.

- **Visualization and Imagination**
  - Visualizing and building lively, vivid, rich and appealing images, wondering about and predicting things that have never happened – “Guessing and Hypothesizing”.

- **Independence**
  - Thinking or doing on one’s own, independent in making judgments, planning, decision making, figuring out things without any help.

- **Tolerance of Ambiguity**
  - Tolerating ambiguous, open – ended and messy situations, which puzzle or challenge thinking.

- **Complexity**
  - Appreciating and tackling different problems and ideas, bringing order out of chaos, enjoying something harder.

- **Risk - Taking**
  - Having the courage to make guesses, not afraid of failures or of trying new and difficult tasks, preferring to take a chance, defending one’s own ideas.

- **Improvisation**
  - Creating resources without much resources or facilities.

- **Openness**
  - Receptivity to new ideas, resistance to premature conclusions, deferring judgment.

- **Redefinition** (J.P. Guilford and E. Paul Torrance).
  - The ability to recognize what is known to make it useful in solving a problem.
  - It is providing new meanings for old words and involves new ways of knowing.
Penetration (J.P. Guilford and E. Paul Torrance).

- The ability to see more things than what appears on the surface in any given situation.
- It is the ability to go beyond the information given.

CREATIVITY AND SCIENCE TEACHING

Education commission (1964–66) opines that, “The aim of education can no longer be the mere imparting of knowledge, preparation of a finished product, but it is the training of character to fit the students to participate creatively as citizens in the emerging democratic order. Therefore, a function of the school is to provide opportunities for creative growth as democracy matures and flourishes on the creative efforts of its pupils, who later become the adults. But, what of it, in the schools of today?” It is generally accepted that Creativity is highly desirable and precious commodity and prized by teachers, scientists, engineers, industrialists, politicians, advertisers and others.

Despite research done in the past and currently in progress, little is known about those experiences and conditions that foster creativity. However it is generally accepted that creativity can be developed in students if in the learning process the teacher initiates creative situations to which students can react accordingly. Creativity teaching demands creative teachers.

James A. Smith states, “There are currently several barriers to Creativity teaching which must be removed. Chief among these are: Lack of intelligence, Excessive conformity to predetermined methods of teaching or teaching plans, over planning for classroom teaching, making the same plans for all children, the excessive use of stereotyped questions, the improper use of gimmicks, the overuse of the text books as a teaching device, the inability on the part of the teachers and administrators to differentiate between research and the opinion of the experts, and the attitude and practices of the school administrators who does not recognize the value of unique performance among his personnel”.

Smith further states, “Creativity as such, cannot be taught. It is not a subject or a skill that can be learned like history or demonstrated like baseball. It is an inborn,
developmental quality, like love and can only be developed. Various aspects of creative thinking and doing can be modified through learning to the degree that all learning can be modified. But, because Creativity is a quality already present in every individual, it needs to be cooled to help to develop. The uncreative children in our schools today are live testimony to the degree to which it can be killed off easily. Once it appears on the surface its reappearance can be assured by use of all those techniques, which cause behavior to reappear. But it does not appear unless certain conditions are present which cause it to come forth. The problem then seems to be to get it to reappear so the teacher can work with it, and by reinforcement stimulate its reappearance, in other words set conditions for Creativity”.

Creativity thinking differs from critical thinking in that it is concerned with new ideas. Creativity is the act of drawing on all past experiences and the act of selection from these to yield a construct of new pattern, new ideas or new products. The key word appears new, new to whom? Usually we are concerned with the newness being related to its contribution to society. However, if an elementary school student generates a new idea – new to him – this would be temporarily sufficient. His contribution to society can come later. Some what like the expression, “Science is what scientists do”, Creativity is what Creative people do”. Science is nothing but Creative thinking and Creative doing.

According to India Parliamentary and Scientific Committee (1964) - “Science in our culture is a creative intellectual activity leading to unifying concepts of man’s natural environment”.

Science is a creative venture. Creativity is as vital at the frontier of science as it is within the interior. Science grows when new facts are added to old and when new concepts and theories are formulated. Science is thinking curiously and deriving new ideas from this creativity. Everyday more opportunities should be provided for children to think creatively and to meet this need in part it is recommended that children be provided with numerous Situational Science Experiences (SSE). SSEs are brief situations conjured up by the teacher or students to provide the class with short–term daily problems that provide exercise in creative thinking. Involvement in SSEs is
often regulated primarily to “thinking” ones way through a particular situation. Conditions for creative development may be greatly enhanced by improving the physical aspects of the classroom environment.

The teacher and the school should provide not only the environment but also resources for the development of varied and related experiences. The elements of convergent and divergent thinking should be continuously stressed and applied to the solution of problems throughout the entire curriculum. The development of productive thinking and creativity among various groups of pupils at various ages right throughout the school is a major educational problem in the area of science education and teaching which has not been yet tackled satisfactorily in our country. This is because our educational system is still dominated by examination.

Finally it is clear that “Science is natural for Creativity”. Science teaching and creativity should go hand in hand. The scientist is one of the most creative persons in our society. Frontiers in science are constantly being advanced by his creations. The qualities or characteristics of scientists are in many ways analogous to those traits associated with creative individual. Creative thinking is problem solving and more. Problems, experiments and opportunities for children where in they can use their imagination, originality and curiosity will undoubtedly foster creativity.

**CREATIVITY AS INCREMENTAL PROBLEM SOLVING**

Weisberg (1986) presents that creativity occurs through a series of small steps in which earlier ideas are modified and elaborated. The incremental nature of creativity occurs as the problem solvers runs into obstacles, proposes solutions, runs into further obstacles, and so on, refining and elaborating the earlier solutions. Weber and Dixon (1989) apply the same point about the incremental nature of creativity to the historical analysis of inventions. They argue that inventions often involve over long periods of time by the gradual accumulation of the best ideas and allow the problem solver to view the problem in a new way. When the problem has been appropriately viewed, the solution comes clear. Thus, it is suggested that Creative thinking involves sudden insights (Wallas, 1926) often bring in the idea that the problem has been re-represented. Creativity training techniques often try to get the
problem solvers to think about the problem in new ways until a solution comes to them (Gordon, 1961). The use of analogy is a common tool in creativity training and creative problem solving (Holyoak and Thagard, 1995). Analogies facilitate extensive exploration of possibilities of problem solving before committing to an approach. Thus Creativity is incremental to problem solving (Dunbar, 1995; Newell, Shaw, and Simon, 1962).

Thus, the conceptual features of “Problem Solving Ability” are presented in the next section.

2.2 PROBLEM SOLVING ABILITY

“What we are doing is sponsoring independent thinking. It’s really a matter of providing the resources for the academy’s research to go on without us specifically guiding, telling them which problems they ought to study or he solutions they should be coming to”

– Steve Wittrig, Director, BP Group Technologies

Life is nothing but a series of problems. Experience in dealing with problems will help the individual in cultivating strategies, which may prove to be of great value at crucial moments of life. A major objective of instruction, especially in mathematics and science, is to strengthen students’ skills in solving problems.

What must a student know in order to solve problems in a domain?

The knowledge in texts and instructional materials is certainly needed, but insufficient. In addition student must also have knowledge of how to apply those concepts and propositions to find the solutions of problems. This “How to” kind of knowledge is in the general category of “skills”, and until recently, very little is known about the skills needed for solving problems (James G. Greeno, 1978).

In recent years, cognitive psychologists have developed detailed analyses and descriptions of psychological processes involved in many cognitive tasks and the specific variable that influenced them. Now, with increasing frequency, investigators go beyond identifying variables that have effects on processes and specify relatively detailed models of how they believe the processes occur, including the nature of component sub processes and the way in which sub processes are organized into a complete procedure for doing the task.
A PROBLEM SOLVING PROCESS

A problem must satisfy three criteria as depicted below. In terms of Newell and Simon Model the blocks to problem solving is:
1. Incorrect perception of the task environment.
2. Incorrect problem space.
3. Lack of information, either with the problem or in memory.
4. Mind – set

A problem will no longer be a problem once algorithms that have been previously learned can solve it. A problem for someone may not be a problem for another, who has more experience in the concerned field. The following diagram is self illustrative about the criteria involved in problem solving processes.

Figure 2.2: Illustration for “Criteria of a Problem Solving Process”
“IDEAL” PROBLEM SOLVER

John Bransford and Barry Stein (1993) used the letters of the acronym IDEAL to stand for the five major steps that underlie effective problem solver.

1. Identify the problem: Before to solve a problem, there is need to recognize that there is, in fact, a problem.

2. Define the problem: It involves the representation of the problem information in the most efficient way. It involves correctly interpreting the components of the problem.

3. Explore a variety of strategies: Once the problem solver has identified the problem, defines the goal, and developed some understanding of the information he had to work with, its time to move forward toward a possible solution. To do this he must decide on a strategy. Most solution strategies amount to “Rules of Thumb”. They don’t guarantee a solution, but they can speed up problem solving process or at least move the problem solver close to his goal.

4. Act on the Problem Strategy: The problem solver works through the solution strategy, and as part of the process tries to anticipate any dead ends or obstacles that might prevent him from reaching the goal.

5. Look Back to evaluate the effectiveness of the selected strategy: Had he in fact solved the problem? Its important to identify and correct any errors that have occurred before moving on and trying something new.

The processes involved in the above steps need to be understood in greater detail.

Identifying and Defining: Problem Representation

To identify and define a problem correctly it is essential to represent the problem information in the correct way. By problem representation, psychologists mean that you need to understand what information is given and how that information can potentially be used.

Sometime people allow their pre conceptions, even their prejudices, to lock them into an incorrect view of the problem information (Bassok et al. 1995; Dixon and More, 1997). Psychologists used the term functional fixedness to refer to this
tendency to objects and their functions, in certain fixed and typical ways. Functional fixedness is an obstacle to problem solving because it prevents the solver from recognizing the problem solving tools that are present in the situation.

**Explaining and Acting: Problem Strategies**

A perfect representation of a problem alone cannot guarantee a solution. The problem solver also needs an arsenal of problem strategies and techniques that allow him to move systematically toward a problem solution. Two classes of problem solving strategies can be used – Algorithms and Heuristics.

**ALGORITHMS** are step-by-step rules or procedures that if applied correctly, guarantee a problem solution.

**HEURISTICS** are the rules of thumb we use to solve problems. Heuristics can usually be applied quickly, but they do not guarantee that a solution will be found. Heuristics are extremely adaptive problem solving tools because they often open the door to a quick and accurate solution. In natural environment quick solution can mean the difference between life and death. An organism cannot spend its time wrapped in thought, systematically working through a long list of solution possibilities. Instead, its adaptive for the organism to guess, as long as the guess is based on some kind of rationale. The types of heuristics problem solvers follow are – Means and Ends Analysis (Newell and Simon, 1972), Working Backwards, Searching for Analogies and Mental – Set.

**Means and Ends Analysis** – involves devising actions, or means, that reduce the distance between the current starting point and the desired end (The goal state) (Newell and Simon, 1972). The key ingredients of the problem solving strategy are: Establish where you are, Figure out where you want to be, Devise a means for effectively getting you from here to there.

**Working Backwards** – involves starting at the goal state and moving backwards towards the starting point in order to see how the goal state can be reached.

**Searching for Analogies** – involves trying to find a connection (resemblance) between the current problem and some previous problem you have solved
successfully. A problem solver when sees the relationships between the two problems is unlikely to suffer the same problem solving pit falls he encountered before.

**Mental - Set** – is the tendency to rely on well-established strategies when attempting to solve problems.

**Looking and Learning**

The Ideal problem solver Identifies and defines the problem, seeks the best problem representation, and Explores and Acts on problem strategies. But the whole process is incomplete unless he also looks and learns from his experiences (Bransford and Stein, 1993). By analyzing ones performance in detail, noting both mistakes and correct answers, one can determine whether his strategy will help solve one kind of problem, but not another. Through an after – the – fact analysis, he can gain insight into why a particular item failed or succeeded. Looking and learning facilitates better problem solving ability the next time.

**THOUGHT PROCESSES INVOLVED IN PROBLEM SOLVING**

Problem solving is a Cognitive Activity. Problem solving involves processing information. Conceptualizing problem solving in this way, Newell and Simon (1972) argued that:

- A person perceives raw data and processes these perceptions sufficiently to recognize the task environment – the components of the problem or the terms in which it is presented – that is the task as described by the person.

- The information is next transformed into what might be described as a person’s problem space – in other words, simply the way in which the person views the task. In this representation the person has to be quite clear about the goal – what has to be done; where he or she is in relationship to the goal, and what kinds of acts must be carried out to reach the goal.

- Depending upon how the problem space has been conceived, a person uses various kinds of information drawn from memory, or information that is given with the problem, to process data so as to move toward the goal.

The total set of operations used in the effort to move from the initial perception of the data to the goal is what Newell and Simon call the production
system or programme. In the course of carrying out the programme, a person will notice whether any step or series of steps reduces the distance to the goal. If this is the case then the next step or steps in the programme. If the entire programme fails to materialize in the attainment of the goal, then either the person quits, modifies the programme, or changes the problem space.

Newell and Simon’s analysis draws the conclusion that problem solving involves the search for the most successful programme. However, as Minsky (1974) argues, problem solving may be not so much a search for a successful programme as a search for the best problem space. Whether the case, it would seem logical that a good programme without a good problem space would be likely to be unproductive in terms of solution finding. Similar results will ensue in the case where there is a poor programme and a poor problem space. Problem space and programme, along with accurate perception of the task environment are important components of the problem solving process.

CREATIVITY AND PROBLEM SOLVING

Creativity is the development of new mental patterns. It is an emotional process and an irrational one too. In problem solving we are concerned with finding a workable solution to problem rather than with the generation of ideas alone. Although generation of ideas is essential to problem solving, the number of such ideas is not the criterion. Rather, one must evaluate the final choice. Problem solving is rational and intellectual but by adding the irrational we increase the likelihood that we will generate fresh ideas.

The selection of the best or the most creative solution for a problem is open to question as it may be subjective when problems have many answers. Is there a relationship between the tendency to produce innovative solutions (Creativity) and success in solving difficult problems (Problem solving ability)? Some argue that Creative-problem solving cannot be taught (Torrance, 1986), many others assert that students can learn how to think creatively if they use “disciplined” techniques for thinking through problems.
Colgrove (1968) took up an experiment with the purpose of determining whether students’ superior in solving difficult problems having objectively correct solutions, also achieve solutions rated ‘creative’ or ‘superior’ for a problem with several possible answers. It was concluded that superior problem solvers also generate solutions that are rated as creative when several solutions to given problem are possible.

Problem solving is only one aspect of creativity. Creativity is more comprehensive than problem solving. Creativity has many facets like imaginative writing, aesthetic value etc., besides problem solving, though problem solving does constitute an important aspect of creativity.

**SCIENCE TEACHING AND PROBLEM SOLVING**

Science is of great interest to children and is ever present. Science is concerned with explanations and resolution of problems. Its study provides a natural opportunity for children to grow in ability to solve problems. This growth in ability to solve problems is one of the primary contributions science can make.

Problem solving in science involves the use of scientific habits and attitudes, which include: Careful observations, accurate interpretation of these observations, and skilful recording and communicating them. It includes the habit of withholding judgment, questioning sources of information, consulting many sources, and other familiar aspects of scientific attitude.

The cumulative aspect of science is that knowledge grows as it builds on other previous knowledge. In solving a science problem we do not start from the beginning instead we use what others have discovered and build on it. This is also true when pupils solve problems; it is also true when scientists solve problems. As a human endeavor, science has arisen out of the process of solving in science itself; however its role in the science curriculum is not very clearly established.

Science educators agree that all children should be able to integrate their learning at school to solve problems they face everyday in their life. An increasingly popular view is that the teacher should provide instruction in problem - solving techniques and strategies but opinion differs as to the nature and extent of this
instruction. Instead of teaching pupils to follow a fixed sequence of steps, some teachers have attempted to provide them with Heuristic advice (Polya 1981) that may help them analyze the problem and transform it into something they can solve. Pupils are not likely to learn to apply such advice unless they are given many opportunities to see it applied, practice its application and identify cues to help decide when it might be appropriate. It is also found that a considerable improvement in problem-solving performance can occur when pupils’ responses are encouraged and accepted and the classroom atmosphere is made less threatening.

For the teacher to be effective, they must not only have a thorough knowledge about the subject matter, but also know their students. This knowledge is believed to be critical in designing an instructional process that teaching youngsters the problem solving strategies that can be used in challenging the status quo. Through the use of instructional models such as Concept Attainment Model, Inquiry Training Model and “Synectics”, students’ thinking is extended and problem solving knowledge are introduced, practiced and applied. It is emphasized that students should be engaged in the process of learning as a contextualized experience that relates subject matter, problem solving skills, personal and community issues, and a challenge to the status quo of most culturally diverse families (Ladson – Billings, 1994).

It is the present investigator’s intention to find whether the Creativity fostered through Science Teaching contributes Problem Solving Ability? If so, do the students develop better attitude towards the subject domain taught?

Hence, it is imperative analyze the concept of Attitude and Attitude towards Science.

2.3 ATTITUDE TOWARDS SCIENCE

Science educators have recognized that fostering a favorable attitude towards science is the most important outcome of Science Teaching. Many experiments have been carried on in the field of measuring attitudes. Science teachers and educators are not, however, aware of the unaware of the need of some valuable and reliable research on the measurement of attitude towards science and its influence on certain
school achievements and its development. They have realized the importance of inculcating and developing favorable attitude towards science among different groups of pupils. Development of attitudes can be achieved only through many directions and associated behavioral factors.

**PROCEDURES FOR DEVELOPING A POSITIVE ATTITUDE**

The process of teaching and learning is complicated and when done well, quite intricate and subtle. As a teacher begins to plan for developing a positive attitude toward learning he should clearly shift from conventional instructional practices that emphasize discreet, competitive, ‘ability based’ academic goals to ‘application based’ goals where development of understanding and competence are of primary concern. When the teachers desire to provide equitable motivational opportunities across multiple profiles of intelligences and styles and that allow for learner choice and responsibility, thus develops a positive attitude.

**• LEARNING GOALS PROCEDURE**

Self-determination among learners requires choice and minimizing teacher control. It also requires making available information that is needed for decision-making and for performing the agreed upon learning goal (Deci, Vallerand, Pelletier, and Ryan, 1991). As soon as the people know the goals and procedures of a course, they begin to form a personal theory about the choices and competencies necessary for accomplishing those tasks (Paris and Byrnes, 1989). They ask themselves such questions as, what do I already know about this? Is this worthwhile? Where do I start? What can I do to do this well? Am I able to do this? Is the evaluation system used fair and reasonable?

From this sort of reflection, people hypothesize how much control they can exert and how effective they will be while learning. The conclusions they reach very much influence their attitude towards learning.

**• PROBLEM SOLVING GOALS – ATTITUDE - PROCEDURE**

The problem-solving goal differs in a significant way from the conventional instructional objective. In the problem-solving goal, the learners formulate or are given a problem to solve. The goals that need to be achieved to resolve the problem
can be made fairly clear. But the forms of its solution range from many to infinite (Eisner, 1985; Schon, 1987). The idea here is that the kinds of solutions and the forms they take are highly variable. Alternative solutions to problem solving goals can be shared in class so that learners can appreciate the different perspectives and their related outcomes. This enhanced relevance and self-determination and simultaneously affirms the value of multiple perspectives and ways of knowing.

Problem solving goals are common in the design field, sciences, media arts and technology. The people in these fields are usually given a set of criteria or specifications and asked to generate a creation that will satisfy those criteria. Often they are asked to create several alternatives so that the client can decide which of these options best suits his or her needs. With problem solving goals the potential answers are not difficult or known before hand. The problem is genuine one. The solution learners’ reach has the possibility of being a genuine surprise for them. Problem solving objectives place a premium on intellectual exploration and the higher mental processes while supporting different cultural perspectives and values. Because this approach encourages ingenuity it breeds interest for students from a variety of aspects. Thus positive attitude is fostered.

**ATTITUDE TOWARDS SCIENCE**

The term attitude towards science is composed of two words – ‘Attitude’ and ‘Science’. Attitude according to Thurston (1948) is the degree of positive and negative effect associated with some psychological object. Object here is Science as a discipline. Richard W. More (1970) has rightly defined science attitude as the opinion or position taken with respect to a psychological object in the field of science. Attitude towards science indicates feelings of an individual or a group concerning science like faith in Scientific Method, opinion about scientists, values of science, interaction of science with individual and society, opinion held about science related social issues. It is the tendency to react favorably or unfavorably towards science or in science. Hence attitude towards science is the generalized attitude the universe of science content and being measured in terms of its favorableness estimated from the scores obtained by the subject on an “Attitude Scale towards Science”.

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The foregoing throws light on the need of teaching Science - fostering Creative thinking to induce Problem solving ability and in turn a better Attitude towards Science. Through which kind of logistics the above objective can be inquired?

Ladson – Billings (1994) accentuated the effectiveness of Synectics Model of Teaching in subject domains to meet the challenge of inducing Problem Solving Ability. Eisner (1985) and Schon (1987) believed through their empirical studies that “The Problem Solving Goals Approach” influences “Attitudes” when the learners succeed in solving the goals creatively. Finally the investigator intends to find out what “Synectics” is? Does it suits to his need?

2.4 SYNECTICS MODEL OF TEACHING

Bruce Joyce and Marsha Weil (1980) searched a variety of strategies developed by different theorists, philosophers, therapists and designed more than twenty-five models of teaching. Bruce Joyce, Marsha Weil and Beverley Showers glorified their Compilation of Models of Teaching as follows:

“Models of Teaching are really Models of learning. As we help students acquire information, ideas, skills, values, ways of thinking and means of expressing themselves, we are also teaching them how to learn”.

These models of teaching because of their interactive, participatory, adaptable, implementing and persuasive nature have a great potentiality for achieving the aims and objectives of education. They are classified into four families. Namely

- Information processing Models
- Social – Interaction Models
- Personal Models
- Behavior modification Models

The “Synectics Model” from the Personal Models Family, is one such step by step technique can be used by all students alike to participate in the creative process.
THE SYNECTICS

The word Synectics derived from Greek means “the joining together of different and apparently irrelevant elements”. Synectics theory applies to the integration of diverse individuals into a problem stating problem-solving group. Synectics defines creative processes as the mental ability in problem stating, problem solving situations where artistic or technical inventions are the result.

Synectics is an interesting approach to the development of creativity designed by William J.J.Gordon (1961). Synectics procedures were initially used to develop “Creative Groups” within industrial organizations - that is groups of persons trained to work together to function as Problem solvers or Product Developers. But later Gordon adapted Synectics for use with school children. The chief element in synectics is the use of analogies. Here the students “Play” with analogies until they relax and begin to enjoy making more metaphoric comparisons.

Synectics is based on three important assumptions of psychology of creativity. They are

- By bringing the creative process to consciousness and by developing explicit aids to creativity, we can directly increase the creative capacity of both the individuals and groups.
- The 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.

THE CREATIVE STATE AND THE SYNECTICS PROCESS

The specific processes of Synectics are developed from a set of assumptions about the psychology of creativity.

1. By bringing the creative process to consciousness and by developing explicit aids to creativity, we can directly increase the creative capacity of both individuals and groups.
2. Emotional component is more important than the intellectual, the irrational more important than the rational. the irrational state is the best environment for exploring and expanding ideas, but it is not a decision making stage.

3. Emotional and irrational elements must be understood in order to increase the probability of success in a problem solving situation.

**METAPHORIC ACTIVITY**

The Synectics model of teaching, further developed by Bruce Joyce and Marsha Weil (1985) fosters creativity through ‘Metaphoric activity’ by connecting the familiar with the unfamiliar or creating a new idea from familiar ideas. Three types of metaphors form the basis of synectics exercises viz., - Direct analogy, Personal analogy and Compressed Conflict.

- **DIRECT ANALOGY**

  Direct analogy is a simple comparison of two objects or concepts. The comparison does not have to be identical in all respects. Its function is simply to transpose the conditions of the real topic or problem situation to another situation in order to present a new view of an idea or problem. This involves identification with a person, plant, animal or non-living thing.

- **PERSONAL ANALOGY**

  Personal analogy requires the students to empathize with the ideas or objects to be compared. Students must feel they have become the part of the physical elements of the problem. The identification may be with a person, animal or any non-living thing. The personal analogy requires loss of self as one transports oneself into another space or object. The greater the conceptual distance created by the loss of self, the more likely it is that the analogy is new and that the students have been creative or innovative. Gordon identifies four levels of involvement in personal analogy.

  1. *First person description of facts*. The person recites a list of well known facts but presents no new way of viewing the object or animal and shows no empathetic involvement.
2. *First person identification with emotion.* The person recites common emotions but does not present new insights. It involves statements like “I feel ….”.

3. *Empathetic identification with a living thing.* The student identifies emotionally and kinesthetically with the subject of the analogy.

4. *Empathetic identification with a nonliving object.* This is the most important stage for creative emergence of the student. It requires most commitment. The person sees him or herself as an inorganic object and tries to explore the problem from a sympathetic point of view.

   Gordon believes that usefulness of analogies is directly proportional to the distance created. The greater the distance, the more likely the student is to come up with new ideas.

   **COMPRESSED CONFLICT**

   It is generally a two word description of an object in which the words seem to be opposites or contradict each other. For example nourishing flame and tiredly aggressive are compressed conflicts. According to Gordon compressed conflicts provide the broadest insight into a new subject. They reflect the students ability to incorporate two frames of references with respect to a single subject. The greater the distance between the frames of reference, the greater is the mental flexibility.

   Analogies are of pivotal importance in conceptual change learning, in that they may help to restructure existing memory and to prepare it for new information (Geuter, 1983; Shapiro, 1985). Employing an analogy does not merely help or facilitate learning in a new domain, it also opens up new perspectives for viewing and, hence, restructuring the analogy. Using an analogy is, therefore, essentially a ‘Two way process’ involving developing both ‘analogy’ and ‘target’ (Bauer and Richter, 1986; Steiner, 1988).

   **STRETCHING EXERCISES: USING METAPHORS**

   The above three types of metaphors can also be used separately with groups, as a warm-up to the creative process. This is refereed as “stretching exercises”. Stretching exercises are not related to any particular problem situation nor do they follow a sequence of phases. They teach students the process of metaphoric thinking.
THE SYNECTICS MODEL OF TEACHING

Synectics Model has two strategies of teaching. They are

1. *Creating Something New or Making Familiar Strange (MFS)*

   It helps the students see familiar things in unfamiliar ways by using analogies to create conceptual distance. Except for the final step, in which the students return to the original problem, they do not make simple comparisons.

2. *Making the Strange Familiar (MSF)*.

   It seeks to increase the students’ understanding and internalization of substantially new or difficult material. In this analogy, metaphor is used for analyzing. Using familiar analogies, the students begin to define the characteristics that are present and those that are lacking in the concept. It is both analytic and convergent: students constantly alternate between defining the characteristics of the more familiar subject and comparing these to the characteristics of the unfamiliar topic.

The syntax of the above two strategies are given below.

**Table 2.1: Syntax for Strategy - I**

**Making Familiar Strange (Creating Something New)**

<table>
<thead>
<tr>
<th>PHASE – I</th>
<th>DESCRIPTION OF PRESENT CONDITION</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Teacher has students describe situation or situations as they see it now.</td>
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<tr>
<th>PHASE – II</th>
<th>DIRECT ANALOGY</th>
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<tbody>
<tr>
<td></td>
<td>Students suggest direct analogies, select one and explore (describe) it further.</td>
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<tr>
<th>PHASE - III</th>
<th>PERSONAL ANALOGY</th>
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<tbody>
<tr>
<td></td>
<td>Students become the analogy they selected in phase two.</td>
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<tr>
<th>PHASE - IV</th>
<th>COMPRESSED CONFLICT</th>
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<tbody>
<tr>
<td></td>
<td>Students take their descriptions from phase two and three, suggest several compressed conflicts, and choose one.</td>
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<tr>
<th>PHASE - V</th>
<th>DIRECT ANALOGY</th>
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<tbody>
<tr>
<td></td>
<td>Students generate and select another direct analogy, based on the compressed conflict.</td>
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<tr>
<th>PHASE - VI</th>
<th>RE EXAMINATION OF THE ORIGINAL TASK</th>
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<tbody>
<tr>
<td></td>
<td>Teacher has students move back to original task and use the last analogy and the entire Synectics experience.</td>
</tr>
</tbody>
</table>
Table 2.2: Syntax for Strategy - II
Making Strange Familiar

<table>
<thead>
<tr>
<th>PHASE – I</th>
<th>SUBSTANTIVE INPUT</th>
<th>Teacher provides information on new topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHASE – II</td>
<td>DIRECT ANALOGY</td>
<td>Teacher suggests direct analogy, and asks students to describe the analogy.</td>
</tr>
<tr>
<td>PHASE – III</td>
<td>PERSONAL ANALOGY</td>
<td>Teacher has students become the direct analogy he suggested in phase two.</td>
</tr>
<tr>
<td>PHASE – IV</td>
<td>COMPARING ANALOGIES</td>
<td>Students identify and explain the points of similarity between the new material and the direct analogy.</td>
</tr>
<tr>
<td>PHASE - V</td>
<td>EXPLAINING DIFFERENCES</td>
<td>Students explain where the analogy does not fit.</td>
</tr>
<tr>
<td>PHASE - VI</td>
<td>EXPLORATION</td>
<td>Students reexplore the original topic on its own terms.</td>
</tr>
<tr>
<td>PHASE - VII</td>
<td>GENERATING ANALOGY</td>
<td>Students provide their own direct analogy and explore the similarities and differences.</td>
</tr>
</tbody>
</table>

**SOCIAL SYSTEM**

The model is moderately structured, with the teacher initiating the sequence and guiding the use of the operational mechanisms. The teacher also helps the students intellectualize their mental processes. The students are encouraged to be free and pose their open-ended discussion during metaphoric problem solving. Norms of cooperation, play of fancy, and intellectual and emotional equality are essential to establish the setting for creative problem solving. The rewards are internal, coming from the students’ satisfaction and pleasure with the learning activity.

**PRINCIPLES OF REACTION**

The teachers themselves must use the nonrational to encourage reluctant students to indulge in irrelevance, fantasy, symbolism, and other devices necessary to break out of set channels of thinking. In strategy two teachers should guard against
premature analyses. They also clarify and summarize the progress of learning activity and, hence, the students problem solving behavior.

**SUPPORT SYSTEM**

The group most of all needs facilitation by the teacher competent in synectics procedures. It also needs, in the case of scientific problems, a laboratory in which it can build models and other devices to make problems concrete and to permit practical invention to take place. The class requires a work place of its own and an environment in which creativity will be prized and utilized. Synectics activities need smaller groups.

**INSTRUCTIONAL AND NURTURANT EFFECTS**

The Synectics model contains strong elements of both instructional and nurturant values. Synectics can be applied, not only to the development of creative responses over a variety of subject matter domains. Gordon believes that the creative energy will enhance learning in these areas. He emphasizes a social environment that encourages creativity and uses group cohesion to generate energy that enables the participants to function interdependently in a metaphoric world. The instructional and nurturant effects are presented in the following diagrammatic representation.

**Figure 2.3: Instructional and Nurturant effects: Synectics Model**
RATIONALE IN SELECTING THE SYNECTICS MODEL FOR STUDY

The investigator finds the assumptions of the Synectics Model to be very realistic in educational context as they confront the conventional views about creativity. They are

- Creativity is important in everyday activities.
- Creative process is not at all mysterious.
- Creative invention is similar in all fields.
- Creative inventions are very similar whether they are individual or group in generation.

The Synectics process involved “Play of fancy” which would be a better motivating strategy for a teacher. It is based on a set of three assumptions about the psychology of Creativity. They are

- By bringing the creative process to consciousness and by developing explicit aids to Creativity, one can directly increase the creative capacity of the individuals and groups.
- Emotional component is more important than the intellectual, the irrational more important than the rational. The irrational state is important than the rational (Gordon, 1961).
- “Emotional, irrational elements must be understood in order to increase the probability of success in a problem solving situation”.

In addition, the “Personal Analogy” phase in the Synectics process requires the participant to loose his self thus transporting himself into another space or object. It gives a great chance to maintain a greater conceptual distance from the concept to the analogy. It imbibes the participant so close to the analogy that he involves himself into

1. First-person description of facts.
2. First person identification with emotion.
3. Empathetic identification with a living thing, and
4. Empathetic identification with a non living thing.
While selecting the Synectics Model of Teaching the following were the some more observed criteria that suit better to realize the objectives of the study.

- It fosters Creativity as – “**Disinhibition**”. The pupils need to be able to let go off conventional perspectives (Strickland, 1989). They should feel free to recombine things in new and different ways, even if those combinations seem silly or even wrong.
- The Metaphoric activity in Synectics renders Creativity to emerge as a conscious process. It frees the participant himself to develop imagination and insights into everyday activities.
- The strategy – II facilitates to break set and conceptualize problem in a new way in order to suggest fresh approaches to it in personal life as well as in classroom.
- It lets the pupils throw off their rigidity.
- It suits to pupils of all ages (Krishna Murthy, B. 1989; Kumari Sucheta, 1990)
- It increases pupil’s tendency to combine things in new ways and to see relatedness among divergent stimuli (Isen, Daubman, and Nowicki, 1987).
- It adopts playful attitude – thus “**Suspending Judgment**”.
- Breaks the monotony of the conventional classroom teaching.
- Democratic and Interactive in approach.
- Applicable, functional and workable in Indian settings.
- Instructional and nurturing effects matched with the objectives of the study.
- Suits to explore individual differences. Encourages most timid participants also.
- Universal learning experiences can be applied.
- Emphasizes both processes of skills and knowledge of the content.
- Synectics has so far been used in many schools. Varied teaching material and techniques have been developed to make the use of synectics more effective in school situations. In India a majority of them fall in the fields of languages and social studies.

The above conceptual review of Synectics Model, convinced the investigator both on theoretical and empirical grounds (Gordon, 1961, 1971; Richard Hindley *et al* Bruce Joyce, 1971) mentioned. Hence, the investigator wished to “Review the Related Literature” to settle himself in to the research gap in tandem to his objectives.